MEETING THE COOL NEIGHBORS. II. PHOTOMETRY OF SOUTHERN NLTT STARS

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ABSTRACT

We present BVRI photometry of 180 bright, southern nearby-star candidates. The stars were selected from the New Luyten Two-Tenths proper-motion catalog based on optical/infrared colors, constructed by combining Luyten’s m_r estimates with near-infrared photometry from the Two Micron All Sky Survey. Photometric parallaxes derived from V–K_s, V–I, and J–I colors, combined with the limited available astrometry, show that as many as 108 stars may lie within 20 pc of the Sun. Of these, 53 are new to nearby-star catalogs, including three within 10 pc of the Sun.

Key words: Galaxy: stellar content — stars: red dwarfs

On-line material: color figures, machine-readable tables

1. INTRODUCTION

This is the second in a series of papers that present the results of our search for previously unrecognized stars within the immediate solar neighborhood. As discussed in Paper I (Reid & Cruz 2002), the availability of large-scale sky surveys at near-infrared wavelengths, notably the Two Micron All Sky Survey (2MASS; Skrutskie et al. 1997), in combination with published catalogs and Schmidt-based photographic observations at optical wavelengths, has greatly enhanced our capabilities for detecting the low-luminosity main-sequence stars and brown dwarfs. The primary goal of our project, undertaken under the auspices of the NASA/NSF “NStars” initiative, is the identification of all late-type dwarfs (concentrating on spectral types M and L) within 20 pc of the Sun.

As a first step toward identifying the Sun’s nearest neighbors, we have used 2MASS data to enhance an old technique, cross-referencing the infrared catalog against proper motion stars in the New Luyten Two-Tenths (NLTT) catalog (Luyten 1980). Once correlated, we can use the m_r–K_s color as a crude photometric parallax estimator, with the long baseline compensating to some extent for the uncertainties in the red magnitudes. Paper I describes the definition of an initial sample of nearby-star candidates, drawn from NLTT sources that have potential 2MASS counterparts within a 10" search radius. By applying a series of cuts in color-magnitude and color-color planes, we reduced the list of 23,795 optical/infrared matches to 1245 sources with photometric properties consistent with their being late-type dwarfs within 20 pc of the Sun. These stars constitute NLTT sample 1. Paper I compiles photometric data from the literature for 469 stars and uses color-magnitude relations at (M_V, V–K), (M_V, V–I), and (M_J, I–J) to estimate distances to those stars. Three hundred of those stars, and a further 39 ultracool (spectral type later than M6) dwarfs, have formal distances of less than 20 pc, including 76 stars not previously included in nearby-star catalogs.

The current paper continues analysis of NLTT sample 1, presenting optical photometry of a sample of 180 relatively bright southern stars. The following section outlines the sample and presents the observations. Section 3 describes our procedures for estimating distances to these stars, and § 4 discusses some of the more interesting stars in the sample. Our results are summarized in the final section.

2. OBSERVATIONS

2.1. The Sample

As described in Paper I, the 1245 stars in NLTT sample 1 were selected on the basis of their having locations in the (m_r, m_r–K_s) and (J–H, H–K) planes consistent with mid- or late-type M dwarfs within 20 pc of the Sun. Regions within ±10° of the Galactic plane were excluded a priori, since the NLTT Catalogue has a significantly brighter limiting magnitude at those latitudes. The selected stars have magnitudes in the range 8 < m_r < 20, with over 70% lying between 11th and 16th magnitude. They span the full range of right ascension, although the majority lie at northern declination, reflecting both the areal coverage of the second incremental release of 2MASS data and incompleteness in the NLTT south of δ = −30°. Several hundred stars, however, lie south of the equator.

Southern hemisphere proper-motion stars have generally received less attention than their northern counterparts, and as a result, even relatively bright objects in the current sample have no previous detailed measurements. Figure 1 shows the distribution on the celestial sphere and in the (m_r, m_r–K_s) color-magnitude plane of the 180 NLTT dwarfs targeted here.
MEETING THE COOL NEIGHBORS. II.

