NEW NEIGHBORS: PARALLAXES OF 18 NEARBY STARS SELECTED FROM THE LSPM-NORTH CATALOG

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ABSTRACT

We present astrometric parallaxes for 18 suspected nearby stars selected from the LSPM-north proper motion catalog. 16 objects are confirmed to be main-sequence M dwarfs within 16 pc of the Sun, including three stars (LSPM J0011+5908, LSPM J0330+5413, and LSPM J0510+2714) which lie just within the 10 pc horizon. Two other targets (LSPM J1817+1328, LSPM J2325+1403) are confirmed to be nearby white dwarfs at distances of 14 and 22 pc, respectively. One of our targets, the common proper motion pair LSPM J0405+7116E + LSPM J0405+7116W, is revealed to be a triple system, with the western component resolved into a pair of 16th magnitude stars (LSPM J0405+7116W-A and LSPM J0405+7116W-B) with a 0.7 ± 0.1 angular separation. We find two stars (LSPM J1314+1320 and LSPM J1757+7042) to be significantly overluminous for their colors, and conclude that these may be unresolved doubles/multiples.

Key words: astrometry – binaries: visual – stars: distances – stars: low-mass, brown dwarfs – solar neighborhood – white dwarfs

1. INTRODUCTION

The 20th century has seen considerable advances and efforts in triangulating the distances of nearby stars through measurements of their annual parallax. By 1995, over 8,000 stars had been monitored using ground-based telescopes and their distances compiled in the Yale Catalog of Trigonometric Parallaxes (van Altena et al. 1995). The Hipparcos mission has further increased this sample by over an order of magnitude, obtaining space-based astrometric parallaxes of over 110,000 stars (Perryman 1997). These efforts have been fundamental to modern astronomy, providing reliable absolute magnitudes for most classes of stars, defining the first rung of the cosmic distance ladder, constraining models of stellar structure and evolution, and drawing a three-dimensional map of star systems in the vicinity of the Sun.

However, the map of the Solar neighborhood remains fragmentary to this day. The Hipparcos catalog lists 150 stars within 10 pc, and 1123 stars within 25 pc. However, the catalog is complete only to about magnitude V = 8, and reaches down only to about V = 12. The local stellar field is dominated by low-luminosity red dwarfs (main-sequence M dwarfs) that fall beyond the magnitude limit of the Hipparcos catalog. As a comparison, the Yale catalog lists 256 stars within 10 pc of the Sun, and 2059 stars within 25 pc, with most of the additional stars consisting of low-luminosity red dwarfs and white dwarfs (WDs). Apart from the low-luminosity companions of Hipparcos stars, identified through common proper motion (Gould & Chanamé 2004; Lépine & Bongiorno 2007), astrometric distances of low-luminosity objects, including brown dwarfs and most red dwarfs and WDs, are still largely dependent on ground-based measurements.

Parallax programs now in operation include the CTIOPI survey, carried out from the SMARTS 1.5 m and 0.9 m telescopes in Cerro-Tololo (Jao et al. 2005; Costa et al. 2005, 2006). The survey includes several hundred targets observable from Cerro Tololo Inter-American Observatory (CTIO), most of them high-proper motion stars with photometric and spectroscopic distances placing them within 20 pc of the Sun, with an emphasis on very nearby (d < 10 pc) objects (Henry et al. 2006). In the northern hemisphere, a smaller parallax program has been carried on at the Allegheny observatory, and parallaxes of 21 nearby stars have recently been reported (Gatewood & Coban 2009). The United States Naval Observatory (USNO) has also been supporting a parallax program in the past decades from observations made at the USNO Flagstaff station (Monet et al. 1992; Zacharias et al. 2000; Vrba et al. 2004; Burgasser et al. 2008; Dahn et al. 2008); the program has notably contributed parallaxes for the first representative sample of brown dwarfs (Dahn et al. 2002). The Torino Observatory Parallax Program has also recently contributed data on six WD candidates (Smart et al. 2003) and 22 suspected nearby red dwarfs (Smart et al. 2007). Finally, parallaxes of selected nearby objects have also been reported in recent years by various authors (Hambly et al. 1999; Deacon & Hambly 2001; Thorstensen & Kirkpatrick 2003; Deacon et al. 2005), including parallaxes for 10 nearby T dwarfs (Tinney et al. 2003). Overall, it is a fair assessment that these parallax programs are too modest in scope to keep up with the large numbers of objects which have been identified as probable nearby stars.

