WISEP J180026.60+013453.1: A NEARBY LATE-L DWARF NEAR THE GALACTIC PLANE

JOHN E. GIZIS[1], ADAM J. BURGASSER[2], JACQUELINE K. FAHERTY[3,4], PHILIP J. CASTRO[1], AND MICHAEL M. SHARA[3,4]
[1] Department of Physics and Astronomy, University of Delaware, Newark, DE 19716, USA
[2] Center for Astrophysics and Space Science, University of California San Diego, La Jolla, CA 92093, USA
[3] Department of Astrophysics, American Museum of Natural History, New York, NY 10034, USA

ABSTRACT

We report a nearby L7.5 dwarf discovered using the Preliminary Data Release of the *Wide-field Infrared Survey Explorer* (*WISE*) and the Two Micron All Sky Survey. WISEP J180026.60+013453.1 has a motion of 0.42 arcsec yr^{-1} and an estimated distance of 8.8 ± 1.0 pc. With this distance, it currently ranks as the sixth closest known L dwarf, although a trigonometric parallax is needed to confirm this distance. It was previously overlooked because it lies near the Galactic plane ($b = 12°$). As a relatively bright and nearby late L dwarf with normal near-infrared colors, W1800+0134 will serve as a benchmark for studies of cloud-related phenomena in cool substellar atmospheres.

Key words: brown dwarfs – infrared: stars – proper motions – stars: individual (WISEP J180026.60+013453.1)

1. INTRODUCTION

One of the main scientific goals of the *Wide-field Infrared Survey Explorer* (*WISE*; Wright et al. 2010) is to identify the brown dwarfs and low-mass stars closest to the Sun. *WISE* has now surveyed the entire sky in four mid-infrared filters, with ∼58% of the sky included in the 2011 April Preliminary Data Release. Together with the three near-infrared Two Micron All Sky Survey (2MASS) filters (Skrutskie et al. 2006), the peaks of the spectral energy distributions of any nearby brown dwarfs with $T_{\rm eff} \gtrsim 300$ K are well sampled (Mainzer et al. 2011).

Although hundreds of brown dwarfs with M, L, or T spectral types are now known, very few of them are closer than 10 pc to the Sun. The nearest known L dwarfs with trigonometric parallaxes are the L8 dwarf DENIS-P J0255.0−4700 (Martín et al. 1999) at 4.97 ± 0.10 pc (Costa et al. 2006), the L5 dwarf 2MASSW J1507476−162738 (Reid et al. 2000) at 7.33 ± 0.03 pc (Dahn et al. 2002), the L5 dwarf 2MASSI J0835425−081923 (Cruz et al. 2003) at 8.5 ± 0.8 pc (Andrei et al. 2011), the L3.5 2MASSW J0036159+182110 (Reid et al. 2000) at 8.76 ± 0.06 pc (Dahn et al. 2002), and the L5.5 dwarf 2MASS J17502484−0016151 (Kendall et al. 2007) at 9.2 ± 0.2 (Andrei et al. 2011). The lithium M9 brown dwarf LP 944-20 (Tinney 1998), measured at 4.97 ± 0.11 pc (Tinney 1996), also deserves mention. Other apparently nearby L dwarfs still lack reliable trigonometric parallaxes. The "blue" L6 dwarf SDSS J141624.08+134826.7 (Bowler et al. 2010a; Schmidt et al. 2010a) is thought to lie at 8.4 ± 1.9 or 8.0 ± 1.6 on the basis of photometry, while Scholz (2010) argued for a parallax distance of 7.9 ± 1.7 based on limited astrometry. Looper et al. (2008b) listed five additional L dwarfs with estimated distances between 9.4 and 9.9 pc.[5] Along with these warmer brown dwarfs, more than a dozen T dwarfs are known within 10 pc. *WISE*, whose filters are ideally suited for finding cold late-type T dwarfs, is already adding to the census: Mainzer

et al. (2011) reported a late-T dwarf at $d \approx$ 6–10 pc, while Scholz et al. (2011) identified two high proper motion, late-T dwarfs with $d \approx 5$ pc using *WISE*, 2MASS, and SDSS.