2.2. Photometry

All of the data were obtained (by D. K.) between 2001 February and July, using the St. Andrews photometer with a Hamamatsu R943-02 GaAs photomultiplier on the 1 m telescope at the Sutherland station of the South African Astronomical Observatory. Most observations were made through a 21′′ diameter, though a 31′′ diameter aperture was employed for poorer seeing. As discussed further below, the relatively large apertures sometimes lead to our photometry including a contribution from other stars at small angular separation.

The observations were made using a Johnson-Cousins BVRI filter set and were reduced using standard techniques from the NLTT Catalogue and the 2MASS database.

![Fig. 1.—The $(\alpha, \delta)$ and color-magnitude distributions of the stars in the present sample. The grid lines in the Aitoff projection in the top diagram are plotted at a spacing of 4h in right ascension. The bottom diagram combines photometry from the NLTT Catalogue and the 2MASS database.](image)

TABLE 1

| NLTT (1) | Name (2) | LHS (3) | J2000.0 (4) | (J2000.0) (5) | $m_v$ (6) | V (7) | B-V (8) | V-R (9) | V-J (10) | $n_{obs}$ (11) | J (12) | H (13) | K_s (14) | σ_{eig} (mas) (15) | Ref. (16) |
|----------|---------|---------|-------------|-------------|---------|------|--------|--------|---------|------------|------|-------|--------|----------|-------|
| -7:699... | G156    | 5087    | 03 54 35.4  | -06 49 34   | 9.5     | 9.03 | 1.37   | 0.86   | 1.62    | 1.59       | 6.471| 5.784 | 5.649 | 64 ± 1  | 1     |
| -8:2582... | G134    | 09 06 45.3 | -08 48 24   | 9.6       | 9.49   | 1.44 | 0.91   | 1.82   | 2.02    | 2.72       | 6.627| 5.986 | 5.774 | 68 ± 1  | 1     |
| -3:2870... | G382    | 10 12 17.6 | -03 44 43   | 9.8       | 9.4    | 1.34 | 1.00   | 2.18   | 2.80    | 2.64       | 5.886| 5.253 | 5.099 | 128 ± 1 | 1     |
| -11:2741... | G369    | 09 51 09.4 | -12 19 45   | 9.9       | 10.1   | 1.46 | 0.94   | 1.95   | 2.67    | 2.74       | 7.034| 6.398 | 6.160 | 84 ± 7  | 2     |
| -12:4523... | G628    | 419    | 16 30 18.0  | -12 39 43  | 9.9     | 10.06 | 1.56   | 1.15   | 2.67    | 1.99       | 5.961| ...   | 5.082 | 234 ± 1 | 1     |

Notes.—Table 1 is presented in its entirety in the electronic edition of the Astronomical Journal. A portion is shown here for guidance regarding its form and content. Col. (1) lists the designation from the NLTT Catalogue: R = Ross, W = Wolf, Oxf = Oxford catalog. We have added Lowell Observatory identifications (Giclas, Burnham, & Thomas 1971). Col. (2) lists an alternative name, usually from the pCNS3; col. (3) gives the LHS number; cols. (4) and (5) list the position of the 2MASS source; col. (6) lists $m_v$ from the NLTT, and cols. (7)–(10) list the optical photometry; col. (11) gives the number of observations; cols. (12)–(14) list the 2MASS photometry; col. (15) lists the trigonometric parallax, if available, and col. (16) gives the source of the astrometry: 1 = Hipparcos (ESA 1997); 2 = pCNS3; 3 = US Naval Observatory (Monet et al. 1992; Harrington et al. 1993). Units of right ascension are hours, minutes, and seconds, and units of declination are degrees, arcminutes, and arcseconds.

a $B-V$ too blue for VRIJKH, possibly because of contamination.

b Possible variable.

c Joint optical photometry for known binary: Ross 948/LP 735-11, $m_v(A) = 11.0$, $m_v(B) = 11.3$, $\Delta = 4''$; LP 793-24/25, $m_v(A) = 11.9$, $m_v(B) = 12.2$, $\Delta = 4''$; LP 675-76/77, $m_v(A) = 12.7$, $m_v(B) = 13.0$, $\Delta = 8''$; LP 726-11/12, $m_v(A) = 12.7$, $m_v(B) = 13.6$, $\Delta = 8''$.

d Two stars in aperture for optical photometry; in most cases the second star is too faint to affect the VRI data.
are faintest at those wavelengths, and we have excluded several measurements where the \( B/V \) color was clearly incompatible with the \( VRI \) data. Finally, G163-4 (LHS 2297) lies only 16\,000 from its brighter common proper motion companion, LHS 2296. Comparison between our data and photometry by Weis (1996) suggests that the latter star has contaminated our measurements, and we adopt the magnitudes listed by Weis for this star.

