An optical and near-infrared search for brown dwarfs in the Pleiades cluster

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ABSTRACT
We have carried out a brown dwarf search over an area of 14 × 23 arcmin2 near the central portion of the Pleiades open cluster in five optical and near-infrared bands (i′, Z, J, H, Ks) with 10σ detection limits of i′ ≈ 22.0, J ≈ 20.0 and Ks ≈ 18.5 mag. The surveyed area has large extinction in excess of AV = 3 in the Pleiades region. We detected four new brown dwarf candidates from the colour–colour (J − K, i′ − J) and the colour–magnitude (J, i′ − K) diagrams. We estimated their masses as 0.046 M⊙ down to 0.028 M⊙. The least massive one is estimated to have a mass smaller than Roque25 or int-pl-IZ-69, and possibly the lowest-mass object found so far in the Pleiades cluster.

Key words: stars: low-mass, brown dwarfs – open clusters and associations: individual: Pleiades – infrared: stars.

1 INTRODUCTION
Many brown dwarf (BD) searches have targeted young open clusters or star-forming regions rather than general fields, because here BDs are still relatively bright and warm during their early phase. The Pleiades region is one of the best clusters for this purpose; it is a fairly young, nearby, rich and compact cluster. It has an age of 125 Myr (Stauffer, Schultz & Kirkpatrick 1998) at a distance of 130 pc (Crawford & Perry 1976; Pinfield et al. 2000). 1200 member stars are located within 2.5 of the cluster centre (Pinfield, Jameson & Hodgkin 1998).

A number of optical surveys searching for BDs in the Pleiades cluster have been performed to date and identified a numerous population of bona fide BDs and BD candidates: ‘CFHT-PL’ objects found by an R1 survey (Bouvier et al. 1998); ‘NPL’ objects by an R1JK survey (Festin 1998); ‘MHObd’ objects by a VI survey (Stauffer et al. 1998b); ‘IPMBD’ objects by an R1 survey (Hambly et al. 1999); ‘Roque’ objects by an IZ survey (Zapatero Osorio et al. 1999); ‘BPL’ objects by an IZ survey (Pinfield et al. 2000) and ‘int-pl-IZ’ objects by an IZ survey (Dobbie et al. 2002b). About 20 of these objects are confirmed as Pleiades brown dwarfs on the basis of observed lithium abundance, radial velocity and proper motion (e.g. Rebolo, Zapatero-Osorio & Martin 1995; Basri, Marcy & Graham 1996; Rebolo et al. 1996; Zapatero Osorio et al. 1997a; Stauffer et al. 1998; Martin et al. 2000). However, to date, only one L-type BD candidate (Roque25; Martin et al. 1998) has been spectroscopically identified in the Pleiades cluster. Detection of L-type BDs is difficult at optical wavelengths because they should emit most of their bolometric flux in the infrared region. We have carried out a brown dwarf survey in both the optical and near-infrared of a small region of the central region of the Pleiades cluster or southern portion of Merope. Most existing surveys have ignored this region because of its proximity to a small molecular cloud, which results in large and variable extinction (Breger 1987).

2 OBSERVATIONS
We surveyed an area of 14 × 23 arcmin2 centred at RA 3h 46m 59.6s, Dec. +23° 44′ 59″ (J2000.0) both in the optical and near-infrared bands. The observed area is shown as the shaded rectangle in Fig. 1. The four open rectangles show the area covered at optical wavelengths.
14 \times 1024 pixel HgCdTe arrays, which provides J- (1.25 µm), H- (1.65 µm) and Ks- (2.15 µm) band images simultaneously (Nagashima et al. 1999; Nagayama et al. 2002). The field of view in each band is 4.9 \times 4.9 arcmin² with a pixel scale of 0.28 arcsec at the Cassegrain focus of f/10. We mapped an area of 14 \times 23 arcmin² with 3 \times 5 tiles of the field of view. We obtained each of the tiles by dithering 18 frames. The exposure time was 60 s for each frame. The limiting magnitudes at 10σ are 20.0, 19.2 and 18.5 at J, H and Ks, respectively. The typical seeing in the Ks band was 1.0 arcsec.