L dwarfs are useful probes for studying atmospheric properties of objects below 2200 K, where clouds and dust opacity are important to the observed spectral energy distribution. In addition to their intrinsic interest, the latest-type L dwarfs are potential analogs to massive hot exoplanets such as those found around HR 8799 (Bowler et al. 2010b; Marois et al. 2010; Barman et al. 2011). Because they are isolated in the field rather than found orbiting a nearby bright star they can be studied and characterized in great detail making them vital test beds for refinement.

We have initiated an effort to detect high proper motion stars by comparing the *WISE* and 2MASS surveys. Here we report the identification of a bonafide, nearby late-L brown dwarf, WISEP J180026.60+013453, as a result of this effort. We present our observations and data analysis in Section 2. We discuss the possibility of binarity in Section 3.

2. IDENTIFICATION AND OBSERVATIONS

2.1. WISE Selection

We selected *WISE* sources with $|b| > 10$ that were detected at $W1$ (3.4 μm), $W2$ (4.6 μm), and $W3$ (12 μm) with $W1 < 12$ but had no 2MASS counterpart within 3 arcsec according to the *WISE* Preliminary Source Catalog. All stars or warm brown dwarfs with $W1 < 12$ should have 2MASS detections at K_s band. The *WISE*, 2MASS, and photographic (Digitized Sky Survey) images were examined by eye to look for proper motion candidates. Almost all stars have $W1−W2 < 0.3$ and $W1−W3 < 0.7$, but we noted a number of candidate proper motion objects with redder $W1 − W2$ colors. Most of these turned out to be known late-M or L dwarfs, but the source WISEP J180026.60+013453.1 (Table 1) was previously unrecognized. As seen in Figure 1, this *WISE* source may be paired with 2MASS J18002648+0134565 ($J = 14.30 \pm 0.04$, $H = 13.12 \pm 0.04$, $K_s = 12.42 \pm 0.03$), which otherwise would not have a *WISE* counterpart. We hereafter abbreviate the source name as W1800+0134. The object was likely overlooked previously because it lies near the Galactic plane ($b = 12°$), although the field is not very crowded.

---

[5] We follow Burgasser et al. (2008) in viewing 2MASS J11263991−5003550 as a blue L4.5 at 15 pc rather than a blue L9 at 8 pc (Folkes et al. 2007). Henry et al. (2006) have shown by trigonometric parallax that the GJ 1001 (LHS 102) system (Goldman et al. 1999) lies beyond 10 pc.
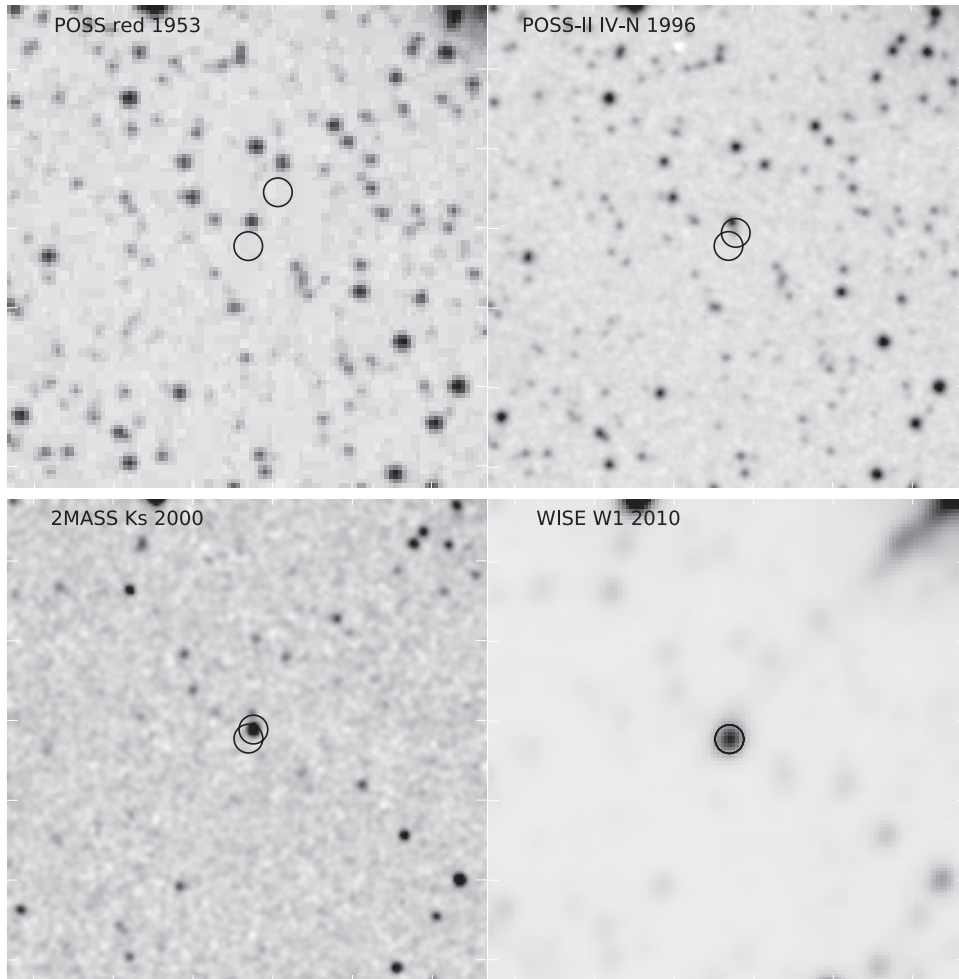
Figure 1. Finder charts for WISEP J180026.60+013453.1: upper left, 1953 July Palomar Sky Survey (POSS) red plate. Upper right: 1996 July Second Palomar Sky Survey (POSS-II) infrared plate. Lower left: 2000 September 2MASS K_s band. Lower right: 2010 March *WISE W*1 band. In each case, the central circle marks the observed *WISE* position and an additional circle marks the expected position at that epoch. All are 3 arcmin on a side.