Four of the five outliers in the \( VIK \) plane are known binaries in which the components have similar magnitudes. All four are resolved by 2MASS, so the \( V-Ks \) color is therefore \( V(AB)-V(A) \). The fifth outlier in \( VIK \) is LP 779-34, which is also an outlier in \( BVK \). LP 779-33 is listed as a common proper motion companion in the NLTT but is several arcminutes distant (and bluer than our \( mr-Ks \) limit). The location of LP 779-34 on the two-color diagram probably reflects the contribution of a nearby, similar-magnitude field star to the SAAO photometry. The measured \( VRI \) colors suggest that the field star is also an M dwarf. We have taken the composite nature of the optical photometry for all of these stars into account in computing the photometric parallaxes given in §3.

2.3. Comparison with Previous Observations

A number of stars observed in the course of our present program are well-known nearby stars and have published broadband photometry. In particular, 26 stars were observed by Bessell (1990) in his survey of late-type dwarfs in the second Catalogue of Nearby Stars (Gliese 1969; Gliese & Jahreiss 1979), while 10 are included in Leggett's (1992) compilation of optical and near-infrared photometry and three were observed by the RECONS group (Patterson, Ianna, & Begam 1998). A further 31 are among the proper-motion stars observed by Weis (1991, 1993, 1996), and finally, 15 stars have photometry by Eggen (1987). The latter two sets of observations are on the Kron \( RI \) system, but we have used the transformations given by Bessell & Weis (1987) to transform to Kron-Cousins magnitudes. As noted above, we adopt Weis's data for G163-4.

Table 2 and Figure 4 show the statistical results from a comparison of our observations and data from the literature. We have excluded one observation from this comparison: Bessell lists \( V = 10.51 \) for Gl 386, while Weis lists \( V = 10.97 \). Our photometry agrees with the latter measurement, so we omit the former. The main discrepancies lie with Eggen's photometry, partly because his \( V-I \) measurements are given to the nearest 0.1 mag and may in some cases be estimates based on the \( R-I \) colors. Overall, the agreement is consistent with our internal estimate of the photometric uncertainties, and there is no evidence for any significant residual color terms.

3. DISTANCE ESTIMATES

Our goal in this project is the identification of stars likely to lie within 20 pc of the Sun. The NLTT sample discussed in this paper includes 71 stars already identified as such in the preliminary version of the Third Catalogue of Nearby Stars (Gliese & Jahreiss 1991, hereafter pCNS3). However, while all 180 stars are relatively bright, only 56 stars have trigonometric parallax measurements. As a result, we must rely on photometric parallax as our primary method of estimating distances. We have followed an identical approach to that outlined in Paper I, computing photometric parallaxes from the observed \( V-I, I-J, \) and \( V-Ks \) color indexes using the polynomial calibrations outlined in that paper, combining those estimates to give an averaged photometric distance estimate, and deriving our final distance estimate.
through a weighted average with the trigonometric measurement, should such exist. Following the discussion outlined in Paper I, we set a lower limit of ±0.3 mag to the weight assigned to the photometric distance modulus, and we note that the trigonometric parallax offers the best estimate of the distance to an individual star. The results are listed in Table 3, where we give the uncertainty associated with the individual measurements. As discussed above and in the notes to the table, we make due allowance for known binaries with joint optical photometry. Table 3 includes several wide common proper motion pairs, notably LP 890-44/45, CD −25°1553A/B, and CD −44°836/LP 993-116. In each case, the photometric parallaxes of both components agree within the formal uncertainties.

