LETTER TO THE EDITOR

Two very nearby (d~5 pc) ultracool brown dwarfs detected by their large proper motions from WISE, 2MASS, and SDSS data*

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

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

Received May 20, 2011; accepted July 1, 2011

ABSTRACT

Aims. WISE provides an infrared all-sky survey which aims at completing our knowledge on the possibly dramatically increasing number of brown dwarfs with lower temperatures. We search for the nearest representatives of the coolest brown dwarfs, which will be very interesting for detailed follow-up observations, once they have been discovered.

Methods. We have used the preliminary data release from WISE, selected bright candidates with colours typical of late-T dwarfs, tried to match them with faint 2MASS and SDSS objects, to determine their proper motions, and to follow-up them spectroscopically.

Results. We have identified two new ultracool brown dwarfs, WISE J0254+0223 and WISE J1741+2553, with much higher proper motions of about 2.5 and 1.5 arcsec/yr, respectively. With their $w1-w2>2.5$ and $J-w2>3$ colour indices we confirm both to have a spectral type of $\sim$T8-T10 and absolute magnitude of $M_w>14$. We confirm WISE J1741+2553 as a T9-T10 dwarf from near-infrared spectroscopy with LBT/LUCIFER1. From their bright WISE $m_w$ magnitudes of 12.7 and 12.3, we estimate distances of 5.5$^{+6.6}_{-1.6}$ pc and 4.6$^{+16}_{-1.5}$ pc and tangential velocities of $\sim$65 km/s and $\sim$34 km/s indicating Galactic thick and thin disk membership, respectively.

Key words. Astrometry – Proper motions – Stars: distances – Stars: kinematics and dynamics – brown dwarfs – solar neighbourhood

1. Introduction

The Wide-field Infrared Survey Explorer (WISE; Wright et al. 2010) observed the sky in four infrared bands ($w1$ at 3.4 $\mu$m, $w2$ at 4.6 $\mu$m, $w3$ at 12 $\mu$m, and $w4$ at 22 $\mu$m). It allows the detection of nearby cool brown dwarfs (spectral types $>$T5) with much higher efficiency than the existing Two Micron All Sky Survey (2MASS; Skrutskie et al. 2006) and the ongoing Sloan Digital Sky Survey with its two recent data releases (SDSS DR7; Abazajian et al. 2009 and SDSS DR8; Aihara et al. 2011). As for the nearest stars in the catalogue of Gliese & Jahreiß (1991) we expect the nearest cool brown dwarfs to be high proper motion (HPM) objects. Fig. 1 shows the correlation between proper motion and parallax. HPM stars with $\mu>1$ arcsec/yr lie typically within 10 pc. Compared to 912 nearby stars shown with their mean values, only few (34) late-T dwarfs with parallax measurements are available. However, seven out of ten HPM late-T dwarfs with $\mu>1$ arcsec/yr fall in the 10 pc sample, whereas the other three are very close to the 10 pc horizon.

This motivated our HPM search for cool brown dwarfs in the immediate solar neighbourhood using the preliminary WISE data release combined with the previous near-infrared (2MASS) and deep optical (SDSS) surveys. First results are presented.

2. Selection of candidates and cross-identification

To identify possible HPM and thus nearby cool brown dwarfs in the WISE data we used the following selection criteria:

- $w1-w2>2$ and $w2-w3<2.5$ - these are the colour constraints also applied by Burgasser et al. (2011) in search of late-T dwarfs, where the second condition aims at excluding extragalactic sources (Wright et al. 2010).
- $w2<13$ - we considered only bright WISE sources, since those have a higher probability to show up in 2MASS or SDSS if we consider the limiting magnitudes of these surveys (see Table 9 in Metchev et al. 2008) and the typical colours of known late-T dwarfs ($J-w2>2$; Mainzer et al. 2011 and $z-J<3.5$; Metchev et al. 2008).

![Fig. 1. Mean distances of nearby stars (from Gliese & Jahreiß1991) with 10% accurate parallaxes vs. their proper motions. The number of stars in each proper motion bin is given on the top. The last two bins are wider to have enough stars per bin. Error bars show the width of the distribution in each bin. Known >T5 dwarfs with parallaxes (from the compilation of Gelino et al. 2011 supplemented by data from Marocco et al. 2010 Liu et al. 2011 Luhman, Burgasser & Bochanski 2011 and Subasavage et al. 2009) are overplotted as red crosses.](image-url)
3. Discovery of two new HPM brown dwarfs