Dark and dome-flat frames were taken at the beginning or the end of each night. We observed standard stars, nos 9105, 9107, 9108, 9116 and 9188, in the faint near-infrared (NIR) standard star catalogue of Persson et al. (1998) on the same nights for photometric calibration, and the red standard stars, LDN 547, BRI B0021-0214 and BRI B2202-1119, in table 3 of Persson et al. (1998) on 2001 August 31 for determination of the colour conversion formula from ours to the CIT system. We obtained the following equations as colour conversion from ours to the CIT system:

\[
J_{\text{CIT}} = J_{\text{obs}} - (0.013 \pm 0.017) \times (J - Ks)_{\text{obs}} + (0.012 \pm 0.030) \\
H_{\text{CIT}} = H_{\text{obs}} - (0.029 \pm 0.029) \times (J - H)_{\text{obs}} + (0.007 \pm 0.033) \\
K_{\text{CIT}} = Ks_{\text{obs}} - (0.024 \pm 0.020) \times (J - Ks)_{\text{obs}} + (0.018 \pm 0.035).
\]

We used pipeline software based on NOAO’s IRAF (Imaging Reduction and Analysis Facility) package to reduce the data. We have applied standard NIR image reduction procedures, including dark-current subtraction, sky subtraction and flat-fielding. Source detection, morphological classification and photometry were performed with the APHOT package in IRAF.

### 2.2 Optical survey

The i′ (0.77 µm, SDSS system) and Z (0.9 µm, RGO) band image was taken on 2000 October 20 with the Wide Field Camera (WFC) on the Isaac Newton Telescope (INT) at La Palma, as part of the INT Wide Angle Survey (McMahon et al. 2001). The WFC accommodates four 2048 \times 4196 pixel E2V charge-coupled devices (CCDs). The field of view for each CCD is 11.4 \times 22.8 arcmin² with a pixel scale of 0.33 arcsec at the prime focus of the INT and the mosaic layout of the four CCDs enables us to encompass the whole field of 14 \times 23 arcmin² taken in the near-infrared bands (Fig. 1). We obtained one frame for each filter; the exposure time of each frame was 600 s. The 10σ detection limits are 22.0 and 20.5 at i′ and Z, respectively, where i′ and Z are on the natural system of WFC.

The observed data were reduced at the Institute of Astronomy, Cambridge, using the WFC data reduction pipeline software (Irwin & Lewis 2001). All the frames were bias-subtracted and then corrected for linearity before the science fields were flat-fielded and defringed. The pipeline was also used to generate photometrically and astrometrically calibrated object catalogues. On the night in question, the i′- and Z-band photometric zeropoints were measured from three standard star fields (observed once each) in the catalogue of Landolt (1992) and were found to be stable to about 1 per cent. The astrometric solution takes account of the radial distortion across the WFC field of view, and resulted in residuals of 0.22 arcsec.

### 3 Selection of Pleiades BD candidates

#### 3.1 The colour–colour diagram

We constructed the colour–colour \((J - K, i' - J)\) diagram for all the objects, 846 sources in total, detected with signal-to-noise (S/N) ratios higher than 10 in the near-infrared and optical bands, differentiating them as extended (149; open circles) and point (697; filled circles) sources in Fig. 2. Seven sources detected with S/N ratios higher than 10 in the near-infrared but lower than 5 in the optical range are also plotted with large error bars. ‘Extended objects’ were sorted with a criterion of the FWHMs being larger by at least 20 per cent than the seeing size of the night in the \(Ks\) images.

The thick solid and dashed curves from the bottom left-hand corner represents the loci of main-sequence and red giant stars (Bessell 1979, 1991); spectral types of K7 dwarf at the cusp at around (1, 0.8) and of M7 at the tip (3.5,1.2) for \((i' - J, J - K)\), while the arrow at the upper right-hand corner shows the reddening vector of \(A_V = 3 \text{ mag}\) (Schultz & Wiemer 1975; Rieke & Lebofsky 1985). Most of the point sources (filled circles) are concentrated above the locus from K7 to M7, along the extinction vector up to 3 mag from the main sequence (reddening band), indicating they are K- or M-type dwarfs lying intrinsically on the main sequence. On the other hand, most of the extended sources and some point sources spread upward from the reddening band. About 20 of the extended sources have galaxy-like shapes. The \(K\)-correction curves from \(z = 0\) to 0.1 of elliptical and spiral galaxies (Furusawa, private communication) are plotted as dotted lines. Thus, objects spread upward of the reddening band including the point sources (182 objects in total) are likely to be elliptical or spiral-type galaxies reddened with \(K\)-corrections of \(z \approx 0\) to 0.1 and \(A_V\) of 0 to several magnitudes.
Figure 2. The $J - K_s$, $i' - J$ colour–colour diagram for all objects detected in all five bands. Small dots are point sources and open circles are extended sources. Asterisks are the known late-type field dwarfs. The thick solid and dashed curves from the bottom left-hand corner represent the loci of main-sequence and red giant stars. The arrow in the upper right-hand corner shows the reddening vector of $A_V = 3$ mag. The thin dashed line is the $\sim 125$-Myr isochrone of the NEXTGEN model (Baraffe et al. 1998), and the thin dot-dashed line is the $\sim 120$-Myr isochrone of the DUSTY model (Chabrier et al. 2000). Numbers with tick marks denote masses in solar mass units for each model.