Figure 5 plots, as a function of $V-I$ color, the residuals between the individual distance modulus estimates and the final averaged value. The larger residuals, and systematic trend in $\delta[\text{avg.} - (I-J)]$, near $V-I = 2.9$ reflect the sharp steepening of the main sequence, and consequent larger uncertainties, at that color (see Paper I). Comparing the trigonometrically based distance modulus estimates against the averaged photometric parallax results gives

$$\langle(m-M)_\pi - (m-M)_\text{ph}\rangle = 0.01 \pm 0.81 \text{ mag}.$$  

Restricting the comparison to the 42 stars with $\pi_{\text{trig}}$ measured to an accuracy of 10% or better gives

$$\langle(m-M)_\pi - (m-M)_\text{ph}\rangle = 0.06 \pm 0.48 \text{ mag}.$$  

As Figure 5 shows, there is no evidence for significant systematic bias, and the residuals are broadly consistent with the expected uncertainties in the photometric parallax calibrations (Paper I). Table 3 gives our distance estimates for each star and identifies those likely to fall within the 20 pc distance limit. Figure 6 plots the distance distribution as a function of $V-I$ color.

4. DISCUSSION

Table 1 lists photometry for 180 NLTT systems, including at least four binary systems. Based on our distance estimates, 86 of those systems, including three binaries (Ross 948, LP 675-76/77, and LP 726-11/12) have distances of less than 20 pc, while a further 28 lie within 1 $\sigma$ of the 20 pc boundary. Sixty-one of the 114 systems are included in the pCNS3, but the remaining 48 are additions to nearby-star catalogs (although some are listed at the pre-CNS4 Web site).1 The additional stars are identified in the final column of Table 3. Moving the distance limit to 25 pc, the value adopted in the pCNS3, embraces 132 systems, 65 of which are not included in that catalog. Given the relatively bright magnitudes of the stars in our sample, this emphasizes the incompleteness of nearby-star surveys in the southern hemisphere.

Considering the immediate solar neighborhood, our distance estimates place 14 of the 180 stars within 10 pc of the Sun. Those systems include Gl 84, 190, 357, 382, 628, GJ 1065, and LHS 1731, all of which have trigonometric parallaxes that exceed 0.1. Four other stars are listed in the pCNS3: Gl 540.2 and LHS 2520, 1723, and 2836. The three new identifications are LP 993-116 ($M_F = 13.45$), LHS 6167 ($M_F = 14.63$), and Gl611-71 ($M_F = 14.76$). All three sys-

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1 At http://www.ari.uni-heidelberg.de/aricns.

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**TABLE 2**

| Reference        | Datum | $V$  | $V-R$  | $V-I$  | $N$ | $B-V$  | $N$ |
|------------------|--------|------|--------|--------|-----|--------|-----|
| Weis.............. | $\Delta$ | -0.010 | -0.006 | -0.005 | 33  | -0.010 | 23  |
|                  | $\sigma$ | 0.033 | 0.018  | 0.024  | 33  | 0.019  | 23  |
| Bessell.......... | $\Delta$ | -0.012 | -0.003 | -0.001 | 25  | -0.014 | 25  |
|                  | $\sigma$ | 0.022 | 0.009  | 0.014  | 25  | 0.017  | 25  |
| Eggen............. | $\Delta$ | -0.039 | -0.037 | -0.067 | 15  | 0.006  | 1   |
|                  | $\sigma$ | 0.106 | 0.082  | 0.139  | 15  | 1      |     |
| Leggett.......... | $\Delta$ | 0.002 | 0.004  | 0.013  | 10  | -0.024 | 8   |
|                  | $\sigma$ | 0.012 | 0.008  | 0.009  | 10  | 0.009  | 8   |
| Patterson et al. | $\Delta$ | 0.019 | -0.016 | 0.014  | 3   | ...    | ... |
|                  | $\sigma$ | 0.025 | 0.013  | 0.034  | 3   | ...    | ... |

Note.—Residuals are given in the sense $V_{\text{SAAO}} - V_{\text{other}}$.

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**Fig. 4.—** Comparison between our SAAO photometry and previously published data. Filled squares mark observations by Weis; open circles are from Bessell; open squares are from Eggen; triangles are from Leggett; and five-pointed stars are data from Patterson et al. The tick marks on the vertical scale correspond to intervals of 0.1 mag.
### Table 3
Distance Modulus Estimates for NLTT Stars

