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MEETING THE COOL NEIGHBORS. VIII. A PRELIMINARY 20 PARSEC CENSUS FROM THE NLTT CATALOGUE

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ABSTRACT

Continuing our census of late-type dwarfs in the solar neighborhood, we present *BVRI* photometry and optical spectroscopy of 800 mid-type M dwarfs drawn from the NLTT proper-motion catalog. The targets are taken both from our own cross-referencing of the NLTT Catalogue and the 2MASS Second Incremental Data Release, and from the revised NLTT compiled recently by Salim & Gould. All are identified as nearby-star candidates based on their location in the (m_r, m_r–K_s) diagram. Three hundred stars discussed here have previous astrometric, photometric, or spectroscopic observations. We present new *BVRI* photometry for 101 stars, together with low-resolution spectroscopy of a further 400 dwarfs. In total, we find that 241 stars are within 20 pc of the Sun, while a further 70 lie within 1 σ of our distance limit. Combining the present results with previous analyses, we have quantitative observations for 1910 of the 1913 candidates in our NLTT nearby-star samples. Eight hundred fifteen of those stars have distance estimates of 20 pc or less, including 312 additions to the local census. With our NLTT follow-up observations essentially complete, we have searched the literature for K and early-type M dwarfs within the sampling volume covered by the 2MASS second release. Comparing the resultant 20 pc census against predicted numbers, derived from the 8 pc luminosity function, shows an overall deficit of ~20% for stellar systems and ~35% for individual stars. Almost all are likely to be fainter than $M_J = 7$, and at least half are probably as yet undiscovered companions of known nearby stars. Our results suggest that there are relatively few missing *systems* at the lowest luminosities, $M_J > 8.5$. We discuss possible means of identifying the missing stars.

Key words: Galaxy: stellar content — stars: low-mass, brown dwarfs — stars: luminosity function, mass function

On-line material: machine-readable tables

1. INTRODUCTION

It is by now a cliché (particularly after this set of papers) that M dwarfs are the most populous members of the Galactic disk. M subdwarfs probably dominate the Galactic halo to a similar extent. It is also now well established that the most recently published local census, the third Catalogue of Nearby Stars (CNS3; Gliese & Jahreiss 1991), becomes incomplete for early-type dwarfs at a distance of ~20–22 pc and is barely complete within 5 pc for spectral types later than M6 (Reid et al. 2002a, hereafter PMSU4; Henry et al. 2002). Thus, while *Hipparcos* (ESA 1997) has given us a complete catalog of over 1000 G dwarfs within 30 pc of the Sun, the statistical properties of dwarfs such as Proxima Cen rest on observations of a volume-complete sample of a mere half-dozen stars.

We are using data from the Two Micron All Sky Survey (2MASS; Skrutskie et al. 1997) to address this issue in a project carried out under the auspices of the NASA/NSF NStars initiative. Our goal is to compile a statistically complete

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census of late-type dwarfs (spectral types late K, M, and L) within 20 pc of the Sun. With the publication of the eighth paper in this series, we provide an assessment of progress toward that goal and map out likely developments in the immediate future.

So far, we have employed two distinct, complementary techniques to identify unrecognized constituents of the immediate solar neighborhood: first, we have used near-infrared photometry to identify ultracool dwarfs (spectral types M7 and later) directly from the 2MASS database; second, we have searched for nearby early- and mid-type M dwarfs by cross-referencing stars in the NLTT proper-motion catalog (Luyten 1980) against the 2MASS data. We have pursued both avenues of exploration in parallel. In both cases, our analysis to date is restricted to the 48% of the sky covered by the 2MASS Second Incremental Data Release (hereafter the 2M2nd), with only limited coverage of regions within 10° of the Galactic plane.

Ultracool dwarfs can be identified directly from 2MASS data alone, since they have distinctively red near-infrared colors, with $J-K_s$ increasing from a color of ~1.0 mag at spectral type M7.5 to over 1.8 mag for late-type L dwarfs. The onset of methane absorption reverses this trend in L8 dwarfs at temperatures of 1300–1400 K (Tsuji 1964; Kirkpatrick et al. 1999; Golimowski et al. 2004). We have used the location of 2MASS point sources in both the (J, $J-K_s$) color-magnitude diagram and in the two-color ($J-H$, $H-K_s$) diagram to select candidate dwarfs within 20 pc of the Sun. The results from this thread of our project are published as follows:

Paper IV (Reid et al. 2003) presents the initial result from the ultracool survey, the identification of an M8 dwarf within 6 pc of the Sun.

Paper V (Cruz et al. 2003) provides a thorough description of the selection criteria used to compile the ultracool sample (the 2MU2 sample) and discusses optical spectroscopy of 298 candidates. The 2MU2 sample is limited to $|b| > 10°$ and specifically excludes areas near star formation regions.

Paper VI (Reid 2003) represents a first attempt to extend photometric ultracool surveys to the Galactic plane, with only limited success.

Paper IX (Cruz et al. 2004) presents observations of the remaining 2MU2 targets accessible to optical spectroscopy on 4 m class telescopes, discusses sample completeness, and derives the luminosity function for spectral types M8 to L7.

Building on these results, we have used analysis of the 2MASS All-Sky Data Release to compile an all-sky high-latitude ($|b| > 15°$) sample of ultracool dwarfs. Follow-up observations of that sample are almost complete, and the initial results, based on optical spectroscopy, will be presented in Paper X in this series. In addition, we have obtained infrared spectroscopy of the faintest ultracool candidates from both samples, and those results will be presented in Paper XI.

Early- and mid-type M dwarfs do not possess the easily recognizable near-infrared colors of ultracool dwarfs, so additional information is required to segregate the nearby stars among the 10^8 sources in the 2M2nd point-source catalog. Proper motion offers a well-tried method of identifying stars in the vicinity of the Sun. The most extensive proper-motion catalogs currently available are those compiled by W. Luyten using photographic material, primarily plates taken with the 48 inch (1.2 m) Palomar Oschin Schmidt. For a variety of reasons, principally the limited information offered by the cataloged photometry, these resources have been little exploited. However, Monte Carlo simulations based on standard disk kinematics (PMSU4) show that between 88% and 90% of stars within 20 pc are expected to have motions $\mu > 0''.18$ yr^{-1}, the proper-motion limit of Luyten's NLTT survey. We have therefore cross-referenced the NLTT Catalogue against the 2MASS database and searched for nearby-star candidates using the optical/infrared colors derived by combining Luyten's red magnitudes, m_r, with the 2MASS JHK_s photometry. The results from this second thread have appeared as follows:

Paper I (Reid & Cruz 2002) outlines the optical/near-infrared color-magnitude criteria that have been used to identify candidate nearby stars. Based on those criteria, we selected two parent samples of NLTT dwarfs, limiting the analysis to $|b| > 10°$: NLTT1, consisting of 1237 NLTT stars with 2M2nd counterparts within 10″ of the predicted NLTT location; and stars not included in the NLTT1 sample but which have 2M2nd sources within 60″ of the predicted position. Literature data were compiled for 469 stars and distance estimates derived using $V-I$, $I-J$, and $V-K_s$ color-magnitude relations. We place 308 of those stars within 20 pc of the Sun.

Paper II (Reid et al. 2002b) presents *BVRI* photometry of 180 southern NLTT1 stars and the corresponding photometric parallax estimates. One hundred eight stars have formal distances estimates less than 20 pc.

Paper III (Cruz & Reid 2002) describes spectroscopic observations of 70 NLTT dwarfs and summarizes the techniques adopted to derive both spectral types and spectrophotometric parallax. Nineteen stars fall within our 20 pc distance limit.

Paper VII (Reid et al. 2004) includes photometric and spectroscopic observations of 453 dwarfs from the NLTT1 sample; we find that 111 of those stars are likely to lie within 20 pc of the Sun.

The present paper completes our NLTT survey, presenting photometric and spectroscopic observations and distance estimates not only for the remaining stars in the NLTT1 sample, but also for candidate nearby stars from two other NLTT samples, NLTT2 and NLTT3, where the latter is derived from Salim & Gould's (2003) revised NLTT Catalogue.

We do not propose to extend our NLTT-based survey to cover the full celestial sphere by extending analysis to the 2MASS All-Sky Data Release—with observations of half of the sky, we have sufficient numbers for statistically significant analyses of the intrinsic properties of K- and M-type dwarfs. However, as discussed in more detail in the concluding sections of this paper, we are exploring the potential of using other techniques to identify nearby early- and mid-type M dwarfs that lie within the area covered by 2M2nd but are not in the NLTT Catalogue.

Previous papers in the NLTT series have concentrated on follow-up observations of the NLTT1 sample. Of the 58,818 NLTT stars, 23,795 meet this criterion; distance estimates for 1090 of the 1237 NLTT1 nearby-star candidates are given in Papers I–VII. The current paper completes observations of that sample and extends coverage to nearby-star candidates from two other NLTT-based samples. First, as described in Paper I, the NLTT1 stars exhibit distinct "holes" in their (α, δ) distribution—notably near the north celestial pole and the south Galactic pole. Many of the unmatched NLTT stars in those holes have 2M2nd sources within 60″ (see Fig. 3 of Paper I), suggesting the presence of systematic offsets in the NLTT astrometry. The latter stars, together with NLTT-2MASS pairs lying at low latitude ($|b| < 10°$), constitute the NLTT2 sample.

Second, we have taken advantage of the independent analysis of the NLTT Catalogue by Salim & Gould (2003). As with our own study, these authors match NLTT stars against the 2M2nd database, although their analysis is limited to regions that overlap the first Palomar Sky Survey (POSS I; effectively, $\delta > -33°$). Salim & Gould have gone to considerable length to correct typographical errors in the original catalog, and they recover 97% of the NLTT dwarfs brighter than $m_r = 17$, and 85% to $m_r = 18$. Coupled with their analysis of *Hipparcos* and Tycho data for brighter stars (Gould & Salim 2003), the revised NLTT Catalogue (rNLTT) includes data for 28,379 stars with infrared photometry from the 2M2nd database. Covering almost the same ground as our own survey, the rNLTT provides both independent verification of our NLTT1 and NLTT2 samples and a means of identifying new candidates. We have therefore compiled a third list of candidate nearby stars, the NLTT3 sample, by applying our (m_r, m_r–K_s) selection criteria to the rNLTT.

The present paper is organized in the following manner: Section 2 describes the NLTT2 sample in more detail, summarizing previously published photometric and spectroscopic data available for those stars. Section 3 provides a similar function for the NLTT3 sample. New *BVRI* photometric observations of stars from both samples are presented in § 4, while § 5 presents optical spectroscopy of stars from all three samples, NLTT1, NLTT2, and NLTT3. Combining all of these results, we can derive reliable distance estimates for 1910 of the 1913 NLTT nearby-star candidates. Section 6 expands the discussion to include early-type M and K dwarfs, drawn from the NLTT and other catalogs, and combines all of the data sets to give a 20 pc census for the part of the sky covered by the 2M2nd. We discuss the statistical properties of the resulting catalog, notably the luminosity function and the binary fraction, in § 7 and compare those properties against similar data for the northern 8 pc sample (Paper IV) and for the 25 pc bright-star census compiled by PMSU4. Section 8 outlines possible methods for identifying additional stars within our 20 pc limit, and the final section, § 9, presents our conclusions.

2. THE NLTT2 SAMPLE

2.1. *Defining the Sample*

Approximately 34,000 NLTT stars either lack a 2M2nd source within 10″ of the predicted position or lie within 10° of the Galactic plane. These stars are not included in the NLTT1 sample, and the overwhelming majority lie beyond the bounds of the 2M2nd. However, expanding the search radius to 60″ for proper-motion stars with $|b| > 10°$ results in matches between 5720 NLTT stars and 25,305 2MASS sources. We have also cross-referenced the two catalogs at lower Galactic latitudes, but with the search radius limited to 10″ to minimize confusion. A total of 886 NLTT dwarfs are matched against 1951 2MASS sources. The final NLTT2 sample is derived by combining these two data sets.

Most of the pairings generated by this exercise are obviously spurious—with a search radius of 60″, many NLTT stars are matched against six or more separate 2MASS sources, even at moderate Galactic latitudes. We have trimmed the list by applying the (m_r, m_r–K_s) color-magnitude selection criteria outlined in Paper I. This reduces the sample to 1468 NLTT-2MASS pairs with colors consistent with nearby M dwarfs, but many of those pairings have incompatible near-infrared colors. Figure 1 plots the (m_r–J, J–K_s) and (J–H, H–K_s) two-color diagrams for all 1468 candidates. The latter diagram also shows the loci of main-sequence dwarfs and red giants, and we have outlined schematically the regions occupied by dwarfs later than spectral type ≈M3 (H–$K_s \geq 0.19$). There are obviously many mismatched red giants among the current candidates, which is not surprising given that this data set includes many NLTT dwarfs close to the plane. Eliminating pairs that have JHK_s colors inconsistent with M or L dwarfs reduces the NLTT2 candidate list to 514 targets.

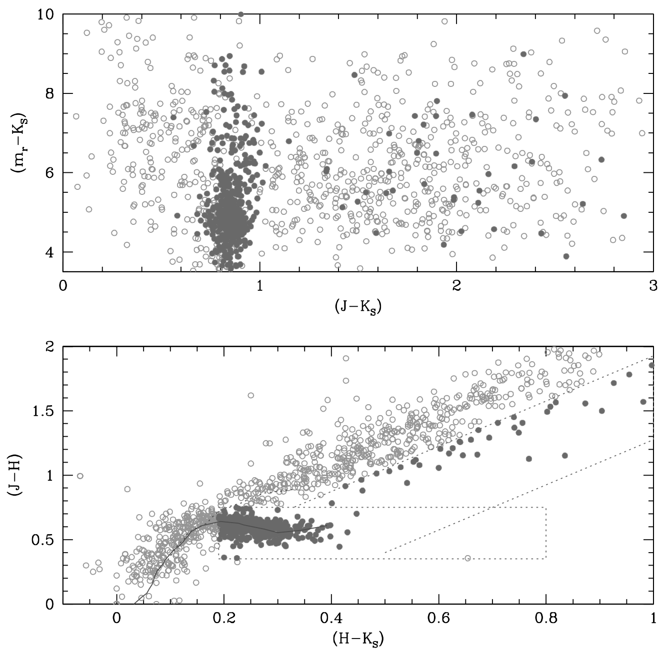

Fig. 1.—Optical and near-infrared color-color diagrams for the 1468 NLTT2 nearby-star candidates. The dotted lines in the JHK_s diagram outline the schematic M dwarf (*horizontal region*) and L dwarf regimes, and sources with dwarflike (J–H, H–K_s) colors are plotted as filled points in both diagrams. All sources that fall in the L dwarf segment in the JHK_s plane have $J - K_s > 1.2$ and implausible $m_r - K_s$ colors; these are likely to be background red giants and mismatched NLTT-2MASS pairings.

Thirty-four of the remaining 514 candidates fall in the L dwarf segment of the JHK_s diagram, although most lie suspiciously close to the giant sequence. Unfortunately, all of these candidates are found in implausible locations in the (m_r–J, J–K_s) diagram, with most having implausibly blue m_r–J colors, so we have not succeeded in finding an L dwarf in the NLTT Catalogue. These are likely to be mismatches to late-type red giants, lying on the redder edge of the giant sequence in the JHK_s diagram. We have eliminated all 34 accordingly. Visual inspection of 2MASS and POSS/UKST photographic images shows that a further 111 pairings are mismatches, either between components in a common proper motion binary or with a random field star. Thus, the final NLTT2 includes 369 candidate nearby M dwarfs. Of these, 117, or approximately one-third, lie within 10° of the Galactic plane.

