A&A 557, A43 (2013)
DOI: 10.1051/0004-6361/201322141

Astronomy & Astrophysics

An overlooked brown dwarf neighbour (T7.5 at $d \sim 5$ pc) of the Sun and two additional T dwarfs at about 10 pc⋆

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

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

Received 25 June 2013 / Accepted 10 July 2013

ABSTRACT

Context. Although many new brown dwarf (BD) neighbours have recently been discovered thanks to new sky surveys in the mid- and near-infrared (MIR, NIR), their numbers are still more than five times lower than those of stars in the same volume.
Aims. Our aim is to detect and classify new BDs to eventually complete their census in the immediate solar neighbourhood.
Methods. We combined multi-epoch data from sky surveys at different wavelengths to detect BD neighbours of the Sun by their high proper motion (HPM). We concentrated on relatively bright MIR ($w2 < 13.5$) BD candidates from the Wide-field Infrared Survey Explorer (WISE) expected to be so close to the Sun that they may also be seen in older NIR (Two Micron All Sky Survey – 2MASS –; DEep Near-Infrared Survey – DENIS) or even red optical (Sloan Digital Sky Survey (SDSS) *i*- and *z*-band, SuperCOSMOS Sky Surveys (SSS) *I*-band) surveys. With low-resolution NIR spectroscopy we classified the new BDs and estimated their distances and velocities.
Results. We have discovered the HPM ($\mu \sim 470$ mas/yr) T7.5 dwarf, WISE J0521+1025, which is at $d = 5.0 \pm 1.3$ pc from the Sun the nearest known T dwarf in the northern sky, and two early T dwarfs, WISE J0457−0207 (T2) and WISE J2030+0749 (T1.5), with proper motions of ∼120 and ∼670 mas/yr and distances of 12.5 ± 3.1 pc and 10.5 ± 2.6 pc, respectively. The last one was independently discovered and also classified as a T1.5 dwarf by Mace and coworkers. All three show thin disc kinematics. They may have been overlooked in the past owing to overlapping images and because of problems with matching objects between different surveys and measuring their proper motions.

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

1. Introduction

The progress in discovering brown dwarfs (BDs) with ever cooler temperatures, that correspond to four spectral classes (M, L, T, and Y), is closely connected with the shift of all-sky surveys to longer wavelengths, from the optical, to the near- and mid-infrared (NIR, MIR). As BDs change their spectral types during their lifetime when cooling down (Burrows et al. 2001), the majority of BDs in the solar neighbourhood with typical ages of several Gyr are expected to be T- and Y-type BDs. This has now been confirmed by the latest observations.

Updating the stellar and substellar census within 8 pc from the Sun after the recently completed MIR WISE survey (Wide-field Infrared Survey Explorer; Wright et al. 2010), Kirkpatrick et al. (2012) listed 3 L-type, 22 T-type, and 8 Y-type objects. The last class was only recently established by Cushing et al. (2011) and consists exclusively of WISE discoveries and will certainly be filled with many more discoveries. The WISE survey detected 7+1 new T and L dwarfs, respectively, in this volume, whereas former NIR surveys, the Two Micron All Sky Survey (2MASS; Skrutskie et al. 2006) and the DEep Near-Infrared Survey (DENIS; Epchtein et al. 1997), contributed 8+1 and 1+1 T and L dwarfs, respectively. Six T dwarfs were found by other surveys, according to their discovery names listed in Kirkpatrick et al. (2012).

Because of the small number density of L dwarfs and the optical faintness of T dwarfs, none of the L/T discoveries from the Sloan Digital Sky Survey (SDSS) with its ongoing data releases (e.g. Abazajian et al. 2009; Aihara et al. 2011) fall into the 8 pc sample, but one peculiar L6p/T7.5 binary, SDSS J1416+1348AB (Bowler et al. 2010; Scholz 2010a; Burgasser et al. 2010a), is missing according to the information given in the DwarfArchives (Gelino et al. 2012). However, the new accurate trigonometric parallax of this binary determined by Dupuy & Liu (2012) placed it at 9.11 pc, clearly outside the 8 pc horizon. Only the nearest ($d = 3.626$ pc) early T dwarf binary, ε Indi Ba,Bb (Scholz et al. 2003; McCaughrean et al. 2004), was originally discovered in the optical as an unresolved high proper motion (HPM) object using two *I*-band photographic Schmidt plates with an epoch difference of several years that were scanned within the SuperCOSMOS Sky Surveys (SSS; Hambly et al. 2001). Also clearly seen on photographic Schmidt plates is the unresolved pair WISE J1049−5319AB of two late-L dwarfs detected at the record-breaking distance of only 2 pc (Luhman 2013; Mamajek 2013).