The four known late-T dwarfs, which we identified on the WISE and 2MASS finding charts with positional separations of about 15 to 25 arcsec, showed up as bright and unusual 'green' sources in the WISE false colour composites and as relatively faint (15.3 < J < 15.9) and 'blue' (−0.2 < J−H < 0.2 and 0 < J−K < +0.3) 2MASS sources. Except for the T8p dwarf, they were still detected in the 2MASS K_s-band. For two new 'green' and 'yellow' WISE sources (see Fig. 2, WISEPC J0254+0045+022359.1 (hereafter WISE J0254+0223) and WISEPC J174124.25+255319.5 (hereafter WISE J1741+2553), we found even fainter (16.4 < J < 16.6) 2MASS counterparts at similar large separations. The latter two objects are not detected in the 2MASS K_s-band, and only the second one is blue (J−H≈0.1 and J−K_s≈0.3), whereas the first one appears to be relatively red (J−H≈0.7 and J−K_s≈0.6). However, the 2MASS magnitudes of the two new objects are close to the survey limits, and the corresponding colours from 2MASS are rather uncertain, compared to those of the four brighter known late-T dwarfs.

The additional identification of WISE J0254+0223 in SDSS DR8 (Aihara et al. 2011) and of WISE J1741+2553 in SDSS DR7 (Abazajian et al. 2009) led to clear proper motion fits (Fig. 3). The very large proper motions are a first hint that these objects should be very close to the Sun. Both objects are only detected in the SDSS z-band which is typical of nearby late-T dwarfs. Metchev et al. (2008) mentioned that there were no T8 and later type brown dwarfs known in the SDSS. The 11 late-T dwarf candidates identified by Scholz (2010) in SDSS and UKIDSS (six of which have been confirmed spectroscopically as T5−T8 dwarfs by Burningham et al. 2010, Burgasser et al. 2010 and Murray et al. 2011) have 19.9 < z < 20.7. None of them were detected in 2MASS. In comparison, our two new objects are with z=19.9 and z=19.7 relatively bright and have at least 2-3 times larger proper motions than the above mentioned 11 objects.

The photometry and different epoch positions of WISE J0254+0223 and WISE J1741+2553 from SDSS, 2MASS and WISE, as well as their proper motions are shown in Table 1. Note that the proper motions are derived from simple linear fitting and may be affected by parallactic motions.

4. Photometric classification and distances

With their large w1-w2 colour indices of +3.04 and +2.92 WISE J0254+0223 and WISE J1741+2553 are expected to have spectral types of ~T7−T10 according to Mainzer et al. (2011), although we find for the four known T7−T8 dwarfs (two of...
which are listed in Mainzer et al. (2011) with different WISE photometry) detected in our HPM search (Sec. 4) somewhat smaller values of +2.30 < w1 < w2 < +2.85. Therefore, we believe our two new objects are more likely ultracool (≳T8) brown dwarfs. In support of this classification we mention their large absolute magnitudes. For comparison, UGPS J0722+0023 and WISE J0254+0223 and WISE J1741+2553 of 5.5 ± 0.2 and 4.6 ± 0.2, respectively.

With these distance estimates, we compute absolute magnitudes M_r ≳ 21.2 and M_r ≳ 21.4, respectively for WISE J0254+0223 and WISE J1741+2553. These values are 1.3–1.5 mag fainter than the M_r ∼ 19.9 of Ross 458C (= Hip 63510C), the only ζ T dwarf with distance and SDSS detection now available (Goldman et al. 2010; Scholz 2010; Burgasser et al. 2010). The latter is in good agreement with the assumed M_r ∼ 20.0 for ζ T dwarfs in Metchek et al. (2008). On the other hand, the z-band photometry obtained by Lucas et al. (2010) for the ζ T10 dwarf UGPS J0722−0540 leads to M_z values between 22.4 and 22.6, about 1 mag fainter than our values.

5. Spectroscopic observations with LBT/LUCIFER

We have used the Large Binocular Telescope (LBT) near-infrared spectrograph LUCIFER1 (Mandel et al. 2008; Seifert et al. 2010; Agee et al. 2010) in long slit spectroscopic mode with the H+K (200 lines/mm + order separation filter) and JHK gratings (210 lines/mm + J filter) to observe UGPS J0722−0540 on 2011 March 06 (only in H+K, total integration 30 min) and WISE J1741+2553 (40 min H+K, 27 min J) together with Ross 458C (30 min H+K, 20 min J) on 2011 May 12. The central wavelengths were chosen at 1.835 μm (H+K) and 1.25 μm (J) yielding a coverage of 1.38–2.26 and 1.17–1.32 μm, respectively. The slit width was of 2 arcsec for UGPS J0722−0540 and 1 arcsec (4 pixels) for the other objects. For the 1 arcsec slit, the spectral resolving power is R = λ/Δλ ≈ 4130, 940, and 1290 at λ = 1.24, 1.65, and 2.2 μm, respectively. Observations consisted of individual 75 s exposures in H+K and 200 s exposures in J with shifting the target along the slit following an ABBA pattern (to allow sky subtraction) until the total integration time was reached. AOD standards were observed just before or after the targets with similar airmass.

