ULAS J141623.94+134836.3 - a faint common proper motion companion of a nearby L dwarf

Serendipitous discovery of a cool brown dwarf in UKIDSS DR6

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ABSTRACT

Aims. New near-infrared large-area sky surveys (e.g. UKIDSS, CFBS, WISE) go deeper than 2MASS and aim at detecting brown dwarfs lurking in the Solar neighbourhood which are even fainter than the latest known T-type objects, so-called Y dwarfs.

Methods. Using UKIDSS data, we have found a faint brown dwarf candidate with very red optical-to-near-infrared but extremely blue near-infrared colours next to the recently discovered nearby L dwarf SDSS J141624.08+134826.7. We check if the two objects are co-moving by studying their parallactic and proper motion and compare the new object with known T dwarfs.

Results. The astrometric measurements are consistent with a physical pair (sep≈75 AU) at a distance d=8 pc. The extreme colour (J−K≈1.7) and absolute magnitude (M_J=17.78±0.46 and M_K=19.45±0.52) make the new object appear as one of the coolest (T eff ≈600 K) and nearest brown dwarfs, probably of late-T spectral type and possibly with a high surface gravity (log g≧5.0).

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

1. Introduction

One of the open questions of low-mass star formation is the ratio of successful/failed star formation processes. In other words, is the Solar neighbourhood populated by as many cool brown dwarfs as red dwarf stars? Several new near-infrared surveys like UKIDSS, CFBDs (Delorme et al. 2008b) and WISE (Wright et al. 2008) try to answer this question by going deeper than the Two Micron All Sky Survey (2MASS; Skrutskie et al. 2006) to detect a new class of ultracool brown dwarfs, so-called Y dwarfs.

The appearance of ammonia absorption in the near-infrared spectra is being discussed as a criterion for the new Y spectral type (Burningham et al. 2008, Delorme et al. 2008b). Whereas the latest-type (coolest) objects discovered in the 2MASS are of spectral type T8 (Burgasser et al. 2002, Tinney et al. 2005, Looper, Kirkpatrick, & Burgasser 2007), a handful of even cooler (T eff ≈500-600 K) brown dwarfs (T8.5-T9) have already been discovered in UKIDSS (Warren et al. 2007, Burningham et al. 2008, 2009) and CFBDs (Delorme et al. 2008a) that do not look obviously different in their near-infrared spectra from late-type T dwarfs. A unique Y dwarf has not yet been found and classified.

In this letter, we describe a new cool brown dwarf, which is probably a late-T dwarf with unusual properties, detected as a wide companion of a nearby L dwarf.

2. Identification of a faint object with unusual colors near the blue L dwarf SDSS J141624.08+134826.7

While inspecting the UKIDSS finding charts around the recently discovered (Schmidt et al. 2009, hereafter S09; Bowler, Liu & Dupuy 2009, hereafter B09) nearby blue L6 dwarf SDSS J141624.08+134826.7 (hereafter called object A), we found a fainter nearest neighbouring object with extreme colours, separated by about 9.4 arcsec. This object, ULAS J141623.94+134836.3 (hereafter called object B) was not detected in the SDSS DR7 (Abazajian et al. 2009), but is well measured in the UKIDSS, where it has J−Y=0.9 but a very blue near-infrared colour of J−K≈−0.3 and J−K≈−1.7 (Fig. 1 Tab. 1). Abazajian et al. (2009) describe the completeness limit of SDSS DR7 with a 95% detection repeatability for point sources at u=22.0, g=22.2, r=22.2, i=21.3, and z=20.5. The non-detection of object B in SDSS DR7 hints at a very red optical-to-near-infrared colour (z−Y>++2.3 and z−J>++3.1). Using two available overlapping z-band FITS images (SDSS runs 3971 and 3996) downloaded from the SDSS DR7, we were able to detect object B (for the astrometry see Tab. 2) and measure its magnitude as $z_{3971} = 21.24±0.50$ and $z_{3996} = 21.02±0.39$. The resulting mean colour indices are $z−J=+2.97±0.32$ and $z−J=+3.87±0.32$.

Comparing the near-infrared colour indices of object B with those of the known T dwarfs (Fig. 2), one can see that similar moderately negative $J−H$ have been measured for the latest-type (T9) but also for other mid- and late-type T dwarfs, whereas the extremely large negative $J−K$ of object B clearly stands out against the rest of the T dwarfs. Both colours are in the range typical of model T and Y dwarfs but rule out a high-redshift quasar (Hewett et al. 2006). However, before further analysis we...
need to check the physical association of object B with object A and to confirm its distance.

