A&A 567, A43 (2014)
DOI: 10.1051/0004-6361/201424070

Astronomy & Astrophysics

WISEA J064750.85-154616.4: a new nearby L/T transition dwarf★ *(Research Note)*

R.-D. Scholz, G. Bihain, and J. Storm

Leibniz-Institut für Astrophysik Potsdam (AIP), An der Sternwarte 16, 14482 Potsdam, Germany
e-mail: [rdscholz;gbihain;jstorm]@aip.de

Received 25 April 2014 / accepted 4 June 2014

ABSTRACT

Aims. Our aim is to detect and classify previously overlooked brown dwarfs in the solar neighbourhood.

Methods. We performed a proper motion search among bright sources observed with the Wide-field Infrared Survey Explorer (WISE) that are also seen in the Two Micron All Sky Survey (2MASS). Our candidates appear according to their red $J-K_s$ colours as nearby late-L dwarf candidates. Low-resolution near-infrared (NIR) classification spectroscopy in the HK band allowed us to get spectroscopic distance and tangential velocity estimates.

Results. We have discovered a new L9.5 dwarf, WISEA J064750.85-154616.4, at a spectroscopic distance of about 14 pc and with a tangential velocity of about 11 km s^{-1}, typical of the Galactic thin disc population. We have confirmed another recently found L/T transition object at about 10 pc, WISEA J140533.13+835030.7, which we classified as L8 (NIR).

Key words. astrometry – proper motions – stars: distances – stars: kinematics and dynamics – brown dwarfs – solar neighborhood

1. Introduction

Proper motion searches continue to play an important role in the search for still missing cool neighbours of the Sun. To find hidden brown dwarfs (BDs) in the solar neighbourhood by their high proper motion (HPM), it is essential to use near-infrared (NIR) and mid-infrared (MIR) multi-epoch observations. The NIR observations of the Two Micron All Sky Survey (2MASS; Skrutskie et al. 2006) with observing epochs between 1997 and 2001 have been successfully combined with recent (≈2010) MIR observations of the Wide-field Infrared Survey Explorer (WISE; Wright et al. 2010) to discover nearby M, L, and T dwarfs previously overlooked in colour-based surveys (see e.g. Gizis et al. 2011a,b, 2012; Castro & Gizis 2012; Castro et al. 2013; Bihain et al. 2013 (B13); Thompson et al. 2013; Scholz 2014).

The multiple epochs from WISE alone already allowed us to find very large numbers of previously unknown HPM objects (Luhman 2014a; Kirkpatrick et al. 2014). Most of these new HPM objects are (according to their moderately red colours) M dwarfs in the extended solar neighbourhood, but spectroscopic follow-up observations have also revealed many ultracool (L-type) subdwarfs (Wright et al. 2014; Kirkpatrick et al. 2014; Luhman & Sheppard 2014) among the new WISE HPM objects. In addition, a few very close (d < 10 pc) new L/T and M dwarf neighbours, which were observed but not discovered before in 2MASS, were found by Luhman (2013) and Kirkpatrick et al. (2014). The even cooler Y-type BDs discovered thanks to WISE observations (Cushing et al. 2011, 2014; Kirkpatrick et al. 2012, 2013) are not seen in 2MASS. The recently discovered coolest BD (Luhman 2014b), ranging now as the third fastest among all HPM objects and fourth nearest among the solar neighbours, is undetected in the J band down to the 23rd magnitude.

In their HPM search for previously overlooked (in 2MASS) nearby BDs, Scholz et al. (2011) and B13 concentrated on relatively bright MIR ($w2 \lesssim 13$) BD candidates selected from the WISE preliminary and all-sky catalogues, respectively. They looked for their 2MASS counterparts with significant proper motion and colours typical of T dwarfs. Some of the candidates in the search of B13 exhibited relatively red NIR colours expected for late-L dwarfs. Here we report the results of spectroscopic follow-up observations for three of these candidates, one of which turned out to be a new L9.5 dwarf within about 15 pc. For all objects described in this research note, we use their AllWISE (Kirkpatrick et al. 2014) designations.

