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Proper motions of field L and T dwarfs

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ABSTRACT
The proper motion measurements for 143 previously known L and T dwarfs are presented. From this sample we identify and discuss 8 high velocity L dwarfs. We also find 4 new wide common proper motion binaries/multiple systems. Using the moving cluster methods we have also identified a number of L dwarfs that may be members of the Ursa Major (age ≈ 400 Myr), the Hyades (age ≈ 625 Myr) and the Pleiades (age ≈ 125 Myr) moving groups.

Key words: stars:kinematics-stars:low-mass,brown dwarfs - open clusters and associations:individual:Ursa Major:Hyades:Pleiades

1 INTRODUCTION

Brown dwarfs may be thought of as failed stars. These low mass ($\leqslant$70 $M_{\rm Jup}$ Burrows et al. (2001)), cool objects are the lowest mass objects that the star formation process can produce. The majority of the brown dwarfs that have been discovered to date are field objects discovered using surveys such as the Two Micron All Sky Survey (2MASS; Skrutskie et al. (2006), see Leggett et al. (2002) for examples), the DEep Near-Infrared Sky survey (DENIS; DENIS Consortium (2005), see Delfosse et al., (1999) for examples), the Sloan Digital Sky Survey (SDSS;York et al. (2000) see Hawley et al. (2002) for examples) and the UKIRT Deep Infrared Sky Survey (UKIDSS; Lawrence et al. (2004), see Kendall et al. (2007) for examples). However, to study brown dwarfs in depth, a knowledge of their age is essential, which means we must study brown dwarfs in open star clusters or moving groups.

Once a brown dwarf has been proved to belong to an open star cluster, or a moving group, then the age of the dwarf is known, allowing meaningful comparisons to evolutionary models to be made. The most recent example of this is the study done by Bannister & Jameson (2007) who used existing proper motions and parallax measurements to show that a selection of field dwarfs in fact belong to the Ursa Major and Hyades moving groups. The importance of this study, is that these are the first brown dwarfs to be associated with an older cluster or group. Older clusters such as the Hyades are expected to contain very few or no brown dwarfs or low mass members, due to the dynamical evolution of the cluster over time (Adams et al. 2002). However, these escaped low mass objects may remain members of the much larger moving group that surrounds the cluster.

To continue the study started by Bannister & Jameson (2007), proper motions need to be measured for the majority of the field brown dwarfs currently known. This has been accomplished using the wide field camera (WFCAM, Casali et al. (2007)) of the United Kingdom Infrared Telescope (UKIRT). Using these WFCAM images and existing data we have measured proper motions for 143 L and T dwarfs listed in the online Dwarf Archive[1].

This proper motion data may be put to a number of uses. Taken with measured radial velocities and distances, it can yield all three components of velocity (U,V,W). Using reduced proper motion diagrams it can be used as an approximate measure of distance. However we have no radial velocities for these objects. These proper motion measurements can however also be used to help identify objects as members of a star cluster or members of a moving group via the moving cluster method.

Our proper motion data is discussed and listed in section 2 of this paper. From the proper motion measurements, we find 5 new wide common proper motion binaries/multiple systems. We also identify 8 high velocity L dwarfs, which are discussed in section 4. We suggest that these L dwarfs are probably old and belong to the thick disc or halo population of the galaxy. This in turn suggests that they are likely to be very faint stars rather than brown dwarfs. Finally in section 5 we identify a number of L and T dwarfs that may be members of the Hyades, Pleiades and Ursa Major moving groups .

[1] See http://spider.ipac.caltech.edu/staff/davy/ARCHIVE/, a webpage dedicated to L and T dwarfs maintained by C. Gelino, D. Kirkpatrick, and A. Burgasser.

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2 PROPER MOTION MEASUREMENTS

2.1 Data acquisition and reduction

In order to measure proper motions for known L and T dwarfs we observed 143 L and T dwarfs from the DwarfArchive (detailed in table 1, see http://spider.ipac.caltech.edu/staff/davy/ARCHIVE/ for discovery references) with declinations between -30° and 60° and *J* band magnitudes of less than 16.5. The images were taken using WFCAM on UKIRT over the period of February 2006 to August 2006. WFCAM is a near infrared imager consisting of 4 Rockwell Hawaii-II (HgCdTe 2048x2048) arrays arranged such that 4 separately pointed observations can be tiled together to cover a filled square of sky covering 0.75 square degrees with 0.4 arcsecond pixels Casali et al. (2007). However, as we only required the image of the brown dwarf in question, we only used array 3 which is regarded as the least noisy array. WFCAM is ideal for this work, as the large field of view per chip means there are many other stars in the image, which can be used as astrometric reference stars. The images were taken in the *J* band in non-photometric conditions using exposure times of ≈5-10 minutes and a nine point dither pattern. These exposure times gave S/N≈100 even in the poor conditions.

The images were reduced at the Cambridge Astronomical Survey Unit (CASU) using procedures which have been custom written for the treatment of WFCAM data (Irwin et al., in preparation, Dye et al. (2006)). In brief, each frame was debiased, dark corrected and then flat fielded. The individual dithered images were stacked before having an object detection routine run on them. The frames were astrometrically calibrated using point sources in the Two micron All Sky Survey (2MASS) catalogue. The accuracy is typically ≈0.1” (Dye et al. 2006) The photometric calibration employed by the CASU pipeline also relies on 2MASS data (there are typically hundreds of 2MASS calibrators per detector) and is found to be accurate to ≈2% in good conditions (Warren et al. 2007), however as we wished to measure proper motions, the astrometric calibration was more important than the photometric calibration for these data.

2.2 Calculating proper motions

The astrometry for 2MASS is good to 80 mas over the whole survey, and to 50 mas over a small area (Skrutskie et al. 2006). Because the WFCAM astrometry is also calibrated to the 2MASS catalogue, accurate relative proper motion measurements could be calculated simply by taking the difference in 2MASS and WFCAM positions and dividing by the epoch difference. We calculated the epoch difference by taking the difference in the Julian date as given in the FITS header for each image, which is between 5 and 9 years with the average epoch difference being 7.1 years. Lodieu et al. (2007a) employ a similar method for calculating proper motions using the UKIDSS Galactic Cluster Survey, also using WFCAM and 2MASS.

The proper motion measurements for each object in every WFCAM image (i.e. array 3) were calculated by this method. This motion, was then converted into mas yr^{-1}. The proper motion has been calculated directly from the RA and dec of the object in question, not from pixel motion on images, hence μ_α=($\Delta\alpha$/ΔT)cos δ “ yr^{-1} if $\Delta\alpha$ is converted to arcseconds. These proper motions are relative proper motions, in the sense that they are relative to the bulk of the background stars in the field, which are generally moving slowly enough to be assumed to have zero motion. However, we checked the reference star motion so that the proper motion of the brown dwarf could be altered if there was a standard offset in the field.

The proper motions were separated in $\mu_\alpha cos\delta$ and μ_δ from -500 to 500 mas yr^{-1} in each direction, in bins of size 20 mas yr^{-1}, and the number of objects falling into each bin were totalled. We then fitted a two dimensional Gaussian to the data for each field to determine the spread of the reference stars, as well as the true centre of the motion. The process was then repeated after the initial fit, rejecting any objects that lay outside 3σ of the fitted Gaussian, before fitting another Gaussian to this data. This fitting was important in some cases as the reference stars had quite a large spread, and in other cases the proper motion of our brown dwarf was of the same order of magnitude as the references. This is illustrated by figures 1 and 2. These centroiding error, or the centres of the fit were then subtracted from the calculated proper motion measurements.

Lodieu et al. (2007a) assumed the errors on their proper motions to be ≈ 10 mas yr^{-1}, but no formal error calculation was made. We used the σ value of the Gaussian to determine the error on our measurements. In general the errors were of the order of ≈ 15 mas yr^{-1}. The quoted errors are the σ value of the Gaussian fitted to the proper motion points for each image. Strictly this should be the σ plus the position error of the object added in quadrature. However, the centroiding errors for WFCAM are less than 2 mas yr^{-1}, and so are small compared to the σ value. Table 1 shows the 2MASS name, RA, dec, proper motion and associated errors for the 143 objects studied. Their discovery papers may be found from the DwarfArchive. All of the objects in table 1 are 2MASS objects and are identified by their 2MASS name. Hereafter they are referred to as J followed by the first 4 digits, the plus or minus sign, and the next two digits.

Since the observations were obtained, a paper by Schmidt et al. (2007) has been published. This paper contains proper motions for 23 of these 143 objects. The proper motions as calculated here and as presented in Schmidt et al. (2007) are shown in table 2.

There are two objects for which we do not find a good agreement between this data and the results of Schmidt et al. (2007). These objects are J1213−04 and J1448+10. Both J1213−04 and J1448+10 have position angles that agree, but the proper motion measurements do not. The discrepancy involving J1213-04 can almost be explained by the errors on the Schmidt et al. (2007) measurement (μ_α=144±80, μ_δ=-25±98). Our μ_δ agrees with that of Schmidt et al. (2007), although the large disagreement with μ_α (our measurement=248±15, Schmidt et al. measurement=708±142) may be explained by the object being faint and a small epoch difference (<4 years) for the Schmidt et al. (2007) measurement.

There are two notes that should be made regarding these 143 objects in table 1. The first is that J1048+01 has a somewhat unclear spectral type. Using an optical spectrum, Hawley et al. (2002) identify it as an L1 dwarf. Using infrared spectra, Kendall et al. (2004) identify it as an L4 dwarf, and Wilson et al. (2003) identify it as an M7 dwarf also using infrared spectra. It is unknown as to why this discrepancy has occurred.

The second note is that J2213−21 has been identified as a possible low gravity object by Cruz et al. (2007) from the VO bands, K I doublet and Na I doublet in the optical spectrum of this object. These features are gravity sensitive, and low gravity features indicate youth and low mass. Hα, also an indicator of youth and activity was not detected in the spectrum.

Table 1. 2MASS Name, RA, Dec,$\mu_\alpha \cos\delta$ and μ_δ for all of the L and T dwarfs for which we measured proper motions.

