A VERY HIGH PROPER MOTION STAR AND THE FIRST L DWARF IN THE KEPLER FIELD

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ABSTRACT

We report two nearby high proper motion dwarfs of special interest identified using the Preliminary Data Release of the Wide-field Infrared Survey Explorer (WISE) and the Two Micron All Sky Survey. WISEP J191239.91−361516.4 has a motion of 2.1 arcsec yr⁻¹. Photometry identifies it as a mid-M dwarf. WISEP J190648.47+401106.8 is a spectroscopically confirmed L1 dwarf in the Kepler Mission field with a motion of 0.48 arcsec yr⁻¹. The estimated distance is 17 pc. Both lie at relatively low galactic latitudes and demonstrate the possibility of discovering proper motion stars independent of the historic photographic sky surveys.

Key words: brown dwarfs – infrared: stars – proper motions – stars: low-mass

Online-only material: color figure

1. INTRODUCTION

The identification of high proper motion stars is an important tool for identifying neighboring stars. The LHS Catalog (Luyten 1979) listed over 4000 stars with proper motions near or above half an arcsecond per year but only 73 stars with motions above 2 arcsec yr⁻¹. Digitized photographic sky surveys and the more recent digital optical and near-infrared sky surveys have allowed many new proper motion stars to be identified (Lépine et al. 2002; Lépine & Shara 2005; Subasavage et al. 2005; Lépine 2005a; Deacon et al. 2005; Finch et al. 2007; Lépine 2008; Sheppard & Cushing 2009; Kirkpatrick et al. 2010). Currently, the Simbad database lists some 108 stars (including white dwarfs and brown dwarfs) with motions above 2 arcsec yr⁻¹.

Nevertheless, high proper motion stars remain to be identified. At low galactic latitudes, crowding makes it difficult to correctly pair stars, even though important progress has been made to bring the completeness in the Galactic plane to at least 90% (Lépine & Shara 2005) and perhaps as high as 99% (Lépine et al. 2002). Lépine & Shara (2005) also estimate that incompleteness sets in at \( |V| = 19 \) for low galactic latitudes \((|b| < 15)\) but \( V = 20 \) at high latitudes, and remark that independent surveys are needed to fully assess the completeness of their catalog. Unfortunately, the vast number of reddened background stars makes it difficult to identify cool, nearby objects by photometry alone. A second potential source of incompleteness is that for very large motions, the stars may move so far that automated pairing programs fail. The relatively recent discovery of such objects as a white dwarf moving at 2.55 arcsec yr⁻¹ (Lépine et al. 2005) and an M6.5 dwarf moving at 5.05 arcsec yr⁻¹ (Teegarden et al. 2003), both detectable on the photographic plate surveys, is illustrative. Third, cooler objects, particularly brown dwarfs, are too faint for photographic plates, though these can often be selected by infrared colors alone.

These problems can be addressed with a new infrared sky survey. The Wide-field Infrared Survey Explorer (WISE) has surveyed the entire sky in four mid-infrared filters (Wright et al. 2010), allowing a comparison with the near-infrared Two Micron All Sky Survey (2MASS; Skrutskie et al. 2006), even in the Galactic plane. The WISE Explanatory Supplement demonstrates that the matching of the two surveys is good to 0′.2 for high signal-to-noise stars and that 99.9% of WISE stars match 2MASS sources to within 3 arcsec. The time baseline is approximately a decade, so objects with \( \mu \gtrsim 0.3 \) arcsec yr⁻¹ are expected to move out of the matching window. The high reliability and completeness of WISE and 2MASS allow us to search for previously unidentified proper motion stars. In this Letter, we report on two particularly important sources.