2.2. *Known Nearby Stars*

A substantial number of NLTT2 stars are already known as denizens of the immediate solar neighborhood. One hundred nineteen stars are included in the CNS3, and most of these were observed as part of the Palomar/Michigan State

University spectroscopic survey (Reid et al. 1995, hereafter PMSU1; Hawley et al. 1996, hereafter PMSU2). Other stars have published spectroscopy, multicolor photometry, or even trigonometric parallax measurements. Those measurements are sufficient to allow reliable distance estimation for 168 of the 369 NLTT2 candidate nearby stars.

Distances are based on the following sources: Sixty-five stars were either observed directly by *Hipparcos* or are companions of brighter stars with *Hipparcos* data and have milliarcsecond-accuracy trigonometric parallaxes. A further 48 stars have ground-based trigonometric parallaxes, including 41 with measurements accurate to $\sigma_\pi/\pi < 0.15$. One hundred twelve NLTT2 stars have published *VRI* photometry and an additional 56 stars have *BV* photometry, allowing photometric parallaxes to be estimated using the color-magnitude relations given in Paper I. Finally, 110 stars have published spectroscopy and spectroscopic parallax estimates. Table 1 collects the available data and summarizes the resulting distance estimates. Ninety-six of the 168 stars in this table have formal distance estimates less than 20 pc, while a further 12 stars lie within 1 σ of the 20 pc limit.

3. THE NLTT3 SAMPLE

3.1. *Defining the Sample*

We have selected nearby-star candidates from the rNLTT (Salim & Gould 2003) using the same (m_r, m_r–K_s) color-magnitude criteria employed in constructing the NLTT1 and NLTT2 samples. A total of 1908 stars meet those criteria, including 1523 stars that are already included in either the NLTT1 or NLTT2 sample. We have cross-referenced the latter stars against our own results and find no discrepancies—that is, both our analysis and the rNLTT match the NLTT dwarfs against the same 2M2nd sources. This includes several cases where that match is incorrect, as discussed further below. The remaining 385 stars are the base NLTT3 sample. A number of those candidates, however, have optical/near-infrared colors that are inconsistent with those of late-type dwarfs.

The rNLTT supplements the red and photographic magnitudes given in the original NLTT with photometry from a variety of sources, notably the USNO-A catalog (Monet et al. 1998) and the Tycho database (Høg et al. 2000). Salim & Gould use those additional data to estimate V magnitudes for each source. Figure 2 plots color-color diagrams for all 1908 color-selected rNLTT stars. The majority have near-infrared colors consistent the M dwarf sequence, but a number of sources are unexpectedly blue in either V–J or J–K_s for the inferred m_r–K_s.

We have identified 46 of the 1908 rNLTT nearby-star candidates that meet at least one of the following criteria:

$$m_r–K_s > 14.44(J–K_s) - 4.44,$$
$$m_r–K_s > 0.91(V–J) + 3.09.$$

These linear relations are plotted in Figure 2. We have checked each outlier using both 2MASS images, provided by the Infrared Source Archive (IRSA), and digitized scans of the POSS/UKST plates maintained at Canadian Data Centre, and our conclusions are listed in Table A1. In a number of cases, the fault lies with either the NLTT photometry or the 2MASS data (usually saturation in the 2M2nd), and generally, those stars are retained in our observing program. However, the majority are misidentifications or merged images. In most cases, the mismatched stars are from common proper motion binary systems, where the fainter optical component (often a white dwarf [WD]) has been matched against 2MASS data for the primary, resulting in an apparently red m_r–K_s color. Salim & Gould explicitly identified this as a potential issue in using the rNLTT, and some of the same mismatches were in our original NLTT1 sample.

Overall, the rNLTT has a false-identification rate of only ~1% (Salim & Gould 2003). However, our selection criteria, targeting sources with the reddest m_r–K_s colors, are ideally suited for turning up mismatched optical/near-infrared sources. We have therefore used the IRSA 2MASS images and photographic Sky Survey data to verify that the base NLTT3 candidates are matched correctly. Table A2 lists a further 63 entries from the rNLTT that either are mismatches with the incorrect 2MASS source or have unreliable m_r–K_s colors due to the close proximity of another star (usually a binary companion). Combining Tables A1 and A2, 78 stars in the base NLTT3 sample are eliminated, giving a final target list of 307 nearby-star candidates from the rNLTT.

3.2. *Known Nearby Stars*

Many NLTT3 stars have previous observations, and we can estimate reliable distances in 151 cases, almost half of the sample. The relevant data for those stars are given in Table 2. Ninety-seven stars have trigonometric parallax data, including 68 stars with either direct *Hipparcos* astrometry or *Hipparcos* measurements of bright companions. One hundred forty-eight stars have at least V-band photometry, including 80 with $V(R)I$ measurements. We have estimated photometric parallaxes for these systems using the color-magnitude relations defined in Paper I, combining individual estimates (including trigonometric data, as appropriate) using the precepts outlined in Paper VII.

Two stars require particular comment. LP 320-16 (G148-47) and G148-48 form a binary system, separation ~4.″5. Fleming (1998) obtained *VI* photometry of this system as part of his follow-up observations of candidate nearby M dwarfs from the *ROSAT* catalog. He derived a photometric distance of 11.2 pc for G148-47, using the linear (M_V, V–I) calibration derived by Stobie et al. (1989). However, no allowance was made for the presence of G148-48, which was included in the photometric aperture (T. Fleming 2003, private communication). We assume Fleming's measurements provide joint photometry of the two stars. Based on inspection of the POSS II images and the 2MASS near-infrared photometry,[2] the two stars have very similar magnitudes and colors, and we assume equal magnitudes in calculating the V magnitudes listed in Table 2. The revised distance estimate for the system is ~12.5 pc.

Eighty-six stars from Table 2 are listed in the CNS3, including 51 that we place within 20 pc of the Sun. In total, 63 stars (in 62 systems) have formal distance estimates less than 20 pc, while 13 stars (from 12 systems) lie within 1 σ of the 20 pc distance limit.

4. NEW PHOTOMETRIC OBSERVATIONS

Photometric follow-up observations of stars from both the NLTT2 and NLTT3 samples were obtained between 2001 December and 2002 July, using the St. Andrews photometer

[2] Note that the data listed in Table 2 for these two stars are from the 2MASS All-Sky Data Release, which provides more accurate photometry for stars in crowded environments.

TABLE 1

KNOWN NEARBY STARS FROM NLTT2

Name (1)	Other (2)	α (J2000) (3)	δ (J2000) (4)	m_r (5)	J (6)	H (7)	K_s (8)	V (9)	$B-V$ (10)	$V-R$ (11)	$V-I$ (12)	Src. (13)	π_{trig} (mas) (14)	Src. (15)	Sp. Type (16)	$m-M$ (17)	M_J (18)	Comment[a] (19)
G130-53[b]	LHS 1037	00 11 56.5	33 03 17	12.4	9.04	8.40	8.12	13.00	1.62	1.12	2.56	1	...	...	...	1.55 ± 0.30	7.49	
86-67	LHS 1049	00 15 43.4	−67 59 35	13.8	8.85	8.24	7.96	12.50	...	1.07	2.39	10	...	...	M2.5	1.77 ± 0.23	7.08	
86-66[b]	LHS 1051	00 15 51.4	−67 59 51	11.6	7.84	7.21	6.93	10.95	...	...	...	10	...	...	M0.5	1.52 ± 0.23	6.32	
404-80	G131-50	00 17 58.6	20 57 19	12.0	8.67	8.03	7.83	11.76	...	0.94	2.00	1	...	...	...	2.42 ± 0.30	6.25	1
881-64[c]	GJ 2005	00 24 44.2	−27 08 25	14.4	9.26	8.53	8.23	15.42	...	1.84	4.02	7	133 ± 9	2	M5.5	−0.69 ± 0.13	9.95	Triple

NOTES.—Units of right ascension are hours, minutes, and seconds, and units of declination are degrees, arcminutes, and arcseconds. Col. (1) lists the designation from the NLTT Catalogue: (R) Ross; (W) Wolf; (Oxf) Oxford catalog. We have added Lowell Proper Motion Survey identifications (Giclas et al. 1971) where appropriate. Col. (2) lists an alternative name, usually from either the CNS3 or the LHS Catalogue; cols. (3) and (4) list the position of the 2MASS source; col. (5) gives the Luyten m_r magnitude; cols. (6)–(8) list the 2MASS photometry; cols. (9)–(12) list the optical photometry, and col. (13) gives the source: (1) Weis 1984, 1986, 1987, 1988, 1991a, 1991b, 1996; (2) *Hipparcos* (ESA 1997); (3) CNS3; (4) Reid 1990; (5) Bessell 1990; (6) Leggett 1992; (7) Patterson et al. 1998; (8) Ryan 1989, 1992; (9) Caldwell et al. 1984; (10) Eggen 1987; (11) Fleming 1998; (12) Laing 1989; (13) USNO, Harrington et al. 1993 and references therein; (14) Dawson & Forbes 1989, 1992; (15) Sandage & Kowal 1986; (16) Norris et al. 1999; (17) van Altena et al. 1995. Col. (14) lists the trigonometric parallax and uncertainty, and col. (15) gives the source: (1) *Hipparcos* (ESA 1997); (2) Ianna & Bessell 1986; (3) Harrington & Dahn 1980; (4) CNS3; (5) Dahn et al. 1988; (6) Oppenheimer et al. 2001, van Altena et al. 1995. Col. (17) gives the estimated distance modulus, and col. (18) the corresponding M_J. 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.

[a] Comments: (1) common proper motion (CPM) companion of G131-51; (2) CPM LP 193-584; (3) CPM G172-34; (4) binary (Jao et al. 2003); (5) CPM HD 263175; (6) CPM G40-7.

[b] Star with formal distance estimate within 1 σ of 20 pc.

[c] Star with formal distance estimate $d \leq 20$ pc.

TABLE 2

KNOWN NEARBY STARS FROM NLTT3

Name (1)	Other (2)	α (J2000) (3)	δ (J2000) (4)	m_r (5)	J (6)	H (7)	K_s (8)	V (9)	$B-V$ (10)	$V-R$ (11)	$V-I$ (12)	Src. (13)	π_{trig} (mas) (14)	Src. (15)	Sp. Type (16)	$m-M$ (17)	M_J (18)	Comment[a] (19)
G217-40	...	00 15 14.6	53 04 45	14.6	10.80	10.21	9.97	14.39	...	1.04	2.38	1	...	...	...	3.91 ± 0.30	6.89	
404-81	G131-50	00 17 59.2	20 57 24	11.0	8.24	7.57	7.41	11.08	...	0.88	1.79	1	...	...	...	2.30 ± 0.30	5.94	
585-86[b]	BRI 0021	00 24 24.6	−01 58 19	19.0	12.02	11.08	10.54	19.42	...	2.20	4.46	10	83 ± 3	4	M9.5	0.42 ± 0.09	11.60	
W4....................	Gl 22.1	00 33 05.6	42 00 05	11.3	8.31	7.63	7.49	10.94	1.31	...	...	2	29 ± 2	1	M0.0	2.64 ± 0.16	5.67	
350-20[b]	LTT 10301A	00 50 33.2	24 49 00	11.7	7.92	7.33	7.09	12.09	...	1.18	2.72	1	83 ± 9	1	M3.5	0.33 ± 0.16	7.59	

NOTES.—Col. (1) lists the designation from the NLTT Catalogue: (R) Ross; (W) Wolf; (Oxf) Oxford catalog. We have added Lowell Proper Motion Survey identifications (Giclas et al. 1971) where appropriate. Col. (2) lists an alternative name, usually from either the CNS3 or the LHS Catalogue; cols. (3) and (4) list the position of the 2MASS source; col. (5) gives the Luyten m_r magnitude; cols. (6)–(8) list the 2MASS photometry; cols. (9)–(12) list the optical photometry, and col. (13) gives the source: (1) Weis 1984, 1986, 1987, 1988, 1991a, 1991b, 1996; (2) *Hipparcos* (ESA 1997); (3) CNS3; (4) Sandage & Kowal 1986; (5) Ryan 1989, 1992; (6) Leggett 1992; (7) Bessell 1990; (9) Koen et al. 2002; (9) Phan-Bao et al. 2001; (10) Dahn et al. 2002; (11) Stauffer et al. 1991; (12) Fleming 1998. Col. (14) lists the trigonometric parallax and uncertainty; col. (15) gives the source: (1) *Hipparcos* (ESA 1997); (2) CNS3; (3) Dahn et al. 2002; (4) van Altena et al. 1995. Col. (17) gives the estimated distance modulus, and col. (18) the corresponding value of M_J. Table 2 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.

[a] Comment: (1) LP 320-16/G148-48—joint optical photometry, JHK_s data taken from 2MASS all-sky release.

[b] Star with formal distance estimate $d \leq 20$ pc.

[c] Star with formal distance estimate within 1 σ of 20 pc.

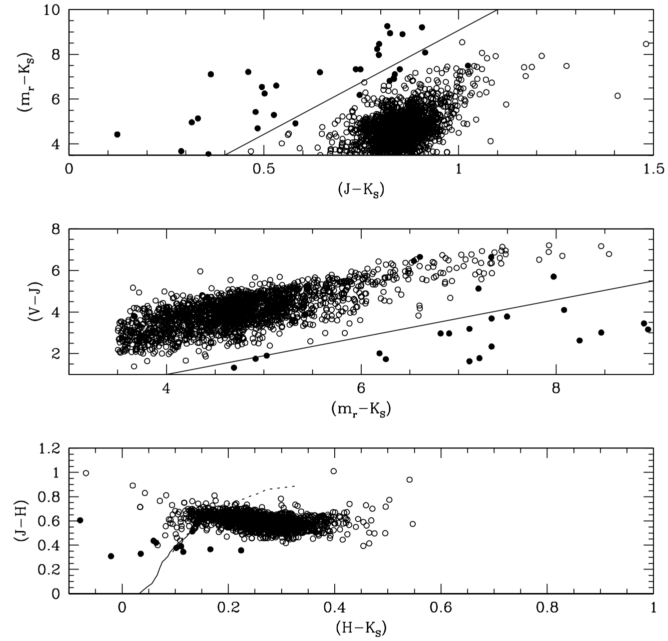

FIG. 2.—Optical/near-infrared color-color diagrams for 1908 nearby-star candidates selected from the rNLTT. We show the mean relation for dwarfs (*solid line*) and giants (*dotted line*) in the JHK_s plane. While most candidates have self-consistent optical/near-infrared colors, there are a number of outliers. We have used the linear relations plotted in the top two panels to pick out the most extreme examples, identified as filled points. Those stars are listed in Table A1.

on the 1 m telescope at the Sutherland station of the South African Astronomical Observatory. As discussed in more detail in Papers II and VII, that photometer is equipped with a Hamamatsu R943-02 GaAs photomultiplier, and observations were made using a Johnson-Cousins *BVRI* filter set. Most measurements used a 21″ diameter aperture, with a 31″ aperture employed for conditions of poor seeing. The relatively large aperture sizes led to the inclusion of other stars in a few cases, as noted further below.

The observations were reduced using identical methods to those outlined in Papers II and VII (see also Kilkenny et al. 1998). The photometry was calibrated using both E-region standards (Cousins 1973; Menzies et al. 1989) and redder standards from Kilkenny et al. (1998). None of the program stars have previous observations, but we have demonstrated that our photometry is consistent with the standard Cousins systems to better than 1%. The formal uncertainties of our program-star measurements seldom exceed 2%, and uncertainties in the derived photometric parallaxes are dominated by the intrinsic width of the main sequence ($\sigma = 0.25$–0.4 mag; see Paper I).