Name 2MASS	RA J2000	Dec	$\mu_\alpha \cos\delta$ mas yr^{-1}	μ_δ
J00001354+2554180	00 00 13.54	25 54 18.94	5.84 ± 19.47	130.03 ± 21.94
J00011217+1535355	00 01 12.23	15 35 34.45	149.65 ± 22.72	−169.14 ± 14.85
J00100009-2031122	00 10 00.15	−20 31 12.10	117.47 ± 19.59	30.74 ± 17.06
J0015447+351603	00 15 44.80	35 16 00.96	83.19 ± 17.57	−245.65 ± 13.80
J00191165+0030176	00 19 11.64	00 30 17.46	−28.79 ± 18.25	−25.01 ± 11.26
J0030438+313932	00 30 43.81	31 39 31.56	−49.44 ± 15.89	−56.86 ± 13.50
J00320509+0219017	00 32 05.26	02 18 59.82	417.19 ± 16.58	−311.77 ± 12.66
J0032431-223727	00 32 43.14	−22 37 27.14	115.06 ± 26.78	20.23 ± 14.88
J00384398+1343395	00 38 44.01	13 43 39.11	63.65 ± 16.16	−40.97 ± 8.33
J00412179+3547133	00 41 21.74	35 47 13.18	−101.90 ± 16.59	−16.66 ± 13.01
J00415453+1341351	00 41 54.46	13 41 34.35	−174.28 ± 23.61	−137.56 ± 36.03
J00452143+1634446	00 45 21.58	16 34 44.46	384.66 ± 17.12	−26.35 ± 12.27
J00464841+0715177	00 46 48.45	07 15 17.44	98.06 ± 21.53	−50.63 ± 10.04
J01033203+1935361	01 03 32.22	19 35 36.37	304.63 ± 16.54	35.18 ± 14.32
J02281101+2537380	02 28 11.15	25 37 37.84	256.53 ± 14.33	−13.98 ± 16.88
J02511490-0352459	02 51 15.48	−03 53 00.02	1128.19 ± 13.32	−1826.44 ± 19.76
J09083803+5032088	09 08 37.73	50 32 05.26	−394.92 ± 26.21	−477.67 ± 14.92
J09440279+3131328	09 44 02.81	31 31 32.46	42.96 ± 15.82	−32.53 ± 13.47
J10042066+5022596	10 04 20.55	50 22 58.18	−133.22 ± 39.63	−185.08 ± 15.42
J10101480-0406499	10 10 14.64	−04 06 49.81	−321.11 ± 15.90	20.12 ± 13.28
J10170754+1308398	10 17 07.57	13 08 39.05	60.54 ± 21.83	−93.74 ± 12.30
J10220489+0200477	10 22 04.81	02 00 45.11	−173.19 ± 18.24	−398.05 ± 15.76
J10292165+1626526	10 29 21.86	16 26 49.60	358.65 ± 14.91	−348.21 ± 17.05
J10352455+2507450	10 35 24.44	25 07 42.68	−181.48 ± 16.86	−271.82 ± 23.18
J10440942+0429376	10 44 09.41	04 29 38.20	−1.87 ± 12.11	94.47 ± 10.49
J10452400-0149576	10 45 23.76	−01 49 57.64	−494.98 ± 17.78	11.75 ± 12.05
J10473109-1815574	10 47 30.89	−18 15 57.10	−347.24 ± 17.09	54.03 ± 14.11
J10484281+0111580	10 48 42.62	01 11 56.71	−442.18 ± 13.09	−208.76 ± 12.19
J10511900+5613086	10 51 18.82	56 13 06.65	−231.49 ± 34.15	−288.05 ± 14.40
J10595138-2113082	10 59 51.45	−21 13 09.52	134.32 ± 17.06	−158.27 ± 13.58
J11040127+1959217	11 04 01.30	19 59 22.56	74.75 ± 14.65	138.77 ± 20.26
J11101001+0116130	11 10 09.91	01 16 11.50	−243.29 ± 20.82	−237.94 ± 17.78
J11131694-0002467	11 13 16.96	00 02 46.82	42.12 ± 21.73	5.91 ± 13.39
J11235564+4122286	11 23 55.56	41 22 28.09	−110.47 ± 25.23	−60.19 ± 13.22
J11455714+2317297	11 45 57.23	23 17 29.31	154.68 ± 16.47	−55.55 ± −6.46
J11480423+0254057	11 48 04.24	02 54 05.41	25.88 ± 24.78	−41.17 ± 10.28
J11480502+0203509	11 48 05.12	02 03 48.88	237.33 ± 25.57	−322.40 ± 13.25
J11533966+5032092	11 53 39.72	50 32 09.60	83.93 ± 22.95	60.19 ± 10.88
J11550087+2307058	11 55 00.89	23 07 05.96	25.80 ± 24.88	37.70 ± 20.68
J11593850+0057268	11 59 38.51	00 57 26.85	12.36 ± 22.82	6.65 ± 17.26
J12035812+0015500	12 03 57.61	00 15 48.33	−1209.29 ± 18.27	−260.69 ± 14.75
J12043036+3212595	12 04 30.40	32 12 59.37	91.42 ± 37.62	−17.54 ± 19.03
J12074717+0244249	12 07 46.96	02 44 25.72	−498.04 ± 17.54	137.51 ± 19.27
J12130336-0432437	12 13 03.18	−04 32 43.97	−353.58 ± 16.21	−12.40 ± 12.42
J12212770+0257198	12 21 27.65	02 57 19.71	−114.73 ± 30.13	−17.60 ± 27.17
J12321827-0951502	12 32 18.20	−09 51 50.97	−156.29 ± 13.04	−100.94 ± 16.93
J12392727+5515371	12 39 27.39	55 15 37.31	160.87 ± 29.34	38.06 ± 5.62
J12464678+4027150	12 46 46.85	40 27 14.45	145.05 ± 11.66	−78.75 ± 16.59
J12565688+0146163	12 56 56.80	01 46 16.14	−182.82 ± 13.21	−17.05 ± 17.81
J12573726-0113360	12 57 37.30	−01 13 36.18	81.10 ± 20.22	−2.79 ± 11.02
J13015465-1510223	13 01 54.61	−15 10 22.94	−69.22 ± 11.67	−74.28 ± 16.06
J13054106+2046394	13 05 41.05	20 46 39.95	−23.27 ± 17.49	73.37 ± 26.87
J13120707+3937445	13 12 07.00	39 37 44.61	−96.57 ± 23.23	13.43 ± 18.33
J13153094-2649513	13 15 30.53	−26 49 53.65	−677.53 ± 15.92	−280.48 ± 14.66
J13204427+0409045	13 20 44.06	04 09 05.90	−483.36 ± 19.44	210.86 ± 17.28
J13233597-1806379	13 23 35.92	−18 06 38.14	−86.89 ± 15.41	−22.18 ± 18.70
J13262009-2729370	13 26 19.90	−27 29 37.30	−363.71 ± 16.48	−15.80 ± 13.80
J13313310+3407583	13 31 32.92	34 07 57.20	−352.59 ± 18.85	−169.29 ± 18.43
J13314894-0116500	13 31 48.74	−01 16 57.65	−407.10 ± 18.61	−1029.84 ± 14.25
J13322863+2635079	13 32 28.53	26 35 08.22	−151.50 ± 12.41	40.80 ± 16.67
J13340623+1940351	13 34 06.19	19 40 36.01	−57.97 ± 12.32	98.09 ± 16.04
J13364062+3743230	13 36 40.49	37 43 22.52	−200.46 ± 8.54	−60.43 ± 13.81