Table 1
WISEP J180026.60+013453.1

Parameter	W1800+0134
WISE R.A. (J2000)	18 00 26.60
WISE Decl. (J2000)	+01 34 53.1
WISE Epoch	2010.22
2MASS J (mag)	14.30 ± 0.04
2MASS H (mag)	13.12 ± 0.04
2MASS K_s (mag)	12.42 ± 0.03
WISE $W1$ (mag)	11.53 ± 0.05
WISE $W2$ (mag)	11.03 ± 0.04
WISE $W3$ (mag)	9.88 ± 0.07
WISE $W4$ (mag)	> 8.39
$\mu_\alpha \cos\delta$ (mas yr^{-1})	220 ± 20
μ_δ (mas yr^{-1})	-360 ± 20
Sp type (Near-IR)	L7.5 $\pm$ 0.5
Distance (pc)	8.8 ± 1.0
v_{tan} (km s^{-1})	18 ± 2
T_{eff} (K)	1430 ± 100
$\log L/L_\odot$	-4.5 ± 0.3

The apparent proper motion from 2MASS to *WISE* is $\mu_\alpha = 0.20 \pm 0.02$ arcsec yr^{-1} and $\mu_\delta = -0.36 \pm 0.02$ arcsec yr^{-1}. This is relative to other stars in the image, with uncertainties based on the uncertainties of the *WISE* and 2MASS astrometry.

However, because the observations were taken in 2010 March 20–23 (*WISE*) and 2000 September 23 (2MASS), parallax will affect the observed positions. Using the NOVAS V3.0 software (Kaplan et al. 2009), we find that the offset in R.A. is 230 mas if W1800+0134 is 8.8 pc away, as estimated later. Applying this correction, we find $\mu_{\mathrm{R.A.}} = 0.22 \pm 0.02$ arcsec yr^{-1} and $\mu_{\mathrm{Decl.}} = -0.36 \pm 0.02$ arcsec yr^{-1}. A possible very faint source is seen at the predicted position on the infrared (*I*-band) Second Palomar Sky Survey plate (Reid et al. 1991), but as expected for an L dwarf, it is not detected on the blue or red photographic plates (Figure 1.) We also identify W1800+0134 with DENIS J180026.4+013457, $J = 14.07 \pm 0.10$ and $K = 12.45 \pm 0.12$ in the third release of the DENIS database. It was apparently not detected in the *I*-band images, suggesting $I \gtrsim 18$. Because the DENIS observation is close in time to the 2MASS observation but is of lower signal-to-noise, the detection confirms that W1800 has moved but was not included in the proper motion determination.