Table 3 presents the results—observations of 77 stars from the NLTT2 sample and 24 stars from NLTT3. In addition to the optical data, we list the positions and near-infrared photometry from the 2M2nd.[3] Several stars with multiple measurements have unexpectedly high residuals and may be variable at the 5%–10% level (see notes to Table 3). We have estimated photometric parallaxes using the $V-I$, $I-J$, and $V-K$ calibrations given in Paper I, combining the individual estimates using the same weighting scheme outlined in Papers II and VII. Nineteen stars in Table 3 are formally within 20 pc, while two others have photometric distances within 1 σ of that limit.

5. SPECTROSCOPY

5.1. *Observations*

We have obtained moderate-resolution spectroscopic follow-up observations of 448 stars, including 120 stars from the NLTT1 sample, 186 from NLTT2, and 142 from NLTT3. The observations were made by several different observing teams using facilities at Kitt Peak National Observatory (2.1 and 4 m telescopes), Cerro Tololo Inter-American Observatory (1.5 and 4 m telescopes), and Apache Point Observatory (3.5 m telescope). All of the spectra cover the wavelength range 6000–10000 Å at a resolution of 2–3 Å. Most observations of NLTT2 and NLTT3 stars were made in tandem with the NLTT1 observations described in Paper VII, and full details of the instrumentation, observers, and observing conditions for those observing runs are given in that paper. However, the present paper also includes observations from three more recent time allocations, as follows:

1. I. N. R. and K. L. C. used the GoldCam spectrograph with the KPNO 2.1 m telescope on 2003 October 8, 9, and 11 to obtain spectra of 130 candidate nearby stars, including most of the NLTT1 stars listed in this paper. As before, the 400 line mm^{-1} grating, blazed at 8000 Å, was employed with an OG 550 order-blocking filter, giving spectra covering the wavelength range 6000–10000 Å at a resolution of 4.3 Å. Conditions were generally nonphotometric, with high cirrus often present. Observations were made using a 1″.5 slit, matching the seeing.
2. K. R. C. obtained spectra of eight stars using the Double Imaging Spectrograph (DIS II) on the 3.5 m telescope at Apache Point Observatory on 2003 October 31. The medium-resolution (300 line mm^{-1}) grating was employed on the red camera, covering the 6000–10000 Å region at a dispersion of 3.15 Å pixel^{-1} and a resolution of 7.3 Å.
3. Finally, I. N. R. and K. L. C. were able to observe 43 nearby-star candidates using the Multi-Aperture Red Spectrometer on the 4 m Mayall Telescope on 2004 February 11, 12, and 13. The VG 0850-450 grism was used with a 1″.5 slit, giving ~6 Å spectral resolution. Conditions were clear and photometric for these observations.

All spectra were bias-subtracted, flat-fielded, corrected for bad pixels, extracted, and wavelength- and flux-calibrated using the standard IRAF routines CCDPROC and DOSLIT. Wavelength calibrations were determined using HeNeAr arcs taken at the start of each night. The spectra were flux-calibrated using observations of standard stars from Oke & Gunn (1983) and Hamuy et al. (1994). At least one flux standard was observed each night, and comparison of repeated independently calibrated observations of individual program stars indicates that the derived spectral energy distributions are consistent to better than 5% over the full wavelength range. This is more than adequate for the purposes of this program.

As in previous studies, we have calculated a series of narrowband indices, measuring the strengths of the more prominent molecular absorption features. Indices measuring TiO (7020 Å band), CaH (6300 and 6800 Å), CaOH (6250 Å), VO (7300 Å), and Hα are given in Table 4. The bandpasses are defined in PMSU1 and Kirkpatrick et al. (1999). As discussed in Paper VII, standard-star measurements from our observing runs show good agreement with previously published data, with no evidence of systematic offsets and typical rms residuals

[3] Note that slight changes in both the astrometry and photometry of these objects may be present in the final 2MASS data release.

TABLE 3
SAAO Photometry of NLTT2 and NLTT3 Stars

Name (1)	Other	α (J2000) (2)	δ (J2000) (3)	m_r (4)	J (5)	H (6)	K_s (7)	V (8)	$B-V$ (9)	$V-R$ (10)	$V-I$ (11)	N_{obs} (12)	$m-M$ (13)	M_J (14)	Comment[a] (15)
							NLTT2								
644-94	...	00 09 13.5	−04 08 02	12.0	8.60	7.94	7.71	12.03	1.51	1.02	2.23	1	1.87 ± 0.23	6.73	
880-803	...	00 16 20.1	−31 27 39	13.3	9.53	8.91	8.68	13.01	...	1.03	2.29	1	2.79 ± 0.23	6.74	
464-511	...	00 17 11.8	14 54 52	13.9	10.09	9.45	9.23	13.70	...	1.06	2.37	1	3.16 ± 0.30	6.93	
86-93	...	00 18 34.7	−68 46 59	11.6	8.58	7.95	7.75	11.32	1.44	0.89	1.75	1	2.75 ± 0.30	5.83	
86-82	...	00 21 54.9	−68 31 25	11.6	8.25	7.57	7.35	11.13	1.45	0.92	1.87	1	2.20 ± 0.23	6.05	
881-50	G267-87	00 22 33.9	−31 10 24	14.5	10.66	10.03	9.74	14.27	...	1.07	2.41	1	3.68 ± 0.23	6.98	

Notes.—Col. (1) lists the designation from the NLTT Catalogue: (R) Ross; (W) Wolf; (Oxf) Oxford catalog. We have added Lowell Proper Motion Survey identifications (Giclas et al. 1971) where appropriate. Col. (2) lists an alternative name, usually from either the CNS3 or the LHS Catalogue; cols. (3) and (4) list the position of the 2MASS source; col. (5) gives the Luyten m_r magnitude; cols. (5)–(7) list the 2MASS photometry; cols. (8)–(11) list the optical photometry; col. (12) gives the number of observations; col. (13) gives the estimated distance modulus, and col. (14) the corresponding M_J. 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.

[a] Comments: (1) Probably variable, constant colors. (2) Probably variable. (3) Possibly affected by nearby field star. (4) Crowded field. (5) LP 767-16 is a close binary, separation ~1″.5. Both 2MASS and the optical data provide joint photometry; the distance estimate assumes an equal-magnitude system.

[b] Star with formal distance estimate $d \leq 20$ pc.

[c] Star with formal distance estimate within 1 σ of 20 pc.

of $\sigma = \pm 0.01$. Repeated observations indicate that the program-star measurements are generally accurate to ±0.02.

Table 4 also lists spectral types. Those values are derived primarily from the TiO5 measurements (using the calibration given in Paper III), although we use the VO-a index and visual inspection to verify results for the relatively small number of stars with spectral types later than M5.

Positions and near-infrared photometry for the NLTT stars with new spectroscopic observations are listed in Table 5. Four systems require special mention.

G73-27/LP 469-118: Luyten identified this as a close binary, separation 3″. The system is unresolved in the 2M2nd data set but resolved in the All-Sky Data Release (see Table A1). The JHK_s magnitudes listed in Table 5 are for 2MASS J02081218+1508424 and 2MASS J02081238+1508443 from the latter source. The system was resolved at the telescope, and each component observed separately, and we estimate distances of 20.6 and 21.5 pc, respectively.

LP 414-108: This 2″ separation equal-magnitude binary was not recognized as such by Luyten, who lists a spectral type of g–k for the system. The photometry listed in Table 5 is for 2MASS J04103830+2002264 and J04103813+2002241 from the 2MASS all-sky release. Spectroscopy of the individual components gives distance estimates of 61.8 and 65.6 pc, respectively.

G199-16: The 2MASS image of this source appears slightly elongated, and the 2M2nd deconvolves the data into two point sources: 2MASS J1229095+623938 ($J = 10.34$, $H = 9.36$, $K_s = 9.32$) and 2MASS J1229096+622939 (10.16, 9.64, 9.37). In Paper I, we noted that the former source has a $J-K_s$ color consistent with an M7 dwarf, although the optical/infrared colors suggested an earlier spectral type and the ($J-H$, $H-K_s$) colors are anomalous. The 2MASS all-sky release lists only a single source at this position, with $J = 10.058$, $H = 9.523$, $K_s = 9.266$, and colors consistent with spectral type derived from our low-resolution spectroscopy. We did not see any evidence for binarity at the telescope, so it seems likely that this object is single. We estimate a distance of 29 pc.

G215-46/LP 188-2: LP 188-2 is one of the photometric outliers listed in Table A1. Luyten lists this star, $m_r = 16.9$, $m_r - m_{pg} = 1.3$, as a close companion of G215-46 ($m_r = 16.1$, $m_r - m_{pg} = 1.3$), with a separation of 1″.5 at $\theta = 86°$. As noted in the table, there is no evidence of significant image elongation on either the 2MASS scans or the POSS I/II photographic plates, and LP 188-2 may not exist. In any case, the trigonometric parallax of G215-46 (2MASS J2226166+483730) indicates a distance of 32 pc (Table 1).

With the exception of the last three systems, the near-infrared photometry listed in Table 5 is taken from the 2M2nd.

5.2. *Metallicities, Absolute Magnitudes, and Distance Estimates*

Narrowband indices provide a means of estimating both spectral types and spectrophotometric parallaxes for the NLTT nearby-star candidates. Paper III presents absolute magnitude

TABLE 4
Narrowband Indices for NLTT Dwarfs

Name	TiO5	CaOH	CaH1	CaH2	CaH3	TiO-a	VO-a	Hα	Sp. Type
				NLTT1					
LP 348-40	0.43	0.47	0.85	0.44	0.74	1.48	1.95	0.97	M3.5
G171-59	0.60	0.61	0.82	0.55	0.78	1.28	1.95	1.42	M1.5
G171-61	0.65	0.62	0.80	0.59	0.80	1.18	1.96	0.97	M1.5
G132-4	0.47	0.51	0.85	0.47	0.76	1.42	1.95	0.95	M3.5
LP 765-74	0.63	0.58	0.81	0.55	0.79	1.21	1.94	0.98	M1.5

Note.—Table 4 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.

TABLE 5
Astrometry and Photometry of Spectroscopic Targets

Name	α (J2000)	δ (J2000)	m_r	J	H	K_s	M_J	d (pc)
NLTT1								
LP 348-40[a]	00 11 53.0	22 59 04	12.0	8.845	8.307	8.002	7.71	16.9 ± 2.8
G171-59	00 26 51.8	42 50 02	13.3	9.402	8.670	8.457	6.74	34.1 ± 5.4
G171-61	00 32 00.1	43 56 37	13.3	9.664	9.170	8.870	6.58	41.4 ± 6.5
G132-4[a]	00 33 20.4	36 50 25	12.2	8.780	8.083	7.858	7.32	29.6 ± 3.1
LP 765-74	00 37 36.3	15 11 52	12.3	9.087	8.432	8.236	6.75	29.3 ± 4.6
G172-22	00 46 29.9	50 38 39	13.6	9.968	9.329	9.082	7.54	30.6 ± 4.8

Note.—Table 5 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.
[a] Star with formal distance estimate $d \leq 20$ pc.
[b] Star with formal distance estimate within 1 σ of 20 pc.
[c] JHK_s from the 2MASS All-Sky Data Release.

(M_J) calibrations for several indices, but those are valid only for stars with near-solar metal abundance. Fortunately, we can verify the metallicities of the NLTT dwarfs in the current sample by comparing the relative strengths of the CaH and TiO indices against reference measurements of disk dwarfs and of intermediate and extreme subdwarfs. Figures 3, 4, and 5 plot those data for the current set of NLTT1, NLTT2, and NLTT3 stars, respectively. The reference data for disk dwarfs are from the PMSU survey (PMSU1, PMSU2), while the subdwarf measurements are from Gizis (1997). The overwhelming majority of the program stars are clearly disk dwarfs, and we have used the TiO5, CaH2, and CaOH indices to estimate absolute magnitudes, deriving a weighted average as described in Paper VII. The resulting distance estimates are listed in Table 5.

Three stars from the NLTT2 sample lie well below the disk sequence in the (CaH2, TiO5)-plane: LP 16-197 (TiO5 = 0.34, CaH2 = 0.31); LP 466-156 (0.47, 0.39); and LP 881-272 (0.58, 0.46). The TiO5 values correspond to disk dwarf spectral types M4.5, M3, and M2, respectively. Considering the distribution in the (TiO5, CaH3)-plane, LP 16-197 lies within the main body of data and is likely to be a disk dwarf. In contrast, the other two stars are offset in CaH3, and we identify both as intermediate subdwarfs.[4] Their spectra are compared with standard stars in Figure 6*a*.

Similarly, several stars lie below the disk sequence in the NLTT3 sample, but only three stars, LP 97-817 (TiO5 = 0.39, CaH2 = 0.33), G174-25 (0.67, 0.49), and LP 109-57 (0.59, 0.46) are offset in both TiO5 versus CaH2 and TiO5 versus CaH3. The TiO5 measurements correspond to disk spectral types of M4, M1.5, and M2, respectively, and their spectra are

[4] Note that this classification indicates only that the stars are mildly metal-poor relative to the local disk population (perhaps [M/H] ∼ −0.7) and does not necessarily imply membership in the halo population.

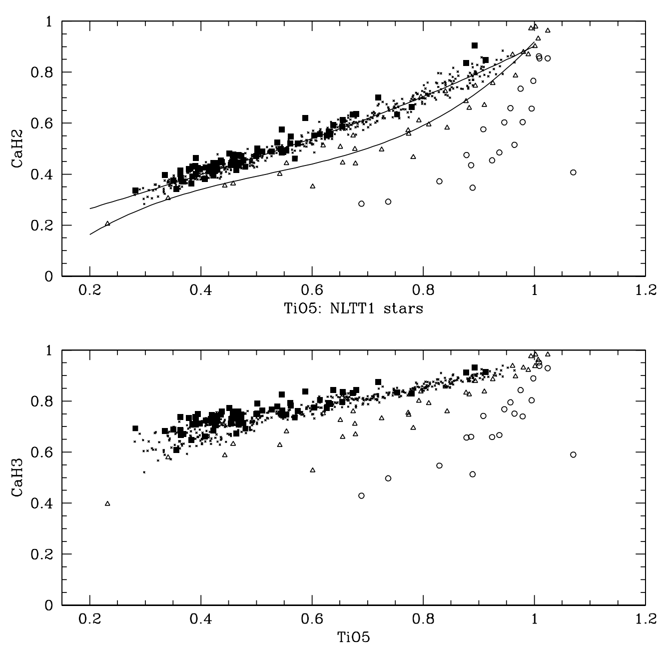

Fig. 3.—TiO and CaH band strengths of the NLTT1 stars listed in Tables 4 and 5. The program stars are plotted as filled squares. Reference data for disk dwarfs (*crosses*) are taken from the PMSU survey (PMSU1, PMSU2), while measurements of intermediate (*triangles*) and extreme (*circles*) subdwarfs are from Gizis (1997). The solid lines in the CaH2-TiO5 diagram mark the mean relations for disk dwarfs and intermediate subdwarfs.