Table 1. continued

Name 2MASS	RA J2000	Dec	$\mu_\alpha \cos\delta$ mas yr^{-1}	μ_δ
J13382615+4140342	13 38 26.04	41 40 31.66	-153.13 ± 24.17	-310.98 ± 24.70
J13384944+0437315	13 38 49.49	04 37 30.13	111.65 ± 13.88	-224.27 ± 12.50
J13422362+1751558	13 42 23.57	17 51 55.59	-70.09 ± 11.13	-1.92 ± 8.31
J13431670+3945087	13 43 16.46	39 45 09.59	-343.16 ± 31.26	115.99 ± 24.80
J13484591+0353545	13 48 46.00	03 53 52.28	206.90 ± 22.82	-355.69 ± 11.19
J14023175+0148301	14 02 31.66	01 48 30.19	-232.37 ± 13.59	7.60 ± 11.06
J14044167+0235501	14 04 41.70	02 35 48.51	53.77 ± 17.37	-248.28 ± 13.22
J14044495+4634297	14 04 44.79	46 34 30.74	-231.37 ± 30.27	142.97 ± 26.38
J14075361+1241099	14 07 53.47	12 41 10.41	-312.48 ± 19.16	81.69 ± 18.75
J14111735+3936363	14 11 16.87	39 36 37.06	-910.82 ± 15.25	136.59 ± 16.18
J14122449+1633115	14 12 24.50	16 33 10.93	28.97 ± 15.90	-80.04 ± 29.96
J14304358+2915405	14 30 43.49	29 15 41.51	-184.81 ± 20.15	142.49 ± 16.41
J14305589+0013523	14 30 55.91	00 13 52.03	57.81 ± 24.21	-35.69 ± 11.98
J14321073-0058483	14 32 10.72	00 58 48.71	-9.00 ± 20.30	-31.78 ± 17.14
J14385498-1309103	14 38 55.08	-13 09 10.57	161.23 ± 21.79	-17.37 ± 15.99
J14393343+0317591	14 39 33.43	03 17 59.25	-5.58 ± 20.66	19.25 ± 16.03
J14394092+1826369	14 39 40.91	18 26 36.95	-13.43 ± 17.75	1.26 ± 25.30
J14400180+0021457	14 40 01.77	00 21 45.90	-73.61 ± 17.97	37.23 ± 17.96
J14413716-0945590	14 41 37.07	-09 45 59.20	-203.39 ± 10.97	-11.16 ± 13.96
J14482563+1031590	14 48 25.74	10 31 58.34	248.93 ± 15.43	-99.49 ± 15.58
J14493784+2355378	14 49 37.86	23 55 37.98	50.32 ± 13.25	26.69 ± 23.62
J15031961+2525196	15 03 19.66	25 25 23.56	8.98 ± 17.07	20.72 ± 17.60
J15065441+1321060	15 06 53.87	13 21 06.07	-1086.93 ± 12.67	13.63 ± 11.38
J15150083+4848416	15 15 00.24	48 47 50.74	-949.93 ± 21.33	1471.48 ± 21.40
J15210327+0131426	15 21 03.18	01 31 43.12	-211.76 ± 19.36	83.55 ± 16.58
J15394189-0520428	15 39 42.18	-05 20 42.02	599.49 ± 13.83	117.47 ± 15.23
J15472723+0336361	15 47 27.21	03 36 36.34	-62.57 ± 12.75	52.34 ± 16.99
J15474719-2423493	15 47 47.12	-24 23 50.32	-133.02 ± 14.53	-121.93 ± 16.23
J15500845+1455180	15 50 08.50	14 55 17.04	105.15 ± 18.60	-127.21 ± 12.86
15525906+2948485	15 52 58.99	29 48 48.20	-157.35 ± 20.31	-50.89 ± 19.89
J15530228+1532369	15 53 02.05	15 32 38.22	-402.29 ± 17.20	170.52 ± 16.47
J15551573-0956055	15 55 16.18	-09 56 22.83	928.70 ± 13.98	-2375.90 ± 16.67
J15552614+0017204	15 55 26.04	00 17 20.15	-234.00 ± 17.60	-40.91 ± 18.14
J16000548+1708328	16 00 05.47	17 08 32.89	-8.80 ± 15.38	15.37 ± 21.45
J16142048+0046434	16 14 20.46	00 46 43.19	-56.83 ± 21.23	-31.32 ± 21.14
J16154416+3559005	16 15 44.15	35 58 56.29	-17.40 ± 11.94	-512.44 ± 15.48
J16184503-1321297	16 18 44.98	-13 21 30.28	-101.25 ± 14.75	-62.28 ± 14.63
J16192830+0050118	16 19 28.33	00 50 11.25	74.16 ± 16.12	-88.01 ± 16.96
J16304139+0938446	16 30 41.36	09 38 44.19	-63.77 ± 15.27	-55.79 ± 13.53
J16304999+0051010	16 30 49.96	00 51 00.15	-80.28 ± 14.87	-138.74 ± 17.95
J16452211-1319516	16 45 21.93	-13 19 57.49	-364.32 ± 17.68	-804.06 ± 15.75
J16573454+1054233	16 57 34.51	10 54 22.94	-83.53 ± 17.38	-61.18 ± 21.24
J17054834-0516462	17 05 48.40	-05 16 47.06	129.32 ± 14.10	-102.57 ± 14.92
J17073334+4301304	17 07 33.21	43 01 30.20	-200.33 ± 22.02	-21.50 ± 13.67
J17111353+2326333	17 11 13.49	23 26 32.96	-53.24 ± 11.33	-35.65 ± 16.02
J17210390+3344160	17 21 02.69	33 44 20.85	-1853.63 ± 17.27	601.67 ± 16.84
J17260007+1538190	17 26 00.05	15 38 18.49	-31.20 ± 12.73	-47.96 ± 14.38
J17282217+5845095	17 28 22.19	58 45 10.12	23.65 ± 13.39	101.69 ± 12.00
J17312974+2721233	17 31 29.71	27 21 21.79	-81.88 ± 15.32	-239.88 ± 17.02
J17502385+4222373	17 50 23.82	42 22 38.02	-43.75 ± 15.94	94.51 ± 14.29
J17580545+4633099	17 58 05.47	46 33 14.57	25.51 ± 15.45	593.64 ± 15.77
J18071593+5015316	18 07 15.94	50 15 30.86	34.61 ± 18.53	-125.71 ± 14.26
J20025073-0521524	20 02 50.69	-05 21 53.29	-97.78 ± 13.02	-104.97 ± 13.65
J20251584-2943124	20 26 15.87	-29 43 15.25	42.87 ± 19.44	-347.63 ± 14.97
J20282035+0052265	20 28 20.39	00 52 26.53	114.08 ± 14.20	6.95 ± 15.27
J20343769+0827009	20 34 37.66	08 26 58.05	-76.65 ± 15.34	-467.88 ± 14.90
J20360316+1051295	20 36 03.11	10 51 28.42	-115.22 ± 13.57	-167.99 ± 14.07
J20543585+1519043	20 54 35.83	15 19 03.79	-44.56 ± 17.50	-82.44 ± 17.60
J20571538+1715154	20 57 15.42	17 15 15.70	90.42 ± 16.27	66.20 ± 14.74
J21041491-1037369	21 04 15.23	-10 37 39.22	614.32 ± 15.90	-280.70 ± 14.53
J21073169-0307337	21 07 31.76	-03 07 33.83	169.62 ± 17.75	-9.94 ± 13.29

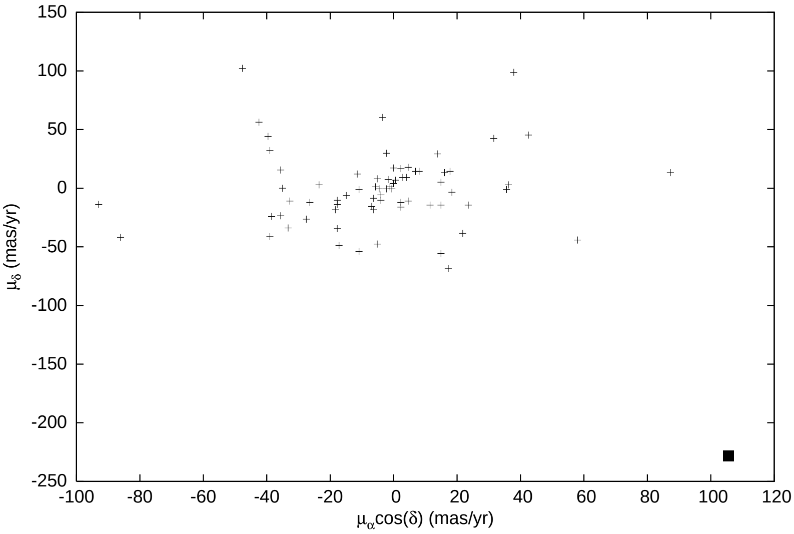

Figure 1. Proper motion vector diagram showing the case where there is a large spread in the reference stars compared to the dwarf motion i.e. they are not all concentrated around zero. The brown dwarf J1338+04 (L1, Reid et al., in prep., $\mu_\alpha\cos\delta$=111.65±13.88, μ_δ=-224.27±12.50) is marked by the filled square.

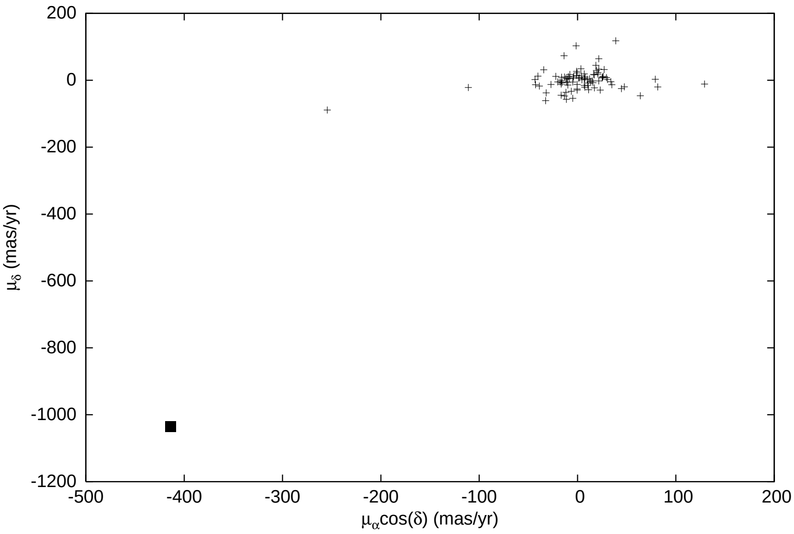

Figure 2. Proper motion vector diagram showing the ideal case. The reference stars are concentrated on zero compared to the dwarf motion, and the brown dwarf is marked by the filled square(J1331-01, L6, Hawley et al. (2002), $\mu_\alpha\cos\delta$=-407.10±18.61, μ_δ=-1029.84±14.25) has a large proper motion.

3 COMMON PROPER MOTION OBJECTS

Brown dwarfs in binary or multiple star systems are of great interest as their properties such as masses and separations can allow constraints to be put on star formation models. This is especially important as no one mechanism has been found that can account for the formation of all known brown dwarf binaries. Many imaging surveys have been undertaken to find close brown dwarf binaries however very few wide brown dwarf binaries are known. Only one brown dwarf-brown dwarf system has been discovered to date with a separation of greater than 15 AU (Billères et al. 2005), in contrast to several known systems with a high mass primary and brown dwarf companion. Allen et al. (2007) estimate the wide binary fraction for these objects to be 2.3% for companions with masses greater than 0.03-0.05 $M_\odot$.

We selected a “standard” σ value of 15 mas yr^{-1}, within which to search for common proper motion companions to the L and T dwarfs. This value was chosen as an average value of the errors, and therefore this search is by no means conclusive. However, as some objects have very little proper motion compared to the background stars, searching for common proper motion objects yields many candidates. No more can be said about these objects, other than they are candidates and more information is required. For the objects that have proper motions that are much higher than the background stars (129 out of the 143 objects), as we would expect for nearby L and T dwarfs, searching for proper motion companions (i.e. objects with proper motions that fall within a radius of 15 mas yr^{-1} of the motion of the dwarf) is more robust, and yields a few results. We find;

(i) Proper motions for 6 previously known close binaries,

Table 1. continued

Name 2MASS	RA J2000	Dec	$\mu_\alpha \cos\delta$ mas yr^{-1}	μ_δ
J21241387+0059599	21 24 13.95	01 00 01.49	201.78 ± 14.07	287.22 ± 14.24
J21304464-0845205	21 30 44.80	−08 45 20.84	360.41 ± 12.75	−31.18 ± 14.18
J21373742+0808463	21 37 10.38	14 50 46.82	−138.19 ± 13.82	−122.41 ± 17.00
J21371044+1450475	21 37 37.70	08 08 46.91	704.52 ± 21.14	102.28 ± 18.58
J21404656+0112594	21 40 46.51	01 12 58.38	−78.42 ± 20.34	−164.35 ± 22.03
J21522609+0937575	21 52 26.20	09 37 58.42	293.64 ± 18.65	170.15 ± 17.32
J21580457-1550098	21 58 04.60	−15 50 10.14	69.64 ± 11.27	−33.12 ± 14.92
J22081363+2921215	22 08 13.70	29 21 21.33	111.25 ± 14.37	−11.47 ± 14.05
J22134491-2136079	22 13 44.94	−21 36 08.56	59.56 ± 10.65	−62.73 ± 16.88
J22425317+2542573	22 42 53.40	25 42 56.94	408.77 ± 15.46	−45.19 ± 16.17
J22443167+2043433	22 44 31.81	20 43 41.34	251.74 ± 13.97	−213.74 ± 10.81
J22521073-1730134	22 52 10.92	−17 30 12.48	404.85 ± 20.23	153.57 ± 20.33
J22541892+3123948	22 54 18.96	31 23 51.33	67.94 ± 15.11	200.74 ± 11.26
J22545194-2840253	22 54 51.94	−28 40 25.20	8.20 ± 18.69	51.81 ± 30.09
J22591388-0051581	22 59 13.91	00 51 57.87	83.81 ± 16.71	67.87 ± 16.80
J233302258-0347189	23 30 22.71	−3 47 18.84	231.86 ± 17.43	31.93 ± 13.63
J23440624-0733282	23 44 06.25	−7 33 28.72	21.34 ± 16.63	−51.27 ± 7.71
J23453909+0055137	23 45 39.07	00 55 13.45	100.97 ± 18.74	−34.01 ± 14.45
J23515044-2537367	23 51 50.65	−25 37 35.27	377.56 ± 20.85	210.93 ± 22.14