2.2. Near-infrared Spectroscopy

A low-resolution IRTF SpeX (Rayner et al. 2003) spectrum was obtained on 2011 June 22 (UT) and processed using SpexTool (Vacca et al. 2003; Cushing et al. 2004). Spectra were obtained in prism mode using the 0′′.8 slit aligned at the parallactic angle. The resolution of the corresponding data

Table 2
WISE Data for L7–L8 Dwarfs

Discovery Name	WISEP	$W1$	$W1-W2$	$W2-W3$	Double?	Ref.
2MASS J03185403−3421292	J031854.37−342128.7	12.62	0.50	0.97 ± 0.11	···	1
SDSSp J042348.57−041403.5	J042348.32−041402.5	12.18	0.61	1.03 ± 0.09	Y	2, 3
2MASS J05185995−2828372	J051859.89 −282840.2	13.41	0.59	1.09 ± 0.17	Y	4, 3
2MASSI J0825196+211552	J082519.24+211548.5	12.08	0.52	1.02 ± 0.09	···	5
SDSSp J085758.45+570851.4	J085757.95+570847.5	12.03	0.61	1.12 ± 0.06	···	2
2MASSW J1632291+190441	J163229.39+190439.9	13.14	0.52	0.92 ± 0.19	···	6
2MASSW J1728114+394859	J172811.53+394859.1	13.10	0.49	0.94 ± 0.12	Y	5, 7
WISEP J180026.60+013453.1	J180026.60+013453.1	11.53	0.55	1.16 ± 0.08	···	8

Notes. The uncertainty in $W1$ is 0.03 mag and in $W1 - W2$ is 0.04 mag for all objects.
References. (1) Kirkpatrick et al. 2008; (2) Geballe et al. 2002; (3) Burgasser et al. 2006; (4) Cruz et al. 2004; (5) Kirkpatrick et al. 2000; (6) Kirkpatrick et al. 1999; (7) Gizis et al. 2003; (8) This paper.
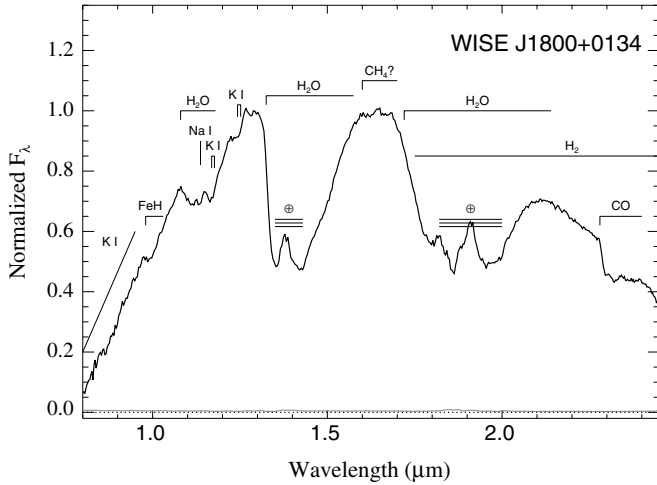

Figure 2. Low-resolution near-infrared spectrum of W1800+0134 obtained with SpeX. Data are normalized at 1.27 μm, and the uncertainty spectrum is shown in gray. Prominent atomic and molecular features are labeled. The CH$_4$ region at 1.6 μm shows some flattening, but fits to the spectrum including an unresolved T dwarf companion are not statistically robust.

spanning 0.7–2.5 μm was $\lambda/\Delta\lambda \approx 90$. Conditions were clear and the seeing was 0″7 at K. We obtained four individual exposure times of 120 s in an ABBA dither pattern along the slit. Immediately after the science observations we observed the A0V star HD 171149 at a similar airmass for telluric corrections and flux calibration. Internal flat field and Ar arc lamp exposures were acquired for pixel response and wavelength calibration, respectively.

