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Letter to the Editor

Discovery of very nearby ultracool dwarfs from DENIS

T. R. Kendall[1], X. Delfosse[1], E. L. Martín[2], and T. Forveille[3]

[1] Laboratoire d'Astrophysique de Grenoble, Université Joseph Fourier, 38041 Grenoble Cedex 9, France
e-mail: `delfosse@obs.ujf-grenoble.fr`
[2] Instituto de Astrofísica de Canarias, via Láctea, 38200 La Laguna, Tenerife, Spain
e-mail: `ege@ll.iac.es`
[3] CFHT Corporation, 68–1238 Mamalahoa Highway, Kamuela, HI 96743, USA

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Abstract. We report new spectroscopic results, obtained with UKIRT/CGS4, of a sample of 14 candidate ultracool dwarfs selected from the DENIS (Deep Near-Infrared Survey of the Southern Sky) database. A further object, selected from the 2MASS Second Incremental Release, was observed at a later epoch with the same instrument. Six objects are already known in the literature; we re-derive their properties. A further four prove to be very nearby ($\lesssim$10 pc) mid-to-late L-dwarfs, three unknown hitherto, two of which are almost certainly substellar. These findings increase the number of L-dwarfs known within ~10 pc by ~25%. The remainder of the objects discussed here are early L or very late M-type dwarfs lying between ~45 and 15 pc and are also new to the literature. Spectral types have been derived by direct comparison with J-, H- and K- band spectra of known template ultracool dwarfs given by Leggett et al.[⋆] For the known objects, we generally find agreement to within ~1 subclass with previously derived spectral types. Distances are determined from the most recent M_J vs. spectral type calibrations, and together with our derived proper motions yield kinematics for most targets consistent with that expected for the disk population; for three probable late M-dwarfs, membership of a dynamically older population is postulated. The very nearby L-type objects discussed here are of great interest for future studies of binarity and parallaxes.

Key words. stars: low mass, brown dwarfs – stars: late-type – stars: kinematics – stars: distances – infrared: stars – surveys

1. Introduction

The analysis of current near-infrared sky surveys such as 2MASS (Two Micron All Sky Survey; Skrutskie et al. 1997), DENIS (Epchtein 1997) and the Sloan Digital Sky Survey (SDSS; York et al. 2000) is rapidly revolutionising our knowledge of the very low-mass dwarf population in the solar neighbourhood. Observations have required the establishment of new spectral classes (L, T) to characterise the very coolest dwarfs (Kirkpatrick et al. 1999; Martín et al. 1999) and very recently Cruz et al. (2003) have increased the number of known M 7–L 6 dwarfs by a further 127% (186 new objects), by exploitation of the 2MASS Second Incremental Release. It is the clear goal of current efforts, using existing data, to produce a complete, volume-limited sample of ultracool dwarfs, over the whole sky.

Such dwarfs (of spectral types M 7 and later) are likely to have ages of a few Gyr and, with reference to theoretical models (e.g. Baraffe et al. 2003, and references therein) are likely to be substellar. Indeed, as pointed out by Leggett et al. (2001) any object later than L 5 has to be substellar; i.e. incapable of sustaining core hydrogen fusion at any point in its lifetime. The field population of L- and T-dwarfs thus represents an important link to even less massive, younger objects known in nearby star-forming regions.

The DENIS survey has demonstrated its ability to detect very cool stellar objects with the detection of the first L-dwarf populations (Delfosse et al. 1997). To date, 5700 deg^2 of survey data have been explored, yielding a sample of 300 ultracool dwarf candidates selected to have $(I - J) > 3.0$, complete to $I \sim 18$ and reaching $I = 19.0$. These objects are plotted in Fig. 1 (crosses). Optical spectroscopy of the complete sample is underway and will be published in a future paper. In this Letter, we discuss near-infrared spectroscopy obtained for selected relatively bright ($I \sim 15{-}17.5$) objects with $3.0 < (I{-}J) < 4.0$. The previously published DENIS L-dwarfs (Delfosse et al. 1999; Martín et al. 1999) have $(I - J) > 3.1$.