2. Candidate selection and proper motion

The new object WISEA J064750.85-154616.4 (hereafter WISEA J0647−1546) was found with the same selection criteria as described in B13. Its proper motion was first obtained from the comparison of only two epochs in the WISE all-sky and 2MASS data. Later we further improved it by including the positions measured in the WISE post-cryo data and in the Large Binocular Telescope (LBT) acquisition image observed for our spectroscopic follow-up (Sect. 3). Because of its red $J-K_s$ colour (Table 1), WISEA J0647−1546 was considered as a late-L dwarf candidate. Two more red candidates were selected for our spectroscopic follow-up (see Sect. 3).

Figure 1 shows the field around the new nearby target as observed with the optical Digitized Sky Surveys (DSS), near-infrared (NIR) 2MASS, and mid-infrared (MIR) WISE. The object was not detected in the I-band measurements of the SuperCOSMOS Sky Surveys (SSS; Hambly et al. 2001), but it can be seen in the corresponding image (top right in Fig. 1) at the expected position at epoch 1983, close to the south-west inner border of the circle. On the other hand, its proper motion leads to a shifted position in the north-east direction with respect to the circle centre at the later WISE epoch (bottom row).

★ Based on observations with the Large Binocular Telescope (LBT).

Table 1. Parameters of WISEA J0647−1546.

Parameter	WISEA J0647−1546
2MASS α (J2000)	06 47 50.763
2MASS δ (J2000)	−15 46 18.00
2MASS epoch	1999.041
DENIS α (J2000)[a]	06 47 50.812
DENIS δ (J2000)[a]	−15 46 18.06
DENIS epoch[b]	2001.047
WISE all-sky α (J2000)	06 47 50.848
WISE all-sky δ (J2000)	−15 46 16.55
WISE all-sky epoch	2010.244
WISE post-cryo α (J2000)[c]	06 47 50.858
WISE post-cryo δ (J2000)[c]	−15 46 16.40
WISE post-cryo epoch	2010.770
LBT α (J2000)	06 47 50.880
LBT δ (J2000)	−15 46 16.06
LBT epoch	2014.036
$\mu_\alpha \cos\delta$ (mas/yr)	+113 ± 3
μ_δ (mas/yr)	+131 ± 3
2MASS J (mag)	15.31 ± 0.05
2MASS H (mag)	14.29 ± 0.05
2MASS K_s (mag)	13.74 ± 0.06
DENIS J (mag)	16.04 ± 0.21
DENIS K_s (mag)	13.90 ± 0.25
AllWISE $w1$ (mag)	13.04 ± 0.02
AllWISE $w2$ (mag)	12.52 ± 0.02
AllWISE $w3$ (mag)	11.59 ± 0.22
H_2O-H (SpT)[d]	0.622 (T0)
CH_4-H (SpT)[d]	0.986 (T0)
CH_4-K (SpT)[d]	0.800 (T0)
Spectral type	L9.5 ± 0.5
d_{spec} (pc)	$13.9^{+3.6}_{-2.9}$
v_{tan} (km s^{-1})	11^{+3}_{-2}

Notes. [(a)] The original DENIS coordinates of the target were corrected for the mean offsets of three reference stars around the target with respect to their 2MASS coordinates. The DENIS data were not used for the final proper motion determination. [(b)] The DENIS catalogue gives an epoch of 2000.47, whereas according to the DENIS FITS images it is 2001.47. [(c)] Mean position from 15 single exposures. [(d)] Spectral index (and corresponding spectral type) as defined in Burgasser et al. (2006).

The target also appears as a very faint object in the DEep Near-Infrared Survey (DENIS; Epchtein et al. 1997). However, the DENIS position deviates by about 0.8 arcsec from the expected position at the DENIS observing epoch, which is not known exactly (see footnote in Table 1). We corrected the DENIS position of the target for the mean offset of three reference stars close to the target (marked in J-band image in Fig. 1) with respect to their 2MASS positions, as we also did for the positions measured in the LBT acquisition image. These three stars have no significant proper motions (<10 mas/yr) in the PPMXL (Röser et al. 2010).