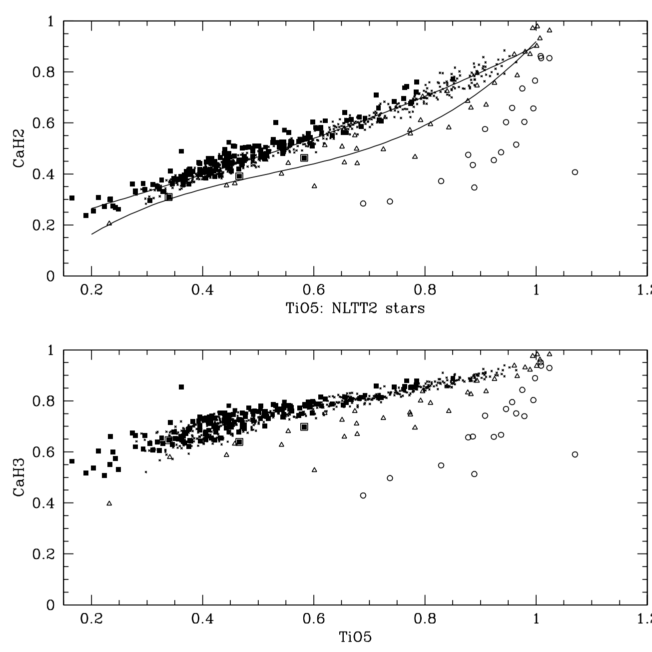

Fig. 4.—Relative TiO/CaH band strengths of the NLTT2 stars listed in Tables 4 and 5. The symbols have the same meaning as in Fig. 3. The three potential intermediate subdwarfs mentioned in the text (LP 16-197, 466-156, and 881-272) are identified by the points enclosed in open squares.

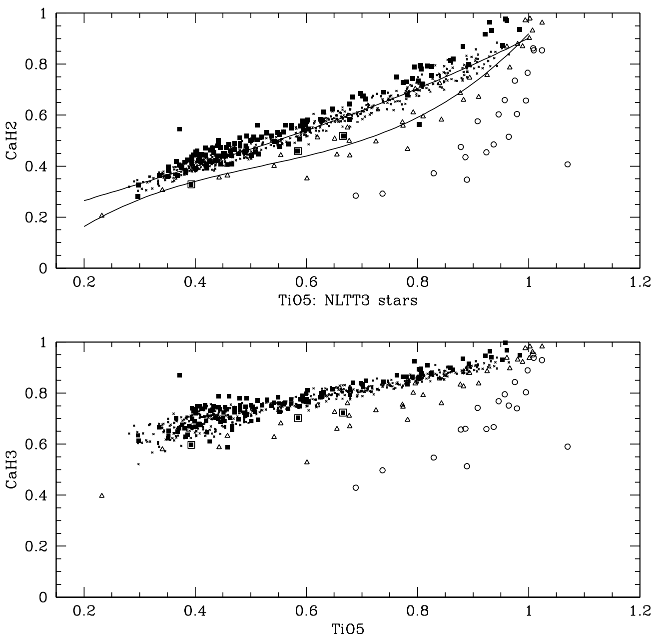

FIG. 5.—Relative TiO/CaH band strengths of the NLTT3 stars listed in Tables 4 and 5. This data set includes a higher proportion of early-type M dwarfs than the NLTT1 and NLTT2 samples. The three mildly metal-poor stars mentioned in the text (LP 97-817, G174-25, and LP 109-57) are identified by the points enclosed in open squares. The symbols have the same meaning as in Figs. 3 and 4.

compared with standards in Figure 6*b*. As with the NLTT2 stars, all three are likely to be intermediate subdwarfs. We have assigned spectral types using the CaH2 calibration derived by Gizis (1997).

All five intermediate subdwarfs are expected to be subluminous in M_J. We can estimate the extent of this effect using 2MASS photometry of late-type dwarfs and subdwarfs with known trigonometric parallaxes. Figure 7 plots the (M_J, TiO5) and (M_J, CaH2) color-magnitude diagrams—sdM and esdM stars fall below the disk main sequence in these diagrams. Since the NLTT stars lie near the upper edge of the sdM sequence in the TiO/CaH planes, we adopt offsets of $\Delta M_J = +0.6$ for LP 881-272, G174-25, and LP 109-57 (sdM3) and $\Delta M_J = +0.3$ for LP 466-156 (sdM4) and LP 97-817 (sdM5). All five remain beyond the 20 pc limit, although LP 97-817 has a formal distance estimate of only $\sim$24 pc.

Fifty-seven stars, all from NLTT2, have both *VRI* photometry (Table 2) and optical spectra. Figure 8 compares the photometric and spectrophotometric distance estimates. The agreement is within the formal uncertainties, with a mean offset of -0.11 mag (photometric minus spectrophotometric) and a dispersion of 0.36 mag.

6. A LOCAL CENSUS: K AND EARLY-TYPE M DWARFS

The main goal of the present program is to compile a census of late-type dwarfs within 20 pc of the Sun. With the addition of the observations described in this paper, we have essentially completed our NLTT follow-up observations. We have trigonometric, photometric, or spectroscopic parallax estimates for all save three of the 1913 nearby-star candidates in the NLTT1, NLTT2, and NLTT3 samples.[5] Eight hundred fifteen stars are placed within 20 pc of the Sun, including 312 additions to nearby-star catalogs. A further 224 stars are estimated to lie within 1 σ of the 20 pc boundary of our NStars survey.

The three NLTT samples discussed so far in this series of papers are limited to colors $m_r – K_s > 3.5$ mag. This corresponds to stars with $M_V > 11$, or spectral types later than

[5] The three stars that still require observation are F I-325, NLTT 23767, $m_r = 11.1$, $m_r - K_s = 3.6$; Grw +74°5033, NLTT 37764, $m_r = 11.8$, $m_r - K_s = 4.4$; and Grw +69°3815, NLTT 21156, $m_r = 11.9$, $m_r - K_s = 5.0$.

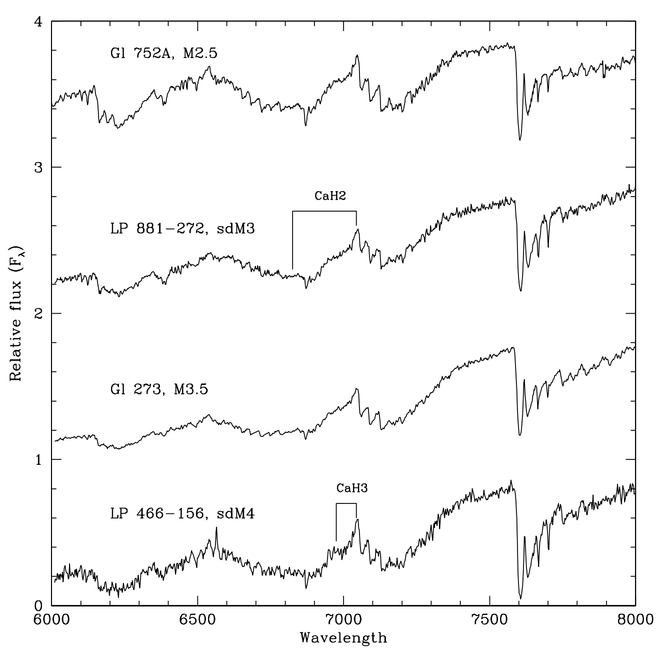

FIG. 6*a*

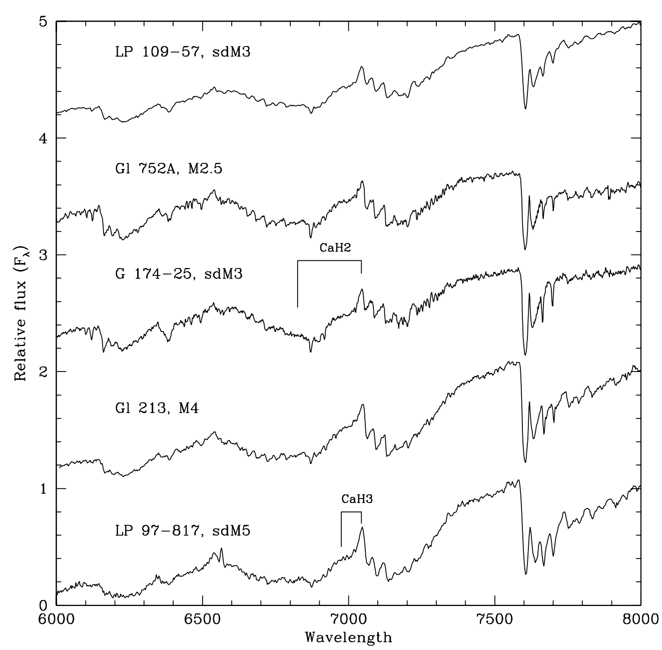

FIG. 6*b*

FIG. 6.—(*a*) LP 466-156 and LP 881-272, candidate intermediate subdwarfs from the NLTT2 sample. The locations of the CaH2 and CaH3 in-band and pseudocontinuum measurements are shown; the latter is centered on the peak flux immediately shortward of the 7050 Å TiO band. (*b*) LP 109-57, G174-25, and LP 97-817, a further three candidate intermediate subdwarfs from the NLTT3 sample. We again identify the location of the reference points for the CaH2 and CaH3 band indices.

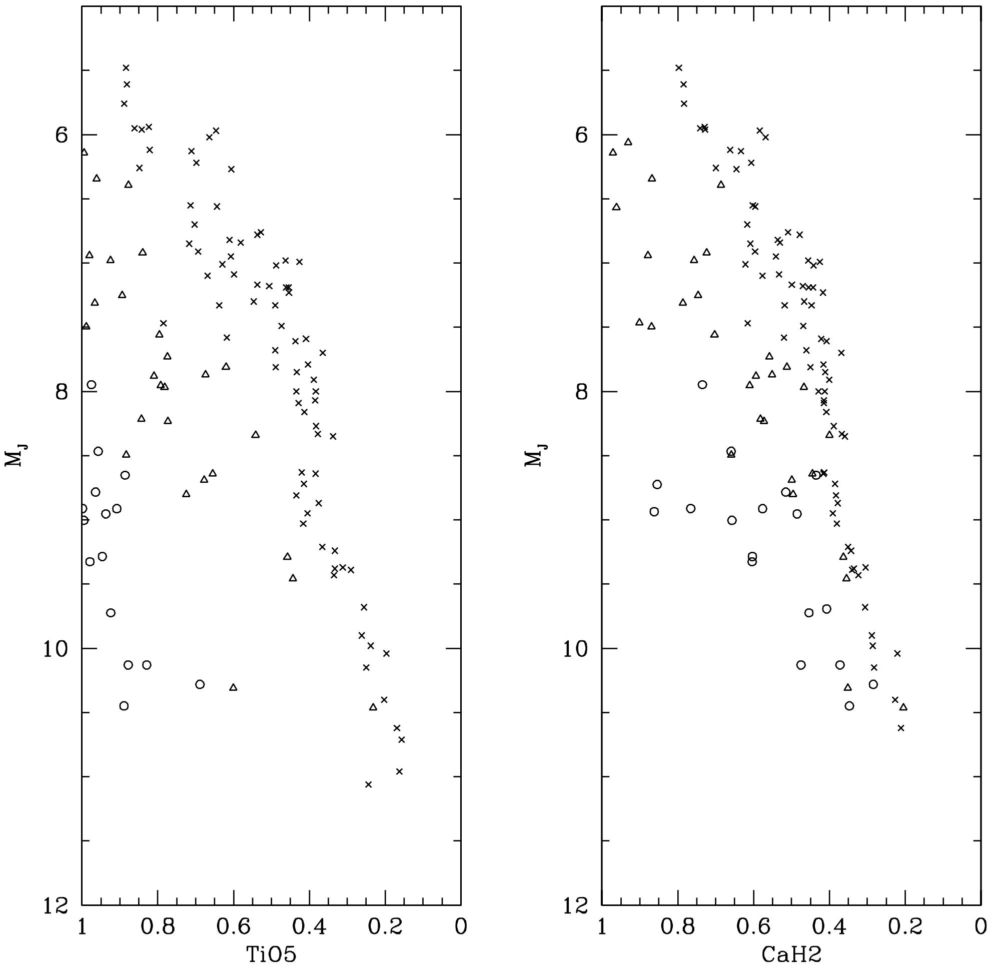

FIG. 7.—The (M_J, TiO5) and (M_J, CaH2) H-R diagrams for late-type dwarfs and subdwarfs. The crosses mark data for single stars with accurate trigonometric parallax measurements ($\sigma_\pi/\pi < 7\%$) from the 8 pc sample; sdM dwarfs are plotted as triangles, and esdM dwarfs as circles.

≈M3. This section explores ways of extending coverage through spectral type K, using the NLTT together with previously published nearby-star catalogs. This also allows us to identify nearby M dwarfs, particularly stars with low proper motions, that have escaped inclusion in the NLTT samples.

6.1. *Nearby Early-Type M Dwarfs in the NLTT*

The optical/infrared selection criteria used to isolate candidate nearby stars in the NLTT were aimed primarily at mid- and late-type M dwarfs. However, in Paper VII, we matched those criteria against data for known M dwarfs cataloged in the PMSU survey, including spectral types M0 to M2.5. That comparison shows that the linear relation adopted at the bluest colors, $m_r - K_s < 5$, provides an effective means of selecting stars within 20 pc with $m_r - K_s > 2.0$ mag, 1.5 mag bluer than the cutoff adopted in constructing the NLTT1, NLTT2, and NLTT3 samples. We have therefore compiled a list of K and early M nearby-star NLTT candidates by selecting stars from the rNLTT with colors in the range $2.0 < m_r - K_s \leq 3.5$ and apparent magnitudes that meet the criterion $m_r < 2.17(m_r - K_s) + 3.65$ (Paper I).

Four hundred two NLTT stars fulfil these criteria (Fig. 9, *top*). Three hundred eighty-eight of these candidates are either included directly in the *Hipparcos* Catalogue or are companions of *Hipparcos* Catalogue stars, and most have accurate trigonometric parallax measurements. Only 71 stars in 69 systems (all save seven listed in the CNS3) have formal distance estimates of less than 20 pc (Table 6). Four binary companions of these stars (Gl 282B, 414B, 420B, and 425B) are already included in the three NLTT samples; a further 15 unresolved companions also need to be taken into account. In two cases, BD +14°251 and Gl 225.2ABC, the *Hipparcos* parallax has a substantial uncertainty (>30%), reflecting the influence of close optical or binary companions. As discussed further below, photometric parallax measurements suggest that both systems lie well beyond 20 pc.

Table 7 lists relevant data for the 14 stars that lack *Hipparcos* data. Most have no direct trigonometric parallax data, but the available distance estimates, principally the $V - K_s$ photometric parallax, place all save four well beyond 20 pc. The remaining stars include the eclipsing binary system DV Psc (but see further below), both components of HD 95174, and G204-45. None of these systems is listed in the CNS3.

The bottom panel of Figure 9 plots the (M_V, $V - J$) color-magnitude distribution for stars with $\pi_{\rm Hip} > 50$ mas (Table 7) and stars with no *Hipparcos* data (Table 6). We include data for 14 fainter companions of those stars. Several stars fall well below the main sequence. BD +14°251, Gl 225.2B, Gl 225.2AC, and DV Psc all lack accurate trigonometric parallax measurements. There is no evidence that any of these stars is genuinely subluminous, and these three systems probably have distances of 30–40 pc. We have excluded them from the

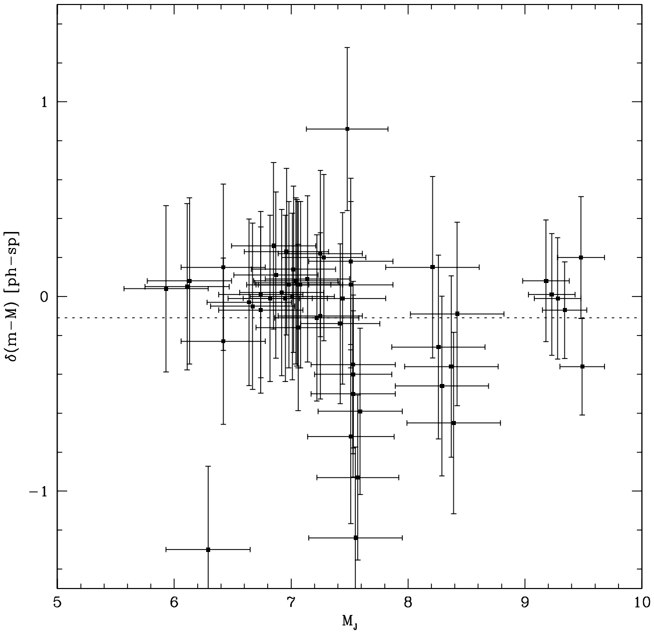

FIG. 8.—Comparison between photometric and spectrophotometric distance moduli for stars from the NLTT2 sample included in the present paper. The dotted line marks the formal mean difference (−0.13 mag). The scatter ($\sigma = 0.36$ mag) is consistent with the formal uncertainties in the individual measurements.