2. Observations and data reduction

Near-infrared spectra were obtained on Jun 25–27, 2001, using CGS4 (Cooled Grating Spectrometer 4) on the UK Infrared Telescope (UKIRT). Conditions were good and the seeing was ~1.1″. The 40 mm^{-1} grating was employed using the long camera yielding complete wavelength coverage of in the H and K passbands at a resolution $R \sim 400$. The 2MASS object, 2MJ1112, was observed in the J-band on 3 Feb. 2003 with a similar instrumental setup.

Send offprint requests to: T. R. Kendall,
e-mail: `tkendall@obs.ujf-grenoble.fr`

[⋆] `ftp://ftp.jach.hawaii.edu/pub/ukirt/skl/dL.spectra/`

Table 1. Basic and derived data for observed targets. The abbreviated name Dnnnn will be used throughout this paper. Co-ordinates are Equinox J2000 and are given in unabbreviated form. Previously known objects are referenced in the final column. *IJK* magnitudes are from the DENIS database and have typical errors 0.05–0.1 mag. The modified Julian date of the DENIS observation, galactic latitudes, derived spectral types and distances are given in Cols. 6–9. Spectral types quoted are the mean of those derived from independent *K*- and *H*-band derivations, where both are available (see Col. 10). For 2MJ1112, the *I*-band magnitude is from UKST/SuperCosmos[1]; *JK* from 2MASS.

Name	DENIS-P	*I*	*J*	*K*	MJD	*b*	Sp.	d/pc	Band	Ref.
D1048	J104842.81+011158.2	16.2	12.9	11.5	51 828.0	+50.79	L 4	$9.1^{-0.9}_{+1.0}$	*K*	H02
D1411	J141121.30–211950.6	15.5	12.5	11.3	51 366.5	+37.83	M 9	$16.0^{-0.9}_{+1.1}$	*H*, *K*	C03
D1425	J142527.97–365023.4	17.7	13.7	11.7	51 828.0	+22.32	L 5	$10.6^{-1.1}_{+1.2}$	*K*	–
D1456	J145601.39–274736.4	16.4	13.2	12.2	51 374.5	+27.89	M 9	$22.0^{-1.3}_{+1.6}$	*H*, *K*	C03
D1510	J151047.85–281817.4	16.0	12.8	11.4	51 828.0	+25.27	M 8	$21.0^{-1.5}_{+2.0}$	*H*, *K*	G02
D1514	J151450.16–225435.3	17.1	14.0	12.9	51 828.0	+29.14	M 7	$44.1^{-4.4}_{+6.0}$	*K*	–
D1539	J153941.96–052042.4	17.5	13.8	12.4	51 828.0	+37.98	L 2	$19.5^{-1.5}_{+1.5}$	*H*	–
D1705	J170548.38–051645.7	16.6	13.2	12.1	51 698.6	+20.62	L 4	$10.7^{-1.0}_{+1.1}$	*H*, *K*	–
D2036	J203608.64–130638.3	18.2	14.7	13.5	51 828.0	–29.07	M 9.5	$41.7^{-2.4}_{+2.7}$	*H*, *K*	–
D2057	J205754.10–025229.9	16.6	13.2	11.6	51 786.7	–29.26	L 1.5	$16.2^{-1.1}_{+1.2}$	*H*, *K*	C03
D2200	J220002.05–303832.9	16.7	13.4	12.4	51 776.7	–52.54	L 0	$21.7^{-1.3}_{+1.4}$	*H*, *K*	–
D2229	J222958.15–065043.2	18.0	14.5	13.2	51 828.0	–50.80	M 9.5	$38.0^{-2.2}_{+2.5}$	*H*, *K*	–
D2252	J225210.73–173013.4	17.9	14.2	12.8	51 435.6	–60.88	L 7.5	$8.3^{-0.5}_{+0.7}$	*H*, *K*	–
D2254	J225451.90–284025.4	17.4	14.1	12.8	51 775.8	–64.26	L 0.5	$28.2^{-1.7}_{+1.8}$	*H*	C03
2MJ1112	2MASS J11124910-2044315	18.3	14.9	13.5	50 930.6	+36.51	L 0.5:	$41.1^{-10.2}_{+11.7}$	*J*	–

[1] `http://www-wfau.roe.ac.uk/sss`; C03: Cruz et al. (2003); G02: Gizis et al. (2002); H02: Hawley et al. (2002).