The corrected DENIS position (Table 1) is still off by about 0.5 arcsec in right ascension and 0.3 arcsec in declination from the expected position (see left and right panels in Fig. 2). Therefore we tried to measure the target position in the DENIS J and K_s FITS images, but failed because the target image is almost completely buried in noise. We assigned large error bars (±300 mas) to the (corrected) DENIS catalogue position, whereas the errors of the 2MASS, LBT, and two WISE positions range between 60 mas and 100 mas. The linear proper motion fit with and without the DENIS position does not change significantly, but the proper motion error in the solution without DENIS is much smaller so that we adopted this as our final

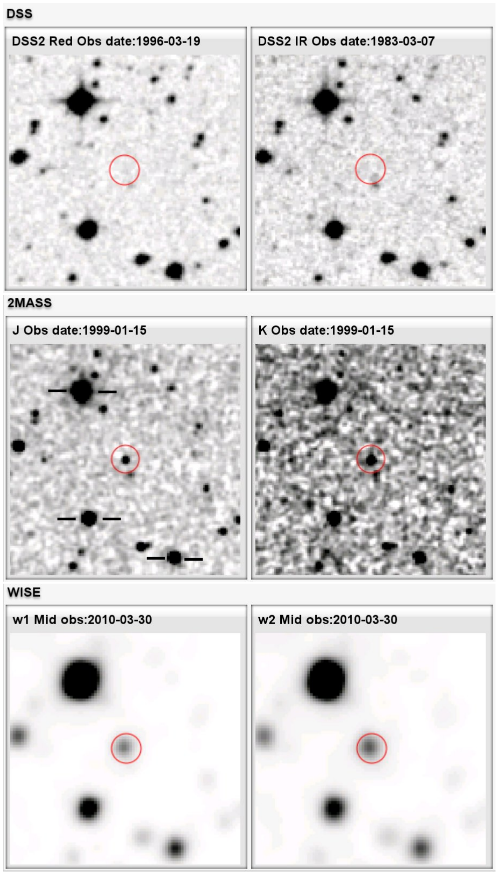

Fig. 1. DSS R and I, 2MASS J and K_s, and WISE $w1$ and $w2$ finding charts (2 × 2 arcmin^2, north is up, east to the left) for WISEA J0647−1546. Circles are centred on target position at the 2MASS epoch. Three reference stars (see text) are marked in J band.

solution (Table 1 and Fig. 2, central panel). The four precise positions are consistent with a purely linear motion. They are also consistent with a combined proper motion and parallax solution, where the parallax and its error are of the order of 50 mas (Fig. 2 right panel). However, we consider this parallax to be unreliable not only because of the large formal error, but also because of the small number of positions, their partly similar seasons, and the different NIR and MIR observations used.

The multi-epoch positions, the determined proper motion, and the available NIR and MIR photometry of WISEA J0647−1546 are listed in Table 1. The proper motion given in the AllWISE catalogue is $\mu_\alpha \cos\delta$ = +344 ± 65, μ_δ = +312 ± 66 mas/yr. Because of the very small time interval between the WISE observations of about six months, it is much less precise and probably more affected by parallactic motion than our proper motion.

3. Near-infrared spectroscopic classification

Our target WISEA J0647−1546 and two additional candidates found in our survey were placed in a bad-weather backup programme at the LBT that had already started in 2012. The two other objects are WISEA J140533.13+835030.7 (hereafter WISEA J1405+8350), which has been meanwhile discovered and described as an L9 dwarf (NIR) at a distance of 9.7 ± 1.7 pc by Castro et al. (2013), and WISEA J042144.33+192943.8 (hereafter WISEA J0421+1929). For these relatively red (J−K_s > 1.5) targets with K_s < 14, we used the NIR spectrograph LUCI 1 (Mandel et al. 2008; Seifert et al. 2010;