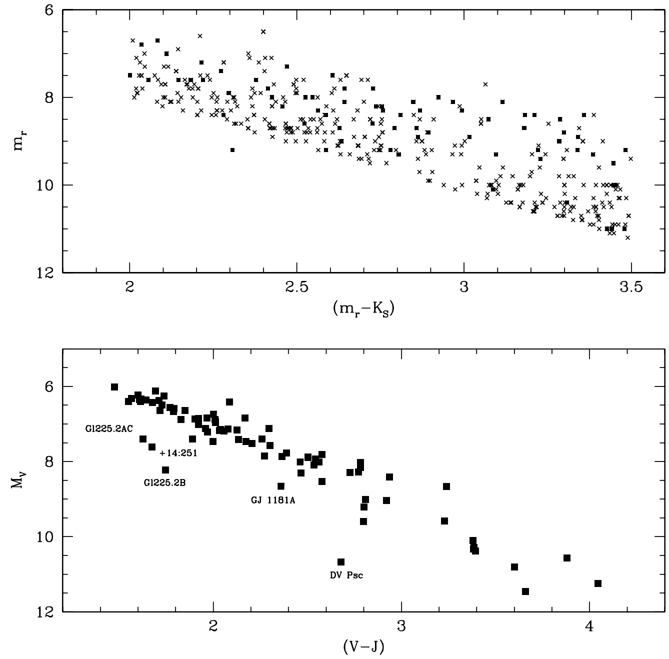

FIG. 9.—Photometric data for K and early-type M dwarf nearby-star candidates selected from the rNLTT. *Top*: The (m_r, m_r–K_s) distribution. Stars with distances measured at less than 20 pc are plotted as filled points. *Bottom*: The (M_V, V–J) distribution of the latter stars. The labeled points are discussed in the text; with the exception of GJ 1181A, the distances to these stars are probably underestimated.

20 pc sample. In the case of GJ 1181A, the trigonometric parallax appears secure, and the problem probably rests with current estimates of the relative photometry of the two components.

Retaining GJ 1181, this sample of K and early-type M NLTT dwarfs adds 80 stars in 69 systems to the 20 pc census. The bottom panel of Figure 9 shows that the m_r–K_s = 2.0 color limit adopted for this sample corresponds to $M_V \sim 6.5$, or spectral type ≈K1. These stars therefore bridge the gap between the later-type dwarfs in the NLTT samples and the more luminous samples discussed further below.

6.2. *Additional Nearby Stars*

We have searched the literature for cool dwarfs that fall in the area covered by the 2M2nd and are within 20 pc, but are not included in our NLTT sample. The additions are drawn from three main sources: the PMSU survey, the *Hipparcos* Catalogue, and the recent proper-motion surveys by Lépine and collaborators. We concentrate on K and M dwarfs and postpone discussion of ultracool dwarfs, including results from our own survey, to future papers.

6.2.1. *The PMSU Survey*

Most of the additions to the 20 pc census are drawn from the Palomar/Michigan State University M dwarf spectroscopic survey (PMSU1, PMSU2). That survey used narrowband indices, derived from moderate-resolution optical spectra, to compute spectroscopic parallaxes for ∼2000 M dwarfs cataloged in the CNS3, supplementing available astrometric and photometric data. As discussed in Paper VII, 468 of the 502 PMSU stars that both are in the NLTT Catalogue and have distance estimates $d_{\rm PMSU} < 20$ pc meet our color-magnitude selection criteria and are included in the NLTT1–NLTT3 samples. However, there are a further 137 M dwarfs in the PMSU catalog that have formal distance estimates less than 20 pc but are not included in the present sample, for a variety of reasons.

Table 8 lists relevant data for the additional PMSU stars. Those stars fall into five categories. First, as discussed in Paper VII, 27 stars are not in the NLTT Catalogue and therefore are excluded a priori from our sample. Second, 39 NLTT dwarfs with formal distance estimates of less than 20 pc fail our color/magnitude selection criteria (m_r too faint, or m_r–K_s colors too blue). Thirty-four of those stars were included in the Paper VII statistical analysis. Three of the five additional stars (GJ 1054B, LHS 2658, and G273-186A) have $d_{\rm PMSU} > 20$ pc but have companions with $d_{\rm PMSU} < 20$. The remaining two stars are HD 129715, a K7 dwarf that was not included in PMSU but has a spectroscopic parallax of 54 mas, and its M4.5 companion, LP 858-23, which has $d_{\rm PMSU} = 22 \pm 4$ pc. Given the proximity of the latter star to the M3-M4 break in the color-magnitude diagram, we adopt 54 mas as the parallax estimate for both stars. Note that several other stars in the "too blue" NLTT category also lie near this pronounced discontinuity in the main sequence.

The third category includes 34 brighter dwarfs, eliminated from the NLTT sample because of saturation in one or more passbands (usually H) in the 2M2nd. The 2MASS all-sky release includes analysis of shorter exposure scans, allowing photometry of bright stars, and we list final release data for those stars in Table 8. The earlier-type stars in this data set (such as Castor and Pollux) are included because they are companions of later-type dwarfs in the 20 pc census.

Half a dozen PMSU stars listed in the NLTT were omitted from our sample because neither our NLTT cross-referencing nor the rNLTT succeeded in identifying the correct 2MASS counterpart. Finally, 39 PMSU stars are secondary or tertiary companions, merged with the primary star in the 2MASS

TABLE 6

EARLY-TYPE M DWARFS FROM THE REVISED NLTT: *Hipparcos* STARS

NLTT	Name	HIP	α (J2000)	δ (J2000)	V^a	J	H	K_s	π_{Hip} (mas)	M_J	Comments
157	Gl 3	436	00 05 17.69	−67 49 57.3	8.49	6.492	5.872	5.737	62.5 ± 0.8	5.47	
1263	Gl 18	1936	00 24 25.93	−27 01 36.4	7.92	6.204	5.700	5.544	55.5 ± 1.1	4.93	
2941	Gl 42	4148	00 53 01.14	−30 21 24.9	7.15	5.537	5.049	4.889	71.0 ± 0.8	4.79	Note 1
4527	Gl 57	6351	01 21 34.59	−41 39 23.1	10.15	7.340	6.754	6.553	59.3 ± 1.6	6.20	
5563	BD +14°251	7765	01 39 56.06	15 15 33.7	8.68	7.006	6.454	6.309	61.3 ± 36.7	5.94	Not in CNS3; note 2

NOTES.—(1) J, H from final 2MASS data release. (2) Optical companion affects *Hipparcos* astrometry; $V-K$ colors give a photometric parallax of $m-M \sim 2.2$ mag. (3) Unresolved in 2MASS scans, M_J values estimated based on M_V from the CNS3 and average main-sequence colors. Gl 100B: $V = 11.5$, $M_J = 6.7$. Gl 157B: $V = 11.8$, $M_J = 7.2$. Gl 200B: $V = 11.7$, $M_J = 6.7$. Gl 225.3B: $V = 8.3$, $M_J = 5.8$. Gl 225.3C: $V = 9.3$, $M_J = 6.5$. Gl 340B: $V = 8.1$, $M_J = 4.9$. GJ 1181B: $V = 14.1$, $M_J = 8.4$. Gl 627B: $V = 7.85$, $M_J = 4.9$. GJ 1294B: $V = 10.6$, $M_J = 6.8$. (4) Gl 171.2A: Gl 171.2B is a DC8 white dwarf, $M_V = 15.8$, $\delta \sim 150''$. (5) All three components merged on 2MASS; deconvolution assumes average main-sequence colors. Van Altena et al. (1995) measure $\pi = 0\farcs058 \pm 0\farcs0128$, but the derived $V-K_s$ colors suggest a distance of ~30 pc. (6) Binary companion included in NLTT sample. Table 6 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.

[a] V magnitudes from the rNLTT.

scans. Some of these systems have high-resolution images at near-infrared wavelengths, but in most cases we have used the relative optical magnitudes, mainly from the CNS3, with standard color-magnitude relations to estimate the relative flux at near-infrared wavelengths and deconvolve photometry of the individual components from the 2MASS data.

6.2.2. *The Hipparcos Catalogue*

The *Hipparcos* satellite provided milliarcsecond-accuracy astrometry for 110,000 preselected, bright ($V < 13$ mag) stars, including most stars listed in the CNS3. The resulting catalog (ESA 1997) is statistically complete to 25 pc for stellar systems with components brighter than $M_V = 9$ (Jahreiss & Wielen 1997). We can use this data set to provide complete coverage of K dwarfs in the 2M2nd survey. We have identified all *Hipparcos* stars with $M_V > 5.0$ and parallaxes $\pi_{Hip} > 50$ mas and cross-referenced that sample against the 2M2nd. Most late K and M dwarfs are already in the 20 pc sample. The majority of the additions are included in the CNS3 (but not PMSU) and are sufficiently bright that the 2M2nd near-infrared magnitudes are saturated. As with the bright PMSU-selected stars, we have used the 2MASS all-sky release to obtain JHK_s for these stars. A number of stars have binary companions, and we have added those to the census, deconvolving infrared magnitudes for the individual components where necessary.

Relevant data for the *Hipparcos*-selected 20 pc stars are listed in Table 8. Eleven of the 62 stars listed there were identified directly by *Hipparcos* as members of the solar neighborhood. However, not all stars with $\pi_{Hip} > 50$ mas are confirmed as immediate neighbors. We have excluded two such stars from the present sample: HIP 114110 (BD −15°6346B) and HIP 114176 (CD −32°17393B). In both cases, the formal uncertainty in the measured parallax is ~10%. Each is a secondary star in a binary system: BD −15°6346, or HD 218251, has a *Hipparcos* parallax of $\pi_{Hip} = 13.26 \pm 1.01$ mas; CD −32°17393, or HD 218318, has $\pi_{Hip} = 13.01 \pm 1.00$ mas. It is likely that the apparently large parallaxes measured for the two secondary stars are spurious, perhaps as a result of the proximity of the bright primary.

6.2.3. *The LSR Surveys*

The proper-motion surveys undertaken by Lépine et al. (2002b, 2003, hereafter LSR1 and LSR2, respectively) are a modern reprise of Luyten's all-sky surveys. Rather than use visual or automated plate-blinking techniques, proper-motion stars are identified through digital subtraction of scans of first- and second-epoch Palomar and UK/AAO Schmidt sky

TABLE 7

EARLY-TYPE M DWARFS FROM THE rNLTT WITH NO *Hipparcos* DATA

NLTT	Name	α (J2000)	δ (J2000)	V_{rNLTT}	J	H	K_s	π (mas)	M_J	Notes
629	DV Psc	00 13 09.20	05 35 43.0	10.72	8.040	7.425	7.262	71 ± 40	7.25/7.25	1
7251	BD +45°565	02 11 43.26	45 45 38.3	9.83	7.892	7.433	7.283	24 ± 5	4.8	2
13091	HD 27678	04 21 15.86	−20 11 26.1	8.63	6.845	6.417	6.287	35 ± 7	4.6	2
17178	HD 50841	06 56 16.50	32 26 40.1	8.64	6.816	6.382	6.266	33 ± 10	4.4	3
18883	G111-51	08 05 01.85	48 14 19.6	9.31	7.243	6.729	6.633	34 ± 7	4.9	2
20631	HD 76772	08 57 36.35	−19 08 02.2	8.44	7.133	6.784	6.691	23 ± 5	3.9	2
25155	HD 305544	10 42 47.27	−60 02 38.9	9.18/9.6	7.372	6.987	6.939	16 ± 4	4.1/4.4	2, 4
25925	HD 95174A	10 59 38.31	25 26 15.5	8.57	6.444	5.972	5.842	52 ± 9	5.0	2
25926	HD 95174B	10 59 38.68	25 26 13.7	9.22	6.643	6.119	5.979	52 ± 9	5.2	2
29831	734-35	12 10 33.61	−11 26 60.0	11.49	8.469	7.835	7.665	33 ± 6	6.1	2
33231	737-81	13 12 22.35	−10 07 06.6	10.83	8.019	7.424	7.286	36 ± 7	5.8	2
38244	HD 129715	14 44 35.52	−22 15 11.3	9.41	7.230	6.758	6.584	38 ± 7	5.2	2
45991	G204-45	18 07 44.45	39 04 26.9	9.07	6.795	6.249	6.077	52 ± 9	5.4	2

NOTES.—(1) Equal-magnitude eclipsing binary system (Lu et al. 2001); (2) distance estimated using (M_V, $V-K_s$) relation from Paper I; (3) parallax from Yale parallax catalog; (4) Yale parallax catalog lists $\pi = 10 \pm 12$ mas.