3. Confirmation of common proper motion

For a first check of a possible common motion of objects A and B, one can use the accurate UKIDSS data alone. There are two different epochs for the \(HK\) and \(YJ\) observations, respectively (Tab. 2). The corresponding multiframe numbers are listed in Tab. 1. Short-term proper motions have been determined from simple linear fitting over the four epoch positions of objects A and B as well as of 6 field stars in their vicinity, well-measured on the same multiframes (Fig. 3). Significant results, which agree within their errors, were obtained for A and B (solution 1-A and 1-B in Tab. 3) in comparison to those of field stars (crosses). Typical proper motion errors of \(\sigma \approx 75\) mas/yr were achieved in both directions. The dashed circle represents a 4\(\sigma\) significance level.

Using two \(z\)-band SDSS images containing object A, we were able to detect object B with the help of the ESO skycat tool and the "pick object" option which is based on Gaussian fitting (Tab. 2). We think the reason why object B does not appear in the SDSS DR7 is that it is >0.5 mag fainter than the already mentioned 95% detection limit in \(z\) and can not be detected in \(ugri\), where it should be much fainter than the corresponding limits. Using now our two SDSS positions of object B together with its four UKIDSS positions, we get again similar proper motions (solutions 2-A and 2-B in Tab. 3), now also approaching the known long-term proper motion of object A obtained by S09 and B09. We will show that this discrepancy can be explained by the expected common parallactic motion.

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The spectrophotometric distance of object A is still very uncertain (8.0±1.6 pc according to S09 and 8.4±1.9 pc according to B09), because the spectral type-absolute magnitude relations are not yet well-determined for the class of blue L dwarfs. B09 mentioned a notable parallactic motion of object A, but their trigonometric parallax (πrel = 107±34 mas) leads to a less accurate distance (9.3±3.0 pc) than the aforementioned spectrophotometric distance estimates.

We have applied the software of Gudehus (2001) for combined proper motion and parallax solutions. In the full solution for object A (solution 4-A), we made use of all 10 available epochs assigning the following uncertainties to the α, δ given in Tab. 2: 70 mas for UKIDSS and SDSS, 100 mas for 2MASS, 150 mas for SSS J-band, 200 mas for SSS R-band, and 250 mas for the SSS measurement of the old E plate (expected colour-dependent systematic errors in the different α, δ are much smaller and have been neglected). As an alternative, we used only the most accurate data (UKIDSS and SDSS) and the proper motion obtained in solution 3-A as a fixed input parameter in fitting only the parallactic motion of object A (solution 5-A in Tab. 3) and object B (solution 5-B). In the latter case we assigned uncertainties of 200 mas to our SDSS α, δ measurements.

Our preferred solution for object A (4-A) gives a proper motion nearly identical to the linear fit (3-A) and provides a parallax leading to a distance of 7.9±1.7 pc in perfect agreement with the spectrophotometric distances of S09/B09, respectively. Its accuracy is also comparable with that of the spectrophotometric estimates. However, the full range of the parallaxes ±errors in solutions 4-A, 5-A, and 5-B implies a larger uncertainty for the system. Figure 6 shows that the short-term (UKIDSS only) proper motion of both objects (solutions 1-A and 1-B) is well-explained by their common parallactic motion (the parallax results of solutions 5-A and 5-B agree within their errors).

4. Conclusions and discussion

We have discovered a faint common proper motion companion (object B) of a blue nearby L6 dwarf (object A). Based on the astrometric measurements, which are consistent with a wide binary (projected physical separation 75 AU) at a distance of about 8 pc, and on the accurate near-infrared colours placing object B at the end of the T dwarf sequence (Figs. 2,7), we conclude that

![Fig. 4. Linear proper motion fit for object A (solution 3-A).](image)

![Fig. 5. Combined proper motion and parallax solution with all available epochs for object A (solution 4-A). Zero point is the UKIDSS J epoch.](image)

### Table 1. SDSS DR7 z (on the AB system) and UKIDSS DR6 YJHK (on the Vega system using the MKO photometric system) photometry

| object | mean z (3971+3996) | Y | J | H | K |
|--------|-----------------|---|---|---|---|
| SDSS J141624.08+134826.7 (object A) | 15.897±0.005 | 14.255±0.003 | 12.995±0.001 | 12.469±0.001 | 12.053±0.001 |
| ULAS J141623.94+134836.3 (object B) | 21.13±0.32 | 18.162±0.027 | 17.259±0.017 | 17.581±0.030 | 18.933±0.244 |

Notes: * - not detected in SDSS DR7 (see text). z magnitudes are mean values from two SDSS runs (given in brackets). YJHK magnitudes are aperMag3 derived from the multiframes (given in brackets) for point sources (Dye et al. 2006). A second set of YJHK measurements was not used due to the location of objects A and B close to the edge of the frames.