| NLT  | $(m - M)_{V-K}$ | $(m - M)_{V-I}$ | $(m - M)_{I-J}$ | $(m - M)_{ph}$ | $(m-M)_V$ | $d_f$ (pc) | $M_K$ | $M_V$ | 20 pc? |
|------|----------------|----------------|----------------|----------------|----------|-----------|-------|-------|--------|
|      | (2)            | (3)            | (4)            | (5)            | (6)      | (7)       | (8)   | (9)   | (10)   |
| 7:699....      | 0.79 ± 0.41    | 0.82 ± 0.40    | 0.92 ± 0.42    | 0.84 ± 0.24    | 0.94 ± 0.04 | 15.3 ± 0.3 | 4.72  | 8.10  | Y      |
| 8:2582........ | 0.61 ± 0.41    | 0.65 ± 0.40    | 0.66 ± 0.42    | 0.64 ± 0.24    | 0.81 ± 0.06 | 14.3 ± 0.4 | 5.00  | 8.72  | Y      |
| 3:2870........ | -0.77 ± 0.41   | -0.87 ± 0.40   | -0.54 ± 0.42   | -0.73 ± 0.24   | -0.54 ± 0.03 | 7.7 ± 0.1  | 5.56  | 9.79  | Y      |
| 11:2741........| 0.85 ± 0.41    | 0.71 ± 0.40    | 1.14 ± 0.42    | 0.90 ± 0.24    | 0.36 ± 0.20 | 13.2 ± 0.9 | 5.55  | 9.41  | Y      |
| 12:4523........| -1.85 ± 0.41   | -1.66 ± 0.40   | -1.56 ± 0.42   | -1.69 ± 0.24   | -1.85 ± 0.02 | 4.3 ± 0.0  | 6.92  | 11.90 | Y      |
| 788-6..........  | 0.37 ± 0.41    | 0.30 ± 0.40    | 0.80 ± 0.42    | 0.49 ± 0.24    | -0.23 ± 0.04 | 9.4 ± 0.2  | 6.59  | 11.04 | Y      |

**Notes.**—Table 3 is presented in its entirety in the electronic edition of the Astronomical Journal. A portion is shown here for guidance regarding its form and content. Col. (1) lists the designation from the NLTT Catalogue, adding Lowell Observatory identifications; col. (2) gives the distance modulus derived from the $V-K_s$ photometric parallax; cols. (3) and (4) list distance moduli based on $V-I$ and $I-J$, respectively, for stars with $I$-band photometry; col. (5) gives the weighted average of the photometric parallax measurements; col. (6) lists the distance modulus indicated by the trigonometric parallax; col. (7) gives our final estimate of the distance, based on a weighted average of the photometric average and the trigonometric result; cols. (8) and (9) list the resultant absolute magnitudes at $K$ and $V$, respectively; col. (11) indicates whether the star lies within our distance limit of 20 pc ("Y"), within 1 $\sigma$ of the boundary ("?"), or beyond the limit ("N"). A plus sign indicates that the star is not included in the pCNS3.

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**Fig. 5.**—Residuals between the averaged distance modulus and individual estimators plotted as a function of $V-I$ color. The increased residuals near $V-I \sim 2.9$ reflect the steepening in the main sequence at that color.
tems have formal distance estimates between 6 and 7 pc. As noted above, LP 993-116 is identified in the NLTT as a common proper motion companion, separation $44\arcsec$, of CD $-44\arcdeg 836$, an M5 dwarf. The latter star is in our sample, and we derive an estimated distance of 10.5 pc. Given the individual uncertainties, the agreement is reasonable.

There are currently approximately 250 systems known with 10 pc of the Sun. Thus, the five new identifications listed in this paper and Paper I represent an increase of only $\sim$2% in the inferred local stellar space density. However, these additions are drawn from a relatively well studied subset of our NLTT candidates. Combined with the literature data discussed in Paper I, we have optical photometry and photometric parallaxes for 649 of the 1245 stars in NLTT sample 1, while a further 39 ultracool dwarfs have distance estimates based on either optical spectroscopy or $J$–$K_s$ colors. Four hundred fifty-six of those stars are identified as potentially within 20 pc of the Sun. Subsequent papers in this series will provide distance estimates for the remaining 596 stars in NLTT sample 1 and also extend coverage to include NLTT dwarfs that lack 2MASS counterparts within 10" of the nominal position.

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Fig. 6.—Distance distribution of the stars in Table 1 as a function of both $V-I$ color and the inferred absolute magnitude. The dotted line marks a distance of 20 pc.