Kirkpatrick et al. (2012) found that there are currently about six times more stars than BDs within 8 pc. They also expressed their expectation that this factor will decrease with time as new discoveries are catalogued, and Luhman (2013) provided the first evidence that these expectations are justified. His discovery was based on an HPM survey taking advantage of the WISE data obtained in different seasons (with a mission lifetime of 13 months) and subsequent comparison with other surveys. Note that Luhman's object was possibly overlooked in previous BD searches using 2MASS and DENIS, and even photographic Schmidt plates, bacause of image crowding and resulting

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

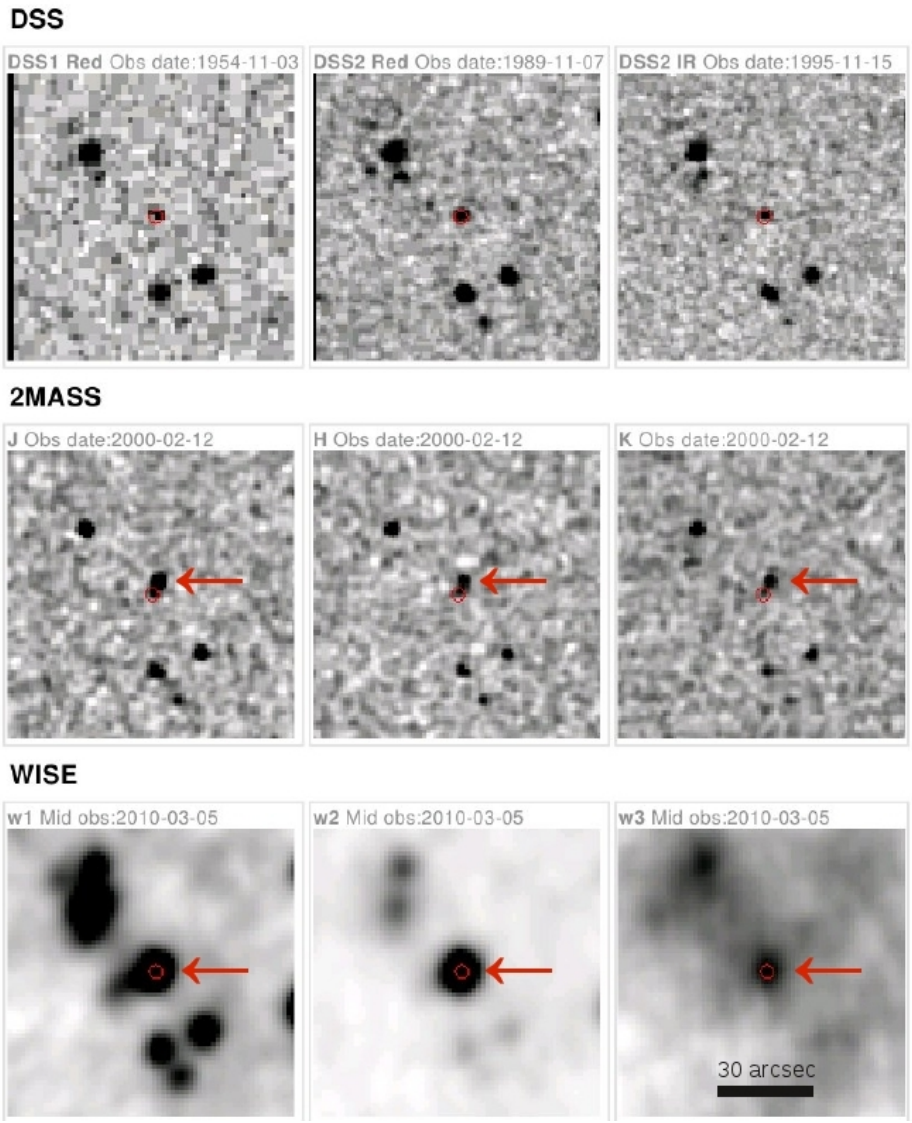

Fig. 1. Digitised Sky Surveys (DSS), 2MASS, and WISE finding charts (90×90 arcsec^2, north is up, east to the left) for WISE J0521+1025. The red open circle marks the position of the target at the WISE epoch (i.e. the centre of each image). The red arrows mark the bright WISE source and the correct counterparts in 2MASS and DSS (if detected) of the HPM object. In this particular case, we see an overlapping background object in both 2MASS and DSS (within the open circle), whereas the correct counterpart is only seen in 2MASS as the brighter object north of the background object. Compared to the other finding charts (Figs. 2 and 3), a higher magnification was chosen to better show the source confusion in this case.

problems with the cross-matching of measured objects from different surveys.

Our BD search is also based on the identification of HPM objects; we first use WISE colour criteria and magnitude cuts and then check the candidates for shifted counterparts in other surveys with different epochs. This allowed us to detect two very nearby ($d \sim 5$ pc) late T dwarfs (Scholz et al. 2011) when the preliminary WISE data release first became available. Now we have used the WISE All-Sky data release with similar selection criteria and have paid special attention to possible mismatches with other surveys, which may prevent us from finding the correct counterparts. Three newly found nearby BDs, one of which is a previously overlooked close neighbour, are presented in this paper.

2. Candidate selection and cross-identification

We used the WISE All-Sky source catalogue with a mean observing epoch in the first half of 2010 for the selection of bright MIR candidates with colours typical of T dwarfs and hints on their possible HPM according to their cross-identification with 2MASS (epoch ~2000) sources:

- Candidates were selected to have [$w1-w2 > 1.5$ (later than ~T5) and $w2 < 13.5$] or [$0.5 < w1-w2 < 1.5$ (~T0–T5) and $w2 < 12.5$], aiming at nearby ($d < 15$ pc) T or Y dwarfs according to Figs. 1 and 29 in Kirkpatrick et al. (2011).
- To reduce crowding effects, only point sources outside the Galactic plane ($|b| > 5°$) were included.
- To exclude extragalactic sources, only those with $w2-w3 < 2.5$ were considered (see Wright et al. 2010).
- Only objects without a 2MASS counterpart (within 3 arcsec) or with a counterpart's separation between 1 arcsec and 3 arcsec were selected as potential HPM candidates.