2. DATA ANALYSIS

Our strategy is based on the fact that nearby hydrogen-burning stars should appear as relatively bright, high signal-to-noise sources in both WISE and 2MASS. We initially obtained a list of possible proper motion stars by querying the WISE Preliminary Source Catalog for stars with \( 5 < W₁ < 12 \) that lacked 2MASS pairings within 3 arcsec. We then matched this list with the Lépine & Shara (2005, hereafter LSPM) catalog of stars with motions greater than 0.15 arcsec yr⁻¹. We found that nearly all LSPM stars had \( 0.1 < W₁ - W₂ < 0.3 \) and \( -0.1 < W₁ - W₃ < 0.7 \) (with the exception of a few very bright stars affected by saturation), and so we applied these color cuts to the sample. This selection for the initial analysis, it should be noted, is intended to select main-sequence stars and will likely exclude white dwarfs and brown dwarfs. We furthermore excluded known stars by requiring no Simbad sources within 12 arcsec and no matches to the PPMXL catalog (Roester et al. 2010). This left only 118 sources, each of which were examined in the Digitized Sky Survey, 2MASS, and WISE images. Because we had made no additional cuts based on WISE source quality, this list included many bright star artifacts, as expected in the Preliminary processing. However, we also found and recovered a number of known proper motion stars, such as the 5′ yr⁻¹ star SO 025300.5+165258 (Teegarden et al. 2003) [WISEP J025303.27+165214.2], which move quickly enough that they were not excluded by the Simbad query, as well as previously unknown stars. We extended this analysis to \(|b| > 10\) without difficulty. For yet lower galactic latitudes, \(|b| < 10\), we found we could exclude most of the bright star artifacts, and none of the proper motion stars, by requiring that the source not be extended \(|e_x . f l g = 0|\) in WISE. We also had to drop the W3 color cuts, because the 12 μm data do not reach as deep in regions of high background. No matches at the lowest latitude to PPMXL were attempted given its potential unreliability in
crowded fields. The resulting 492 sources were also examined by eye, and 229 appear to be genuine proper motion objects. The main sources of false matches in the plane were apparently real but non-moving sources whose 2MASS detections were masked or flagged due to nearby bright stars in the crowded fields. As expected, most of the genuine high proper motion stars were listed by Luyten (1979) or more recent publications (Lépine 2005a, 2008). Complete details and a full list of detected stars are tied directly to the 2MASS positions, which can be attributed primarily to the WISE–2MASS uncertainties. The photometry is consistent with a mid-M (~M4) dwarf. The photometry and a 3200 K model atmosphere (Hauschildt et al. 1999) are plotted in Figure 2. Comparing to the parallax sample of Costa et al. (2006), we expect \( M_I \approx 9.0 \) for \( I - J = 1.2 \) for a disk main-sequence dwarf. This suggests a distance of 13 pc and \( v_{tan} \approx 120 \text{ km s}^{-1} \), but if the star is metal-poor, it would be closer with a lower velocity, and a distance within 10 pc is possible. (If an equal-luminosity binary, it may be more distant.)

A trigonometric parallax is needed. According to Simbad, it is the 103rd fastest proper motion star known.

We identify WISEP J190648.47+401106.8 (hereafter W1906+40) with 2MASS J19064801+4011089 and SDSS J190648.29+401107.6 (Abajian et al. 2009). The 10 photometric measurements are shown in Figure 2, with \( g = 22.357 \), \( r = 20.029 \), \( i = 17.419 \), and \( z = 15.578 \). The \( WISE \) observations are from 2010 April 16 to 2010 April 22 and the 2MASS observations are from 1998 May 23. A finder chart is shown in Figure 3. Both \( i - z = 1.84 \) and \( J - K_s = 1.31 \) are consistent with a late-M or an early-L type (Schmidt et al. 2010). A low-resolution IRTF SpeX (Rayner et al. 2003) spectrum was obtained on 2011 April 19 and processed using SpeXTool (Vacca et al. 2003; Cushing et al. 2004). It is shown in Figure 4. We classify W1906+40 as spectral type L1. The source may be a hydrogen-burning star or a brown dwarf. According to the relations of Cruz et al. (2003), the distance is \( 16.6 \pm 1.9 \) pc and the tangential velocity is \( 38 \text{ km s}^{-1} \), but again, a trigonometric parallax is needed. The most compelling property of this nearby L dwarf is that it lies in the Kepler Mission field (Koch et al. 2010), as Kepler ID 4996077, making it the coolest dwarf known in the field. It was not on the Kepler observing list, but...

![Figure 1](image1.png)

**Figure 1.** Finder chart for WISEP J191239.91−361516.4. This image is the DSS scan of the 1992 July 27 AAO-SES red photographic plate. Both the 1992 position and the 2010 WISE position are marked with circles.