As of 2008 August, the NStars database4 has parallax confirmation for 234 systems within 10 pc containing 325 individual stars, and for 2027 systems within 25 pc totaling 2629 stars. However, the census remains incomplete to this date. Catalogs of stars with large proper motion still contain thousands of stars which are suspected to be within the Solar neighborhood but for which there is no parallax data. The large catalogs assembled by W.J. Luyten through the 1970s, the Luyten half-second (LHS) and NLTT catalogs (Luyten 1979a, 1979b) are still being mined for nearby star candidates. Recent all-sky proper motion surveys have also added to the bounty, identifying thousands more high

4 http://nstars.nau.edu

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proper motion stars that had been overlooked in earlier surveys (Scholz et al. 2002; Hambly et al. 2004; Lépine & Shara 2005; Subasavage et al. 2005; Lépine 2005, 2008; Finch et al. 2007). The difficulty in selecting nearby stars from proper motion catalogs is to separate the stars whose large proper motion is due to their proximity from the stars whose large proper motion reflects a large transverse velocity. For this, reliable photometric and/or spectroscopic distances must first be obtained. A host of recent spectroscopic follow-up observations have identified significant numbers of candidate nearby stars (Gizis & Reid 1997; Scholz et al. 2001, 2002, 2004, 2005; Henry et al. 2002; Lépine et al. 2003; Lodieu et al. 2005; Reid & Gizis 2005; Crifo et al. 2005; Phan-Bao & Bessel 2006; Reylé et al. 2006; Jahreiss et al. 2008). But the main break in extracting large samples of nearby stars from proper motion catalogs has come from the availability of accurate infrared photometry, from which reliable photometric distances can be obtained from the optical-to-infrared color term (Reid & Cruz 2002; McCaughrean et al. 2002; Reylé et al. 2002; Henry et al. 2004; Reid et al. 2004, 2007; Reylé & Robin 2004; Lépine 2005). As a result, there are now thousands of stars suspected to be within 25 pc of the Sun but for which there is no parallax distance confirmation. The need for an accurate map of the Solar vicinity thus justifies maintaining existing nearby-star parallax programs, as well as the development of new ones.

Recently, Thorstensen (2003) had demonstrated the use of the 2.4 m Hiltner telescope at the MDM observatory to obtain reliable parallaxes at the 1–2 mas accuracy. MDM parallaxes of six known nearby stars were found to be similar to USNO parallaxes of the same objects. Parallaxes of 27 relatively distant cataclysmic variables have so far been successfully obtained from MDM (Thorstenсен 2003; Thorstensen et al. 2006, 2008). Based on this demonstrated success of using the Hiltner telescope for accurate astrometry, we have initiated a program to measure the parallaxes of selected nearby star candidates from the list generated by Lépine (2005).

In this paper, we present the first results of our program, which yield the first parallax determinations for 18 stars predicted to be within 15 pc of the Sun. Our astrometric observations are described in Section 2. We analyze the results in Section 3, where we also test the accuracy of the photometric distance estimates for low-mass stars. Conclusions follow in Section 4.

2. OBSERVATIONS

2.1. Target Selection

We have observed a subsample of 16 suspected nearby main-sequence M dwarfs, selected from our own list of candidates from the LSPM-north proper motion catalog (Lépine & Shara 2005). The stars all have photometric distances placing them within 15 pc of the Sun (Lépine 2005). Several of them have been proposed to be nearby stars in recent years, based on photometric/spectroscopic distance estimates from various authors (see Section 2.6).

We have also selected two new candidate WDs from the LSPM-north, both suspected to be within 12 pc of the Sun based on photometry alone. Their presumed status as WDs is strongly suggested by their location in the reduced proper diagram, where they show up as blue stars of low luminosity.

2.2. Astrometry and Photometry

Astrometric imaging was carried out from the 2.4 m Hiltner telescope at MDM observatory, located on the southwest ridge of Kitt Peak, Arizona. Observations were scheduled in blocks of 4–6 nights, separated by 1–3 months over a period of three years. The general program included observations of several classes of targets, including cataclysmic variables, low-mass halo subdwarfs, and our test sample of 18 suspected very nearby stars.

Observations were made with the MDM 2 k × 2 k CCD camera (dubbed “Echelle”). A typical pointing consisted of a series of 5–12 short 30–60 s exposures using either the $I$-band filter or a 7000 Å narrowband filter, which was used for targets bright enough to saturate the camera in a 30 s $I$-band exposure. An additional exposure in the $V$ band was typically obtained in each visit. Stars were observed within 1 hr of the meridian whenever possible, but sometimes as far as 2 hr. A journal of observations for the 18 nearby star candidates is provided in Table 1 for reference.

Astrometric solutions were determined following the method described and documented in detail in Thorstenсен (2003), including the setup of reference objects in the field, corrections for field scale and orientation, and a correction for differential atmospheric refraction. A typical astrometric solution for one of the stars (LSPM J0011+5908) is shown in Figure 1. The vector rms centroiding accuracy for well-exposed stars was typically 5 to 7 mas per exposure, as judged from the scatter around the best fits; these residuals are shown in Figure 1 for LSPM J0011+5908. We estimated the parallax errors both from the formal fit errors and from the scatter of the fitted parallaxes of the reference stars.