Table 2. Name, proper motion (from Schmidt et al. (2007)), position angle (from Schmidt et al. (2007)), proper motion (from this study), position angle (from this study) for the 23 dwarfs which appear in Schmidt et al. (2007)

Name 2MASS	μ (Schmidt) ” yr^{-1}	PA (Schmidt) °	μ ” yr^{-1}	PA °
J0045+16	0.36±0.04	102±7	0.38± 0.02	93±2
J0251-03	2.17±0.11	148±2	2.14±0.02	148±0.6
J0908+50	0.52±0.25	202±21	0.61± 0.02	220±1
J1045-02	0.46±0.12	266±8	0.49±0.02	272±1.5
J1048+01	0.52±0.1	241±9	0.48±0.01	240±0.6
J1051+56	0.32±0.09	197±23	0.36±0.0	219±3
J1104+19	0.14±0.08	24±31	0.15±0.02	28±1
J1203+00	1.00±0.15	257±6	1.23±0.02	258±0.5
J1213-04	0.15± 0.09	260±38	0.35±0.02	268±2
J1221+02	0.09± 0.16	258±76	0.11±0.02	262±11.5
J1448+10	0.71± 0.15	98±13	0.26±0.02	111±4
J1506+13	1.11± 0.08	274±3	1.08±0.01	271±0.6
J1515+48	1.71± 0.05	327±1	1.75±0.02	328±1
J1539-05	0.6± 0.04	85±7	0.61±0.01	78±1
J1721+33	1.92± 0.11	287±3	1.94±0.02	288±0.6
J1731+27	0.28± 0.05	200±5	0.25±0.02	199±2
J1807+50	0.16± 0.05	167±15	0.13±0.01	164±9
J2028+00	0.14± 0.09	105±28	0.11±0.01	86±7
J2036+10	0.26± 0.09	216±21	0.20±0.01	215±1
J2057-02	0.08± 0.02	171±17	0.07±0.01	170±12
J2104-10	0.66± 0.05	115±3	0.68±0.02	114±1.6
J2251-17	0.45± 0.12	71±10	0.43±0.02	69±1.6
J2351-25	0.42± 0.11	62±15	0.43± 0.02	60±01

J1239+55, J1430+29, J1553+15, J1600+17, J2152+09 and J2252−17.

(ii) We confirm two previously known common proper motion wide binaries. J1004+50 also known as Gl96-3B and its companion Gl96-3A (Salim & Gould 2003). J1441−09 is a binary consisting of two L1 dwarfs with an M4.5 primary (Seifahrt et al., 2005).

(iii) We find 6 new possible multiple systems, although one appears unlikely, see table 3 and comments below.

Of the 6 new systems, 4 have not previously been identified as binaries. They are J1153+50, J0041+13, J1547+03 and J2259−00. These objects all appear to have proper motion companions. The proper motions, distance from the dwarf, J,H and K_S magnitudes of these objects and the L dwarf “primary” are given in table

3. J1017+13 and J144923 are known binaries to which we add another wide proper motion component.

J0041+13 has a spectral type of L0 (Hawley et al. 2002) and has very similar proper motion to a brighter field object 2MASSJ00415543+1341162 is also known as NLTT 2274, and is labelled as a high proper motion star.SIMBAD, lists a proper motion of $-191,-167$ mas yr^{-1} (Salim & Gould 2003), which is consistent with our measurements.

J1017+13, a brown dwarf of spectral type L2 (Cruz et al. 2003) was reported as a candidate binary system by Bouy et al. (2003). Their HST imaging program using WFPC2 determined that it has a separation of 104$\pm$2.8 mas and a position angle of $92^{\circ}.6\pm1^{\circ}.2$. The two components are found to have differences in magnitudes, suggesting they are of different mass. The photometric distance for this object was calculated to be $\approx$21.4 pc. In our data this dwarf appears to have common motion with another object in the field, 2MASSJ10171515+1307419. This wide companion appears to be a T dwarf at the distance of 22.8 pc (as calculated from spectral type of the L dwarf) from its colours (Leggett et al. 2002) and absolute magnitude. This object does form a sequence with the L2 primary, which may also be a binary. We caution that this object is faint so the 2MASS measurement and the WFCAM measurement of it are of low S/N. More information is needed before conclusions can be drawn.

J1153+50 has a spectral type of L1 (Reid et al., in preparation) and appears to have a much fainter field object associated with it. Assuming a distance of 27.4 pc for this dwarf (calculated from its spectral type using equation 1) and the companion, the colours of the companion indicate a spectral type of between L5 and L8 (Leggett et al. 2002) and the absolute magnitude of the companion fit the L-T dwarf sequence, strengthening the case that these dwarfs are companions.

J1449+23 is reported as being a binary by Gizis et al. (2003). This is currently one of the widest L dwarf doubles known, at a separation of 13 AU. J1449+23 has a spectral type of L0 (Kirkpatrick et al. 2000) and it is not known if the components are very low mass stars or brown dwarfs. This pair appears to have very similar proper motion to another object in the field, J14493550+2357118. J14493550+2357118 has impossibly blue colours (J-K=-0.197, J-H=-1.046), but it is at the survey limit of 2MASS, making it likely these measurements have large errors. In fact this object is so faint that errors are not given for some of the 2MASS photometry. It may thus be considered that this object is only detected in the J band. If the J, H and K photometry proves to be accurate then it is possible that this object is a white dwarf. When the SDSS colours are compared to the Holberg & Bergeron (2006) synthetic hydrogen white dwarf photometry, it falls along the hydrogen track, with a mass of 0.2 $M_{\odot}$, $T_{\rm eff}\approx$4000, log g$\approx$1.75 if the optical Sloan colours are used. A spectrum is needed to substantiate this hypothesis.

J1547+03 has a spectral type of L2 (Hawley et al. 2002) and appears to be associated with a field object, that appears to be only slightly fainter. This object however has blue J-K and J-H colours that are not consistent with a T dwarf of the same distance as J1547+03 as it would be too bright (Leggett et al. 2002). The Sloan photometry and JHK photometry is however consistent with a white dwarf at the same distance (58.8 pc) as the brown dwarf according to the Helium track of the Holberg & Bergeron (2006) models. This white dwarf would have a log g of 7.4, a $T_{\rm eff}$=5500 and a mass of 0.3$M_{\odot}$. This white dwarf would have an age of $\approx$ 1.7 Gyr. If this object is a white dwarf it will be one of only a few confirmed white dwarf$-$brown dwarf known binaries (GD165 Becklin & Zuckerman (1988), GD1400 Farihi & Christopher (2005), WD0137-349 Burleigh et al. (2006a), SDSS1212 Burleigh et al. (2006b) although others are suspected. However, this white dwarf may also be a background high proper motion, metal poor K dwarf, which would also exhibit these colours. Many common proper motion objects are in fact high velocity background dwarfs, particularly at large separations (Farihi, Becklin & Zuckerman 2005). A spectrum of this object was taken using ISIS on the William Herschel Telescope on 18 August 2007. Spectra were taken in the red arm using the R316 grating and the R300 grating in the blue arm. This spectrum proved this "companion" to be a metal poor K dwarf.

J2259-00 has a spectral type of L2 (Hawley et al. 2002) and has similar proper motion to two field objects, one which is much brighter and one, which is much fainter. This fainter object has a possible spectral type of L3 (using the colours and Leggett et al. (2002)), at a distance of 64.7 (derived from spectral type). However, when plotted on the $M_{\rm K}$, J-K colour magnitude diagram, these three objects do not form a sequence. The brighter object has colours that are approximately those of a G8 dwarf main sequence star, but at this distance, the object in question is too faint. We do not believe that this brighter object is a companion to the dwarf. The fainter companion also does not lie on a sequence with the L2 dwarf. We believe that these three objects have similar proper motions, but are not related.

Out of the 129 dwarfs with isolated enough motion to study, 5 appear to have companions. Of these 5, only 2 appear to be possible brown dwarfs. From this study the wide brown dwarf-brown dwarf binary fraction is 1.55%, which is in agreement with the 2.3% upper limit calculated by Allen et al. (2007). This fraction will not include any binaries with very faint companions due to the limiting depth of 2MASS. Many more such binaries will ultimately be found by the UKIDSS large area survey when its second epoch for proper motions is complete.

4 HIGH VELOCITY L DWARFS

From the proper motions calculated using the WFCAM and 2MASS data,we selected all (nine in total) objects with an extremely high proper motion (>0.85" yr^{-1}, figure 3). Five of these nine objects appear in Schmidt et al. (2007) and two are mentioned in the text as having large proper motions. Our proper motion and position angle measurements agree with those that appear in table 1 of Schmidt et al. (2007) to within the errors as shown in table 4. Tables 4 and 5 show the data for the L dwarfs selected as high velocity L dwarfs. The distances were calculated using the M_J spectral type relation given by Cruz et al. (2003), equation 1.

$$M_J = -4.410 + 5.043(ST) - 0.6193(ST)^2 + 0.03453(ST)^3 - 0.0006892(ST)^4, \quad (1)$$

where ST=0, 10 and 18 for spectral types M0, L0 and L8 respectively. J1645$-$31, while having a relatively high proper motion, is close and has a small tangential velocity, and so is not believed to actually be be a fast moving object.

Table 3. Name, proper motion for each component, *J*, *H* and K_S magnitudes and distance from L dwarf for the 6 new possible binaries.