TABLE 8

Additional Stars in the 2M2nd 20 Parsec Sample

Name	2MASS ID	V	J	H	K	Sp. Type[a]	$m - M$	Comments
				PMSU Non-NLTT				
GR 4	J0015367−294600	14.32	9.78 ± 0.03	9.25 ± 0.02	8.91 ± 0.03	M3.5	1.44 ± 0.40	
GJ 1009	J0021560−312421	11.16	7.68 ± 0.01	7.05 ± 0.03	6.77 ± 0.01	M1.5	1.30 ± 0.09	
GJ 1033	J0113239−225407	14.16	9.91 ± 0.02	9.30 ± 0.02	9.04 ± 0.03	M4.0	1.44 ± 0.15	
Hya 207	J0330311+200555	10.79	8.05 ± 0.02	7.40 ± 0.01	7.43 ± 0.03	K7.0	1.36 ± 0.27	
Steph 430	J0354256−090931	11.23	7.84 ± 0.02	7.18 ± 0.03	6.98 ± 0.02	M1.0	1.37 ± 0.40	

Notes.—(1) All near-infrared magnitudes for bright stars are from the 2MASS full data release. (2) Relative magnitudes and spectral types for binary components are estimated using δV cited in the CNS3 and standard color-magnitude relations, except as noted otherwise. (3) Relative magnitudes from Ianna et al. (1988). (4) LP 771-95/LP 771-96: see Delfosse et al. (1999a) and Jao et al. (2003). (5) Gl 140A/B: see Weis (1991a) and Morlet et al. (2002). (6) Gl 185A/B: relative optical magnitudes from Fabricius & Makarov (2000). (7) Assumed equal magnitudes. (8) Optical data and spectral type from Chance & Hershey (1998). (9) Gl 268A/B: relative magnitudes derived from mass estimates by Tomkin & Pettersen (1986) and mass-luminosity relations by Henry & McCarthy (1993). (10) Identified as SB2 by Delfosse et al. (1999a); assumed equal magnitudes. (11) YY Gem B. (12) LHS 1955A/B: optical magnitudes from Jao et al. (2003). (13) GJ 2069Aa/Ab: relative magnitudes from Delfosse et al. (1999b). (14) GJ 2069B/C, Gl 381A/B, LHS 2887A/B, Gl 747A/B, Gl 829A/B: relative magnitudes from Delfosse et al. (1999a). GJ 2069D: cited by Ségransan et al. (2000). (15) Gl 508A/B: optical data from Fabricius & Makarov; near-infrared from Henry & McCarthy (1993). (16) CM Dra B. (17) Relative magnitudes from Delfosse et al. (1999c). (18) Gl 914A/B/C: relative magnitudes inferred from analysis by Fernandes et al. (2002). (19) Gl 106A/B: relative magnitudes deduced from the masses derived by Halbwachs et al. (2003) and mass-luminosity relations of Henry & McCarthy (1993). (20) Gl 233Aa/Ab: OU Gem, relative magnitudes deduced from the masses derived by Halbwachs et al. (2003) and mass-luminosity relations of Henry & McCarthy (1993). (21) Burnham's star (Burnham 1891; Baize 1972). (22) BD +39°2376A/B/C: also known as HIP 52600 and ADS 7915; the relative optical magnitudes for the AC + B pair are from Van Biesbroeck (1974). Hartkopf et al. (1994) identify component C based on speckle imaging. For our present purposes, we assume that A and C constitute an equal-magnitude system. (23) Listed as an SB in the CNS3, but we have been unable to find subsequent confirmation in the literature. (24) Gl 649.1A/B/C: all three components are resolved in the full 2MASS data release. (25) Gl 762.1A/B: Balega et al. (2002) give $\delta V = 0.33$ mag; we assume equal magnitudes at *JHK*. (26) Gl 770A/B: equal-magnitude system; see Fekel & Beavers (1983). (27) See Lépine et al. (2002b) and Paper VI. (28) See Lépine et al. (2002a). (29) See Paper IV in this series for photometry and trigonometric parallax data. Table 8 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.

[a] Taken from the PMSU for M dwarfs, and from either the CNS3 or SIMBAD for earlier-type stars.

survey plates. To date, the published catalogs are limited to northern hemisphere stars with motions exceeding 0".5 yr^{-1}. We cross-referenced their low Galactic latitude sample (LSR1) against the 2M2nd database in Paper VI. Most of the newly identified proper-motion stars are either white dwarfs or halo subdwarfs. We have estimated distances for the disk dwarfs in the sample using either the spectral type–M_J relation (Paper V) or, if spectral types are not available, the $R-K_s$ colors. Similarly, we have cross-referenced the high-latitude discoveries from LSR2 against the 2M2nd and estimated distances using the same techniques. Table 9 lists LSR stars likely to lie within 20 pc of the Sun. More detailed information is available for two stars: LSR 1826+3014, a high-motion (2".38 yr^{-1}) star, has broadband *VRI* photometry (Lépine et al. 2002a), and LSR 1835+3259 is 2MASS 1835+32, which has a measured trigonometric parallax (Paper IV).

6.3. *The* 20 pc *Census*

Combining the early-type dwarfs listed in Table 6 and the literature data from Table 8 with our NLTT sample gives a total of 1027 stars, in 890 systems, within 20 pc of the Sun.

TABLE 9

A Rough Guide to Absolute J Magnitudes for K/M Dwarfs

M_J	$V-J$	$J-K_s$	$H-K_s$	M_V	Sp. Type
4.5	1.4	0.55	0.11	5.9	K2
5.5	2.3	0.8	0.16	7.8	M0
6.5	3.3	0.8	0.20	9.8	M1
7.5	4.0	0.75	0.25	11.5	M3
8.5	4.4	0.8	0.25	12.9	M4
9.5	4.6	0.85	0.30	14.1	M5
10.5	6.2	1.0	0.35	16.7	M6
11.5	7.5	1.25	0.42	19.0	M8
12.5	8.5	1.5	0.55	21.0	L0

Figure 10 plots the absolute magnitude distribution of the full data set, identifying the contribution from stars previously cataloged in the CNS3. Since we are considering stars on an individual basis in this figure, we have not applied any statistical corrections to the absolute magnitudes (see § 7.3 below).

As discussed in Paper VII, the main impact of the present survey lies at fainter magnitudes, $M_J > 7$, although we note that our study also provides improved, self-consistent distance estimates for a number of brighter stars. The data set discussed in this paper adds relatively few stars at the faintest magnitudes, $M_J > 10.5$ (spectral types later than M8), but that is not unexpected given the limiting magnitude of the NLTT survey.

7. THE LUMINOSITY FUNCTION

One of the main goals of this project is a statistically improved determination of the luminosity function for low-mass stars and brown dwarfs. With the effective completion of our NLTT follow-up observations, and the addition of complementary data discussed in the previous section, we can construct a preliminary luminosity function and examine the likely completeness of the current census. The following sections summarize stellar properties at near-infrared wavelengths and identify two reference samples

7.1. *The Main Sequence in* M_J

Most previous luminosity function studies have centered on the distribution at visual absolute magnitudes, $\Phi(M_V)$. We lack accurate V-band photometry for many stars in the NLTT sample, precluding direct derivation of that quantity. On the other hand, we have, by construction, 2MASS JHK_s photometry for all stars in our 20 pc census, and the photometric and spectrophotometric luminosity relations applied to late-type dwarfs are calibrated against M_J. Under these circumstances, it clearly makes sense to construct a near-infrared luminosity function.

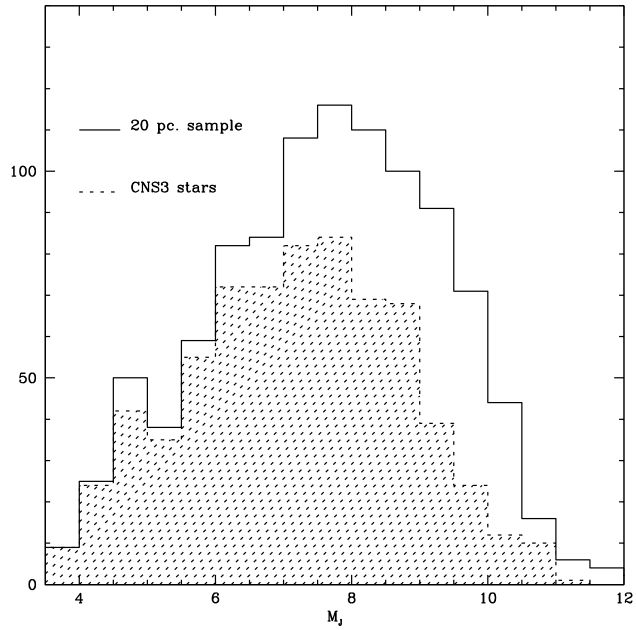

FIG. 10.—Statistics of the 20 pc census. We plot the number-magnitude distribution for all stars identified as within 20 pc of the Sun, with the hatched area marking the contribution from stars cataloged in the CNS3. Most of the additions lie at faint magnitudes, $M_J > 7$.

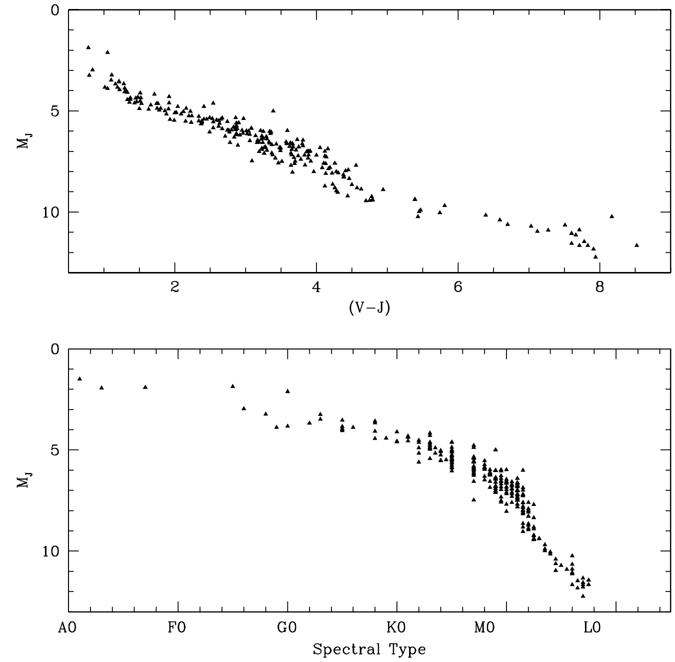

FIG. 11.—The (M_J, $V-J$) and (M_J, spectral type) relations, defined by stars with reliable photometry and trigonometric parallaxes measured to an accuracy $\sigma_\pi/\pi < 7\%$. Note the significant change in slope in the main sequence at $4 < V-J < 4.5$, corresponding to spectral types M2/M3.

Figure 11 provides an overview of stellar properties in this less familiar regime. We plot the (M_J, V–J) and (M_J, spectral type) diagrams for a sample of single stars with accurate photometry and trigonometric parallaxes measured to an accuracy better than 5%. The main sequence shows significant dispersion ($\sigma \sim 0.35$ mag) brighter than the M3-M4 discontinuity, which occurs at $M_J \sim 8.5$ (see Papers I and III for further discussion of this feature). As in all other planes, the main sequence narrows significantly at later spectral types. Table 6 provides a coarse reference guide to average colors and spectral types as a function of M_J.

7.2. *Calibrating J-Band Statistics: The* 8 pc *Sample*

The northern 8 pc sample includes stars and brown dwarfs with distances $d < 8$ pc and declinations $\delta \geq -30°$. This data set provides a baseline guide to the space densities of late-type dwarfs in the solar neighborhood and, hence, the expected numbers of stars in the 20 pc census. The sample was defined originally by Reid & Gizis (1997), and subsequent modifications are summarized in Reid et al. (1999) and in Paper IV of this series.

The present analysis takes two further corrections into account: Gl 831AB is eliminated, based on the parallax of 0.″1175 derived by Ségransan et al. (2000) in their reanalysis of *Hipparcos* data, allowing for orbital motion; and Teegarden et al. (2003) have discovered an M6.5 high proper motion star with a likely distance of ~3.6 pc. We note that Ducourant et al. (1998) have published a trigonometric parallax measurement of 156 ± 4 mas for the M5 dwarf G180-60, formally placing that star within our sample. However, at that distance, G180-60 falls ≈1 mag below the main sequence.[6] Since the spectrum shows no evidence for low metal abundance (PMSU1), we regard the previous photometric and spectroscopic distance estimates (10–12 pc) as more reliable.

Seven stars in our survey have formal distance estimates of less than 8 pc.

LP 467-16: An M5 dwarf, cataloged in the CNS3 with a photometric parallax of 118 ± 21 mas and a PMSU spectroscopic distance estimate of 10.5 ± 3 pc. Our revised estimate, based on multicolor photometry (Paper I), is 7.6 ± 1.2 pc, corresponding to $M_J = 9.68$.

LP 993-116: Lying at −43°, this star is well south of the −30° declination limit of the 8 pc sample. We estimate a photometric distance of 7.0 ± 1.7 pc (Paper II) and $M_J = 8.85$. However, LP 993-116 is a wide companion of BD −44°836, for which we estimate a photometric distance of 10.6 ± 1.6 pc (Paper II). With $V-I = 2.99$, LP 993-116 lies near the M3-M4 break in the main sequence, and the longer distance estimate to the earlier-type BD −44°836 ($V-I = 2.72$) is likely to be more reliable.

LHS 6167: Also known as G161-7, this mid-type M dwarf is not listed in the CNS3. We derive a photometric distance of 6.7 ± 1.3 pc (Paper II), corresponding to $M_J = 9.47$.

G161-71: Another new candidate from our SAAO observations (Paper II); we derive a distance estimate of 6.2 ± 1.2 pc and $M_J = 9.51$.

G165-8: Listed in the CNS3 with a parallax of 126 ± 22 mas, the PMSU distance estimate is 10.5 ± 3 pc. Combining the available trigonometric, photometric, and spectroscopic data (this paper), we derive 7.9 ± 0.8 pc and $M_J = 8.12$ for this M4 dwarf.

LP 71-82: An M4.5 dwarf, our spectroscopic parallax gives a distance estimate of 6.9 ± 1.4 pc and $M_J = 9.35$ (Paper VII).

LP 876-10: Our SAAO *BVRI* photometry leads to a photometric distance of 7.2 ± 1.4 pc and $M_J = 8.81$ (Paper VII).

All of these stars are mid-type M dwarfs (spectral types M3 to M5), lying near the break in the main-sequence relation,

[6] Similar situations prevail for the other nearby-star candidates (P1, P5, and P18) identified in the Ducourant et al. paper.

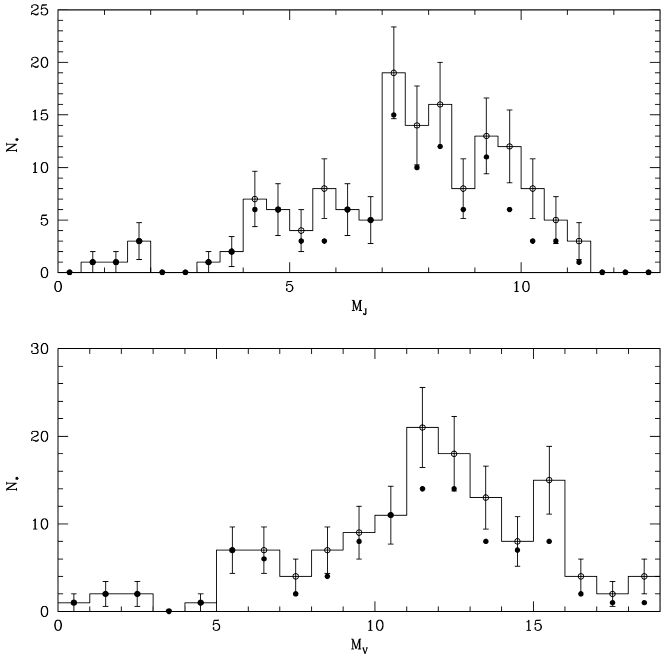

FIG. 12.—Comparison between the *V*-band and *J*-band luminosity functions derived from the northern 8 pc sample. The histograms (and open circles) plot data for all stars, with the error bars showing the formal Poisson uncertainties; the filled points mark the contribution from single stars and primaries in multiple systems.

and accurate trigonometric parallax data are required to verify the photometric/spectroscopic distance estimates.

Only three of the seven new 8 pc candidates (LHS 6167, G161-71, and LP 71-82) are retained in the luminosity function analysis; the Malmquist-corrected distances (see § 7.4 below) for the remaining northern stars all exceed 8 pc. Thus, integrating all changes since the original definition of the northern 8 pc sample gives a net result of stasis: 13 stars in 10 systems have been eliminated from the original sample, while 13 new stars (in 10 systems) have been added.

The current northern 8 pc sample therefore consists of 140 main-sequence stars (including the Sun), three brown dwarfs (Gl 229B, Gl 570D, and LP 944-20), and nine white dwarfs in 108 systems. The overall multiplicity, $(N_{\rm bin} + N_{\rm triple} + \cdots)/N_{\rm sys}$, is 29%. Only four systems lack accurate $(\sigma_\pi/\pi < 7\%)$ trigonometric parallax data; all of the resolved main-sequence stars have direct JHK_s photometry, while there are sufficient ancillary data to estimate M_J for unresolved close binaries. Figure 12 plots the visual and *J*-band luminosity functions derived from this data. We identify the separate contribution from primaries or single stars and secondary components, and the error bars show the formal Poisson uncertainties derived from the total counts in each bin.