With the first two conditions we relied on the WISE MIR photometry of point sources, which may however be affected by saturation for the brightest objects and by overlapping background objects not resolved by WISE, and effectively excluded most of the earlier-type BDs and stars from our target list. As we applied a relatively bright WISE magnitude cut, we expected to see these objects also in the 2MASS, if they were not as cool as Y dwarfs. Therefore, our fourth condition was aimed at finding either HPM objects with $\mu > 0.3$ arcsec/yr or with $0.1 < \mu < 0.3$ arcsec/yr given the WISE-2MASS epoch difference of about ten years. However, we considered the 2MASS counterparts with 1–3 arcsec shifts as suspicious and wanted to visually inspect the corresponding WISE sources for alternative HPM counterparts outside of the search radius of 3 arcsec.

About 2000 candidates were found with the above conditions. With the help of the IRSA Finder Charts tool[1], we were able to inspect all these candidates to identify HPM objects. These were then checked for known objects in DwarfArchives (Gelino et al. 2012) and SIMBAD[2]. Although most of the 2000 initial candidates were rejected as ghosts/stripes, reddened or extended/diffuse objects, we found some variable stars (e.g. a new Galactic Nova; Scholz et al. 2012b) and many previously known BD and stellar neighbours of the Sun: more than 40 T dwarfs, about 20 L dwarfs, but also about 20 M dwarfs and earlier-type stars. Among about ten new candidates, we selected three with photometrically estimated distances of less than about 10 pc and moderately low declinations for spectroscopic follow up (see Sect. 3) with the Large Binocular Telescope (LBT) (other early T-type and red L-type candidates were placed in different observing programmes and will be published elsewhere). We matched them with 2MASS and also with later WISE observations, and two could be identified in other NIR/optical surveys as well (Table 1). Finally, we used the recently measured positions of our targets on the LBT acquisition images (Sect. 3) calibrated with the PPMXL (Röser et al. 2010) to confirm the proper motions and improve their accuracy.

WISE J052126.29+102528.4 (hereafter WISE J0521+1025) – For this late T candidate ($w1-w2 = +1.8$) the WISE catalogue lists a 2MASS counterpart separated by 1.4 arcsec. This is obviously a background object that is also visible in the DSS (Fig. 1). However, the brighter 2MASS object north of it appears blue in the NIR and has no optical counterpart, indicating already on the basis of the 2MASS data alone a HPM T-type BD candidate. Both objects are flagged in the 2MASS as deblended in J and K_s, and as the astrometry may also be affected, we measured the 2MASS position of the blue object visually using the ESO Skycat tool. We also found a second epoch in the WISE 3-band cryo data (Table 1).

WISE J045746.08−020719.2 (hereafter WISE J0457−0207) – In this case, the 2MASS counterpart shifted by 1.6 arcsec is not seen in the optical (Fig. 2) and is moderately red, $J-K_s = +0.9$, consistent with an early T dwarf with a relatively small proper motion. The colours $w1-w2 = +1.0$ and $J-w2 = +2.5$ agree with this classification. In addition, this object is detected by DENIS and by the Galactic Clusters Survey (GCS) within the UKIRT InfraRed Deep Sky Surveys (UKIDSS)[3]. Later we found another detection in the WISE 3-band cryo data (Table 1).

WISE J203042.79+074934.7 (hereafter WISE J2030+0749) – No 2MASS counterpart (<3 arcsec) was listed for this one, but the finding charts in Fig. 3 show a clear HPM object with growing separation from 2MASS to older DSS IR. From the SSS we found three I-band positions, and the object was also detected in the SDSS iz bands (Table 1). Its colours ($i-z = +4.6$, $J-K_s = +0.9$, $J-w2 = +2.1$, $w1-w2 = +0.8$) fit a T2 dwarf (Hawley et al. 2002; Kirkpatrick et al. 2011). However, there is only one T2 dwarf listed in Hawley et al. (2002) that has $i-z = +4.2$, whereas the average values of <T2 and >T2 dwarfs are generally smaller and reach $i-z = +4.0$ only for the latest-given class of T6 dwarfs. From