Name	$\mu_\alpha \cos\delta$ mas yr^{-1}	μ_δ	*J*	*H*	K_S	Distance ”
J0041+13	−174.28±23.60	−137.55±36.02	14.454±0.031	13.673±0.036	13.236±0.024	–
2MASSJ00415543+1341162	−182.28±23.60	−141.99±36.02	10.164±0.029	9.574±0.033	9.347±0.018	32.02
J1017+13	60.53±21.83	−93.74±12.29	14.096±0.021	13.284±0.026	12.710±0.021	–
2MASSJ10171515+1307419	58.08±21.83	−93.74±12.29	16.827±0.157	16.497±0.296	17.365	125.32
J1153+50	83.92 ±22.95	60.19±10.88	14.189±0.026	13.305±0.024	12.851±0.025	–
2MASSJ11535018+5035593	87.50±22.95	70.37±10.88	17.145±0.173	16.349±0.233	15.832±0.203	251.12
J1449+23	40.31±13.25	26.69±23.61	15.818±0.074	15.004±0.086	14.311±0.084	–
2MASSJ14493550+2357118	48.3±13.25	30.71±23.61	16.663±0.154	17.709	14.311	99.36
J1547+03	−62.56±12.74	52.33±16.98	16.077±0.071	15.070±0.062	14.270±0.072	–
2MASSJ15470234+0338260	−51.91±12.74	57.67±16.98	16.275±0.094	15.843±0.124	15.691±0.233	388.44
J2259−00	83.81±16.70	67.87±16.79	16.357±0.097	15.315±0.087	14.651±0.087	–
2MASSJ22590929−0051556	69.93±16.70	72.91±16.79	11.264±0.026	10.993±0.026	10.872±0.021	68.80
2MASSJ22590491−0052407	87.59±16.70	60.30±16.79	17.123±0.214	16.300±0.231	15.692±0.229	141.11

Table 4. Name, spectral type(from optical spectra), distance (as calculated from spectral type), proper motion (from Schmidt et al. (2007)), position angle(from Schmidt et al. (2007)), proper motion (from this study), position angle (from this study) for the 8 high velocity dwarfs, 5 of which appear in Schmidt et al. (2007).

Name	Spt	d pc	μ (Schmidt) ” yr^{-1}	PA (Schmidt) °	μ ” yr^{-1}	PA °
J0251-03	L3	11.98	2.17±0.11	148±2	2.14±0.02	148±0.6
J1203+00	L3	18.53	1.00±0.15	257±6	1.23±0.02	258±0.5
J1331-01	L6	19.53	–	–	1.07±0.01	202±0.6
J1411+39	L1.5	31.56	–	–	0.92±0.02	279±01.1
J1506+13	L3	13.80	1.11±0.08	274±3	1.08±0.01	271±0.6
J1515+48	L6	10.50	1.71±0.05	327±1	1.75±0.02	328±1
J1555-09	L1	12.94	–	–	2.55±0.02	158±0.5
J1645-13	L1.5	11.52	–	–	0.88±0.01	205±1
J1721+33	L3	15.56	1.92±0.11	287±3	1.94±0.02	288±0.5

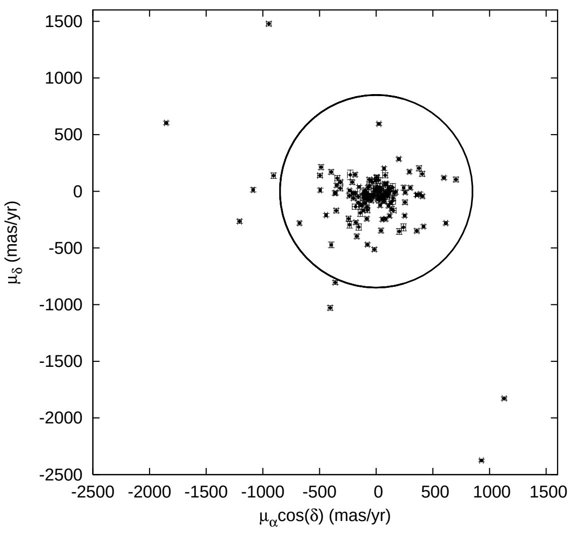

Figure 3. Proper motions of the 143 brown dwarfs. The circle has a radius of 0.85”. The objects outside this circle, are the nine fast moving objects.

We have calculated an approximate error of 13% on the distance, based on the scatter in the Cruz relation, and an assumed uncertainty of ± half a spectral class. Cruz et al. (2003) state that the error on this relationship comes from the uncertainties in spectral types. This is a tighter relationship than using *J*-K_S colours to derive M_J, which shows a fair amount of scatter. The tangential velocities were then be derived from the proper motions and distances. Most of the eight dwarfs have tangential velocities exceeding 70 km s^{-1}. The error on the velocities has been taken to be 13%, dominated by the distance error. Schmidt et al. (2007) find the mean tangential velocity for a sample of M and L dwarfs to be 31.5 km s^{-1}, with a velocity dispersion of 20 km s^{-1}. Thus these L dwarfs clearly have extreme velocities and the natural interpretation is that they belong to the old disc, thick disc or possibly galactic halo population. Schmidt et al. (2007) also identified two of these dwarfs, J1721+33 and J2051-03 as high velocity dwarfs.

To better understand the motion of these fast moving objects, we transformed the proper motion measurements in right ascension and declination ($\mu_\alpha cos\delta$, μ_δ) into proper motion on the galactic co−ordinate (μ_l, μ_b) system and calculated the velocities. To be able to study these velocities in relation to the galaxy, these velocities were then transformed onto a right handed co−ordinate system, with orthogonal axes directed towards the Galactic centre, the

U velocity, in the direction of Galactic rotation (l=90°, b=0°), V velocity and perpendicular to the galactic plane, W velocity. The radial velocity is unknown for these dwarfs, however if l≈0 or 180° it is possible to find V, since $V_r$sinl≈0 Likewise if l≈90 or 270° it is possible to find U.

Table 5 gives approximate U and V velocities for those dwarfs close to such special locations. J0251-03 and J1555-09 have V=−120.20 km s^{-1} and V=-73.18 km s^{-1} respectively and J1203+00 and J1515−09 have U=−81.61 and U=−86.81 km s^{-1} respectively. These velocities are typical of a thick disc population (Burgasser, Cruz & Kirkpatrick, 2007a). All eight L dwarfs have spectral types derived from optical spectra (Cruz et al. 2003; Fan et al. 2000; Hawley et al. 2002; Kirkpatrick et al. 2001; Gizis et al. 2000; Wilson et al. 2003; Gizis 2002) and none of the authors comment on any of the spectra being abnormal.

Burgasser et al. (2007a) discuss 16 spectroscopically confirmed subdwarfs. The L4 subdwarf 2MASS J1626+3925 shows a broad dip from 6700 - 7300 Å when compared to a "standard" L4 dwarf. This dip is much less pronounced in the L7 subdwarf 2MASS J0532+8246 when compared to a "standard" L7 dwarf. Indeed, it is difficult to distinguish the L7 subdwarf from an ordinary L7 dwarf by its 6500 - 9000 Å spectrum. The 6700 - 7300 Å dip is not obvious in the published spectrum of the L3 dwarf J1721+33 and is not expected in the L6 spectra of J1331-01 and J1555-09. Thus the only supporting evidence that these high velocity dwarfs are subdwarfs is their blue J-K_S colour. Blue J, H and K_S colours are expected for metal poor stars since the collisionally induced molecular hydrogen opacity is relatively more important and this increases rapidly from J to K depressing the longer wavelengths (Burgasser 2007b). Figure 4 shows J-K_S for all the L dwarfs in the dwarf archive. Our 8 high velocity dwarfs are marked as squares followed by their names. It can be seen that they all have bluer than average J-K colours. These colours however are not blue enough to indicate that these objects are subdwarfs as defined by (Burgasser et al. 2007a).

If we assume that all 8 of these dwarfs are likely to belong to the thick disc population (they are not blue enough to belong to the population II halo) then it is to be expected that they are old, with an age of ≈10 Gyr. This is most likely for the three having the most obviously blue J-K_S colour, J1721+33, J1331-01 and J1555−09. With an age of ≈10 Gyr however they cannot be brown dwarfs, which would have cooled to much lower effective temperatures (Burrows et al. 2001). We suspect that they are in fact extremely low luminosity stars. To check this, we have calculated their luminosities. Leggett et al. (2002) find that the K_S band bolometric correction is 3.3 for L dwarfs. Using this number and the absolute *K* magnitude we can calculate $L/L_\odot$ as shown in table 5. It should be noted that assuming BC_K =3.3 may be slightly unreliable for dwarfs that are unusually blue in *J-K*. These $L/L_\odot \approx 10^{-4}$ are in agreement with theoretical models for very low mass old stars (Burrows et al. 2001). Indeed, J1331−01, J1515+48 may be the lowest luminosity stars found to date.

5 MOVING GROUPS

Following the method of Bannister & Jameson (2007), we used the moving cluster method to search for members of the Ursa Major/Sirius, Hyades and Pleiades moving groups. If any of the L and T dwarfs that we have measured proper motions appear to be moving towards the convergent point of any of these groups, then it is a potential member. The moving group distance can then be calculated from equation 2,

$$d_{mg} = \frac{v \sin\theta}{4.74\mu}, \qquad (2)$$

where v is the moving group velocity (km s^{-1}), θ the angular distance of the dwarf from the convergent point, and μ the proper motion in arcseconds.

Bannister & Jameson (2007) used objects with known parallax measurements, to check if the distance provided by the moving cluster method was comparable to the measured distance. We do not have parallax measurements for any of our objects, and so must rely on a different distance check. We have again used the Cruz distance relationship based on spectral type (equation 1). Once the distance to the star, assuming it is a moving group member has been calculated, the distance formula can be used to calculate the absolute magnitude of the object in question, and plot it on a colour−magnitude diagram. The objects that have been selected - i.e. have the correct proper motion angle, which must be less than 14° for the difference between the observed and calculated angles as in Bannister & Jameson (2007), and the correct distance to fit on a colour-magnitude diagram, were then subject to another check.

If the ratio between the moving cluster distance and the Cruz spectral type distance was greater than 0.72 and less than 1.28, as calculated in Bannister & Jameson (2007) then the objects were considered to be members. Parallax measurements for these members could confirm these distances. While some objects may have the correct direction and magnitude of motion, few will have the correct distances and appear to sit in the correct position on the colour magnitude diagram. In their study, Bannister & Jameson (2007) estimated 0.5% probablility of an object passing all three tests (distance, direction and colour magnitude diagram). They suggest that it is likely that 99.5% of selected objects therefore are members of the moving groups.