7.3. *Earlier Spectral Types: The PMSU4* 25 pc *Sample*

With a total of only 152 objects, the 8 pc sample provides sparse statistics for stars more massive than the Sun. While the present project centers on K and M dwarfs, data for earlier-type stars are useful in setting those results in context. Reid et al. (PMSU4) have compiled a *Hipparcos* all-sky 25 pc census to $M_V = 8.0$ $(M_J < 4.5)$, adding photometric data for lower luminosity, main-sequence companions that lack separate *Hipparcos* entries. The PMSU4 sample is drawn from a volume approximately 4 times that of the present 2M2nd census (all-sky to 25 pc versus 48% of the sky to 20 pc), and 40 times that of the northern 8 pc sample. As a consequence, these data provide a more reliable reference for stellar space densities at bright absolute magnitudes.

The PMSU4 sample includes 1024 main-sequence stars in 764 systems. The overall multiplicity fraction is only 30%, significantly lower than the value of 44% derived for solar-type stars by Duquennoy & Mayor (1991), suggesting that as many as 150 binary companions remain to be discovered. However, the overwhelming majority of those stars are likely to be fainter than $M_V = 8$.

Most of the PMSU4 *Hipparcos* stars have direct JHK_s photometry from the all-sky 2MASS data release. We have used optical photometry (usually *B* and *V*) to estimate M_J for the brightest stars, saturated in even the final 2MASS catalog, and for unresolved companions (see Reid & Gizis 1997 for further details). Individual stars have absolute magnitudes spanning the range $-1 < M_J < 8.5$, but the sample clearly becomes incomplete at $M_J > 5.5$. The PMSU4 data set therefore provides a semi-independent[7] check of the completeness of the 20 pc census at bright magnitudes.

7.4. *The J-Band Luminosity Function,* $\Phi(M_J)$

As described in the previous section, our 20 pc census includes 1027 stars in 890 stellar systems. Before deriving the luminosity function from this data set, we need to make due allowance for systematic statistical bias present in the absolute magnitudes estimated for individual stars. Those corrections are applied on a system-by-system basis. In the case of systems with trigonometric parallax data, the corrections are small, since the astrometric accuracies are typically 2% or better. This corresponds to Lutz-Kelker bias of less than 0.05 mag in M_J (Lutz & Kelker 1973).

However, while 544 systems have trigonometric parallax measurements, the distance estimates for over 340 NLTT/PMSU stars are derived from either photometric or spectrophotometric parallaxes. The latter stars are effectively drawn from a magnitude-limited sample at each spectral type or color, so it is appropriate to use Malmquist bias (Malmquist 1936) to adjust the individual absolute magnitudes for statistical analysis. Defining M_0 as the true absolute magnitude and $M_{\rm obs}$ as the observed absolute magnitude for a given star, we have

$$M_0 = M_{\rm obs} - \frac{\sigma^2}{\log e}\frac{d\log A_S}{dm},$$

where σ is the uncertainty in M_J, and $d\log A_S/dm$ is the slope of the logarithmic number-magnitude distribution for a given color or spectral type. The last parameter varies significantly with apparent magnitude for a proper-motion–limited sample, but it is close to 0.6 per magnitude (a uniform-density distribution) for the brightest/nearest stars sampled in our survey. As noted above, we set σ to match the dispersion in the calibrating color-magnitude relations: 0.25 mag for low-luminosity stars $(I-J > 1.75)$, 0.4 mag for stars above the M3-M4 break in the main sequence $(I-J < 1.4)$, and 0.5 mag at the break. Thus, for

$$M_0 = M_{\rm obs} - 1.38\sigma^2$$

[7] *Hipparcos* stars lying within the area covered by the 2M2nd and with parallaxes $\pi_{\rm Hip} > 50$ mas are common to both samples.

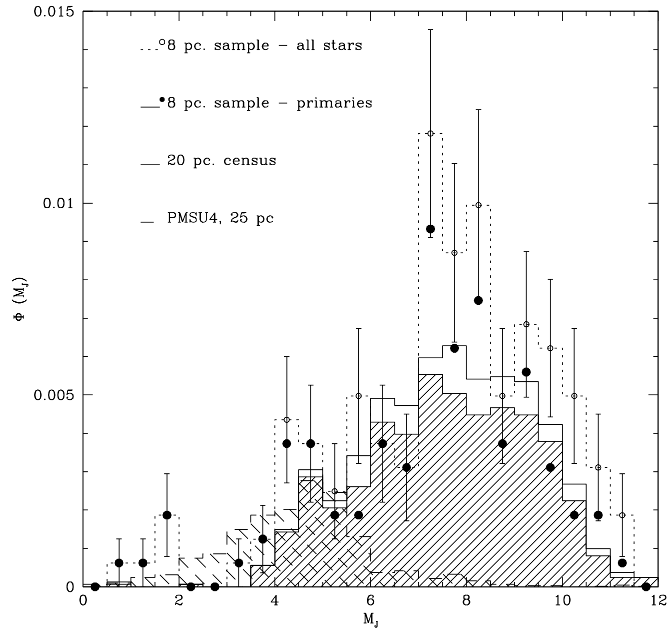

FIG. 13.—The *J*-band luminosity function. The space densities derived from the 20 pc census are plotted as an open solid-line histogram. The contribution from single stars and primaries is indicated by the histogram with solid hatching. These results can be compared against data for the PMSU4 sample at bright magnitudes (*dashed histogram with dashed hatching*) and for the northern 8 pc sample (*open circles and dotted histogram*). As in Fig. 12, the filled points mark the number densities of single stars and primaries in the latter sample. Malmquist and Lutz-Kelker corrections, as appropriate, have been applied in constructing these luminosity functions.

the absolute magnitudes are corrected by −0.09, −0.22, and −0.35 mag, respectively.

Figure 13 compares the *J*-band luminosity function derived from our 20 pc census against corresponding results for the northern 8 pc sample and the PMSU4 25 pc sample. Since the present survey covers 48% of the sky while the 8 pc survey covers 75% of the sky, there is a factor of 10 difference in the sampling volume. Since this is a statistical comparison, Malmquist and Lutz-Kelker bias are taken into account, and we show the relative contribution of systems (single stars and primaries) and companions to both data sets.

Clearly, despite the new discoveries from our NStars project, the current 20 pc census is far from complete. Based on the 8 pc sample, we expect $\sim 1290 \pm 110$ stars in $\sim 920 \pm 96$ systems over the absolute magnitude range $4 < M_J < 11$, where the uncertainties reflect the Poisson statistics of the local sample.[8] In contrast, the current 20 pc census includes only 853 stars (∼66% completeness) in 727 systems (∼80% completeness).

Comparing the predicted and observed results in more detail, several points can be made:

Late G and K dwarfs, $4 < M_J < 6$.—There is good agreement between the space densities derived from the PMSU4 and 20 pc samples at these magnitudes. The current 20 pc census becomes incomplete at $M_J = 4.25$, reflecting the $M_V > 5$ selection imposed on the *Hipparcos* sample, while the PMSU4 data set becomes incomplete at $M_J > 5.5$ ($M_V > 8$). Note that the 8 pc number densities at $4 < M_J < 5$ are higher than the corresponding densities derived from the PMSU4 sample. The former values, however, are based on only seven and six stars at $M_J = 4.25$ and $M_J = 4.75$, respectively, so the differences are equivalent to offsets of $\sim 1.5\ \sigma$.

M dwarfs, $11 > M_J > 6$.—Most of the deficit between the observed and predicted number counts resides at faint magnitudes, $M_J > 7$ (indeed, the 20 pc sample shows a $\sim 1\ \sigma$ excess at $6 < M_J < 7$). Based on the 8 pc data, we predict 910 stars in 630 systems at magnitudes $7 < M_J < 10$; this compares with 547 stars in 461 systems in the present census. This suggests that at these absolute magnitudes, approximately 25% of the stellar systems and 40% of the individual stars are missing from our census. The most substantial shortfalls in density (>2 σ) lie at intermediate magnitudes, $7 < M_J < 8.5$ ($10 < M_V < 13$, spectral types M2 to M4).

Binarity.—The binary fraction ($N_{\rm bin}/N_{\rm sys}$) in our 20 pc census is only 15%, significantly lower than value measured for the 8 pc sample (35%).

Proper motions.—Only ∼4% of the stars in the current 20 pc sample have motions below the NLTT limit, $\mu < 0\farcs18\ \rm yr^{-1}$. This is a factor of 2–3 lower than expectation, based on the measured velocity dispersion of local disk dwarfs (PMSU4).

The main conclusions that we draw from this comparison are, first, that significant numbers (∼150) of low-luminosity companions remain to be discovered within the 20 pc sample. This result, echoing the PMSU4 study, is not surprising, since at least half of the binaries in the 8 pc sample would be unresolved at distances approaching 20 pc. Second, between 150 and 200 stellar systems, mainly mid-type M dwarfs, are missing from the current census. Third, the relatively good agreement between the 8 pc and 20 pc number densities for systems with $8.5 < M_J < 10.5$ suggests that relatively few (∼20?) low-luminosity M dwarf *systems* remain to be discovered within the regions covered by the present survey.[9] Finally, it is likely that at least 60–70 stars with proper motions $\mu < 0\farcs18\ \rm yr^{-1}$ are missing from the current census.

8. COMPLETING THE CENSUS: A COMPARISON OF SEARCH METHODS

Traditionally, nearby-star catalogs have been constructed through a four-step process. Wide-field proper-motion surveys, coupled with rudimentary photometric data, provide the first cut, flagging thousands of systems with substantial tangential motions. Photometric and spectrophotometric follow-up observations are used to select the most likely candidates. Trigonometric parallax surveys, such as the US Naval Observatory program (Monet et al. 1992; Dahn et al. 2002) and the CTIOPI survey (Henry et al. 2002), generally target the latter stars, providing more accurate distance measurements. With the exception of surveys like *Hipparcos*, parallax programs rarely discover new nearby systems—they confirm or reject previously selected candidates. Finally, high-sensitivity, high-resolution imaging and spectroscopy of those same targets are required to complete the local census by searching for lower mass and lower luminosity companions.

Our survey fits squarely in this mold. Starting with 23,795 NLTT stars overlapping the 2M2nd survey, we have selected 1913 sources with colors consistent with nearby main-sequence M dwarfs and used follow-up *BVRI* photometry and spectroscopy to trim that sample to 815 stars likely to lie within 20 pc of the Sun. As noted in § 1, we expect some

[8] As a reference, the predicted numbers in this magnitude range for an all-sky 20 pc survey are 2690 stars in 1915 systems. Adding earlier spectral types, we expect 2915 main-sequence stars in 2125 systems.

[9] We note that our ultracool-dwarf survey (Paper V) fills in the apparent deficit between the 20 pc and 8 pc space densities at $M_J > 10.5$ in Fig. 12.

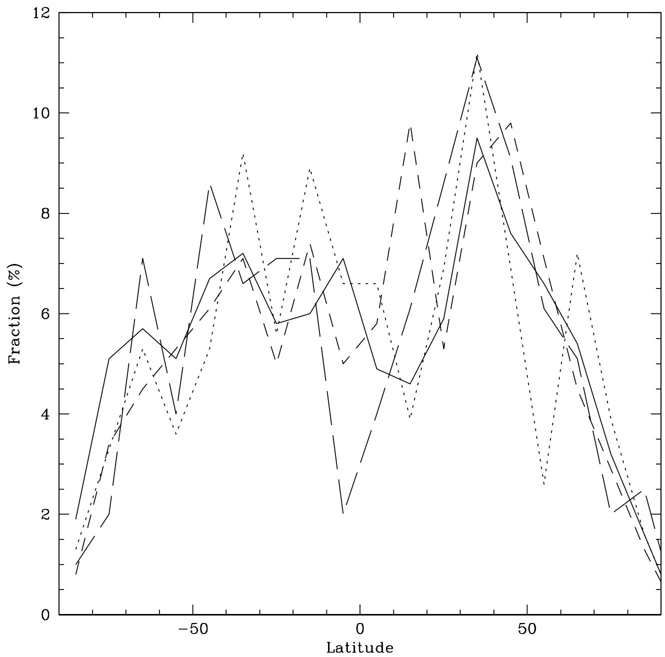

Fig. 14.—Latitude distribution of stars in the 20 pc sample. We plot the percentage of stars in 10° bins in latitude for three absolute magnitude intervals: $M_J < 7$ (*dotted line*), $7 \leq M_J < 9$ (*dashed line*), and $M_J \geq 9$ (*long-dashed line*). The solid line plots similar data for all 2M2nd NLTT dwarfs with $8 < m_r < 10$. There is evidence of a moderate deficit in the Galactic plane at the faintest luminosities.

incompleteness in the final sample, since 10%–12% of the local disk stars have tangential motions lower than the proper-motion cutoff of the NLTT. We have identified approximately one-third of the low-motion stars from other sources, but even so, our present census is incomplete by 20%.

What are most effective methods of finding the missing stars? To answer that question, we need to consider the likely characteristics of those objects. Based on the luminosity function comparison in the previous section, we can divide them into three broad groups: ∼150–180 companions of known (or as yet undiscovered) nearby stars; 20–30 cool, isolated dwarfs (spectral types M4.5 to M8); and ∼150 mid-type M dwarfs (spectral types M2 to M4). Each requires a somewhat different approach.

In the case of the missing companions, both the targets and the search techniques are obvious. These objects can be discovered through high-resolution imaging and high-accuracy radial velocity monitoring of 20 pc stars that currently lack such data. These are straightforward, if observationally intense, programs.

Large-scale surveys, such as the NLTT, are a prerequisite for identifying isolated systems. The NLTT itself is known to be incomplete in two important respects at faint magnitudes: the primary source catalog at southern declinations ($\delta < -40°$) is the Bruce proper-motion catalog, limited to $m_{\rm pg} \sim 15$, and the high star density near the Galactic plane complicated the identification of fainter proper-motion stars on the Palomar plates. Both effects are clearly evident in the (α, δ)-distributions plotted in Figure 1 of Paper I, and both percolate, to some extent, to the present 20 pc census, although the bright limiting magnitude in the deep south is less important, since only 3% of the 2M2nd lies south of $\delta = -40°$.

Figure 14 shows the latitude distribution of the 20 pc stars, divided into three absolute magnitude intervals: $M_J < 7$, $7 \leq M_J < 9$, and $M_J \geq 9$. Since the 2M2nd has a complex distribution on the celestial sphere, we have binned the stars in 10° intervals in latitude and calculated the fraction in each zone. As a reference, we plot the same distribution for NLTT stars with $8 < m_r < 10$ and 2M2nd counterparts—those stars are sufficiently bright that they do not suffer from either selection effect. There is some evidence of a deficit near the plane at the faintest luminosities in the 20 pc sample, although the shortfall corresponds to only ∼10 systems.

New proper-motion surveys, such as those by Lépine et al. (2003), can avoid these systematics to some degree, since better plate material and more sophisticated search techniques, such as digital image subtraction, are now available. However, crowding can still lead to problems in finding faint proper-motion stars in the regions of highest star density. Moreover, just as with the NLTT survey, supplementary photometric (or spectroscopic) data are required to unequivocally identify solar neighborhood members.