Our spectrum is shown in Figure 2. We fit the spectrum to L and T dwarf templates also observed with SpeX.[6] The best matching template is 2MASS J02572581−3105523, classified as L8 in the optical by Kirkpatrick et al. (2008) on the Kirkpatrick et al. (1999) system and observed with SpeX by Siegler et al. (2007). The indices and spectral type relations defined by Burgasser (2007) give L6.5 ± 0.07 (H2O-J), L5.8 ± 0.07 (H2O-H), L6.9 ± 0.09 (H2O-K), and L7.7 ± 0.04 (CH4-K), for a mean classification of L7 ± 1. The scatter is typical for near-infrared spectral typing of L dwarfs (e.g., Burgasser 2007; Stephens et al. 2009). Combining the index type with the best-fit template type, we adopt a near-infrared spectral classification of L7.5 ± 0.5 for W1800+0134.

Using the Looper et al. (2008a) spectral-type–absolute-magnitude relationships, and propagating uncertainties through

Monte Carlo analysis, we estimate a distance of 8.8±1.0 pc from the 2MASS J and K_s photometry. Comparison of this estimated distance to the L dwarf distances listed in Section 1 suggests W1800+0134 ranks as the sixth closest known L dwarf, but even a 1 pc change could move it up to third or down to eighth or later. In any case, a trigonometric parallax is needed to realize W1800+0134's scientific potential as one of the closest, brightest late-L dwarfs for detailed study.

2.3. Physical Properties

The Looper et al. (2008a) polynomial fits to the Golimowski et al. (2004) temperature scale indicate that $T_{\rm eff} = 1490$ K and $BC_K = 3.24$ for L7.5 dwarfs. With our estimated distance, W1800+0134 is then $\log L/L_\odot \approx -4.5 \pm 0.3$. The Stephens et al. (2009) relations, also based on a reanalysis of Golimowski et al. (2004), make them somewhat cooler at $T_{\rm eff} = 1430 \pm 100$ K. The tangential velocity (18 ± 2 km s^{-1}) is below the median for late-L dwarfs (Faherty et al. 2009). According to the Burrows et al. (1997) models, for ages of 0.5, 1, and 5 Gyr, the mass of a $T_{\rm eff} = 1430$ K dwarf is 0.04 $M_\odot$, 0.05 $M_\odot$, and 0.074 $M_\odot$ respectively; the Chabrier et al. (2000) models give similar results. For all ages, it is below the hydrogen-burning limit. An optical spectrum could determine whether W1800+0134 is above or below the lithium-burning limit (Magazzu et al. 1993; Kirkpatrick et al. 2000).

3. IS W1800+0134 A BINARY?

Some ∼20% of very low mass binaries in magnitude-limited samples are typically resolved as doubles (Gizis et al. 2003; Bouy et al. 2003; Burgasser et al. 2006). If W1800+0134 were a near-equal luminosity double, the estimated distance would increase to ∼12 pc. The low-resolution spectrum shows some evidence of structure in the H band around the region of the 1.6 μm CH$_4$ band, but no indication of CH$_4$ at K band (see Figure 2.) Unresolved L dwarf plus T dwarf binary spectra frequently show this pattern of CH$_4$ onset in the near-infrared (Cruz et al. 2004; Burgasser 2007). To investigate this possibility, we compared the SpeX spectrum to combinations of L and T dwarf binary templates from the SpeX Prism Spectral Libraries, following the procedures described in Burgasser (2007). The best-fit binary has the same χ^2 residual as the best-fit single source; as such, there is no statistically robust evidence of W1800+0134 being an L plus T dwarf binary.

The 2MASS $J - K_s = 1.88 \pm 0.05$ color is neither unusually blue nor red compared to other L7–L8 dwarfs (Faherty et al. 2009; Schmidt et al. 2010b). The DENIS non-detection at I band (corresponding to $I - J \gtrsim 3.7$) is also consistent

---

[6] Low-resolution L and T dwarf templates were drawn from the SpeX Prism Spectral Libraries, http://www.browndwarfs.org/spexprism.