### Table 3. Proper motion and parallax solutions for objects A and B

| Solution | μα cos δ (mas/yr) | μδ (mas/yr) | πrel (mas) |
|----------|------------------|-------------|------------|
| 1-A      | -488.1±87.8      | +381.3±49.4 |            |
| 1-B      | -378.6±83.3      | +323.5±45.7 |            |
| 2-A      | +123.9±10.1      | +132.7±28.3 |            |
| 2-B      | +138.3±05.8      | +126.7±25.4 |            |
| 3-A      | +86.8±02.1       | +139.1±00.9 |            |
| 4-A      | +86.2±02.6       | +138.8±02.6 | 127.0±27.0 |
| 5-A      | 153.7±20.5       |            |            |
| 5-B      | 104.4±45.5       |            |            |
this object is one of the coolest known brown dwarfs, probably with a late-T spectral type.

The latest-type brown dwarfs with trigonometric parallaxes available are the T8.5 dwarfs Wolf 940B at a distance of 12.5±0.7 pc (= ULAS J214638.83-001038.7; 
Burningham et al. 2009) with a parallax measurement for the primary Wolf 940A by Harrington & Dahn [1980] and 
ULAS J003402.77–005206.7 (Warren et al. 2007) Smart et 
[2009] at a distance of 12.6±0.6 pc. Gelino et al. [2009] list only one more T8.5 (ULAS J123828.51+095335.1; Burnett
ingham et al. [2008] and two T9 dwarfs (ULAS J133553.45+113005.2; 
Burningham et al. [2008] and CFBDs J005910.90–011401.3; 
Delorme et al. [2008a]) still lacking trigonometric parallaxes. However, their spectrophotometric estimates hint at distances of (slightly) more than 8 pc. Object B is by 0.5-1.7 magnitudes brighter in the J- and H-band than the above mentioned five objects. In particular, the possibly nearest of the objects, the T9 dwarf ULAS J133553.45+113005.2 at 8-12 pc according to 
Burningham et al. [2008], is 0.5-0.6 mag fainter than object B in the YJH-bands whereas it is about 0.5 mag brighter than object B in the K-band. Adopting the mean distance of 10 pc for 
ULAS J133553.45+113005.2 and 8 pc for object B, their absolute YJH magnitudes are comparable, whereas object B is fainter in $M_K$ (Fig. 7). Therefore, we think that object B is probably the nearest among the latest-type brown dwarfs offering excellent opportunities for follow-up observations.

With an $H-K \approx -1.35$ and $M_K \approx 18.1$, object B falls outside 
Fig. 9 (top panel) in Leggett et al. [2010], where these authors compare T dwarf observations with models. However, extrapolating the model line with solar metallicity but high gravity (log $g = 5.0$) gives the best fit, possibly with a Teff $\approx 600$ K. Alternatively, a slightly lower metallicity would also fit, but B09 excluded an L subdwarf classification of object A, and the kinematics of the system is clearly not typical of the Galactic halo or thick disk. The blue colour of object A could also be caused by high surface gravity as discussed by Burgasser et al. [2008] for the class of blue L dwarfs. If the high gravity is correct, then the evolution models of Saumon & Marley [2008], their Fig. 4) show that the system is likely $\approx$5 Gyr old, and object B could have a mass of $\approx$30 Jupiters. Further investigation will show whether objects A+B represent a wide binary brown dwarf or a much older analogue of the young low-mass star+massive planet system 2MASS 1207$-$3932AB (Gizis [2002] Chauvin et al. [2004]).

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Fig. 6. Parallax solution for objects A (top, solution 5-A; top, 
right shows the parallax fit with the proper motion removed) and 
B (bottom, solution 5-B) using UKIDSS+SDSS and the known 
long-term proper motion (from solution 3-A) as fixed input pa-

Fig. 7. Absolute magnitudes $M_K$ (bottom) and $M_J$ (top) vs. 
$J-K$ colour (in MKO system) for all T dwarfs with measured 
trigonometric parallaxes as listed in Leggett et al. [2010] and 
for ULAS J141623.94+134836.3 (object B) with error bars ob-
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