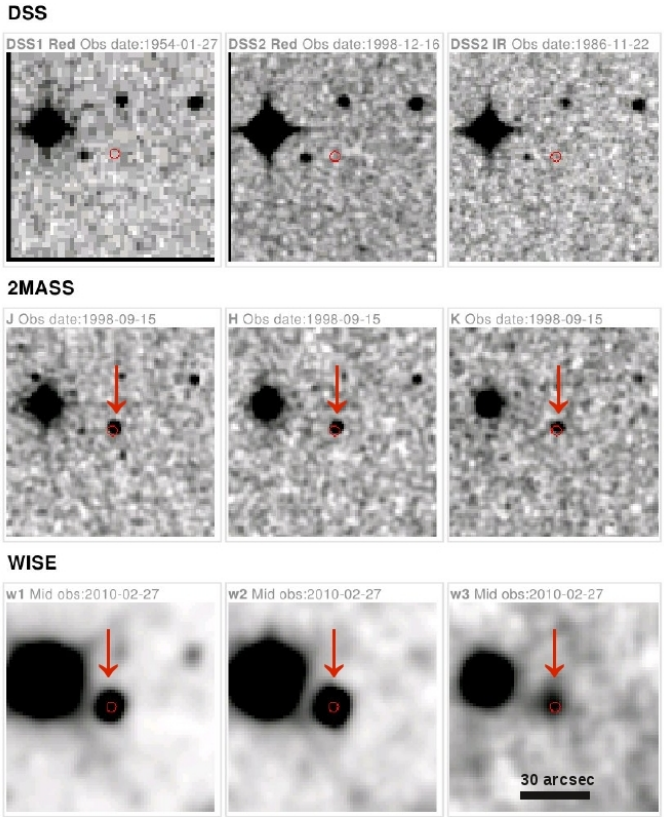

Fig. 2. Finding charts as in Fig. 1 for WISE J0457−0207.

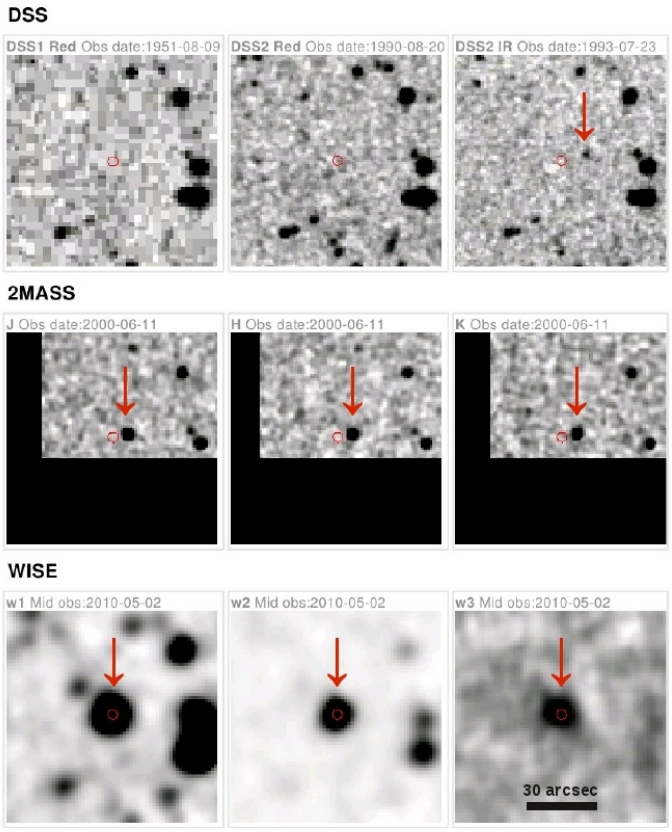

Fig. 3. Finding charts as in Fig. 1 for WISE J2030+0749.

[1] http://irsa.ipac.caltech.edu/applications/finderchart/ providing DSS, 2MASS, and WISE images for a given object at a glance (see e.g. Figs. 1–3).

[2] http://simbad.u-strasbg.fr/

[3] The UKIDSS project is defined in Lawrence et al. (2007). UKIDSS uses the UKIRT Wide Field Camera (WFCAM; Casali et al. 2007) and the photometric system described in Hewett et al. (2006), which is situated in the Mauna Kea Observatories (MKO) system (Tokunaga et al. 2002). The pipeline processing and science archive are described in Hambly et al. (2008) and Irwin et al. (in prep.).

Table 1. Positions (J2000), proper motions [mas/yr], photometry [mag], spectral indices/types, distances [pc], and tangential velocities [km s^{-1}].