A major problem in this kind of survey is to distinguish stars from distant galaxies at faint magnitudes (e.g. Festin 1997). The optical and near-infrared colour–colour diagram allows us to easily distinguish them. Note that the near-infrared colour–colour diagram ($J - H$, $H - K$) alone cannot distinguish low-mass stars from these galaxies, due to merging of them in the diagram (e.g. Kirkpatrick et al. 1999; Jarrett et al. 2000).

To highlight the expected location of Pleiades BDs in the colour–colour diagram, two theoretical isochrones for the Pleiades cluster are also plotted in Fig. 2; the dashed line is the 125-Myr isochrone of the NEXTGEN model (Baraffe et al. 1998), while the dot-dashed line is the 120-Myr isochrone of the DUSTY model (Chabrier et al. 2000; Baraffe, private communication for the 120-Myr model). The $I_C$ magnitudes of these models have been transformed on to our system using the following relation:

$$i' = I_C + 0.211(R_C - I_C) + 0.011(V - I_C)^2 - 0.003(V - I_C).$$

This transformation is derived via the Landolt system ($I_{lan}$); the transformation between $i'$ and $I_{lan}$ is from an INT web page,$^2$ and that between $I_{lan}$ and $I_C$ is from Bessell (1990). The NEXTGEN model is based on the non-grey dust-free atmosphere (Hauschildt, Allard & Baron 1999), and describes successfully various observed properties of early mid-M dwarfs, but predicts near-infrared colours that are too blue compared with the observed ones for cooler objects. The DUSTY model includes the effect of grain formation, i.e. (i) the photospheric depletion of dust-forming elements and (ii) scattering and absorption by dust, explaining successfully the near-infrared colours of the late M and L types with $1800 < T_{eff} < 2200$ K (e.g. Jameson et al. 2002). Because of the inadequacy of the NEXTGEN model in the cooler BD region, we have adopted the DUSTY model in the following discussion. Using near-infrared photometry and lithium tests of low-mass cluster members, Zapatero Osorio, Martin & Rebolo (1997b) estimated the stellar/substellar boundary to be located at an absolute magnitude of $(\sim 0.075 M_\odot)$ for Pleiades ($\sim 120$ Myr) to be at $M_I = 12.4$, $M_J = 10.0$ and $M_K = 9.0$ mag. This corresponds to the point ($i' - J$, $J - K$) = (2.9, 1.0) in our colour–colour diagram, highlighted by a cross, at approximately spectral type M6. 12 late-type field dwarfs from Dobbie et al. (2002a) were also plotted as asterisks. We adopt the redder side of the line running from the cross in parallel with the extinction vector as the location of Pleiades BDs in Fig. 2. Note that this location coincides with that of late-M and L-type field dwarfs. There remain 12 sources on the redder side of the line.

$^2$http://www.ast.cam.ac.uk/~wfcsur/photom.php
3.2 The colour–magnitude diagram

To separate Pleiades BDs from field dwarfs, we construct the colour–magnitude diagram ($J$, $i'$ − $K$). The 12 red objects selected by Fig. 2 are plotted in Fig. 3. The theoretical tracks representative of the low-mass stellar and substellar members of the Pleiades are also plotted; NEXTGEN model (Baraffe et al. 1998) and DUSTY model (Chabrier et al. 2000). We choose the $J$ magnitude as the ordinate of the diagram because $i'$ magnitudes of the red objects have larger errors and $K$ magnitudes are less sensitive to the mass difference on the theoretical tracks. The arrow at the upper right-hand corner indicates the reddening vector of $A_V = 3$ mag, which runs nearly in parallel with the tracks.

We adopt the distance modulus used by Dobbie et al. (2002b), $(m - M)_V = 5.53$, to estimate the ordinate displacement ($J$ magnitude) of the isochrone. Different age estimates (70–150 Myr) result in a displacement of $\sim -0.3$ and $\sim +0.1$ mag. Different distance estimates result in a displacement of $\sim -0.2$ mag ($Hipparcos$) and $\sim +0.1$ mag (photometry). The effect of the cluster depth results in a displacement of $\sim \pm 0.2$ mag. Additionally, location of unresolved binaries is by 0.75 mag above the single-star sequence (e.g. Pinfield et al. 2000). Accounting for all of these uncertainties and allowing for a small degree of error in both of the theoretical models and photometry, BDs belonging to the Pleiades cluster should be located between 0.3 mag below and 1.0 mag above the relevant single-star isochrone.