From our extended sets of CCD images, we also calculated apparent magnitudes in the $V$ and $I$ bands. Photometry was calibrated from observations of a set of photometric standards (Landolt 1992). Most of our fields have photometry from three or more observing runs, with independently derived calibrations. Comparisons between runs indicate that the zero points for the quoted magnitudes and colors should be accurate to < 0.05 mag. Although we observed standard stars that spanned a wide range of color (0.0 < $V - I$ < 2.0), most of the program stars are so red ($V - I$ > 3) that they required some extrapolation of the color transformation. This can lead to systematic effects that are difficult to estimate reliably, but the good run-to-run reproducibility suggests that the $V-I$ colors of the reddest objects are determined to better than 0.2 mag. Fortunately, Two Micron All Sky Survey (2MASS) infrared magnitudes are available for our program objects; the $V-J$ colors are relatively insensitive to small errors in $V$, and the latter were used to estimate the photometric distance. Table 2 presents our final reduced astrometric and photometric results.

2.3. LSPM J0405+7116: A Triple System

Our target list included one known double star: the common proper motion pair composed of the $V = 14$ star LSPM J0405+7116E, and its companion the $V = 16$ star LSPM J0405+7116W. The two stars have an angular separation of 5″ on the sky. The system made it into our sample of candidate nearby stars because of the short photometric distance of its secondary, which places it at a distance of only 12.6 ± 0.7 pc (Lépine 2005). The primary’s photometry places it at a somewhat longer distance of 14.6 ± 1.2 pc.

Our astrometric images revealed that, in fact, LSPM J0405+7116W is itself a visual double, with the two components (LSPM J0405+7116W-A and J0405+7116W-B) separated by ≈ 2″. The system is thus revealed to be a triple. Our best-seeing images (0″9) from 2006 October shows the two stars just
Figure 1. Astrometric solution for the star LSPM J0011 + 5908 based on our five-epoch measurements. Left panel: motion on the plane of the sky, with the dashed line showing the solution for the combined proper motion and parallax. Right panel: fit of the parallactic ellipse, after the proper motion has been subtracted. Each vector shows the residual from the fit for each astrometric measurement; each epoch having several data points. Note that the shape and orientation of the parallactic ellipse is preconstrained by the star’s position on the sky and is not part of the fit; only the size of the ellipse is fit to the data points and yields the parallax measurement.

Table 1
Journal of Observations

| Star     | \(N_{\text{ref}}\) | \(N_{\text{meas}}\) | \(N_{\text{pix}}\) | Epochs                                                                 |
|----------|---------------------|---------------------|---------------------|----------------------------------------------------------------------|
| J0011+5908 | 61                  | 68                  | 48                  | 2005.71(6), 2005.88(12), 2006.64(9), 2006.84(13), 2007.73(8)          |
| J0300+5413  | 55                  | 87                  | 64                  | 2004.86(6), 2005.71(4), 2005.88(23), 2006.03(8), 2006.63(5), 2006.84(12), 2008.05(6) |
| J0330+3118  | 15                  | 36                  | 64                  | 2005.88(11), 2006.04(1), 2006.84(13), 2007.72(16), 2008.04(6), 2008.15(7) |
| J0405+7116W | 31                  | 53                  | 63                  | 2004.86(7), 2005.20(6), 2005.71(5), 2005.87(13), 2006.04(2), 2006.66(6), 2006.84(10), 2007.07(8), 2008.05(6) |
| J0439+1615  | 28                  | 61                  | 57                  | 2004.86(2), 2005.08(6), 2005.21(2), 2005.71(5), 2006.03(5), 2006.66(6), 2006.84(10), 2007.07(8), 2008.15(4) |
| J1119+4641  | 9                   | 14                  | 64                  | 2005.09(10), 2005.20(7), 2005.30(10), 2006.05(5), 2006.38(6), 2007.08(3), 2007.34(8), 2007.91(5), 2008.14(4) |
| J1314+1320  | 14                  | 20                  | 53                  | 2005.21(13), 2006.05(6), 2006.20(4), 2006.38(6), 2007.07(4), 2007.35(8), 2007.48(6), 2008.15(4) |
| J1428+1356  | 14                  | 28                  | 24                  | 2005.71(3), 2006.39(8), 2007.34(3), 2007.47(6), 2008.15(4)          |
| J1757+7042  | 32                  | 58                  | 64                  | 2005.31(7), 2005.48(7), 2005.70(5), 2005.89(6), 2006.38(8), 2006.44(10), 2006.66(7), 2007.34(4), 2007.48(5), 2007.73(5) |
| J1817+1328  | 89                  | 115                 | 51                  | 2004.86(6), 2005.70(6), 2006.38(7), 2004.44(9), 2007.34(8), 2007.48(6), 2007.72(8) |
| J1826+0146  | 33                  | 49                  | 79                  | 2005.31(7), 2005.49(5), 2005.70(5), 2005.89(14), 2005.37(16), 2006.44(10), 2006.63(8), 2007.34(4), 2007.48(10) |
| J1839+2952  | 55                  | 92                  | 52                  | 2005.30(10), 2005.48(7), 2005.70(5), 2006.38(1), 2006.44(10), 2006.63(1), 2007.35(6), 2007.47(9), 2007.73(3) |
| J1840+7240  | 36                  | 58                  | 73                  | 2005.48(9), 2005.70(3), 2005.89(5), 2006.38(8), 2006.44(7), 2006.44(4), 2007.34(9), 2007.47(20), 2007.73(4), 2008.47(6) |
| J1926+2426  | 104                 | 110                 | 70                  | 2005.49(3), 2005.70(6), 2005.88(6), 2006.37(9), 2006.44(19), 2006.64(10), 2006.84(8), 2007.34(7) |
| J2325+1403  | 18                  | 43                  | 46                  | 2004.86(2), 2005.88(13), 2006.63(9), 2006.84(12), 2007.72(7)        |