![Figure 2](image2.png)

**Figure 2.** Observed flux densities for the two stars (WISEP J191239.91−361516.4 as triangles and WISEP J190648.47+401106.8 as diamonds). Magnitude zero points are from Abazajian et al. (2009, SDSS), Fouqué et al. (2000, DENIS), Cohen et al. (1992, 2MASS), and Wright et al. (2010, WISE). Model spectra for 3200 K (Hauschildt et al. 1999) and 2000 K (Allard et al. 2001), shown as dotted lines, are illustrative only.

The reported WISE–2MASS positional uncertainties of 0′′2 lead to an uncertainty of the proper motions of 0′′02 yr\(^{-1}\). (We can also directly compare WISE–2MASS proper motions to those reported in the LSPM catalog, and we find that the standard deviation of the differences is 0′′013 yr\(^{-1}\) in each coordinate, which can be attributed primarily to the WISE–2MASS uncertainties.)

![Table 1](image3.png)

**Table 1**

| WISEP Name       | \( \mu_\alpha \) | \( \mu_\delta \) (′ yr\(^{-1}\)) | \( J \) | \( H \) | \( K_s \) | \( W_1 \) | \( W_2 \) | \( W_3 \) | \( W_4 \) |
|------------------|-----------------|-------------------------------|--------|--------|----------|--------|--------|--------|--------|
| J191239.91−361516.4 | 0.78            | −1.94                        | 9.52   | 9.01   | 8.77     | 8.55   | 8.35   | 8.20   | 8.17   |
| J190648.47+401106.8   | 0.44            | −0.18                        | 13.08  | 12.26  | 11.77    | 11.45  | 11.22  | 10.77  | >9.32  |

3. Discussion

We identify WISEP J191239.91−361516.4 with 2MASS J19123922−3614555, DENIS 191239.2−361455, and USNO-B 0537−0751534. A finder chart is shown in Figure 1. The WISE and 2MASS photometry and astrometry are listed in Table 1, and in addition, \( I = 10.98 \) from DENIS (Epchtein et al. 1997) and \( R_F \approx 12.6 \) from USNO-B (Monet et al. 2003). The WISE observations are from 2010 April 1 to 2010 April 7 and the 2MASS observations are from 1999 June 25. Since the WISE positions are tied directly to the 2MASS positions, we can compute the proper motion of 2′09 yr\(^{-1}\) directly.
We have identified two nearby proper motion stars at low galactic latitudes, demonstrating the value of an infrared proper motion survey based on the WISE and 2MASS catalogs. Wright et al. (2010) note that an important WISE mission objective is to identify unknown, nearby low-luminosity brown dwarfs. Proper motion selection using WISE promises to also contribute to the Galactic plane. The objects detected here are consistent with the evidence (Lépine & Shara 2005; Lépine 2008) that the vast majority of high proper motion hydrogen-burning stars have been detected. Lépine (2005b), however, estimates that a third of nuclear-burning stars within 33 pc remain unidentified but have motions below 0.15 yr−1. WISE and 2MASS photometry and astrometry appear to be accurate enough to allow many of these to be identified, even at low Galactic latitudes, although optical follow-up will be required.

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The UK Schmidt Telescope was operated by the Royal Observatory Edinburgh, with funding from the UK Science and Engineering Research Council (later the UK Particle Physics and Astronomy Research Council), until 1988 June, and thereafter by the Anglo-Australian Observatory. The blue plates of the southern Sky Atlas and its Equatorial Extension (together known as the SERC-J), as well as the Equatorial Red (ER), and the Second Epoch [red] Survey (SES) were all taken with the UK Schmidt.

4. CONCLUSIONS

We have identified two nearby proper motion stars at low galactic latitudes, demonstrating the value of an infrared proper motion survey based on the WISE and 2MASS catalogs. Wright et al. (2010) note that an important WISE mission objective is to identify unknown, nearby low-luminosity brown dwarfs. Proper motion selection using WISE promises to also contribute to the solar neighborhood stellar census over the entire sky, including the Galactic plane. The objects detected here are consistent with the evidence (Lépine & Shara 2005; Lépine 2008) that the vast majority of high proper motion hydrogen-burning stars have been detected. Lépine (2005b), however, estimates that a third of nuclear-burning stars within 33 pc remain unidentified but have motions below 0.15 yr−1. WISE and 2MASS photometry and astrometry appear to be accurate enough to allow many of these to be identified, even at low Galactic latitudes, although optical follow-up will be required.

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