With these criteria, we identified four Pleiades BD candidates from 12 red objects. The remaining eight objects lie more than 1 mag below the isochrone in the colour–magnitude diagram, although they fall in the Pleiades BD domain in the colour–colour diagram. They could be late-M and L-type dwarfs lying in the background of the Pleiades. Finally, we list the four sources (PL– number of Fig. 3) as BD candidates from our five-colour survey. All of them are previously unpublished. The positions and magnitudes of four BD candidates are provided in Table 1, and those of the remaining eight objects are given in Table 2. Finding charts of four BD candidates are presented in Fig. 4.

4 DISCUSSION

4.1 Estimation of the BD candidate masses

To estimate masses of BD candidates from their observed magnitudes, we should determine the level of interstellar extinction towards them. The distribution of the background field stars in Fig. 2 indicates that the interstellar extinction in the surveyed portion of Pleiades ranges from 0 to 3 mag in $A_V$. The foreground extinction towards Pleiades is relatively uniform with a value of $A_V \sim 0.12$ mag, except for a region south of Merope, which contains a small molecular cloud (Crawford & Perry 1976). Because the cloud is assigned to be inside the cluster from polarimetry and reddening of the member stars and the field stars (Breger 1987), the extinctions estimated from background stars should be regarded as an upper limit for the BD candidates.

To estimate the maximum interstellar extinction for the individual BD candidates, we constructed an extinction map in the surveyed area from all the field stars (small dots between the two straight lines in Fig. 2), assuming them to be K- or M-type main-sequence stars (the thick line in Fig. 2). Visual extinction, $A_V$, towards each star was calculated from its $i' - J$ and $J - K$ colours with the
and the effect of the cluster depth contribute an additional error of 3. Note that uncertainties in the age and the distance of the cluster possibly we estimate the mass of the faintest candidate to lie in the range \(0.028 M_\odot\) – \(0.028 M_\odot\) for the case of no extinction and that of maximum possible extinction towards individual candidates are shown in Table 3.

The estimated maximum extinctions for individual candidates are shown in Fig. 3 with dotted arrows. If extinction is neglected, PL–2 and –3 are estimated to have \(M \sim 0.035 M_\odot\), similar to Roque25 (Martín et al. 1998) and int-pl-Iz-69, –81, –84 (Dobbie et al. 2002b), the coolest candidate members so far detected. On the other hand, assuming the maximum likely level of extinction, their masses are estimated to be \(M \sim 0.04 M_\odot\). Similarly we estimate the mass of the faintest candidate to lie in the range 0.033–0.028M_\odot. Therefore, PL–4 may be the lowest-mass member of the Pleiades identified to date. The estimated masses from \(J\) magnitudes for the case of no extinction and that of maximum possible extinction towards individual candidates are shown in Table 3. Note that uncertainties in the age and the distance of the cluster and the effect of the cluster depth contribute an additional error of 10–20 per cent in the mass estimation; e.g. the mass of PL–4 for the case of no extinction is \(0.028 \pm 0.002 M_\odot\). We note that our mass

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**Table 1.** The positions and magnitudes of new brown dwarf candidates.

| ID  | RA (h : m : s) | Dec. (\(\degr\) : \(\arcmin\) : \(\arcsec\)) | \(i'\) | \(Z\) | \(J\) | \(H\) | \(K\) | Name   |
|-----|---------------|---------------------------------------------|------|-----|------|------|------|--------|
| c06 | 03:45:50.6    | +23:44:37                                   | 20.02 ± 0.02 | 18.19 ± 0.01 | 16.34 ± 0.06 | 15.68 ± 0.07 | 15.19 ± 0.07 | PL–1   |
| c08 | 03:46:34.3    | +23:50:04                                   | 21.36 ± 0.06 | 19.52 ± 0.03 | 17.35 ± 0.06 | 16.63 ± 0.07 | 16.01 ± 0.08 | PL–2   |
| c10 | 03:45:11.7    | +23:41:44                                   | 21.98 ± 0.09 | 19.88 ± 0.05 | 17.59 ± 0.06 | 16.79 ± 0.07 | 16.13 ± 0.08 | PL–3   |
| c12 | 03:45:58.5    | +23:41:54                                   | 23.40 ± 0.20 | 21.69 ± 0.29 | 18.54 ± 0.08 | 17.42 ± 0.09 | 16.53 ± 0.09 | PL–4   |