Notes. Overview of the data included in the parallax solutions. \(N_{\text{ref}}\) is the number of reference stars used to define the plate solution, \(N_{\text{meas}}\) is the total number of stars measured, and \(N_{\text{pix}}\) is the number of images used. The epochs represent different observing runs, and the numbers in parentheses are the number of images included from each run.

barely resolved, with an angular separation \(\rho = 0.7 \pm 0.1\). The southwest component, which is marginally fainter, makes a position angle \(\text{pma} = 245^\circ \pm 1^\circ\) on the sky relative to the northeast component. We measure the centroid of the two components in turn to be \(5.3 \pm 0.1\) away from G 221-27, with a position angle \(\text{pma} = 240^\circ \pm 4^\circ\).

The three stars are listed in Table 2, with the two “west” components tabulated both individually and as a pair. While we have \(V\) and \(I\) magnitudes for \(W-A\) and \(W-B\), we only have 2MASS \(J\) magnitudes for the unresolved pair.

2.4. Spectroscopy

Medium-resolution spectra were obtained for 11 of the targets as part of our ongoing spectroscopic follow-up survey of stars from the LSPM-north proper motion catalog. Four stars were observed at the Lick observatory with the 3 m Shane telescope equipped with the KAST dual-channel spectrograph. Three more stars were observed at MDM on the 2.4 m Hiltner telescope with the MKIII spectrograph. The other four stars were observed at MDM on the 1.3 m McGraw-Hill telescope, also with the MKIII spectrograph. Standard reduction of all the spectra was performed with IRAF. Spectra were all wavelength calibrated against NeAr comparison arcs, and flux calibrated based on observations of the NOAO spectrophotometric standards Feige 66, Feige 67, and Feige 110. Spectra from three of the stars (LSPM J0011+5908, LSPM J0510+2714, and LSPM J1817+1328) were published in an earlier paper (Lépine et al. 2003) but are presented here again for completeness.
Nine of the stars are confirmed to be late-type M dwarfs, with spectral subtypes between M4.5 and M8.0. Spectral subtypes are determined based of the strength of the Ca II, TiO, and VO molecular bands, as described in Lépine et al. (2003). The tenth object, LSPM J1817+1328, is confirmed to be a cool DA WD with a very weak, but detectable, Hα absorption line. A blackbody fit of the spectral energy distribution indicates a spectral subtype of DA 10. The reduced spectra are shown in Figure 2.

We searched the literature for published spectroscopic data on the other seven systems, and found formal spectral classifications for five of them, including spectral subtypes for LSPM J0405+7116E and for the (unresolved) pairs LSPM J0405+7116W and LSPM J0405+7116W-A (Cruz & Reid 2002). All available spectral subtypes are tabulated in Table 3, along with the bibliographical source for the classification.

### 2.5. X-ray Emission Activity

We have examined our spectra for signs of activity, which in M dwarfs is diagnosed by a strong Hα line in emission. Hα emission was detected in nine of our targets; equivalent widths are listed in Table 3. Four of the stars have Hα equivalent widths in excess of 2Å, which qualifies them as active stars.

We further searched for bright X-ray counterparts in the ROSAT All-Sky catalog of point sources (Voges et al. 1999) and ROSAT All-Sky catalog of faint sources (Voges et al. 2000). X-ray sources within 20 arcsec of our targets were selected as probable counterparts. The search turned up probable X-ray counterparts to five of our target M dwarfs; count rates per second are noted in Table 3. One of the stars for which we lack spectroscopic data happens to be an X-ray bright source. The ROSAT X-ray count rate for LSPM J0011+5908 is at a level similar to the Hα-bright stars. We take this as an indication that LSPM J0011+5908 is also an active M dwarf. We predict that spectroscopic observations should reveal the presence of significant Hα emission in that object.