Param.	J0521+1025	J0457−0207	J2030+0749
LBT α	05 21 26.349	04 57 46.114	20 30 42.897
LBT δ	+10 25 27.41	−02 07 19.59	+07 49 34.44
LBT ep	2012.773	2012.770	2012.855
WISE α	05 21 26.2967	04 57 46.0884	20 30 42.7986
WISE δ	+10 25 28.494	−02 07 19.239	+07 49 34.741
WISE ep	2010.175	2010.156	2010.332
WISE[c] α	05 21 26.3165	04 57 46.1024	20 30 42.8069
WISE[c] δ	+10 25 28.439	−02 07 19.186	+07 49 34.602
WISE[c] ep	2010.701	2010.682	2010.830
GCS[b] α	n/a	04 57 46.0785	n/a
GCS[b] δ	n/a	−02 07 19.202	n/a
GCS ep	n/a	2010.019	n/a
SDSS α	n/a	n/a	20 30 42.357
SDSS δ	n/a	n/a	+07 49 35.64
SDSS ep	n/a	n/a	2000.748
2MASS α	05 21 26.147[a]	04 57 46.022	20 30 42.357
2MASS δ	+10 25 32.74[a]	−02 07 17.95	+07 49 35.83
2MASS ep	2000.118	1998.707	2000.444
DENIS α	n/a	04 57 46.038	n/a
DENIS δ	n/a	−02 07 18.34	n/a
DENIS ep	n/a	1998.953	n/a
SSS I α	n/d	n/d	20 30 42.149
SSS I δ	n/d	n/d	+07 49 36.18
SSS I ep	1995.874	2001.862	1995.654
SSS I^f α	n/a	n/a	20 30 42.051
SSS I^f δ	n/a	n/a	+07 49 37.35
SSS I^f ep	n/a	n/a	1993.545
$\mu_\alpha \cos\delta$	$+232 \pm 9$	$+82 \pm 9$	$+653 \pm 6$
μ_δ	-418 ± 6	-97 ± 8	-138 ± 16
SSS I	n/d	n/d	∼19.5
SSS I^f	n/a	n/a	$\sim 18.9 \pm 0.3$
SDSS i	n/a	n/a	21.810 ± 0.140
SDSS z	n/a	n/a	17.195 ± 0.014
DENIS J	n/a	14.879 ± 0.12	n/a
2MASS J	15.262[d]	14.897 ± 0.040	14.227 ± 0.029
2MASS H	15.222 ± 0.103	14.198 ± 0.046	13.435 ± 0.033
2MASS K_s	14.665[d]	14.022 ± 0.055	13.319 ± 0.039
GCS H^e	n/a	14.190 ± 0.003	n/a
GCS K^e	n/a	13.975 ± 0.003	n/a
WISE $w1$	14.098 ± 0.031	13.391 ± 0.026	12.956 ± 0.025
WISE $w2$	12.286 ± 0.026	12.443 ± 0.025	12.122 ± 0.025
WISE $w3$	10.306 ± 0.085	11.020 ± 0.114	10.964 ± 0.110
H_2O-H	0.246 (T7)	0.509 (T2)	0.599 (T0/T1)
CH_4-H	0.155 (T7/T8)	0.798 (T2/T3)	0.859 (T2)
CH_4-K	0.084 (T7/T8)	0.488 (T3)	0.595 (T2)
SpT_{vis}	T7.5	T2	T1.5
SpT_{adopt}	T7.5	T2	T1.5
d	5.0 ± 1.3	12.5 ± 3.1	10.5 ± 2.6
v_{tan}	11 ± 3	8 ± 2	33 ± 8

Notes. Basic WISE data are from the All-Sky source catalogue, SDSS data from DR8 (Aihara et al. 2011). For other data references, see text (n/a – not available, n/d – not detected). [(a)] Visual measurement in 2MASS FITS image, [(b)] mean coordinates from four measurements at one epoch, [(c)] WISE 3-band cryo source working database or mean of Post-Cryo Single Exposure (L1b) data (for J2030+0749), [(d)] 2MASS image deblended in this band, [(e)] mean GCS aperMag3 magnitudes from two measurements, [(f)] mean from two additional epochs – 1993.533+1993.557.

WISE post-cryo single exposures we determined an additional mean position at a later epoch (Table 1).

3. Near-infrared spectroscopic classification

Our three targets were observed with the LBT NIR spectrograph LUCI 1 (Mandel et al. 2008; Seifert et al. 2010; Ageorges et al. 2010) in long-slit spectroscopic mode with the HK (200 lines/mm + order separation filter) and $zJHK$ gratings (210 lines/mm + J filter). The dwarf WISE J0521+1025 was observed on 2012-Oct-09 with total integration times of 40 min in HK and 20 min in J, WISE J0457−0207 and WISE J2030+0749 on 2012-Oct-08 and 2012-Nov-08, respectively, but both with only 16 min (HK) and 10 min (J). As in Scholz et al. (2011, 2012a), central wavelengths were chosen at 1.835 μm (HK) and 1.25 μm (J) yielding a coverage of 1.38–2.26 and 1.18–1.33 μm, respectively. The slit width was always 1 arcsec, corresponding to a spectral resolving power of $R = \lambda/\Delta\lambda \approx 4230$, 940, and 1290 at $\lambda \approx 1.24$, 1.65, and 2.2 μm, respectively. Observations consisted of individual exposures of 60 s in HK (75 s for WISE J0521+1025) and 150 s in J with shifting the target along the slit using an ABBA pattern until the total integration time was reached. For more details and a description of the spectroscopic data reduction we refer the reader to Scholz et al. (2011, 2012a). Note that the above given wavelength coverage is not wide enough at both the blue and red ends to compute spectrophotometric colours in the 2MASS system (using spectral response curves from Cohen et al. 2003). The J band is also too narrow to compute spectral indices for classifying T dwarfs according to Burgasser et al. (2006) so that only HK indices can be used.

In Figs. 4–6, we show J- and HK-band spectra normalised at 1.2−1.3 μm and 1.52−1.61 μm, respectively. The J-band spectrum of WISE J0521+1025 fits best to that of a T8 standard, but is more similar to T7/T7.5 in the HK band, with a better fit to T7.5 at 1.7 μm (Fig. 4). Except for the H band, we note a good agreement, including the K I doublet (at 1.24/1.25 μm) in the J band and the high peak in the K band, with Ross 458C (discovered by Goldman et al. 2010 and Scholz 2010b) observed with the same instrument (Fig. 5). Because of these features, Ross 458C was characterised as a young (low surface gravity) and super-solar metallicity T8 dwarf by Burgasser et al. (2010b), whereas Burningham et al. (2011) typed it as T8.5p. We visually classified WISE J0521+1025 as T7.5 in good agreement with the measured spectral indices in the HK band (Table 1) as defined in Burgasser et al. (2006).