In principle, optical/infrared photometric surveys offer the best chance of finding the later-type dwarfs—later than M4 the main sequence has low dispersion, with color increasing monotonically with decreasing absolute magnitude, as illustrated in Figure 10. In practice, the effectiveness of this approach is limited by the availability of accurate optical photometry—particularly at low Galactic latitudes and in the south. The Sloan Digital Sky Survey, for example, covers only 1 sr, at high latitudes and predominantly in the northern hemisphere. Version 2.2 of the Guide Star Catalog, derived from the digitized Palomar and UKST Sky Surveys, offers a potential alternative, but that survey offers photometry of only moderate accuracy (∼0.1–0.15 mag), and the current catalog includes multiple (uncorrelated) measurements of stars with significant proper motions (from plates taken at different epochs). The 2MASS database lists optical photometry for sources within 5″ of the infrared source, but those data (from the USNO-A catalog) are derived from first-epoch Sky Survey material and are therefore absent for sources with moderate proper motion. Clearly, the 2MASS near-infrared photometry (notably $J-K_s$) offers an alternative search method, which we have exploited in the other main thread of the current project (see Papers V and IX). That search technique, however, is effective only for dwarfs with spectral types later than M8.[10]

Surveys for the missing mid-type M dwarfs are further complicated by the fact that those stars lie near a break in the main sequence. The substantial width (in absolute magnitude) at these spectral types (see Fig. 10) leads to substantial Malmquist bias, and a correspondingly high proportion of distant interlopers in any photometrically selected sample.

Under these circumstances, a direct photometrically based search for the missing 20 pc stars is not likely to be fully effective. We are therefore pursuing a hybrid approach, taking advantage of the optical data present in the 2MASS catalog. First, we can use the USNO photometry to search directly for 2MASS sources with optical/infrared colors consistent with nearby M dwarfs; these should include stars with low tangential motions, $\mu < 0''.15$ yr^{-1}. Second, we can couple the *absence* of an optical counterpart in 2MASS with appropriate near-infrared photometric criteria and identify nearby M dwarfs with significant proper motions. As indicated in § 1, we are

[10] M7 dwarfs may prove particularly tricky to locate, since they do not have distinctive near-infrared colors but are sufficiently faint at optical wavelengths to have eluded previous surveys, such as the NLTT.

TABLE A1
PHOTOMETRIC OUTLIERS IN THE rNLTT

N_{NLTT}	Name	m_r	Comment
166[a]	LP 824-355	14.4	CPM LP 824-355, m_r = 13.2, separation = 7″, V magnitude probably affected
1574	LP 240-22	18.8	Mismatch to 2MASS data for CPM, LP 240-23, 18.1
3411	G268-98	13.5	Mismatch to 2MASS data for CPM, BD −16°168, 9.0
5244	LP 468-114	17.0	Mismatch to 2MASS data for CPM, LP 468-115, 13.2
6886	LP 829-5	18.8	WD?, mismatch to 2MASS data for CPM, LP 829-4, 15.2
7084[a]	G73-27	14.3	CPM LP 469-118, 14.4, separation = 3″, JHK affected in 2M2nd
7679	LP 245-18	17.0	WD, mismatch to 2MASS data for CPM, G74-15 = GJ 3151A
8721	LP 470-44	18.7	Mismatch to 2MASS data for CPM, LP 470-43, 13.1
9354	LP 198-66	17.1	Mismatch to 2MASS data for CPM, G134-59, 12.5
10033	LP 411-59	16.0	Merged with LHS 1509, 14.2
11110	LP 31-157	14.7	Merged with LP 31-158, JHK may be affected
11112	LP 31-158	14.3	Merged with LP 31-157, JHK may be affected
11139	LP 413-1	16.0	Mismatch with CPM, LP 413-2, 10.8
13343[a]	BD +21°652	8.6	2MASS J, H photometry saturated
14262	LP 835-51	17.0	Mismatch with 2MASS data for CPM, LP 835-52, 12.1
14342	LP 416-231	18.2	Mismatch to field star; correct ID 2MASS J05010197+1552161, J = 15.25, J–K = 0.67
14868	BD −3°1061B	11.2	Mismatch to BD −3°1061A, 8.4
15665	LP 658-112	18.2	Mismatch to 2MASS data for CPM, G99-36, 14.1
17738[a]	LP 782-1	11.6	BD −15°1776, HIP 35633; π_{Hip} = 17.7 mas, Luyten m_r too faint
18020	G89-28	14.2	Mismatch to CPM, G89-29, 12.1
19122	LP 664-38	17.4	Probable WD, mismatch to G113-17, 14.7
20777	LP 845-8	19.0	Probable WD, mismatch to CPM LP 845-9, 14.6
25280	LP 791-55	16.2	Probable WD, mismatch to BD −18°3019, 12.9
30211	LP 554-63	15.0	WD, mismatch to 2MASS data for CPM, LP 554-64, 12.8
31551	LP 377-48	16.0	Mismatch to CPM, Ross 963, 10.9
32069	BD +0°2980	8.6	2MASS J, H photometry saturated
35133[a]	BD +15°2620	10.1	2MASS J, H photometry saturated
35442	LP 856-53	15.2	Probable WD, mismatch to LP 856-54, 12.4; 2MASS J13512268−2733574, J = 14.91, J–K = 0.16
36313[a]	Grw +69°5608	13.4	Single, no obvious anomaly on 2MASS/POSS; m_{pg}−m_r = 0.6, type g—Luyten m_r incorrect?
36746[a]	BD +19°2776	11.4	Single, no obvious anomaly on 2MASS/POSS
37633	LP 271-32	18.8	Probable WD, mismatch to LP 271-33, 12.8
43834	LP 863-15	18.5	NLTT m_r is incorrect, $m_r \sim 14$
44601	LP 920-43	13.4	Elongated image on DSS/2MASS, probably binary
45041	LP 448-12	16.0	Mismatch to 2MASS data for CPM, LP 448-11, 12.8
45190[a]	BD +68°946	9.3	2MASS J, H photometry saturated
46690	LP 229-17	11.5	GJ 4063, 2MASS JHK inaccurate
47625	BD +46°2654	11.2	G208-16, 2MASS K magnitude inaccurate
48991[a]	LP 514-18	13.5	G143-43, V = 10.75; NLTT m_r incorrect
49703	LP 693-351	19.0	NLTT B magnitude and rNLTT V are incorrect
51109[a]	LP 286-7	11.6	Single, no obvious anomaly on 2MASS/POSS
52786	LP 639-15	17.0	Mismatch to CPM, LP 699-14, 11.6
53861	LP 188-2	16.9	Luyten lists this star as a companion to G215-46, m_r = 16.1, Δ = 1″.5, θ = 86°; 2MASS data show no evidence for elongation (see text)
55272[a]	LP 933-25	15.0	Merged with LP 933-24, 11.0
56041	BD +48°3952B	10.0	Mismatch with BD +48°3952A, 7.2
56911	LP 878-33	18.5	Mismatch with CPM, LP 878-32, 13.0
58639	LP 879-49	17.5	Mismatch with CPM, LP 879-49, 13.8

[a] Additional observations included in the current program.

currently pursuing both techniques, and we will discuss the results in a future paper in this series.

Finally, we should emphasize that the current 20 pc census is not immutable. It is likely that some of the stars added through the present program are unresolved binaries, with correspondingly overestimated photometric or spectroscopic parallaxes. We need to refine the current distance estimates and, in particular, acquire accurate trigonometric parallax measurements for the 40% of the sample that currently lacks such data.

9. SUMMARY AND CONCLUSIONS

As part of our continuing survey of the late-type dwarfs in the immediate solar neighborhood, we have presented photometric and spectroscopic observations of over 800 proper-motion stars from the NLTT Catalogue. These stars are drawn from three separate compilations, matching the NLTT against 2MASS point-source data from the Second Incremental Data Release. Two of those compilations are our own work, matching sources with positional coincidence less than 10″ (NLTT1) and 60″ (NLTT2); the third (NLTT3) is derived from the independent analysis by Salim & Gould (2003). In each case, the nearby-star candidates are selected using location in the (m_r, m_r–K_s) plane. There are a total of 1237, 369, and 307 nearby-star candidates, respectively, in the final three samples—a total of 1913 stars. With the addition of the observations presented in this paper, we have compiled

TABLE A2

Comments on rNLTT Stars

$N_{\rm NLTT}$	Name	m_r	Comment
2804	LP 350-19	12.0	Merged with CPM, LP 350-20, 11.7
2805	LP 350-20	11.7	Merged with CPM, LP 350-19, 12.0
3462	LP 406-76	11.7	Merged with CPM, LP 406-77, 11.7
3463	LP 406-77	11.7	Merged with CPM, LP 406-76, 11.3
3482	LP 194-20	13.7	Mismatch to 2MASS data for CPM, G132-51, 12.7
3642	LP 294-49	14.1	Merged with CPM, G132-54, 14.9
3916	LP 767-16	13.6	Merged with CPM, LP 767-17, 14.1
3917	LP 767-17	14.1	Merged with CPM, LP 767-16, 13.6
5504	LP 768-26	12.2	Merged with CPM, LP 768-27, 12.7
5505	LP 768-27	12.7	Merged with CPM, LP 768-26, 12.2
6606	LP 828-46	15.0	Merged with CPM, LP 828-45, 14.5
6680	LP 469-41A	14.1	Merged with CPM, LP 469-41B, 14.2
6681	LP 469-41B	14.2	Merged with CPM, LP 469-41A, 14.1
6704	LP 884-75	13.6	Close double? Spectral type = M0.5, barely consistent with $m_r - K_s = 4.9$
7318	LP 649-66	12.1	Merged with CPM, LP 649-67, 12.2
7319	LP 649-67	12.2	Merged with CPM, LP 649-66, 12.1
8465	LP 298-7	12.6	Merged with CPM, LP 298-8, 12.8
8466	LP 298-8	12.8	Merged with CPM, LP 298-7, 12.6
11834	BD +38°807	10.8	Listed as binary system in rNLTT
12688	LP 414-108	13.3	Close double, suspect 2MASS photometry; not listed as such in NLTT, spectral type g–k
13437	LP 715-51AB	11.5	Listed as binary system in rNLTT, *Hipparcos*
15845	G100-48	13.8	Previously uncataloged companion, $m_r \sim 17.5$; 2MASS J05571910+1708279, $J = 11.80$, $H = 11.30$, $K = 11.00$
16695	BD −10°1583	10.8	Listed as binary system in rNLTT, *Hipparcos*
16784	LP 363-7	13.6	Previously unrecognized companion; 2MASS J06385265+2255115, $J = 12.24$, $H = 11.62$, $K = 11.34$
18027	L456-55	11.2	Listed as binary system in rNLTT
19133	LP 664-38	17.4	Mismatch to 2MASS data for CPM, G113-17, 14.7
20496	LP 726-18	12.0	Merged with CPM, LP 726-19, 12.5
20497	LP 726-19	12.5	Merged with CPM, LP 726-18, 12.0
20589	LP 606-27	13.4	Merged with CPM, LP 606-28, 11.2
25612	LP 731-15	15.0	Merged with CPM, LP 731-14, 14.5
26194	BD −3°3040	10.4	Listed as binary system in rNLTT, ADS 8048BC
28729	LP 319-36	14.0	Merged with CPM, LP 319-37, 13.0
30211	LP 554-63	15.0	WD, mismatch to 2MASS data for CPM, LP 554-64, 12.4
31576	LP 171-46	13.2	Mismatch to 2MASS data for CPM, G198-71, 10.1
33949	LP 65-440	14.2	Merged with CPM, G238-34, 13.4
35585	LP 270-9	17.4	Mismatch to 2MASS data for CPM, LP 270-8, 15.7
40101	LP 68-70	15.8	Merged with CPM, LP 68-71, 16.1
40102	LP 68-71	16.1	Merged with CPM, LP 68-70, 15.8
44624	LP 277-26	14.8	Mismatch to 2MASS data for CPM, Wolf 692, 13.2
45088	T 36	16.2	Crowded, low-latitude field, no evidence of motion
45242	LP 44-48	13.9	Mismatch to 2MASS data for CPM, LP 44-47, 12.1
45974	G154-45	14.1	DA, *JHK* photometry affected by IRAS 18049−1417
47260	G229-20	13.0	Merged with CPM, LP 141-13, 13.2
47261	LP 141-13	13.2	Merged with CPM, G229-20
48070	LP 813-5	14.5	Merged with CPM, LP 813-6, 13.4
48223	BD +31°3767A	10.1	Gl 767A, merged with BD +31°3767B, 10.8
48224	BD +31°3767B	10.8	Gl 767B, merged with BD +31°3767A, 10.1
49365	BD +26°3915	10.8	HD 340345, close binary system
50692	LP 637-5	16.2	Merged with CPM, LP 637-4, 15.0
51535	LP 638-79	11.2	Close binary system (Balega et al. 2002)
53279	LP 639-15	17.0	May not be real, mismatch to 2MASS data for LP 699-14
53719	LP 931-58	14.0	Merged with CPM, LP 931-57, 13.1
54303	LP 288-40	18.2	Mismatch to 2MASS data for CPM, LP 288-39, 16.3
54522	G27-39	14.9	Close pair; spectral type = M0.5, $d \sim 90$ pc
54777	Ross 223B	12.7	Merged with Ross 223A, 10.4
56476	BD −5°5966B	11.0	*JHK* affected by BD −5°5966A (96 Aqr, $\pi = 28.7$ mas)
56598	LP 290-18	15.0	Mismatch to 2MASS data for CPM, G190-19, 13.1
57086	LP 462-51	12.2	Merged with CPM, LP 462-52, 11.6
57087	LP 462-52	11.6	Merged with CPM, LP 462-52, 12.2
57491	LP 763-43	15.1	Merged with CPM, LP 763-44, 16.0
57498	LP 763-44	16.0	Merged with CPM, LP 763-43, 15.1
57499	LP 763-45	15.1	Looks extended on *I*-band/2MASS
58510	LP 704-11	13.7	Merged with CPM, LP 704-12, 12.2

astrometric, photometric, and/or spectroscopic distance estimates for 1910 stars. We identify 815 of those stars as likely to be within 20 pc of the Sun.

The nearby stars identified from our NLTT follow-up observations are M dwarfs, predominantly spanning spectral types between M2 and M7. We have extended coverage to earlier spectral types (late G, K, and early M), coupling color selection from the NLTT with literature data, notably stars from the *Hipparcos* Catalogue. The resulting 20 pc census, drawn from the 48% of the celestial sphere covered by the 2M2nd, spans the absolute magnitude range $4 < M_J < 10.5$ and includes 1027 stars in 890 systems.

We have computed the *J*-band luminosity function, $\Phi(M_J)$, of our 20 pc sample and compared the results against reference data for the northern 8 pc sample, spanning the full stellar mass range (see Paper IV), and a *Hipparcos*-based analysis of AFGK stars within 25 pc of the Sun (PMSU4). In passing, we note that the present survey produced only three additions to the former sample. The comparison indicates that the 20 pc census is complete to $M_J \sim 7$. At fainter magnitudes, and relative to the 8 pc predictions, there is an apparent deficit of ~170 stellar systems (~25% incompleteness) and ~360 individual stars (~40% incompleteness) at $7 < M_J < 10.5$. At least half of the missing stars are companions of known nearby stars, while approximately 90% of the missing systems are likely to be concentrated between $M_J = 7$ and $M_J = 8.5$—spectral types M2 to M4.

We have discussed a number of techniques that could be used to supplement our current survey and complete the 2M2nd 20 pc survey, and we are currently pursuing them. Finding the missing systems, however, will only mark the completion of stage 2 in compiling a reliable nearby-star census. Approximately one-third of the current sample (~350 stars) lacks accurate trigonometric parallax measurements, while even more stars lack close scrutiny for either spectroscopic or resolved lower luminosity companions. Those observations are beyond the scope of our current NStars project but are essential if we are to establish a complete catalog of stars and brown dwarfs within 20 pc of the Sun.

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