Overall, most of our active objects show only moderate signs of activity, typical of M dwarfs with detected Hα emission. The only exception is LSPM J0510+2714, whose Hα emission is quite significant.
This one is a very recent discovery, identified as a high proper motion star by Lépine & Shara (2005). With a proper motion of only $\mu = 0\farcs151 \text{ yr}^{-1}$, the star does not particularly stand out among the nearby stars, which tend to have much larger proper motions; the star, however, was estimated to be at $12.5 \pm 4.2$ pc based on photometry. While the star has no formal spectral classification as yet, its color suggests a spectral type of about M5. Our geometric parallax again places it within the 10 pc horizon, at a distance $d = 9.63 \pm 0.13$ pc. The proper motion is consistent with a relatively low transverse velocity of $6.9 \text{ km s}^{-1}$, which suggests the star may be part of the young Galactic disk population. The moderate levels of X-ray would be consistent with this suggestion; it would be interesting to verify whether the star also shows significant Hα emission.

This star was also first identified as a high proper motion star in Lépine & Shara (2005). A photometric distance of $10.9 \pm 3.8$ pc was estimated by Lépine (2005). The star happens to be in the direction of the Perseus star-forming region. Its polarization was measured in a study of the Perseus dark cloud complex (Goodman et al. 1990) but found to be negligible, consistent with the star being a foreground object. Our parallax indeed places the star at a distance of $12.56 \pm 0.39$ pc. The relatively low proper motion yields a transverse velocity of only $0.6 \pm 0.3 \text{ km s}^{-1}$ consistent with the young disk population. The star indeed shows signs of being relatively young, with significant Hα and X-ray emission. We classify the star as M4.5e.

One of the high proper motion objects from the Lowell proper motion survey (Giclas et al. 1971); its large proper motion was remeasured and updated by Salim & Gould (2003) and Lépine & Shara (2005). The M4.0 dwarf was first suspected to be a very nearby star by Cruz & Reid (2002), based on a spectroscopic distance estimate of $14.7 \pm 1.2$ pc. Scholz et al. (2005), however, estimated a spectroscopic distance of $17.0 \text{ pc}$ with a $\pm 20\%$ uncertainty, while Lépine (2005) estimated a photometric distance of $19.4 \pm 7.2$ pc. Our parallax places the star at $17.51 \pm 0.37$ pc, more on line with the Scholz estimate. The large proper motion yields a transverse velocity of $34.9 \pm 0.7 \text{ km s}^{-1}$. The star is found to be the more massive component in a triple system.

This companion to G 221-27 was initially identified by Luyten (1979b), with a reported $5^\circ$ separation and magnitude difference $\Delta R = 1.2$ mag from the primary. Cruz & Reid (2002) also noted the existence of the M5.0 dwarf companion while estimating the distance at $12.6 \pm 0.7$ pc based on the spectral type. Our estimated photometric distance placed the star at $12.6 \pm 3.7$ pc (Lépine 2005). Our astrometric parallax for the system, however, clearly places the star at the larger distance of $17.51 \pm 0.4$ pc. The existence of an unresolved companion explains the underestimate of the spectroscopic and photometric distances.

This faint companion to G 221-27 is reported here for the first time. At the $17.5 \text{ pc}$ estimated distance, the two components have a projected distance of about 13 AU, while
both together have a projected separation of 90 AU from the primary component (G 221–27). Note that our parallax estimate for this triple system is based on the astrometric motion of the primary, which is clearly resolved from the two companions on all the frames and is thus not affected by the presence of the two companions.

2.6.7. LSPM J0439+1615 = LHS 1690

This is one of the very high proper motion stars from the LHS catalog (Luyten 1979a); its high proper motion was confirmed and remeasured by Bakos et al. (2002), Salim & Gould (2003), and Lépine & Shara (2005). It was identified as a probable nearby star by Cruz & Reid (2002) based on a spectroscopic distance estimate of $12.3 \pm 1.1$ pc, while our photometric estimate placed the star at $12.0 \pm 4.0$ pc (Lépine 2005). Both estimates are largely consistent with our astrometric parallax which places the star at $11.55 \pm 0.33$ pc. We classify the star to be an M5.5e dwarf, with a weak but clearly detected H$_\alpha$ emission. The large proper motion yields a transverse velocity of $43.7 \pm 1.2$ km s$^{-1}$.

2.6.8. LSPM J0510+2714

This one was identified as a high proper motion star by Lépine et al. (2002), confirmed by Reid (2003). It is a low galactic latitude object ($b = -7.4$) in a relatively dense field. The star was identified as a probable nearby star by Reid et al. (2004), based on a photometric distance modulus of $0.70 \pm 0.48$ mag, which suggests a distance of $\approx 14$ pc. Our own photometric estimate placed the star at $10.1 \pm 3.2$ pc (Lépine 2005). Our geometric parallax places the star just within the 10 pc horizon, at a distance of $9.93 \pm 0.16$ pc. The proper motion yields a transverse velocity of $31.4 \pm 0.5$ km s$^{-1}$. Our spectrum reveals the star to be an ultracool dwarf with spectral type M8.0e. The star has a strong H$_\alpha$ line in emission and is also detected in X-ray which suggest it may be relatively young.