The spectra of WISE J0457−0207 (with a remarkably high K-band peak that cannot be explained by uncertainties of the flux calibration) and WISE J2030+0749 are of earlier (∼T2) type (Fig. 6), fitting in parts better to the T1, T2, or T3 standard. As standards are single, this may indicate possible close binary components with different types or peculiarities related to age or metallicity. The extreme $i-z$ index of WISE J2030+0749 makes this object even more interesting. Visually we classified WISE J0457−0207 as T2 and WISE J2030+0749 as T1.5 and adopted these types consistent with those obtained from spectral indices.

Using mean absolute WISE magnitudes of single T7.5 and T1/T2 dwarfs from Dupuy & Liu (2012), we estimated distances of 5.0 ± 1.3 pc for WISE J0521+1025, 12.5 ± 3.1 pc for WISE J0457−0207, and 10.5 ± 2.6 pc for WISE J2030+0749.

4. Conclusions

We have discovered three new BDs close to the Sun in an HPM search using MIR, NIR, and optical surveys: WISE J0457−0207 has a relatively small proper motion for an object at the

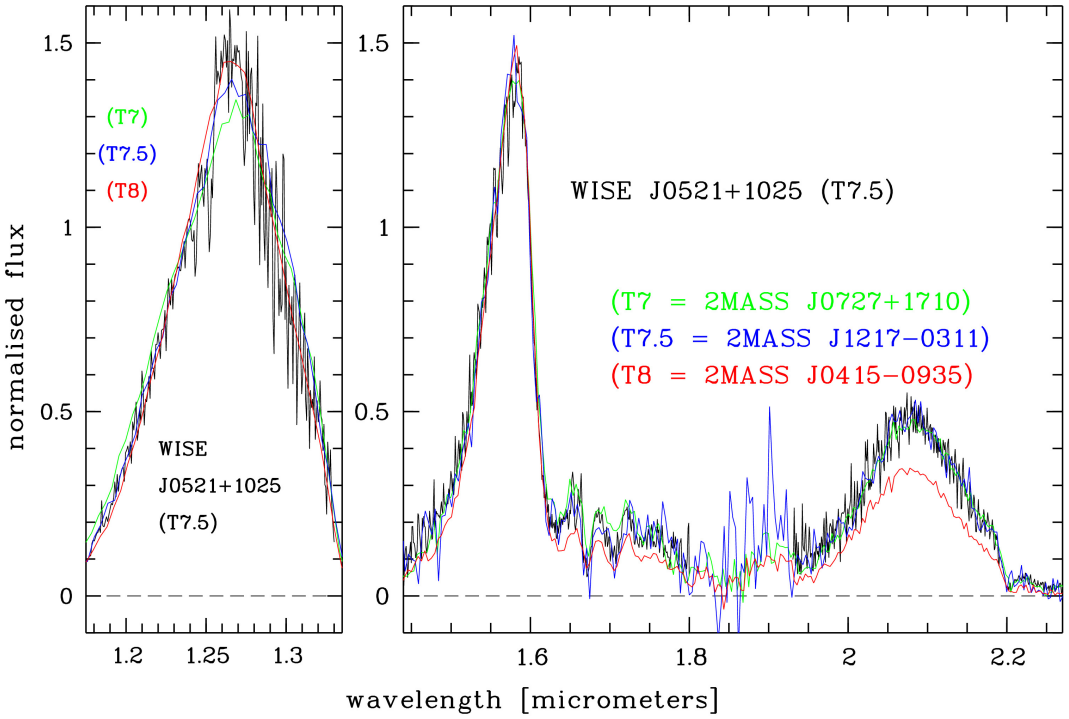

Fig. 4. LBT/LUCI *J*-band (*left*) and *HK*-band (*right*) spectra of WISE J0521+1025 (black) overplotted with lower resolution standard spectra of 2MASS J0727+1710 (T7, green), 2MASS J1217−0311 (T7.5, blue) (Burgasser et al. 2006), and 2MASS J0415−0935 (T8, red) (Burgasser et al. 2004).