The raw spectroscopic data were reduced using standard routines within the IRAF1 environment. The spectra were sky-subtracted, aligned, combined, optimally extracted, and

1 IRAF is distributed by the National Optical Astronomy Observatories, which are operated by the Association of Universities and Institutions.
wavelength-calibrated using vacuum wavelengths of Ar arc lamps and the deep telluric absorption features. No flat division was applied to avoid including additional noise features from the halogen lamp. The instrumental response and telluric bands were removed by dividing by the A0 star spectra and multiplying by a black-body spectrum with the same effective temperature. The intrinsic lines in the hot-star spectra were removed before dividing the science spectra. Residuals from intense sky emission was applied to avoid including additional noise features from the object (Burgasser et al. 2010), whereas the field brown dwarfs are assumed to be older (0.2-10 Gyr; see e.g. Lucas et al. 2010).

Table 2. Spectral indices obtained from LBT/LUCIFER1 spectra (SpT from comparison with T9 average from Lucas et al. 2010 in brackets)

| Object          | SpT  | Reference for SpT | \(W_J\) | \(NH_3 - H\) | \(H_2O - H\) | \(CH_3 - H\) | \(CH_3 - K\) |
|-----------------|------|-------------------|---------|-------------|-------------|-------------|-------------|
| Ross 458C       | T8p  | Burgasser et al. 2010 | 0.264 (<T9) | 0.664 (<T9) | 0.206 (<T9) | 0.107 (<T9) | 0.054 (>T9) |
| UGPS J0722−0540 | T10  | Lucas et al. 2010  | 0.530 (>T9) | 0.141 (<T9) | 0.055 (>T9) | 0.079 (>T9) |
| WISE J1741+2553 | T9-T10 | this paper         | 0.234 (>T9) | 0.551 (<T9) | 0.119 (<T9) | 0.066 (>T9) | 0.056 (>T9) |

Notes. In the T dwarf classification system originally defined by Burgasser et al. (2006) the \(CH_3 - K\) index was shown to be degenerate for types >T6. Extending the system to T9 Burningham et al. (2008) showed that the \(CH_3 - H\) index is also degenerate with >T7, whereas the T8, T9 average, and T10 values of the latter show a clear trend in Lucas et al. (2010). We consider Ross 458C as T8p since it is a relatively young (0.15-0.80 Gyr) object (Burgasser et al. 2010), whereas the field brown dwarfs are assumed to be older (0.2-10 Gyr; see e.g. Lucas et al. 2010).

6. Conclusions

1. While WISE J0254+0223 and WISE J1741+2553 are very similar, including a possible common \(NH_3\) feature expected for Y-type objects, whereas both spectra \((H+K)\) and \(J\) of WISE J1741+2553 indicate a type later than T8 (Fig. 3). We have computed spectral indices used for the classification of ultracool brown dwarfs (see Burningham et al. 2008 and references therein) and compare them with average values of T9 dwarfs given by Lucas et al. (2010) in Table 2. Unfortunately, no other indices than \(W_J\) could be determined in the J-band, since the LUCIFER J grating provides a very narrow wavelength interval. Our indices are in good agreement with the measurements of Lucas et al. (2010) for UGPS J0722−0540 and of Burgasser et al. (2010) for Ross 458C, except for \(NH_3 - H\), where our indices are larger by about 0.04 and 0.06, respectively. As in the case of the known T10 dwarf, all but one indices of WISE J1741+2553 classify it as >T9, although the usefulness of some indices has been questioned (see Notes to Table 2). We assign conservatively a spectral type of T9-T10, reduce the assumed absolute magnitude uncertainty to 0.5 mag, and get a more accurate spectroscopic/photometric distance of 4.6\(\pm\)1.0 pc.

3. Our photometric/spectroscopic distances place both objects at about 5 pc from the Sun, probably nearly as close as the T10 dwarf WISE J0254+0223 to the Galactic center \((b=+4^\circ)\), and make them highly interesting targets for near-infrared parallax programs. With the upper limits of our distance estimates they fall still clearly in the 10 pc sample.

4. The larger proper motion and slightly larger distance of the higher Galactic latitude object WISE J0254+0223 \((b=-48^\circ)\) lead to a relatively high tangential velocity of ~65 km/s (possibly indicating a Galactic thick disk membership), compared to ~34 km/s for WISE J1741+2553 \((b=+26^\circ)\), which is typical of the thin disk population.