2.6.9. LSPM J0515+5911

Like the preceding object, this star was discovered as a high proper motion star in a low galactic latitude field by Lépine et al. (2002), and reconfirmed by Levine (2005). It was classified as a probable old disk object. Our geometric parallax yields a distance of $12.85 \pm 0.50$ pc, which confirms the spectroscopic and photometric distance underestimation from the unresolved binary. The proper motion yields a transverse velocity of $41.1 \pm 1.6$ km s$^{-1}$.

2.6.11. LSPM J1119+4641 = LHS 2395

Another star from the LHS catalog (Luyten 1979a), the star also known as LP 169-22 was on the photometric list of Weis (1996), but was formally identified as a nearby star by Gizis & Reid (1997) who estimated a spectroscopic distance of 18.2 pc, from a spectral type M5.5. Reid & Cruz (2002) estimated a photometric distance of $10.7 \pm 0.8$ pc, while our own estimation suggested a photometric distance of $11.2 \pm 3.8$ pc. Our parallax places the star just beyond the 10 pc horizon at $10.31 \pm 0.28$ pc, with the proper motion yielding a transverse velocity of $33.1 \pm 0.9$ km s$^{-1}$.

2.6.12. LSPM J1314+1320 = NLTT 33370

This is a star from the NLTT catalog (Luyten 1979b) which was re-identified by Lépine & Shara (2005) and has received little attention so far (like many of the stars in the NLTT catalog not listed in the LHS). Lépine (2005) identified it as a probable nearby star based on a $9.7 \pm 3.0$ pc photometric distance estimate. Our parallax places the star at a much larger distance of $16.39 \pm 0.75$ pc. Our spectrum yields a spectral type M7.0e with a very strong H$_\alpha$ line in emission. The significant underestimate in the photometric distance strongly suggests that the star may be an unresolved double. This would have to be tested by adaptive optics observations or radial velocity monitoring. Alternatively, the star could be overluminous due to being extremely young, which would also be consistent with the strong H$_\alpha$ line. The proper motion yields a transverse velocity of $23.8 \pm 1.1$ km s$^{-1}$, consistent with the young disk population.

2.6.13. LSPM J1428+1356 = LHS 2919

This is another star from the LHS catalog (Luyten 1979a) identified as a nearby star by Reid et al. (2003) from an estimated spectroscopic distance of $13.0 \pm 1.4$ pc. Scholz et al. (2005) quoted a spectroscopic distance of 13.1 pc, while we estimated the photometric distance at $10.7 \pm 3.6$ pc (Lépine 2005). We classify the star as an M7.5e dwarf with weak but detectable H$_\alpha$ line in emission. Our parallax places the star at $12.08 \pm 0.60$ pc, consistent with all the estimates above, with a transverse velocity of $34.6 \pm 1.7$ km s$^{-1}$.

2.6.14. LSPM J1757+7042 = LP 44-162

This ultracool dwarf (M7.5) was identified as a probable nearby star by Gizis et al. (2000) based on its very red optical-to-infrared color, with a photometric distance estimate of $11.7$ pc (spectral type M7.5). A photometric distance of $12.5 \pm 1.2$ was estimated by Cruz et al. (2003), with our own estimate at $12.6 \pm 4.2$ pc (Lépine 2005). Scholz et al. (2005) estimated a spectroscopic distance of 16.0 pc. Our parallax places the star at $19.08 \pm 0.40$, significantly larger than the photometric distance estimates, and suggesting the star may be an unresolved double. The star was examined with adaptive optics, but no companion was found (Sieglar et al. 2003, 2005). Radial velocity observations might reveal the star to be a spectroscopic double.

2.6.15. LSPM J1817+1328

This high proper motion star was discovered by Lépine et al. (2002), and spectroscopically identified as a WD by Lépine et al. (2003). The star is identified to be within the 20 pc horizon by
Holberg et al. (2008), from the photometric distance of 15.6 ± 2.5 pc estimated by Subasavage et al. (2007). Our parallax indeed places the WD at 14.22 ± 0.24 pc. Our spectrum suggests that the object is a very cool hydrogen WD, with spectral type DA 11. The large proper motion yields a transverse velocity of 80.4 ± 1.4 km s⁻¹, consistent with the old disk population.

2.6.16. LSPM J1826+0146 = NLTT 46476

This high proper motion star from the NLTT catalog was identified as a probable nearby star by Lépine (2005), from a photometric distance of 12.6 ± 3.7 pc. We classify the star as an M4.5 dwarf. Our parallax places the star at 18.69 ± 0.70 pc, which yields a transverse velocity of 30.6 ± 1.2 km s⁻¹.