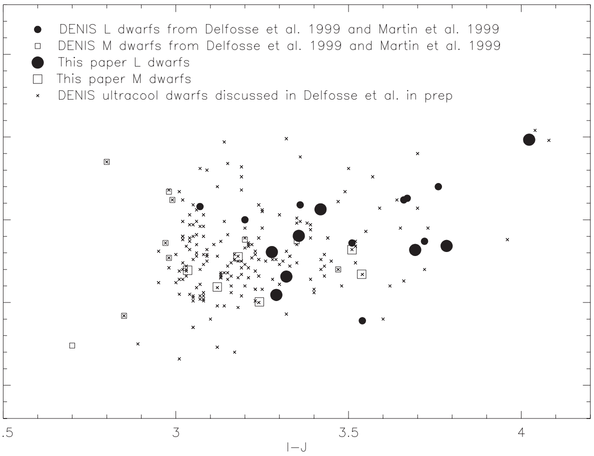

Fig. 1. DENIS colour–colour diagram. The objects discussed in this Letter are represented by large circles (L-dwarfs) and large squares (M-dwarfs). Small symbols are the previously published DENIS ultracool dwarfs (Delfosse et al. 1999; Martín et al. 1999). The complete sample of DENIS candidate ultracool dwarfs are plotted as crosses. Note that the diagram excludes objects without a DENIS-*K* magnitude: some such objects are retained in our overall sample on the basis of their $(I - J)$ colour only.

Data reduction was performed using the ORAC pipeline developed at UKIRT. However, telluric correction, performed using standard (A- and F-type) spectra taken before and after each science exposure, yielded spurious residual features resulting from hydrogen line absorptions in the standard spectra. Such features were fitted and removed and, after division by an appropriate Planck function, the divisor spectra were re-divided into the target spectra. In cases where divisor spectra suffered from fringing, a different standard spectrum (selected to be as close as possible a match in observation time and airmass) was employed. This does not affect the relative flux calibration (i.e. spectral shape) important for spectral typing.

3. Spectral types, distances and kinematics

Spectral types have been estimated by direct comparison with known template objects. In Fig. 2, these results are shown over the whole wavelength range so employed. The ranges are constrained by the presence of telluric water vapour absorptions: we used *K*: 1.95–2.42 μm and *H*: 1.45–1.8 μm. The templates used have the following sources: Geballe et al. (2002): 2M 1632 L 8, SDSS 2249 L 5, SDSS 0236 L 6, Kelu-1 L 2: Reid et al. (2001): 2M 0036 L 3.5, 2M 0746 L 0.5: Leggett et al. (2001): BRI 0021 M 9.5, LP 944 M 9, LHS 429 (=GL 644C) M 9, t513 (=TVLM 513–46546) M 8.5. All have been allocated spectral types on a common system (Kirkpatrick et al. 1999); hence our derived types are also on this system. While as many templates as possible were compared to the data, the grid of templates is not uniform in terms of wavelength or spectral type coverage: we have plotted the best fits to the data and adopted the spectral types so suggested (Fig. 2). In some cases it was found necessary to create a new template by averaging two template spectra, whose types differ by no more than 1.5 subclasses, to yield a satisfactory fit to the data. Where possible, independent types have been derived from *K*- and *H*-band spectra, in which cases the spectral type quoted in Table 1 is a mean of the two estimates. Separate derivations from the *K*- and *H*-bands are shown in Fig. 2. In almost all cases we find good agreement, to ±1 subclass, for objects which have both *K*- and *H*-band spectra, and a similar level of agreement between our spectral types and those given for previously characterised objects. Exceptions are D1048, for which Hawley et al. (2002) give L 1 from far-red data, but for which our near-infrared data require a later type of L 4, and the M 9 object D1456, for which the *H*-band data suggest M 7; in this case we adopt M 9, as indicated by the *K*-band data. The discrepancy in the former case might suggest binarity, with the later-type component having a larger relative contribution to

Table 2. The nearest L-dwarfs to the Sun, ordered by distance. Where distances are measured from a parallax determination, this is indicated. Otherwise, distances are based on current calibrations and have been obtained from the literature. Rather few L-dwarfs have been found within ~10 pc and this work increases the known database of such objects by ~25%.