with the observed ($I - J \approx 4$) colors of other L7–L8 dwarfs (Phan-Bao et al. 2008). To assess whether the *WISE* colors are typical, we have searched for known objects with an L7, L7.5, or L8 classification in the *WISE* Preliminary database with uncertainties less than 0.1 in W1 and W2 and 0.2 in W3. The seven matching dwarfs are listed in Table 2. The observed mean and standard deviations of the apparently single objects are $W1-W2 = 0.54 \pm 0.05$ and $W2-W3 = 1.01 \pm 0.09$, consistent with W1800+0134's colors (0.50 ± 0.06, 1.16 ± 0.08). The doubles SDSSp J042348.57−041403.5 and 2MASS J05185995−2828372 are somewhat redder but the uncertainties in W_3 are large (0.08 and 0.17, respectively).

We note for completeness that we found no other common proper motion companions within 30 arcmin of W1800+0134, in *WISE* or 2MASS, ruling out widely separated main sequence to late-T brown dwarf companions to a projected separation of 15,000 AU.

4. CONCLUSION

We have identified a previously overlooked bright and nearby L7.5 dwarf, near the Galactic plane. Together with the recent discoveries of the M9 DENIS-P J115927.4−524718 at 9.6 pc ($b = 9°$; Phan-Bao et al. 2008), the T6 DENIS J081730.0−615520 at 4.9 pc ($b = -14°$; Artigau et al. 2010), the T9 UGPS J072227.51−054031.2 at 4.1 pc ($b = 4°$; Lucas et al. 2010), and the T9 WISEPC J045853.90+643451.9 at 6–10 pc ($b = 13°$; Mainzer et al. 2011), it is clear that multi-color, multi-survey searches for nearby brown dwarfs in the Galactic plane region are now feasible. Such objects are important because their proximity enables more detailed studies of the physical properties of brown dwarfs, as well as any potential planetary companions. As a very bright late-L dwarf with normal colors, studies of W1800+0134's cloud properties through variability and polarization measurements (e.g., Artigau et al. 2009; Goldman et al. 2009), and rotation through high-resolution spectroscopy (e.g., Zapatero Osorio et al. 2006), will be helpful in characterizing the structure and dynamics of cloudy atmospheres at the L/T transition, and will be relevant to exploring the cloud properties of hot exoplanets (Madhusudhan et al. 2011).