2.6.17. LSPM J1839+2952 = LP 335-12

This was identified as a nearby star by Reid & Cruz (2002). Spectroscopic distances of 12.7 pc and 13.1 pc were estimated by Reid et al. (2003) and Scholz et al. (2005), respectively, from a spectral type M6.5. This is to be compared with our own photometric distance of 12.6 ± 4.2 pc (Lépine 2005). Our astrometry places the star at 16.86 ± 0.63 pc, with a transverse velocity of 15.3 ± 0.6 km s⁻¹.

2.6.18. LSPM J1840+7240 = LP 44-334

This was identified as a nearby star by Reid et al. (2004) from a spectroscopic distance of 12.5 ± 1.4 pc (spectral type M6.5), while we estimated a photometric distance of 13.6 ± 4.6 pc (Lépine 2005). Our astrometry places it at 18.94 ± 0.54 pc, in line with the spectroscopic distance, with a transverse velocity of 18.8 ± 0.5 km s⁻¹. Our spectrum yields a subtype M4.5e, with Hα clearly detected.

2.6.19. LSPM J1926+2426 = G 185-23

This is another star from the Lowell Proper Motion catalog (Giclas et al. 1971), which was identified as a nearby star by Reid et al. (2004) from a spectroscopic distance of 17.1 ± 2.9 pc, while we estimated the photometric distance at 12.2 ± 3.6 pc (Lépine 2005). Our astrometry places it at 18.94 ± 0.54 pc, in line with the spectroscopic distance, with a transverse velocity of 8.8 ± 0.5 km s⁻¹. Our spectrum yields a subtype DA10 WD by Vennes & Kawka (2003) and Kawka & Vennes (2006). The star also was flagged as a cool WD in the Sloan Digital Sky Survey (Kilic et al. 2006), and identified as a member of the nearby WD population by Holberg et al. (2008) with a photometric distance of 18.7 ± 6.0 pc. Our astrometry places it at 22.27 ± 0.99 pc, beyond the 20 pc horizon for the local WDs, with a transverse velocity of 38.6 ± 1.7 km s⁻¹.

3. ANALYSIS AND DISCUSSION

One of our goals was to verify the reliability of the photometric distance estimates for stars in the LSPM-north catalog, which is based in part on photographic magnitudes. This is important for evaluating whether more extensive lists of candidate nearby stars can be efficiently assembled out of our proper motion catalogs. Current photometric distances for stars in the LSPM-north catalog are based on the \([M_V, V - J]\) color–magnitude relationship, calibrated by Lépine (2005) using nearby stars with trigonometric parallaxes. The dispersion in the color–magnitude relationship (±0.68 mag) suggests that those distance estimates should be accurate to ±37%.

Figure 3 compares our photometric distance estimates to the measured parallax distances. Filled squares plot the relative errors in the distance moduli for \(d_{\text{phot}}\) based on the photographic magnitudes \(V_r\). There is a clear trend for the more distant stars \((d > 14\, \text{pc})\) to have \(d_{\text{phot}}\) underestimating their distances, while the nearer objects \((d < 14\, \text{pc})\) have their distances slightly overestimated by the photometry. This can be explained by selection effects: our target sample was largely assembled out of stars with \(d_{\text{phot}} < 15\, \text{pc}\) (this selection limit is shown as a dashed line in Figure 3). Overall, photographic distance moduli have a rms error of 0.546 over the parallax distance moduli. These are largely comparable with the rms for nearby stars with existing parallax measurements (Lépine 2005) which show a 1σ dispersion about the mean of 0.65.

To verify how much the errors on \(d_{\text{phot}}\) are due to statistical/systematic errors on the photographic magnitudes \(V_r\), we also plot in Figure 3 the errors on \(d_{\text{phot}}\) when calculated using the photometric CCD magnitudes from our astrometric sequences (open circles). We find that the CCD magnitudes do improve the accuracy of \(d_{\text{phot}}\) for two of the more distant stars (around 19 pc), replacing them in line with \(d_{\text{plx}}\). However, the CCD magnitudes appear to systematically overestimate the distances for the nearest stars. Furthermore, three of the more distant objects stubbornly remain with significantly underestimated distances. Overall, the CCD photographic distance moduli have an rms error of 0.588, from which we conclude that the CCD photometry does not significantly improve the photographic distance estimates.

It is clear that significant errors remain which must be explained by intrinsic uncertainties. Possible sources of bias...
on the photometric distances include: (1) systematic or random errors in the photometry, (2) unresolved binaries or multiples, which tend to underestimate the distance of the pair, and (3) intrinsic scatter in the local $[M_V, V - J]$ color–magnitude relationship due to the dependence of the color and absolute magnitude on age and metallicity. These biases introduce uncertainties on the photometric distances of individual stars, no matter how well defined the mean color–magnitude relationship is. The multiplicity fraction in M dwarfs, in particular, is known to be $\approx 40\%$ (Fischer & Marcy 1992), so significant numbers of doubles/multiple systems are expected to contaminate lists of candidate nearby stars.