Name	Survey id and Ref.	Sp.	d/pc	Ref.
–	DENIS-P J025503.5–470050	L 8	4.9 ± 0.3	1, 2
–	2MASSW J1438082+640836	L 6	7.2	3
–	2MASSI J1507476–162738	L 5	7.33 ± 0.03*	2, 4
D2252	DENIS-P J225210.7-173013.4	L 7.5	8.3 ± 0.6	5
–	2MASSI J0835425–081923	L 5	8.3 ± 0.9	2
–	2MASSW J2306292+154905	L 4	8.6	3
–	2MASSI J0036159+182110	L 3.5	8.76 ± 0.06*	3, 6
D1048	DENIS-P J104842.8+011158.2	L 4	9.1 ± 1.0	5
–	2MASSI J1515009+484739	L 6.5	9.2 ± 1.8	2
–	GJ 1001B (=LHS 102B)	L 5	9.6 ± 1.2*	7, 8
–	2MASSW J0045214+163445	L 3.5:	10.4	9, 10
–	LSR0602+3910	L 1	10.6 ± 0.8	9
D1425	DENIS-P J142528.0–365023.4	L 5	10.6 ± 1.1	5
D1705	DENIS-P J170548.4–051645.7	L 4	10.7 ± 1.0	5
–	2MASSW J0825196+211552	L 7.5	10.7	3
–	2MASSI J0439010–235308	L 6.5	10.8 ± 1.1	2

* Distances from parallaxes in the given references. 1. Martín et al. (1999); 2. Cruz et al. (2003); 3. Bouy et al. (2003); 4. Dahn et al. (2002); 5. This Letter; 6. Reid et al. (2000); 7. van Altena et al. (1995); 8. Goldman et al. (1999); 9. Salim et al. (2003); 10. Wilson et al. (2003).

the K-band flux. A special case is the object 2MJ1112 typed in the J-band; for this star, the spectral type can only be constrained to be later than M 8.5 and earlier than L 3.5. We adopt L 0.5 ± 2 subclasses. Distances have been derived using the M_J vs. spectral type calibration of Cruz et al. (2003); errors on the distance corresponding to ±0.5 subclasses in spectral type are given in Table 1. Of the known objects – apart from D1048 which may be rather later and closer than previously cited, distances have been derived using the previously published spectral types, with errors also representing ±0.5 subclasses.

In Table 2, we present our findings in the context of the currently known L-dwarf population in the immediate solar neighbourhood. It is clear that four mid-to-late L-type dwarfs presented here, D1048, D1425, D1705, and D2252, have properties which strongly imply that they lie at distances of no more than ~10 pc, if single. For D1048, our spectral type derivation of L 4 brings this object newly into the $\lesssim$10 pc sample. Together, these objects represent a significant addition to the known sample of such dwarfs close to the Sun. We caution that, as is the case for many ultracool dwarfs, distances based on parallaxes are unknown and the distances we determine rely on calibrations derived from larger samples of field objects. We note also that the known object 2MASSI J0746425+200032 has a spectral type and photometry which suggest a distance of only 9.5 pc, which would place it in Table 2; yet, further study has revealed this object as a binary (Reid et al. 2001; Bouy et al. 2003), with $d_\pi = 12.2$ pc (Dahn et al. 2002). Moreover, we note that 2MASSI J0423485–041403, recently reclassified T0 and with $\pi = 65.9$ mas (G. R. Knapp et al., in preparation) also no longer belongs in the $\lesssim$10 pc sample. The nearby L-dwarfs identified in this Letter are therefore excellent candidates to be inspected for binarity, or for giant planet companions.

Table 3. Proper motions for the target objects derived from SuperCosmos and 2MASS positions with the epoch difference indicated. For typical positional errors ~0.3″, uncertainties on the proper motions are therefore ~100 mas yr^{-1}, for $\Delta_{\rm epoch} = 4$ yr. Transverse velocities are derived using the distances in Table 1 and the proper motion values, added in quadrature.