REFERENCES

Andrei, A. H., Smart, R. L., Penna, J. L., et al. 2011, AJ, 141, 54
Artigau, É., Bouchard, S., Doyon, R., & Lafrenière, D. 2009, ApJ, 701, 1534
Artigau, É., Radigan, J., Folkes, S., et al. 2010, ApJ, 718, L38
Barman, T. S., Macintosh, B., Konopacky, Q. M., & Marois, C. 2011, ApJ, 733, 65
Bouy, H., Brandner, W., Martín, E. L., et al. 2003, AJ, 126, 1526
Bowler, B. P., Liu, M. C., & Dupuy, T. J. 2010a, ApJ, 710, 45
Bowler, B. P., Liu, M. C., Dupuy, T. J., & Cushing, M. C. 2010b, ApJ, 723, 850
Burgasser, A. J. 2007, ApJ, 659, 655
Burgasser, A. J., Kirkpatrick, J. D., Cruz, K. L., et al. 2006, ApJS, 166, 585
Burgasser, A. J., Looper, D. L., Kirkpatrick, J. D., et al. 2008, ApJ, 674, 451
Burrows, A., Marley, M., Hubbard, W. B., et al. 1997, ApJ, 491, 856
Chabrier, G., Baraffe, I., Allard, F., & Hauschildt, P. 2000, ApJ, 542, 464
Costa, E., Méndez, R. A., Jao, W., et al. 2006, AJ, 132, 1234
Cruz, K. L., Burgasser, A. J., Reid, I. N., & Liebert, J. 2004, ApJ, 604, L61
Cruz, K. L., Reid, I. N., Liebert, J., Kirkpatrick, J. D., & Lowrance, P. J. 2003, AJ, 126, 2421
Cushing, M. C., Vacca, W. D., & Rayner, J. T. 2004, PASP, 116, 362
Dahn, C. C., Harris, H. C., Vrba, F. J., et al. 2002, AJ, 124, 1170
Faherty, J. K., Burgasser, A. J., Cruz, K. L., et al. 2009, AJ, 137, 1
Folkes, S. L., Pinfield, D. J., Kendall, T. R., & Jones, H. R. A. 2007, MNRAS, 378, 901
Geballe, T. R., Knapp, G. R., Leggett, S. K., et al. 2002, ApJ, 564, 466
Gizis, J. E., Reid, I. N., Knapp, G. R., et al. 2003, AJ, 125, 3302
Goldman, B., Delfosse, X., Forveille, T., et al. 1999, A&A, 351, L5
Goldman, B., Pitann, J., Zapatero Osorio, M. R., et al. 2009, A&A, 502, 929
Golimowski, D. A., Leggett, S. K., Marley, M. S., et al. 2004, AJ, 127, 3516
Henry, T. J., Jao, W., Subasavage, J. P., et al. 2006, AJ, 132, 2360
Kaplan, G., Bangert, J., Bartlett, J., Puatua, W., & Monet, A. 2009, User's Guide to NOVAS 3.0, Vol. USNO Circular 180 (Washington, DC: USNO)
Kendall, T. R., Jones, H. R. A., Pinfield, D. J., et al. 2007, MNRAS, 374, 445
Kirkpatrick, J. D., Cruz, K. L., Barman, T. S., et al. 2008, ApJ, 689, 1295
Kirkpatrick, J. D., Reid, I. N., Liebert, J., et al. 1999, ApJ, 519, 802
Kirkpatrick, J. D., Reid, I. N., Liebert, J., et al. 2000, AJ, 120, 447
Looper, D. L., Gelino, C. R., Burgasser, A. J., & Kirkpatrick, J. D. 2008a, ApJ, 685, 1183
Looper, D. L., Kirkpatrick, J. D., Cutri, R. M., et al. 2008b, ApJ, 686, 528
Lucas, P. W., Tinney, C. G., Burningham, B., et al. 2010, MNRAS, 408, L56
Madhusudhan, N., Burrows, A., & Currie, T. 2011, ApJ, 737, 34
Magazzu, A., Martin, E. L., & Rebolo, R. 1993, ApJ, 404, L17
Mainzer, A., Cushing, M. C., Skrutskie, M., et al. 2011, ApJ, 726, 30
Marois, C., Zuckerman, B., Konopacky, Q. M., Macintosh, B., & Barman, T. 2010, Nature, 468, 1080
Martín, E. L., Delfosse, X., Basri, G., et al. 1999, AJ, 118, 2466
Phan-Bao, N., Bessell, M. S., Martín, E. L., et al. 2008, MNRAS, 383, 831
Rayner, J. T., Toomey, D. W., Onaka, P. M., et al. 2003, PASP, 115, 362
Reid, I. N., Brewer, C., Brucato, R. J., et al. 1991, PASP, 103, 661
Reid, I. N., Kirkpatrick, J. D., Gizis, J. E., et al. 2000, AJ, 119, 369
Schmidt, S. J., West, A. A., Burgasser, A. J., Bochanski, J. J., & Hawley, S. L. 2010a, AJ, 139, 1045
Schmidt, S. J., West, A. A., Hawley, S. L., & Pineda, J. S. 2010b, AJ, 139, 1808
Scholz, R. 2010, A&A, 510, L8
Scholz, R., Bihain, G., Schnurr, O., & Storm, J. 2011, A&A, 532, L5
Siegler, N., Close, L. M., Burgasser, A. J., et al. 2007, AJ, 133, 2320
Skrutskie, M. F., Cutri, R. M., Stiening, R., et al. 2006, AJ, 131, 1163
Stephens, D. C., Leggett, S. K., Cushing, M. C., et al. 2009, ApJ, 702, 154
Tinney, C. G. 1996, MNRAS, 281, 644
Tinney, C. G. 1998, MNRAS, 296, L42
Vacca, W. D., Cushing, M. C., & Rayner, J. T. 2003, PASP, 115, 389
Wright, E. L., Eisenhardt, P. R. M., Mainzer, A. K., et al. 2010, AJ, 140, 1868
Zapatero Osorio, M. R., Martín, E. L., Bouy, H., et al. 2006, ApJ, 647, 1405