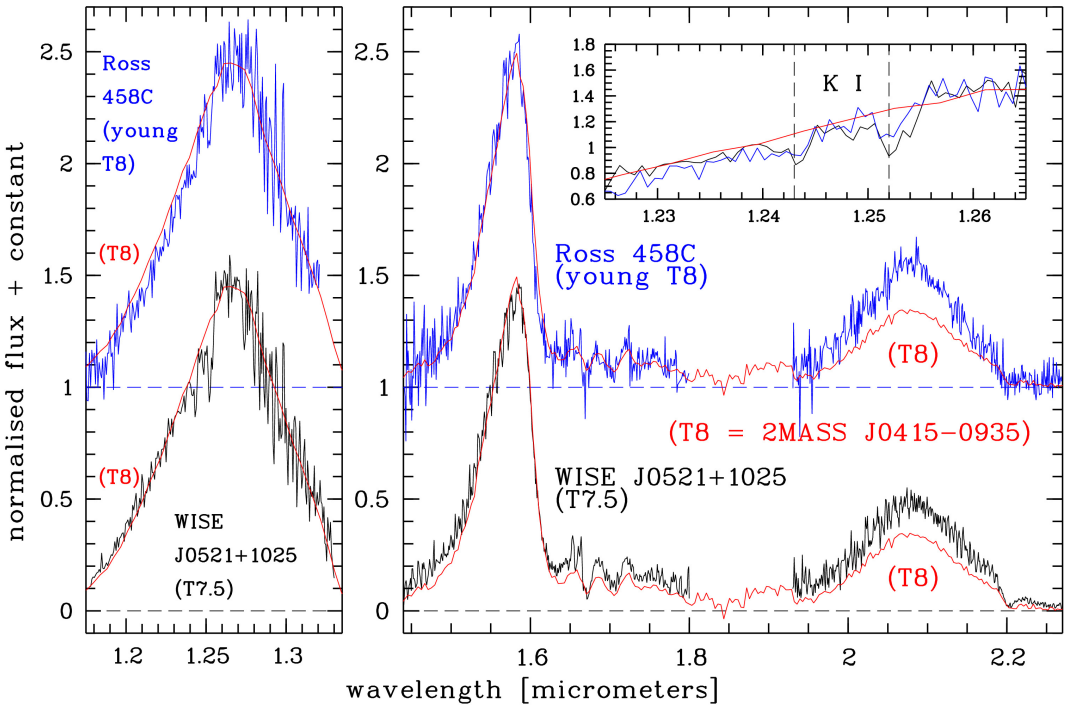

Fig. 5. LBT/LUCI spectra of WISE J0521+1025 (black) and Ross 458C (blue, from Scholz et al. 2011) overplotted with lower resolution spectrum (red) of the T8 standard 2MASS J0415−0935 (Burgasser et al. 2004). The insert shows the region of the K I doublet at 1.243/1.252 μm.

10 pc horizon (cf. Fig. 1 in Scholz et al. 2011) not detectable in the past because of similar 2MASS and DENIS epochs. WISE J2030+0749, with similar 2MASS and SDSS epochs, was previously not associated with its SSS measurement, whereas WISE J0521+1025 was probably overlooked in previous BD and HPM searches because of problems matching partly blended images in different surveys.

Using NIR spectroscopy with LBT/LUCI we classified WISE J0521+1025 as a new T7.5 dwarf at a distance of about 5 pc. It is currently the nearest T dwarf in the northern hemisphere and may also be the closest free-floating neighbour of its spectral sub-class. The dwarfs WISE J0457−0207 and WISE J2030+0749 lie, according to their T2 and T1.5 types, slightly beyond 10 pc, but may still fall in the 10 pc sample

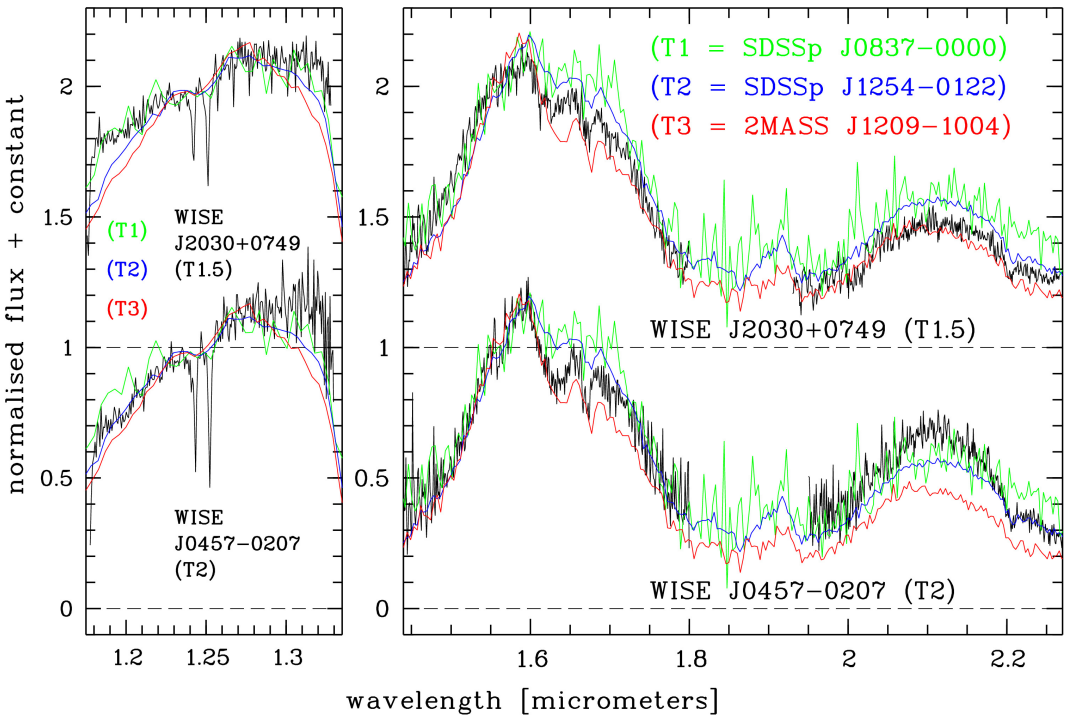

Fig. 6. LBT/LUCI spectra (black) of WISE J0457−0207 and WISE J2030+0749 overplotted with lower resolution standard spectra: SDSSp J0837−0000 (T1, green) (Burgasser et al. 2006), SDSSp J1254−0122 (T2, blue), and 2MASS J1209−1004 (T3, red) (Burgasser et al. 2004).

given their error bars, if they are not unresolved binaries. The latter was independently discovered by Mace et al. (2013), who also classified it as a T1.5 dwarf. However, they did not mention its large proper motion, proximity, and very red $i-z$ colour from the SDSS. The small tangential velocities of all three new BDs are typical of the Galactic thin disc population. They are promising targets for trigonometric parallax programmes and adaptive optics observations.