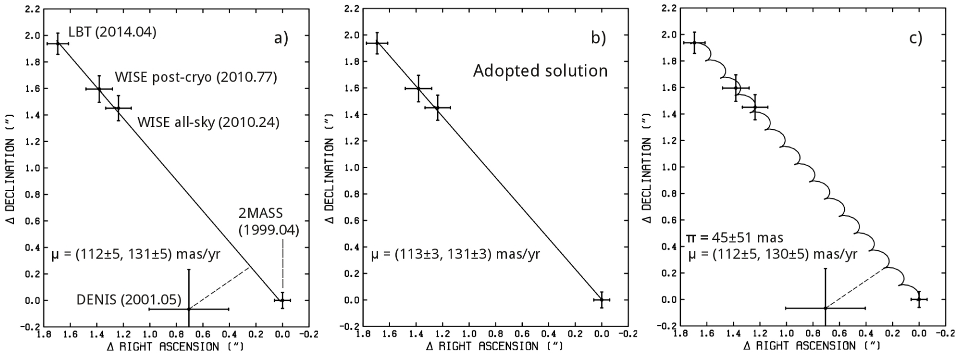

Fig. 2. Proper motion and parallax solutions using the software of Gudehus (2001): **a)** proper motion including the DENIS position with large error bars; **b)** proper motion from only four accurate positions (adopted solution); **c)** combined proper motion and parallax solution using all available positions.

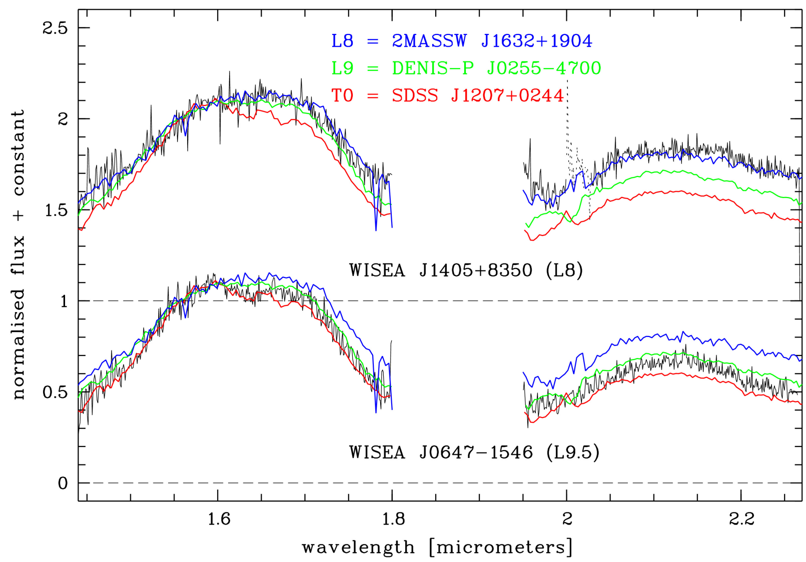

Fig. 3. LBT/LUCI spectra (black) of WISEA J0647−1546 (*bottom*) and WISEA J1405+8350 (*top*) overplotted with lower resolution NIR standard spectra: 2MASSW J1632+1904 (L8, blue; Burgasser 2007), DENIS-P J0255−4700 (L9, green; Burgasser et al. 2006), and SDSS J1207+0244 (T0, red; Looper et al. 2007). The spectrum of WISEA J1405+8350 is affected by strong residuals of telluric absorption correction in the region of 2.00..2.03 micrometers (dotted line), as the A0V standard star used for the correction was observed at higher airmass than the target.

Ageorges et al. 2010) in long-slit spectroscopic mode only with the *HK* (200 lines/mm + order separation filter) grating. The three objects, WISEA J0647−1546, WISEA J1405+8350, and WISEA J0421+1929, were observed on 2014 Jan. 13, 2014 Jan. 12, and 2014 Jan. 15 (UT) with total integration times of 12, 8, and 12 min, respectively. Acquisition images were taken with the K_s filter with exposure times of 15, 5, and 15 s, respectively. The seeing was ≈2 arcsec and the slit width was 1 arcsec. The spectroscopic observations and data reduction were otherwise as described by B13 with the difference that here the frames were illumination corrected before sky subtraction and the wavelength calibration was obtained using the sky OH emission lines, with an accuracy of about 0.9 Å.