In our case we only have spectroscopic distance estimates to compare with the moving group distance, so the group membership probabilities will be lower. The random chance probability of passing the direction test is naively 2×14/360=0.08. However, this assumes that field dwarf proper motions are randomly orientated. Figure 3 shows that they are approximately orientated in a semicircle, so we therefore double the random chance to 0.16. Using a spectroscopic distance of course results in a reasonable colour-magnitude diagram i.e. one that is appropriate to the mean dwarf age, so the third test presented in Bannister & Jameson (2007) is not valid. However, requiring that the moving group distance is approximately equal to the spectroscopic distance is still a valid test since it effectively requires the candidate to have the "correct" amplitude of proper motion. The sample of 143 proper motions peaks at an amplitude of 90 mas yr^{-1}. This number then falls off exponentially towards high proper motions. However, very few of the moving group candidates have proper motions >200 mas yr^{-1}. Thus we take the width of the proper motion distribution to be 30 to 200 mas yr^{-1}, a factor of 200/30=6.67. The errors in the spectroscopic distance is taken to be 13% (see above) and we allow a 28% varaition in d_{mg}/d_{sp} due to the moving group velocity dispersion. Combining these percentages quadratically gives ±31% i.e. a distance factor 1.31/0.69=1.9. Now, 6.67∼$(1.9)^3$ so there is a 1 in 3 random chance of the moving group distance agreeing with the spectroscopic distance. Thus the total random chance of membership is 0.16×0.33=0.05. These rather crude statistics therefore suggest that about 95% of our moving group candidates should be genuine members. It should be noted however that galactic reso-

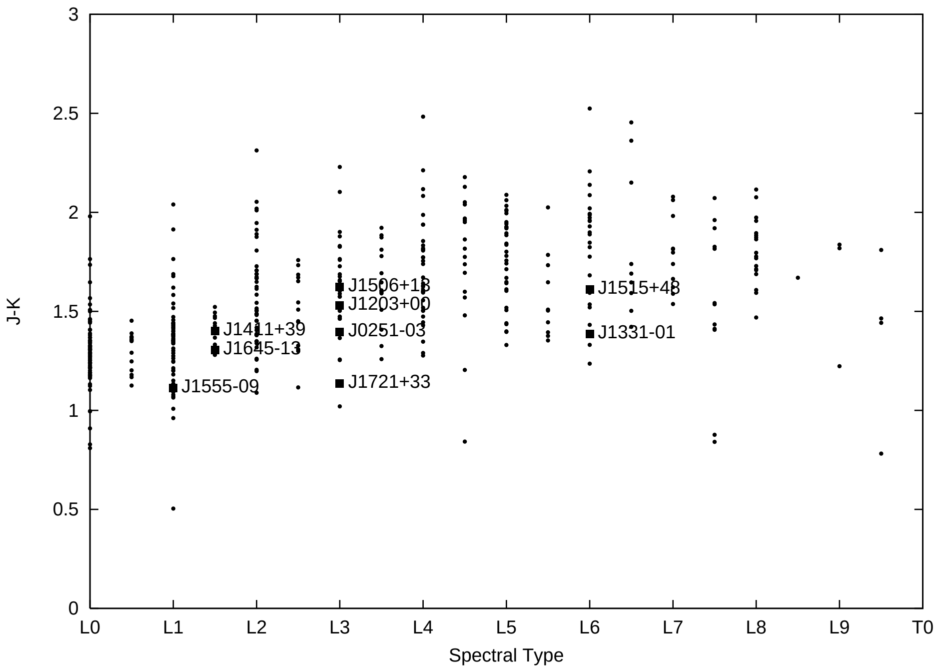

Figure 4. *J*-K_S vs spectral type for all L dwarfs in the Dwarf Archive. The marked objects are the 9 fast moving dwarfs which tend to have bluer *J*-K_S than other dwarfs of the same spectral type.

Table 5. Name, l, b, $V_{\rm Total}$ (total velocity), U(velocity in the direction of the galactic centre), V (velocity in the direction of galactic rotation), *K*, *J-K* and $L/L_\odot$ for the eight fast moving dwarfs.

Name	l	b	$V_{\rm Total}$	U	V	*K*	*J-K*	$L/L_\odot$
	°			km s^{-1}				$\times 10^{-4}$
J0251−03	179.10	−53.15	121.97	–	−120.20	11.662	1.39	1.18
J1203+00	277.98	60.81	108.71	−81.61	–	12.476	1.53	1.33
J1331−01	323.42	59.97	102.55	–	–	14.073	1.38	0.34
J1411+39	74.98	69.25	137.81	–	–	13.239	1.40	1.91
J1506+13	16.21	55.52	71.10	–	–	11.741	1.62	1.45
J1515+48	80.75	54.88	87.18	−86.81	–	12.500	1.61	0.41
J1555−09	359.58	32.05	156.52	–	−73.18	11.443	1.14	1.68
J1721+33	57.35	32.52	143.70	–	–	12.489	1.36	0.92

nances can also produce common velocities similar to those of a moving group (Dehnen 1998). Thus members of a moving group may have the same age, but coevality is not guaranteed.

5.1 The Hyades

The Hyades cluster has a distance of 46 pc and covers $\approx 20^\circ$ of the sky. The Hyades has almost no known low mass members (Gizis, Reid & Monet 1999; Dobbie et al. 2002) as due to its age (625 Myr Perryman et al. (1998)) they have evaporated from the cluster.In fact for a cluster of this age $\sim$ 70% of stars and $\sim$ 85% of brown dwarfs are expected to have escaped the cluster (Adams et al. 2002). The Hyades moving group is made up of objects that may have escaped from the Hyades. Chereul, Creze & Bienayme (1998) first identified escaped Hyads, and more recently Bannister & Jameson (2007) have identified 7 L and T field dwarfs that belong to the Hyades moving group. Zapatero Osorio et al. (2007) have confirmed membership for one of these objects (2MASS J1217110-031113), and have disproved membership for two (2MASS J0205293-115930 and 2MASS J16241436+0029158) using radial velocity measurements. The Hyades moving group has its convergent point situated at α=6^{h}29.48^m, δ=-6°53.4', and the members have a space velocity of 46 km s^{-1} (Madsen, Dravins & Lindgren, 2002).

Fifteen objects had the correct proper motion, direction (distance between the observed angle of proper motion and moving group angle must be less than 14°) and distance (ratio between the moving cluster distance and the Cruz spectral type distance greater than 0.72 and less than 1.28) to belong to the Hyades moving group as shown on figure 5. Of these, 8 are possible binaries as they lie up to 0.75 magnitudes above the main sequence. J1047−18 and J1750+42 had the correct motion, direction and distance to belong to the moving group, however lay in the wrong place on the sequence in the $M_{\rm K}$, *J-K* colour magnitude diagram (figure 6). Four objects, J0103+19, J0908+50, J1326−27 and J1343+29 are marked as being uncertain members to the moving group. They lie above the binary sequence in the colour magnitude diagram when the spectroscopic distance is used making them narrowly non mem-

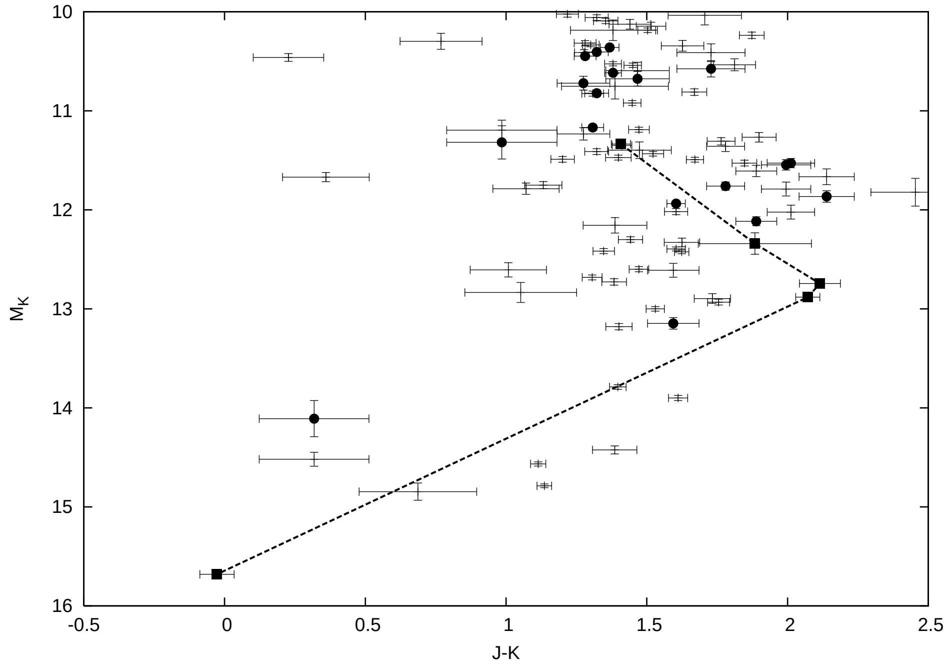

Figure 5. M_K, J-K colour magnitude diagram for the Hyades moving group. The members identified by Bannister & Jameson (2007) are plotted as filled squares. All of the 143 objects are plotted, with M_K calculated from the moving group distance. The objects selected from the moving group method (correct angle of proper motion and distance ratio) are marked as filled circles. The errors are poissonion and from the photometry only. The dashed line indicates the possible single star sequence as calculated from the Bannister objects.

bers, however, when the moving cluster distance is used, J1326−27 and J1343+29 become more likely to be members and the remaining two objects as well as J1206+02 become less likely to be members. It should be noted that J1553+15 is a binary object and also a T dwarf (making the spectroscopic distance incorrect). This object is marked with a diamond on figure 6.
To illustrate the method we also show in figure 5 all the remaining proper motion dwarfs with their M_K calculated from their moving group distances. Since they are not members, they form a scattered distribution.

J1441-09 is believed to be a member of the Hyades moving group as stated by Seifahrt et al., (2005). It was not selected as a member here as the ratio of moving group distance to spectral type distance was 1.47. If the parallax distance is used, this ratio decreases to 1.35 which is still too high to be selected. $\Delta\theta$ however is only small indicating possible membership ($\approx 3^{\circ}$). For the purposes of this study, it is not treated as a member. For clarity figure **??** repeats figure 5 without the obvious non members. The Bannister & Jameson (2007) sequence is shown by a dashed line. Table 6 contains more information about the suggested moving group members.