Acknowledgements. The authors would like to thank Roland Gredel, Jochen Heidt, Jaron Kurk, Ric Davies, and all observers at the LBT for their assistance and help during the preparation and execution of the LUCIFER observations. Adam Burgasser and Ben Burningham for providing T8/T9 template spectra and the anonymous referee for her/his helpful comments and suggestions.

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, and 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, from 2MASS, and from SDSS DR7 and DR8. Funding for SDSS-III has been provided by the Alfred P. Sloan Foundation, the Participating Institutions, the National Science Foundation, and the U.S. Department of Energy. The SDSS-III web site is http://www.sdss3.org/.

References

Abazajian, K. N., Adelman-McCarthy, J. K., Agüeros, M. A., et al. 2009, ApJS, 182, 54
Agéorgos, N., Seifert, W., Jütte, M., et al. 2010, SPIE, 7735, 53
Aihara, H., Allende Prieto, C., An, D., et al. 2011, ApJS, 193, 29
Burningham, B., Pinfield, D. J., Leggett, S. K., et al. 2008, MNRAS, 391, 320
Burningham, B., Pinfield, D. J., Lucas, P. W., et al. 2010, MNRAS, 406, 1885
Burgasser, A. J., Kirkpatrick, J. D., Cutri, R. M., et al. 2000, ApJ, 531, L57
Burgasser, A. J., Kirkpatrick, J. D., Brown, M. E., et al. 2000, ApJ, 541, 421
Burgasser, A. J., Kirkpatrick, J. D., Cutri, R. M., et al. 2000, ApJ, 531, L57
Goldman, B., Marsat, S., Henning, T., Clemens, C., & Greiner, J. 2010, MNRAS, 405, 1140
Hambly, N. C., MacGilivray, H. T., Read, M. A., et al. 2001, MNRAS, 326, 1279
Kirkpatrick, J. D., Reid, I. N., Liebert, J., et al. 1999, ApJ, 519, 802
Heidt, J., Kurk, R., Davies, I. A., & Jahreiß, H. 1991, On: The Astronomical Data Center CD-ROM: Selected Astronomical Catalogs, Vol. I: L.E. Brotzmann, S. E. Gessner (eds.), NASA/Astronomical Data Center, Goddard Space Flight Center
Goldman, B., Marsat, S., Henning, T., Clemens, C., & Greiner, J. 2010, MNRAS, 405, 1140
Hambly, N. C., MacGillivray, H. T., Read, M. A., et al. 2001, MNRAS, 326, 1279
Hambly, N. C., MacGillivray, H. T., Read, M. A., et al. 2001, MNRAS, 326, 1279
Kirkpatrick, J. D., Reid, I. N., Liebert, J., et al. 1999, ApJ, 519, 802
Leggett, S. K., Burningham, B., Saumon, D., et al. 2010, ApJ, 710, 1627
Liu, M. C., Delorme, P., Dupu, T. J., et al. 2011, arXiv:1103.0009
Looper, D. L., Kirkpatrick, J. D., & Burgasser, A. J. 2007, AJ, 134, 1162
Lucas, P. W., Tinney, C. G., Burningham, B., et al. 2010, MNRAS, 408, L56
Luhman, K. L., Burgasser, A. J., & Bochanski, J. J. 2011, ApJ, 730, L9
Mandell, H., Seifert, W., Hofmann, R., et al. 2008, SPIE, 7014, 124

for Research in Astronomy, Inc., under cooperative agreement with the National Science Foundation.
Mainzer, A., Cushing, M. C., Skrutskie, M. F., et al. 2011, ApJ, 726, 30
Marocco, F., Smart, R. L., Jones, H. R. A., et al. 2010, A&A, 524, A38
Metechev, S. A., Kirkpatrick, J. D., Berriman, G. B., & Looper, D. 2008, ApJ, 676, 1281
Murray, D. N., Burningham, B., Jones, H. R. A., et al. 2011, arXiv:1101.4881
Patten, B. M., Stauffer, J. R., Burrows, A., et al. 2006, ApJ, 651, 502
Rodriguez, D. R., Zuckerman, B., Melis, C., & Song, I. 2011, ApJ, 732, L29
Scholz, R.-D. 2010, A&A, 515, A92
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
Subasavage, J. P., Jao, W.-Ch., Henry, T. J., et al. 2009, AJ, 137, 4547
Wright, E. L., Eisenhardt, P. R. M., Mainzer, A. K., et al. 2010, AJ, 140, 1868
Wright, E. L., Mainzer, A., Gelino, C., & Kirkpatrick, D. 2011, arXiv:1104.2560