Acknowledgements. The authors thank Jochen Heidt, Barry Rothberg, and all observers at the LBT 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 anonymous referee for a quick and helpful report and Victor J. Sanchez Bejar for some important hints. This research has made use of the WFCAM Science Archive providing UKIDSS, 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/. This research has benefitted from the M, L, T, and Y dwarf compendium housed at DwarfArchives.org. We have also used SIMBAD and VizieR at the CDS/Strasbourg.

References

Abazajian, K. N., Adelman-McCarthy, J. K., Agüeros, M. A., et al. 2009, ApJS, 182, 54
Ageorges, N., Seifert, W., Jütte, M., et al. 2010, SPIE, 7735, 53
Aihara, H., Allende Prieto, C., An, D., et al. 2011, ApJS, 193, 29
Bowler, B. P., Liu, M. C., & Dupuy, T. J. 2010, ApJ, 710, 45
Burrows, A., Hubbard, W. B., Lunine, J. I., & Liebert, J. 2001, Rev. Mod. Phys., 73, 719
Burgasser, A. J., McElwain, M. W., Kirkpatrick, J. D., et al. 2004, AJ, 127, 2856
Burgasser, A. J., Geballe, T. R., Leggett, S. K., Kirkpatrick, J. D., & Golimowski, D. A. 2006, ApJ, 637, 1067
Burgasser, A. J., Looper, D., Rayner, J. T. 2010a, AJ, 139, 2448
Burgasser, A. J., Simcoe, R. A., Bochanski, J. J., et al. 2010b, ApJ, 725, 1405
Burningham, B., Leggett, S. K., Homeier, D., et al. 2011, MNRAS, 414, 3590
Casali, M., Adamson, A., Alves de Oliveira, C., et al. 2007, A&A, 467, 777
Cohen, M., Wheaton, W. A., & Megeath, S. T. 2003, AJ, 126. 1090
Cushing, M. C., Kirkpatrick, J. D., Gelino, C. R., et al. 2011, ApJ, 743, 50
Dupuy, T. J., & Liu, M. C. 2012, ApJSS, 201, 19
Epchtein, N., de Batz, B., Capoani, L., et al. 1997, The Messenger, 87, 27
Gelino, C. R., Kirkpatrick, J. D., & Burgasser, A. J. 2012, online database for 804 L and T dwarfs at DwarfArchives.org (status: 6 November 2012)
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., Collins, R. S., Cross, N. J. G., et al. 2008, MNRAS, 384, 637
Hawley, S. L., Covey, K. R., Knapp, G. R., et al. 2002, AJ, 123, 3409
Hewett, P. C., Warren, S. J., Leggett, S. K., & Hodgkin, S. T. 2006, MNRAS, 367, 454
Kirkpatrick, J. D., Cushing, M. C., Gelino, C. R., et al. 2011, ApJSS, 197, 19
Kirkpatrick, J. D., Gelino, C. R., Cushing, M. C., et al. 2012, ApJ, 753, 156
Lawrence, A., Warren, S. J., Almaini, O., et al. 2007, MNRAS, 379, 1599
Luhman, K. L. 2013, ApJ, 767, L1
Mace, G. N., Kirkpatrick, J. D., Cushing, M. C., et al. 2013, ApJSS, 205, 6
Mamajek, E. E. 2013 [arXiv:1303.5345]
Mandel, H., Seifert, W., Hofmann, R., et al. 2008, SPIE, 7014, 124
McCaughrean, M. J., Close, L. M., Scholz, R.-D., et al. 2004, A&A, 413, 1029
Röser, S., Demleitner, M., & Schilbach, E. 2010, AJ, 139, 2440
Scholz, R.-D. 2010a, A&A, 510, L8
Scholz, R.-D. 2010b, A&A, 515, A92
Scholz, R.-D., McCaughrean, M. J., Lodieu, N., & Kuhlbrodt, B. 2003, A&A, 398, L29
Scholz, R.-D., Bihain, G., Schnurr, O., & Storm, J. 2011, A&A, 532, L5
Scholz, R.-D., Bihain, G., Schnurr, O., & Storm, J. 2012a, A&A, 541, A163
Scholz, R.-D., Granzer, T., Schwarz, R., et al. 2012b, The Astronomer's Telegram, 4268, 1
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
Tokunaga, A. T., Simons, D. A., & Vacca, W. D. 2002, PASP, 114, 180
Wright, E. L., Eisenhardt, P. R. M., Mainzer, A. K., et al. 2010, AJ, 140, 1868