The following four objects are possible members and are marked by filled circles on figure 6.
J0103+19 is an L6 dwarf as identified by optical spectra (Kirkpatrick et al. 2000).
J0908+50 is an L5 dwarf as identified by optical spectra by Cruz et al. (2003). However Knapp et al. (2004) identify it as an L9±1 dwarf using infrared spectra.
J1326-27 is an L5 dwarf (from optical spectrum) (Gizis 2002). This is another object that was found not to be a member of the TW Hydrae association by Gizis (2002).
J1343+39 is an L5 dwarf, identified by optical spectrum from Kirkpatrick et al. (2000).

The remaining objects were selected as being probable members of the moving group and are plotted as encircled filled circles on figure 6.
J0228+25 is an L0 dwarf as identified by Wilson et al. (2003) using an infrared spectrum and by Cruz et al. (2003) using an optical spectrum.
J1010-04 is an L6 which was discovered in 2003 by Cruz et al. (2003) and identified using an optical spectrum.
J1045-01 is an L1 dwarf (from optical spectrum). Gizis (2002) took a spectrum of this object to search for gravity features in the spectrum that would indicate youth and hence membership of the TW Hydrae association, however it was not found to be a member.
J1047-18 is an L2.5 dwarf (from optical spectrum) (Martín et al. 1999) and was originally discovered using the DENIS catalogue (DENIS Consortium 2005).
J1207+02 is an L8 dwarf as measured from optical spectra by Hawley et al. (2002) and a T0 dwarf as measured from infrared spectra by Burgasser et al. (2006a).
J1402+01 is an L1 dwarf discovered from the SDSS by Hawley et al. (2002).
J1404+46 is identified as an L0 dwarf from its optical spectrum (Cruz et al. 2007).
J1407+12 is identified as an L5 dwarf by Reid et al (in prep).
J2057+17 is identified as a L1 dwarf from its optical spectrum by Kirkpatrick et al. (2000).
J2107-03 is an L0 dwarf (from optical spectrum) (Cruz et al. 2003).
J2130-08 is identified as an L1.5 dwarf by Kirkpatrick et al. (in prep).

J1553+15 is identified as a T7 dwarf, and is also a binary

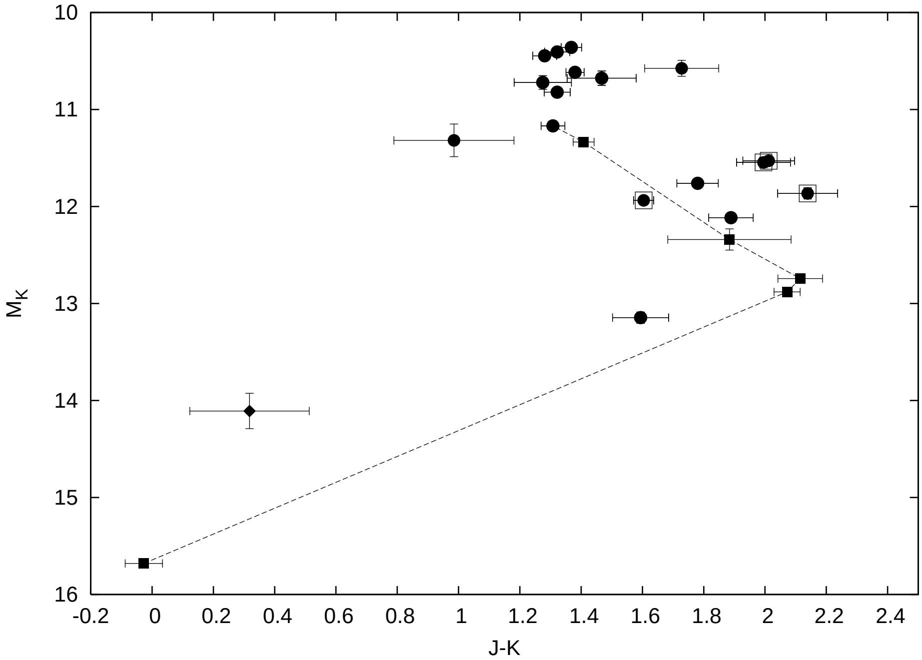

Figure 6. M_K, J-K colour magnitude diagram for the Hyades moving group. The members identified by Bannister & Jameson (2007) are plotted as filled squares. All of the objects that were selected as possible members are marked as filled circles and the selected members are marked by a ring around the filled circle. The diamond is the object J1553+15.The 4 objects that are uncertain members are marked with boxes around the filled circles.The errors are poissonion and from the photometry only.The dashed line indicates the possible single star sequence.

separated by 0.349" (Burgasser et al. 2006a). As the spectroscopic distance used here is only valid for dwarfs with spectral types from M6 to L8, the distance is incorrect and it is likely that this object is not actually a member. Burgasser et al. (2006b) calculate a distance for this object of 12±2 pc using the relationships of Tinney et al., (2003). If this distance is used, a the ratio of moving cluster distance to spectral type distance is 1.31, which while close, is outside the limits of the selection criteria used here. The M_K of this object then becomes too faint to sit on the L−T transition sequence for this moving group. It is plotted as a filled diamond in figure 6.

This result indicates that many brown dwarfs may have escaped the Hyades cluster over time, as has been suggested, however they may have remained members of the Hyades moving group. If so, these objects may allow a study of the initial mass function of the Hyades to be made down to substellar masses. A next step would be to measure parallaxes for these objects.

5.2 Ursa Major

The Ursa Major moving group has been estimated to have an age of between 300 Myr (Soderblom & Mayor 1993) and 500±100 Myr (King et al. 2003).Castellani et al. (2002) found an age of the group to be 400 Myr. The age of 400±100 Myr is adopted in this work. The convergent point of the Ursa Major moving group is located at α=20^{h}18^{m}.83, δ=−34°25'.8 (J2000, Madsen et al. (2002)). Out of the 143 brown dwarfs examined, 4 appear to have the correct motion, distance and the correct direction of motion to be members of the Ursa Major moving group.

These objects are J0030+31, J1204+32, J1246+40 and J1550+14. Three objects had the correct motion, distance and direction however when placed on the colour magnitude diagram didn't fit the sequence. These objects are the binary J1017+13, J1147+02 and J1619+00, all of which lie too low on the main sequence to belong to the cluster. J1017+13 appears to be a possible member of the moving group however, it should be moved downwards to compensate for the fact that it is a binary, hence making it appear more likely to be a non member. It is plotted as a filled diamond on figure 7. The spectral types of these objects agree with their placement on the main sequence.
These objects are shown in figure 7 and their data in table 7.
These objects were selected as being probable members of the moving group and are plotted as encircled filled circles on figure 7.
J0030+31 is an L2 (spectral type from optical spectrum) dwarf identified from 2MASS by Kirkpatrick et al. (1999).
J1204+32 is an L0 dwarf (spectral type from optical spectrum), with an estimated distance of 26.9 pc (from spectral type) (Cruz et al. 2003). Wilson et al. (2003) find a spectral type for this object of M9 from an infrared spectrum.
J1239+55 is an L5 dwarf identified by its optical spectrum by Kirkpatrick et al. (2000). It is also part of a resolved binary system.
J1246+40 is an L4 dwarf (spectral type from optical spectrum) (Kirkpatrick et al. 2000). It has an estimated distance of 25 pc calculated from spectral type.
1550+14 is an L2 dwarf (spectral type from optical spectrum) (Cruz et al. 2007).

5.3 Pleiades

The Pleiades cluster is 125 Myr old and is situated at a distance of 130 pc (Stauffer, Schultz & Kirkpatrick 1998). As a cluster it has been studied in depth and has been found to contain many brown dwarfs (Casewell et al. 2007; Lodieu et al. 2007b; Bihain et al. 2006; Moraux et al. 2003). The Pleiades moving

Table 6. Name J, H, K magnitudes, $\Delta\theta$, d_{mg}/d_{sp} and d_{sp} for the potential Hyades moving group members discussed.

Name	J	H	K	$\Delta\theta$ °	d_{mg}/d_{sp} pc	d_{sp}
J0103+19	16.28 ± 0.07	14.89 ± 0.05	14.14 ± 0.05	2.87 ± 2.68	1.09	28.62
J0228+25	13.83 ± 0.02	12.99 ± 0.02	12.47 ± 0.02	3.78 ± 3.76	1.25	26.44
J0908+50	14.54 ± 0.02	13.47 ± 0.02	12.94 ± 0.02	11.51 ± 2.06	0.80	15.91
J1010-04	15.50 ± 0.05	14.38 ± 0.03	13.61 ± 0.04	7.54 ± 2.36	1.26	19.98
J1045-01	13.15 ± 0.02	12.35 ± 0.02	11.77 ± 0.02	7.17 ± 1.39	1.04	17.09
J1047-18	14.19 ± 0.02	13.42 ± 0.02	12.89 ± 0.02	6.61 ± 2.31	1.17	22.10
J1207+02	15.57 ± 0.07	14.56 ± 0.06	13.98 ± 0.05	-8.77 ± 2.12	1.27	14.72
J1326-27	15.84 ± 0.07	14.74 ± 0.05	13.85 ± 0.05	2.12 ± 2.17	0.89	28.93
J1343+39	16.16 ± 0.07	14.85 ± 0.05	14.14 ± 0.04	-1.38 ± 4.04	0.79	33.44
J1402+01	15.45 ± 0.06	14.65 ± 0.06	14.17 ± 0.07	6.37 ± 2.72	0.78	49.08
J1404+46	14.33 ± 0.02	13.53 ± 0.02	13.05 ± 0.02	-9.35 ± 5.79	1.06	33.27
J1407+12	15.37 ± 0.05	14.34 ± 0.05	13.59 ± 0.04	-1.68 ± 3.33	1.20	23.31
J2057+17	15.96 ± 0.08	15.19 ± 0.08	14.49 ± 0.07	5.82 ± 7.81	1.03	58.11
J2107-03	14.19 ± 0.02	13.44 ± 0.03	12.87 ± 0.02	-10.39 ± 4.4	1.17	31.22
J2130-08	14.13 ± 0.02	13.33 ± 0.03	12.81 ± 0.03	-5.94 ± 2.24	0.76	25.04