We use our parallax measurements and improved photometry to construct a color–magnitude diagram (CMD) for the stars on our program. The CMD is shown in Figure 4. Most M dwarfs fall neatly along the main sequence, while the two WDs lie close to their expected locus. We find that three of our program M dwarfs hover more than 0.8 mag above the main mean sequence. One of them is the known pair LSPM J0405+7116E-AB, which we resolved in our astrometric images; in Figure 4 the unresolved pair is plotted as an asterisk. The other two objects that hover more than 1 mag above the main mean sequence, are the stars LSPM J1314+1320 and LSPM J1757+7042, which we now suspect to be unresolved doubles; these are plotted as stars in Figure 4. This suggest a possible $\approx 10\%$ contamination of the nearby star sample from distant unresolved doubles. The other known unresolved pair, LSPM J0711+4329 (= LHS 1901), also plotted as an asterisk in Figure 4, only falls marginally above the mean color–magnitude relationship, which shows that not all unresolved pairs should appear as significantly overluminous.

The mean main sequence and the WD sequence, shown by the dashed lines in Figure 4, are the relationships we used to estimate the photometric distances. The bottom panel in Figure 4 shows the residuals between the photometric and astrometric distance moduli, as a function of color. The dotted lines shows the intrinsic dispersion in the main sequence locus as observed by Lépine (2005). Our parallax targets show a similar scatter about the mean. No significant correlation is found between the $V - J$ color and the residuals, which suggests that most of the dispersion is due to the intrinsic scatter.

Figure 4. Upper panel: color–magnitude diagram of our parallax targets, based on CCD magnitudes and parallax measurements. The mean locus of the main sequence and white dwarf sequence, used to estimate photometric distances, are shown for comparison (dashed lines). The two stars denoted by star symbols (LSPM J1314+1320 and LSPM J1757+7042), hover significantly above the main sequence and are strongly suspected to be unresolved binaries. The known binary system LSPM J0405+7116E-AB, plotted as an asterisk, also falls significantly above the mean main sequence, as expected. Lower panel: residuals; which suggests that most of the dispersion is due to the intrinsic scatter.

Figure 5. Offsets between the photometric and parallactic distance moduli, with the photometric distances based on the $(V_e, V_e - J)$ color–magnitude relationship of Lépine & Shara (2005). The two suspected unresolved binaries, and the known pair LSPM J0405+7116E-AB are shown as open star symbols, as in Figure 5; all have photometric distances moduli underestimated by 0.7 mag or more. All the nearest stars ($d < 12$ pc) have their distances overestimated, when those distances are derived from photometry; we suspect selection effects to be responsible for the discrepancy (see the text).

Figure 5 again shows the errors on the photometric distances $d_{\text{phot}}$, calculated from the CCD magnitudes, similar to the bottom panel in Figure 4 but now plotted as a function of distance. Different symbols again are used for the known and suspected doubles, and also for the more chromospherically active stars. Again no significant difference is noted between the inactive and more active objects, but there is a clear correlation between the residuals and the parallax distances. This trend was already observed in Figure 3, and appears to be related to selection effects. It is clear that the more distant stars will make it into the sample only if their distances are underestimated by photometry. On the other hand, it remains unclear why the more nearby stars should have their photometric distances systematically overestimated. One possibility is that this is due to selection effects from earlier parallax programs. If these programs have been biased in favor of stars with very short photometric distances, it is possible that the only nearby stars left are those with overestimated photometric distances.

4. CONCLUSIONS

We have obtained reliable parallax distances for 18 high proper motion stars identified in recent years to be probable nearby stars based on photometric and spectroscopic distance estimates. Our parallax measurements confirm that the stars are within the Solar neighborhood, with distances in the $9–22$ pc range. Spectra are presented for most of the stars, which confirms the WD nature of two of the targets.

Three of the stars are found to have absolute parallaxes placing them within 10 pc of the Sun: PM J0011+5908 is an M6.5 dwarf at 9.2 pc; PM J0330+5413 is an active M4.5e dwarf...
at a distance of 9.6 pc; PM J0510+2714 is just within the 10 pc horizon, and is an ultracool dwarf with subtype M8.0e. All three stars add to the current census of ≈ 300 stars confirmed to be within 10 pc of the Sun. The other 15 stars add to the tally of ≈ 2000 confirmed systems with d < 25 pc.

Our sample illustrates some of the systematic and random errors that plague photometric distance estimates. Even with accurate photometric CCD measurements, several stars have photometric distance estimates which significantly over- or underestimate their true distances. One should thus expect some level of incompleteness and contamination in photometrically selected samples of nearby stars, which indicates that only systematic parallax measurements will produce reliable distances of the now several thousand stars suspected to be in the 15 pc–33 pc range (Lépine 2005), and for which no geometric parallax measurement exists to date.

Our parallax measurements yield only a modest (±1%) increment in the census of confirmed nearby stars. However, significantly larger numbers of targets remain to be examined which promise to increase the census significantly, especially beyond the 20 pc horizon.

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