In Fig. 3, we show the LBT/LUCI spectra of the new object WISEA J0647−1546 and of WISEA J1405+8350, together with L8, L9, and T0 standard spectra. For WISEA J0647−1546, the *H*-band spectrum fits slightly better with the T0 than with the L9 standard spectrum, whereas in the *K* band it lies right in between the L9 and T0 standard spectra. All three measured spectral indices (Table 1) are consistent with a spectral type of T0 as shown by Burgasser et al. (2006, his Table 5). The spectral index/spectral type relation for the H_2O-*H* index provided by Burgasser (2007, their Table 3) leads to a spectral type of L9.3; the relation for the CH_4-*H* index is only applicable in the T1-T8 range, and that for the CH_4-*K* index yields an L9.5 type. Because of the good agreement between the results from direct comparison with standard spectra and from the spectral indices, we classified WISEA J0647−1546 as an L9.5 dwarf with an uncertainty of half a spectral subclass.

Dupuy & Liu (2012) provided mean 2MASS and WISE absolute magnitudes for M, L, and T spectral types. Because there are no data for L9.5 dwarfs in their Tables 16 and 18, we used the average absolute JHK_s magnitudes of L9 and T0 dwarfs and the absolute $w1w2$ magnitudes of L9 dwarfs to compute spectroscopic distances of WISEA J0647−1546. They range from 13.1 pc (from $w1$) to 14.8 pc (from *H*) with a mean distance of $13.9^{+3.6}_{-2.9}$ pc, where we conservatively assumed a large uncertainty of 0.5 mag in the absolute magnitude. The resulting tangential velocity is about 11 km s^{-1}.

The spectrum of WISEA J1405+8350 fits best with the L8 standard (slightly closer to L8 than L9 in *H* band and well-fitted by L8 in *K* band), whereas Castro et al. (2013) classified it as L8 in the optical, but L9 in the NIR. From three spectral indices, which we were able to measure for WISEA J1405+8350 (H_2O-*H* = 0.709, CH_4-*H* = 1.051, CH_4-*K* = 0.874), the first leads to L6.2, the second cannot be applied, and the third corresponds to a spectral type of L8.1 according to Burgasser (2007). Based on the direct comparison with the standard spectra and the results from spectral indices, we classified WISEA J1405+8350 as an L8 dwarf.

The spectrum of WISEA J0421+1929 (not shown) represents a noisy red continuum. From the location of WISEA J0421+1929 close to the famous star T Tauri and overlapping with a large molecular cloud, we conclude that this is a strongly reddened early-type star in the background. We measured a proper motion of $(\mu_\alpha \cos\delta, \mu_\delta)$ = (+56 ± 12, −110 ± 11) mas/yr. This translates to a tangential velocity of more than about 100 km s^{-1}, if we assume WISEA J0421+1929 to move behind the nebula and T Tauri, which lies at a distance of about 180 pc as known from HIPPARCOS (van Leeuwen 2007).

4. Conclusions and discussion

Best et al. (2013) have shown that previous surveys for L/T transition dwarfs have been incomplete. We were able to discover a new L/T transition dwarf within about 15 pc from the sun. With its spectral type of L9.5 (found from LBT/LUCI HK-band spectroscopy), WISEA J0647−1546 is a promising target for trigonometric parallax programmes because for this type, with the exception of 2MASSI J0328426+230205 (=WISEA J032842.65+230204.5 with a preliminary parallax of 33.1 ± 4.1 mas measured by Vrba et al. 2004) no reference values are available so far (Dupuy & Liu 2012). Our new L9.5 dwarf WISEA J0647−1546 is brighter than all six L9.5 dwarfs (three of them with very uncertain types) listed in the DwarfArchives (Gelino et al. 2012). With $K_s \approx 13.7$, it is as bright as PSO J140.2308+45.6487 (=WISEA J092055.41+453855.9) newly classified by Best et al. (2013) as a L9.5 dwarf (with signs of spectral variability), which was first photometrically estimated as a mid-L dwarf by Aberasturi et al. (2011) and then classified as an L9 and weak binary candidate by Mace et al. (2013). Although from our spectrum there are no hints of a possible close companion, WISEA J0647−1546 may also be worth high-resolution imaging observations and variability analysis (see Biller et al. 2013; Burgasser et al. 2014; Gelino et al. 2014).