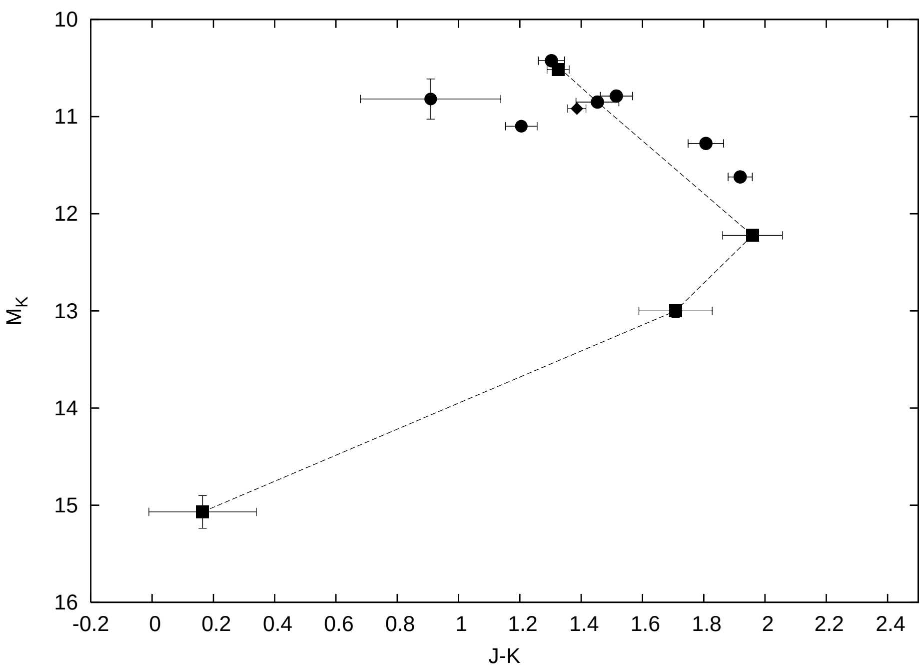

Figure 7. M_K, J-K colour magnitude diagram for the Ursa Major moving group. The members identified by Bannister & Jameson (2007) are plotted as filled squares. All of the objects that were selected as possible members are marked as filled circles and the selected members are marked by a ring around the filled circle. The diamond is the object J1017+13.The errors are poissonion and from the photometry only.The dashed line indicates the possible single star sequence.

Table 7. Name J,H, K magnitudes, $\Delta\theta$, d_{mg}/d_{sp} and d_{sp} for the potential Ursa Major moving group members discussed.

Name	J	H	K	$\Delta\theta$ °	d_{mg}/d_{sp} pc	d_{sp}
J0030+31	15.47 ± 0.05	14.61±0.05	14.02±0.047	6.29±11.33	1.16	43.18
J1204+32	13.81±0.03	13.09±0.03	12.51±0.027	8.02±12.30	1.13	26.18
J1239+55	14.71±0.02	13.56±0.03	12.79±0.027	16.17±3.01	1.00	17.14
J1246+40	15.08±0.04	13.94±0.03	13.28±0.038	12.26±5.41	0.72	25.17
J1550+14	14.77±0.04	13.79±0.03	13.26±0.034	10.83±5.73	0.72	31.23

group has a convergent point of 85.04°±3.67, −39.11°±6.92 (Madsen et al. 2002). This convergent point is very close to that of many other moving groups such as Alpha Persei(96°.78±1.96, -23°.27±3.67, Madsen et al. (2002), 50 Myr Lyngå, G (1987)), Tucana/Horologium (30 Myr Zuckerman & Song (2004)) and the AB Dor moving group (50 Myr Zuckerman & Song (2004)) (see Zuckerman & Song (2004) for a review), and it has been theorised that many of these moving groups have a common origin (Ortega et al. 2007).

Three objects were selected to be potential members of the Pleiades moving group, and in addition to these three, one object with previously measured proper motion, and a parallax measurement also appears to fit the main sequence, while having the moving group distance and the parallax agree, as well as having motion in the correct direction to be a member. These 4 objects were compared to the L-T dwarf sequence for the objects identified as being potential members of the Pleiades cluster by Casewell et al. (2007). The spectral types of all of these objects are consistent with their places on the colour magnitude diagram as shown in figure 8 and their data is in table 8.

These objects were selected as members of the Pleiades moving group and are plotted as encircled filled points on figure 8.

J0001+15 is an L4±1 dwarf as identified by Knapp et al. (2004) who used an optical spectrum.

J1123+41 is an L2.5 dwarf discovered by Kirkpatrick et al. (2000).

J1552+29 has been identified as an L1 dwarf by Wilson et al. (2003).

These two objects with known parallaxes were selected as members of the moving group and are plotted as filled, encircled diamonds on figure 8.

GL417B is a L4.5 dwarf discovered by Kirkpatrick et al. (2000). It has a proper motion of 0.291±0.00072" yr^{-1} and a position angle of 238.67±0.14° (Perryman et al. 1997). This object has a parallax of 46.04±0.9 mas which corresponds to a distance of ≈21.72 pc (Perryman et al. 1997). This L dwarf was identified as a binary by Kirkpatrick et al. (2001) who had noted in Kirkpatrick et al. (2000) that it was in close proximity to GL417, a G type dwarf star. These two objects were found to have a common proper motion. It is noted in Kirkpatrick et al. (2001) that the age of this system is not inconsistent with that of the Pleiades (the age was calculated using the ratio of x−ray to bolometric luminosity vs B−V). Comparing Gl417A to the evolutionary models of Girardi et al. (2000), using the measured parallax as above,of shows that it lies to the left of the main sequence at this point, indicating that it is not a member of the moving group, however it is recorded as a variable star of the BY Dra type which may account for this difference. Further study would be needed of this object to prove a membership of the moving group.

2MASSWJ2101154+175658 is an L7.5 dwarf also identified by Kirkpatrick et al. (2000). Vrba et al. (2004) measure a proper motion of 0.2085±0.00037 " yr^{-1} and a position angle of 136.33±0.51° for it. It has a measured parallax of 30.14±3.42 mas which corresponds to a distance of ≈ 33.17 pc. Gizis et al. (2003) identified this L dwarf as a binary using the HST and suggest that both components must be brown dwarfs and the secondary must have a spectral type of later than L8. The separation is estimated to be 0.232".

6 CONCLUSIONS

We have measured the proper motions for 143 dwarfs from the Dwarf Archive. From these measurements, we find 4 new common proper motion wide binary or multiple systems. We also identify 8 high velocity dwarfs i.e. dwarfs with tangential velocities ⩾ 100 kms^{-1}. These dwarfs also have bluer than average *J-K* colours. We argue that these are probably thick disc objects with an age of order 10 Gyr. We estimate their luminosities which are $\approx 10^{-4} L/L_{\odot}$. This suggests that they are probably very low luminosity stars rather than brown dwarfs. If so, they may be some of the dimmest stars found to date. Finally we have found 15 L dwarfs that are potential members of the Hyades moving group, 5 that are potential members of the Ursa Major moving group and 5 that are potential members of the Pleiades moving group. The next obvious step towards confirming membership of these groups is to measure parallaxes for these dwarfs. Parallaxes will allow accurate distances to be used to compare with the moving group distance. *Spitzer* 3.5, 4.49, 5.73 and 7.87 micron magnitudes will also be valuable for a fuller understanding of the high velocity metal poor dwarfs.

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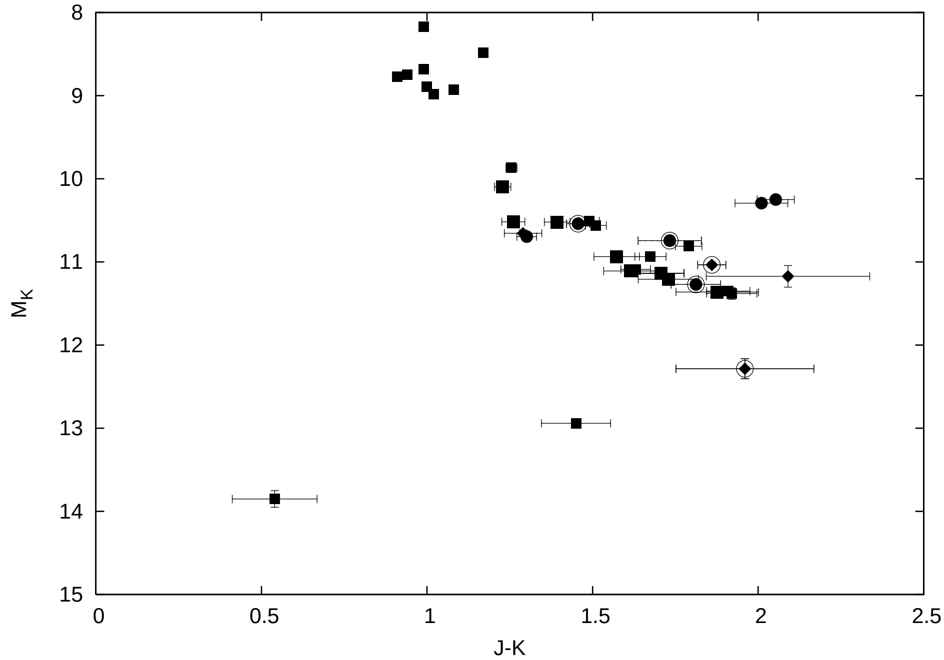

Figure 8. M_K, J-K colour magnitude diagram for the Pleiades moving group. The cluster members members identified by Casewell et al. (2007), Lodieu et al. (2007b), Moraux et al. (2003) and Bihain et al. (2006) are plotted as filled squares. All of the objects that were selected as possible members are marked as filled circles and the selected members are marked by a ring around the filled circle. The filled diamonds are objects that were selected as possible members that had measured parallax, and are outlined by a ring if considered a selected member.The errors are poissonion and from the photometry only.

Table 8. Name J, H, K magnitudes, $\Delta\theta$, d_{mg}/d_{sp} and d_{sp} for the potential Pleiades moving group members discussed. The last two objects have parallax measurements and hence the last but one column is the ratio of moving group distance to parallax distance, not the spectral type distance.

Name	J	H	K	$\Delta\theta$ °	d_{mg}/d_{sp} pc	d_{sp}
J0001+15	15.52 ± 0.06	14.50 ± 0.05	13.71 ± 0.04	9.45 ± 4.98	0.89	30.74
J1123+41	16.07 ± 0.07	15.08 ± 0.08	14.34 ± 0.05	4.77 ± 7.62	0.88	52.41
J1552+29	13.47 ± 0.02	12.60 ± 0.02	12.02 ± 0.02	12.20 ± 6.90	0.77	19.78
Gl 417B	14.58±0.03	13.50±0.03	12.72±0.03	5.00±0.14	0.94	21.72
2MASSWJ2101154+175658	16.85±0.17	15.86± 0.18	14.89±0.12	9.48±0.51	0.67	33.18

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