Name	Sp.	$\mu_\alpha \cos\delta$ mas yr^{-1}	μ_δ mas yr^{-1}	$\Delta_{\rm epoch}$ yr	$v_{\rm trans}$ km s^{-1}
D1048	L 4	–210	–190	4.916	12
D1411[a]	M 9	–30	+90	1.929	7
D1425	L 5	–260	–470	8.063	27
D1456	M 9	–280	–740	3.648	83
D1510[a]	M 8	+80	+50	1.877	9
D1514[b]	M 7	–	–	–	–
D1539	L 2	+640	+80	6.708	60
D1705	L 4	+100	–130	6.741	8
D2036	M 9.5	+400	–290	3.605	98
D2057	L 1.5	+60	–210	3.211	17
D2200	L 0	+250	–80	4.916	27
D2229	M 9.5	+170	–30	4.251	32
D2252	L 7.5	+400	+100	4.864	16
D2254	L 0.5	~ 0	–30	5.909	3
2MJ1112	L 0.5:	–450	~ 0	7.066	88

[a] $\Delta_{\rm epoch}$ small. [b] Uncertain.

Additionally, in Table 3, we have calculated proper motions using positional differences in α and δ between 2MASS Final Release and SuperCosmos images taken at different epochs. $\Delta_{\rm epoch}$ represents the timeline over which the proper motions have been derived. Where this quantity is small ($\lesssim$2 yr) we do not consider the proper motions to be accurate. For one object, D1514, the SuperCosmos position is uncertain; no stellar

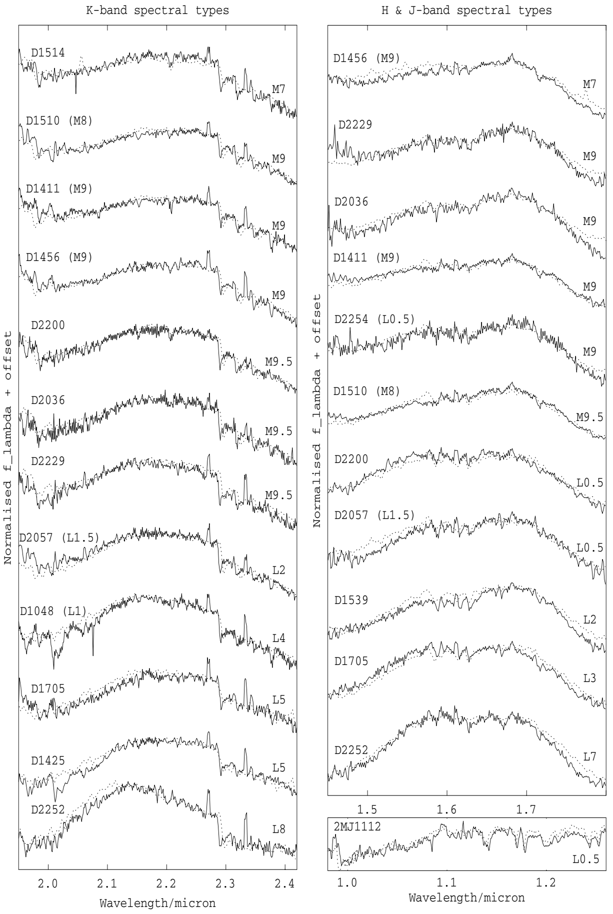

Fig. 2. Spectral typing results at $R \sim 400$. Derived types are given on the right hand side of each panel. Previously known types are given in parentheses. In all cases, K-band spectra have been normalised to the mean flux at $\sim 2.29\,\mu$m, and H-band spectra to the highest point of the spectrum. Template spectral types are on the Kirkpatrick et al. (1999) system (see Sect. 3). For clarity, each spectrum is offset from its neighbours by 0.5 continuum units.

object exists in that database with a similar I-magnitude to that in the DENIS catalogue, within $\sim 10''$. Lastly, we have derived transverse velocities using the spectroscopic distances given in Table 1 and the proper motion measurements. We find values broadly consistent with the kinematics of disk stars. However, two late-M objects, D1456 and D2036, have rather high velocities. For D1456, a proper motion estimate of $\mu_\alpha \cos\delta = -340$ mas yr^{-1} and $\mu_\delta = -650$ mas yr^{-1} is given in the SuperCosmos data, in agreement with our values to $\sim$20%. Of the four very nearby objects, D1425 has the largest proper motion, again in good agreement with SuperCosmos, which gives $\mu_\alpha \cos\delta = -310$ mas yr^{-1} and $\mu_\delta = -440$ mas yr^{-1}. While the current data are not suitable for computing radial velocities, it is clear from our transverse velocities that D1456 and D2036 are likely to belong to the dynamically old M-dwarf population, typified by the template such object, Barnard's Star (GI 699, M4V, $v_{\rm trans} = 89.5\,{\rm km\,s^{-1}}$). 2MJ1112 has a similarly high $v_{\rm trans}$, but we caution that its spectral type is not well enough constrained to yet claim it as an L-dwarf member of this population.