As one of the rare bright L/T transition objects, the new L9.5 dwarf WISEA J0647−1546 could be important for the study of cloud evolution of L and T dwarfs. Therefore, it is again an interesting target for time-resolved photometry (see e.g. Radigan et al. 2014; Wilson et al.2014) and spectroscopy at high signal-to-noise ratio as carried out e.g. by Apai et al. (2013) and Buenzli et al. (2014). Potentially, it could even be included in future Doppler imaging studies such as proposed by Crossfield et al. (2014). Neither the spectrum nor the colours of WISEA J0647−1546 show signs of youth (triangular peak in the H band and very red $J - K_s \gtrsim 2.3$ as observed e.g. by Schneider et al. 2014), and its proper motion and distance are not consistent with membership in one of the known young nearby associations (cf. Gagné et al. 2014). The colours of WISEA J0647−1546 are typical of its spectral type and do not hint at other peculiarities, as can be seen in comparison with the L/T transition objects listed in Dupuy & Liu (2012).

For WISEA J1405+8350, Castro et al. (2013) obtained an optical spectral type of L8 and a NIR type of L9 from high signal-to-noise J-band spectroscopy. In their Fig. 5, they also showed an HK-band spectrum, which they described as being consistent with the L9 type. They used the same L8 and L9 standards for comparison as we did in Fig. 3. We find their HK-band spectrum fits in between the L8 and L9 standards, whereas ours fits better with the L8 standard as do our measured spectral indices. Nevertheless, our bad-weather spectrum of WISEA J1405+8350 is as noisy as their HK-band spectrum so that we think their more accurate classification in the J band is more reliable.

For the reddened star WISEA J0421+1929, the estimated velocity is much higher than the typical velocity of runaway stars and does not point in a direction out of the molecular cloud. Therefore, a location behind but not in the cloud and a Galactic thick disc or halo membership seems to be plausible. This conclusion is in agreement with recent findings of Esplin et al. (2014), who have spectroscopically classified WISEA J0421+1929 as a non-member of Taurus with a spectral type of <M0.

Acknowledgements. The authors thank Jochen Heidt, Barry Rothberg, and the observers at the LBT, D. Rosario and E. Wuyts, for assistance during the preparation and execution of LUCI observations, Adam Burgasser for providing template spectra at http://pono.ucsd.edu/~adam/browndwarfs/spexprism and the referee, Étienne Artigau, for helpful hints, mainly concerning the discussion of our results. This research has made use of the NASA/IPAC Infrared Science Archive, which is operated by the Jet Propulsion Laboratory, California Institute of Technology, under contract with the National Aeronautics and Space Administration, of data products from WISE, which is a joint project of the University of California, Los Angeles, and the Jet Propulsion Laboratory/California Institute of Technology, funded by the National Aeronautics and Space Administration, and from 2MASS. We have also extensively used the M, L, T, and Y dwarf compendium housed at DwarfArchives.org, the SIMBAD database and the VizieR catalogue access tool operated at the CDS/Strasbourg, including the CDS xMatch service.