4. Conclusions

We present spectroscopic and kinematic data for 15 late M and L-dwarfs, all but one taken from the DENIS catalogue. Spectral types have been determined by direct comparison to known L-type templates, in both H- and K-bands. Proper motions derived by comparison of 2MASS and SuperCosmos positions yield transverse velocities consistent with membership of the disk population, at least for all confirmed L-type objects. Three probable very late M-type objects have high transverse velocities ($\sim 100\,{\rm km\,s^{-1}}$) and are likely to belong to a dynamically older thick disk population. Nine objects in the sample are hitherto unpublished; three of these, and one further object, are shown to have have spectral types in the range L 4–L 7.5 and are relatively bright ($17.9 < I < 16.2$); hence, if single objects, they are extremely close, $\lesssim 10$ pc. This last finding represents an increase in the number of known L-dwarfs likely to be within ~ 10 pc of the Sun from 12 to 16.

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References

Baraffe, I., Chabrier, G., Barman, T. S., et al. 2003, A&A, 402, 701
Bouy, H., Brandner, W., Martín, E. L., et al. 2003, AJ, 126, 1526
Cruz, K. L., Reid, I. N., Liebert, J., et al. 2003, AJ, 126, 2421 (C03)
Dahn, C. C., Harris, H. C., Vrba, F. J., et al. 2002, AJ, 124, 1170
Delfosse, X., Tinney, C. G., Forveille, T., et al. 1997, A&A, 327, L25
Delfosse, X., Tinney, C. G., Forveille, T., et al. 1999, A&AS, 135, 41
Epchtein, N. 1997, in The Impact of Large-Scale Near-Infrared Surveys, ed. F. Garzón, N. Epchtein, A. Omont, B. Burton, & P. Persi (Dordrecht: Kluwer Academic Publishers), 15
Goldman, B., Delfosse, X., Forveille, T., et al. 1999, A&A, 351, L5
Geballe, T. R., Knapp, G. R., Leggett, S. K., et al. 2002, ApJ, 564, 466
Gizis, J. E. 2002, ApJ, 575, 484 (G02)
Hawley, S. L., Covey, K. R., Knapp, G. R., et al. 2002, AJ, 123, 3409
Kirkpatrick, J. D., Reid, I. N., Liebert, J., et al. 1999, ApJ, 519, 802
Leggett, S. K., Allard, F., Geballe, T. R., et al. 2001, ApJ, 548, 908
Martín, E. L., Delfosse, X., Basri, G., et al. 1999, AJ, 118, 2466
Reid, I. N., Kirkpatrick, J. D., Gizis, J. E., et al. 2000, AJ, 119, 369
Reid, I. N., Burgasser, A. J., Cruz, K. L., et al. 2001, AJ, 121, 1710
Salim, S., Lépine, S., Rich, M. R., et al. 2003, ApJ, 586, L149
Skrutskie, M. F., Schneider, S. E., Stiening, R., et al. 1997, in The Impact of Large-Scale Near-Infrared Surveys, ed. F. Garzón, N. Epchtein, A. Omont, B. Burton, & P. Persi (Dordrecht: Kluwer Academic Publishers), 25
van Altena, W. F., Lee, J. T., & Hoffleit, E. D., The General Catalogue of Trigonometric Stellar Parallaxes, 4th Ed. (Yale University Observatory), 1995
Wilson, J. C., Miller, N. A., Gizis, J. E., et al. 2003, in Proc. IAU Symp., 211, ed. E. L. Martín (Astronomical Society of the Pacific), 197
York, D. G., Adelman, J., Anderson, J. E., et al. 2000, AJ, 120, 1579