References

Aberasturi, M., Solano, E., & Martín, E. L. 2011, A&A, 534, L7
Ageorges, N., Seifert, W., Jütte, M., et al. 2010, SPIE, 7735, 53
Apai, D., Radigan, J., Buenzli, E., et al. 2013, ApJ, 768, 121
Best, W. M. J., Liu, M. C., Magnier, E. A., et al. 2013, ApJ, 777, 84
Bihain, G., Scholz, R.-D., Storm, J., & Schnurr, O. 2013, A&A, 557, A43 (B13)
Biller, B. A., Crossfield, I. J. M., Mancini, L., et al. 2013, ApJ, 778, L10
Buenzli, E., Apai, D., Radigan, J., Reid, I. N., & Flateau, D. 2014, ApJ, 782, 77
Burgasser, A. J. 2007, ApJ, 659, 655
Burgasser, A. J., Geballe, T. R., Leggett, S. K., Kirkpatrick, J. D., & Golimowski, D. A. 2006, ApJ, 637, 1067
Burgasser, A. J., Gillon, M., Faherty, J. K., et al. 2014, ApJ, 785, 48
Castro, P. J., & Gizis, J. E. 2012, ApJ, 746, 3
Castro, P. J., Gizis, J. E., Harris, H. C., et al. 2013, ApJ, 776, 126
Crossfield, I. J. M. 2014, A&A, 566, A130
Cushing, M. C., Kirkpatrick, J. D., Gelino, C. R., et al. 2011, ApJ, 743, 50
Cushing, M. C., Kirkpatrick, J. D., Gelino, C. R., et al. 2014, AJ, 147, 113
Dupuy, T. J., & Liu, M. C. 2012, ApJSS, 201, 19
Epchtein, N., de Batz, B., Capoani, L., et al. 1997, The Messenger, 87, 27
Esplin, T. L., Luhman, K. L., & Mamajek, E. E. 2014, ApJ, 784, 126
Gagné, J., Lafrenière, D., Doyon, R., Malo, L., & Artigau, É. 2014, ApJ, 783, 121
Gelino, C. R., Kirkpatrick, J. D., & Burgasser, A. J. 2012, Online database for 1281 L, T, and Y dwarfs at DwarfArchives.org (Last update 6 November 2012)
Gelino, C. R., Smart, R. L., Marocco, F., et al. 2014, AJ, 148, 6
Gizis, J. E., Burgasser, A. J., Faherty, J. K., Castro, P. J., & Shara, M. M. 2011a, AJ, 142, 171
Gizis, J. E., Troup, N. W., & Burgasser, A. J. 2011b, ApJ, 736, L34
Gizis, J. E., Faherty, J. K., Liu, M. C., et al. 2012, AJ, 144, 94
Gudehus, D. H. 2001, BAAS, 33, 850
Hambly, N. C., MacGillivray, H. T., Read M. A., et al. 2001, MNRAS, 326, 1279
Kirkpatrick, J. D., Gelino, C. R., Cushing, M. C., et al. 2012, ApJ, 753, 156
Kirkpatrick, J. D., Cushing, M. C., Gelino, C. R., et al. 2013, ApJ, 776, 128
Kirkpatrick, J. D., Schneider, A., Fajardo-Acosta, S., et al. 2014, ApJ, 783, 122
Looper, D. L., Kirkpatrick, J. D., & Burgasser, A. J. 2007, AJ, 134, 1162
Luhman, K. L. 2013, ApJ, 767, L1
Luhman, K. L. 2014a, ApJ, 781, 4
Luhman, K. L. 2014b, ApJ, 786, L18
Luhman, K. L., & Sheppard, S. 2014, ApJ, 787, 126
Mace, G. N., Kirkpatrick, J. D., Cushing, M. C., et al. 2013, ApJSS 205, 6
Mandel, H., Seifert, W., Hofmann, R., et al. 2008, SPIE, 7014, 124
Radigan, J., Lafrenière, D., Jayawardhana, R., & Artigau, E. 2014, ApJ, accepted [arXiv:1404.3247]
Röser, S., Demleitner, M., & Schilbach, E. 2010, AJ, 139, 2440
Schneider, A. C., Cushing, M. C., Kirkpatrick, J. D., et al. 2014, AJ, 147, 34
Scholz, R.-D. 2014, A&A, 561, A113
Scholz, R.-D., Bihain, G., Schnurr, O., & Storm, J. 2011, A&A, 532, L5
Seifert, W., Ageorges, N., Lehmitz, M., et al. 2010, SPIE, 7735, 256
Skrutskie, M. F., Cutri, R. M., Stiening, R., et al. 2006, AJ, 131, 1163
Thompson, M. A., Kirkpatrick, J. D., Mace, G. N., et al. 2013, PASP, 125, 809
van Leeuwen, F. 2007, A&A, 474, 653
Vrba, F. J., Henden, A. A., Luginbuhl, C. B., et al. 2004, AJ, 127, 2948
Wilson, P. A., Rajan, A., & Patience, J. 2014, A&A, 566, A111
Wright, E. L., Eisenhardt, P. R. M., Mainzer, A. K., et al. 2010, AJ, 140, 1868
Wright, E. L., Kirkpatrick, J. D., Gelino, C. R., et al. 2014, AJ, 147, 61