**Table 2.** The positions and magnitudes of other red objects.

| ID  | RA (h : m : s) | Dec. (\(\degr\) : \(\arcmin\) : \(\arcsec\)) | \(i'\) | \(Z\) | \(J\) | \(H\) | \(K\) |
|-----|---------------|---------------------------------------------|------|-----|------|------|------|
| c01 | 03:46:24.9    | +23:46:10                                   | 22.28 ± 0.12 | 20.93 ± 0.13 | 19.30 ± 0.08 | 19.00 ± 0.12 | 18.28 ± 0.13 |
| c02 | 03:45:39.9    | +23:49:51                                   | 22.03 ± 0.11 | 20.45 ± 0.08 | 18.97 ± 0.07 | 18.32 ± 0.08 | 17.91 ± 0.09 |
| c03 | 03:45:59.7    | +23:40:53                                   | 22.33 ± 0.12 | 20.82 ± 0.12 | 18.93 ± 0.07 | 18.35 ± 0.08 | 17.89 ± 0.10 |
| c04 | 03:46:26.6    | +23:39:35                                   | 21.57 ± 0.07 | 20.14 ± 0.06 | 18.01 ± 0.06 | 17.22 ± 0.07 | 16.72 ± 0.08 |
| c05 | 03:46:28.0    | +23:42:39                                   | 22.19 ± 0.11 | 21.11 ± 0.15 | 18.60 ± 0.07 | 17.74 ± 0.08 | 17.29 ± 0.09 |
| c07 | 03:46:20.7    | +23:41:56                                   | 23.18 ± 0.35 | 22.18 ± 0.52 | 19.14 ± 0.08 | 18.75 ± 0.10 | 18.03 ± 0.11 |
| c09 | 03:45:50.9    | +23:44:57                                   | 22.65 ± 0.19 | 20.84 ± 0.13 | 18.63 ± 0.07 | 17.64 ± 0.08 | 17.08 ± 0.09 |
| c11 | 03:45:49.2    | +23:41:26                                   | 24.34 ± 0.40 | 21.93 ± 0.26 | 19.88 ± 0.10 | 18.78 ± 0.13 | 18.33 ± 0.14 |

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**Figure 4.** Finding charts for new brown dwarf candidates (\(Ks\) band). Each panel represents 2 × 2 arcmin², north is up, east is left.

**Figure 5.** The extinction map constructed from the \(J – K\) and \(i' – J\) colours of the point sources in the reddening band. Small dots are field stars and diamonds are BD candidates. Estimation of the extinction is described in Section 4.1. The correspondence between grey-scale and \(A_V\) is indicated in the scale bar.
Table 3. Mass estimates for brown dwarf candidates based on 120-Myr DUSTY model.

| Name | Max $A_V$ | $A_V = 0$ – Max | SpT |
|------|-----------|----------------|-----|
| PL−1 | 2.5       | 0.046–0.063    | M6–M8 |
| PL−2 | 2.0       | 0.035–0.040    | M8–L1 |
| PL−3 | 2.5       | 0.033–0.039    | M8–L1 |
| PL−4 | 3.5       | 0.028–0.033    | L1–L5 |

estimates would increase slightly if we were to take into account the missing M dwarf gap (Dobbie et al. 2002c).

4.2 Broad-band energy distributions

In Fig. 6 we compare the four SEDs with those of cool field dwarfs, determined in previous surveys (M6–M8: Kirkpatrick & McCarthy 1994; L0–L5; Kirkpatrick et al. 1999, 2000). Solid and dashed lines represent SEDs of the four BD candidates for the cases of no extinction and possible maximum extinction, respectively. M6–M8 and L0–L5 field dwarfs are overplotted with dotted lines.

4.3 Contamination of field stars

As discussed in Section 3.1, the optical and near-infrared colour-colour diagram allows us to separate distant galaxies and giants from BD candidates. However, field dwarfs are still possible sources of contamination.

The DUSTY model indicates that Pleiades BDs are overluminous with respect to field stars of similar spectral type by $\sim 1$ mag. The criterion of selecting objects between 0.3 mag below and 1.0 mag above the isochrone means that we are sensitive to single and binary dwarfs at distances of 71–130 and 96–184 pc, respectively. This corresponds to space volumes of 15.5 and 45.1 pc$^3$ for single and binary field stars, respectively. Assuming a space density of M8–L4.5 dwarfs of 0.0066 pc$^{-3}$ (Gizis et al. 2000) and a binary fraction of 50 per cent (e.g. Steele & Jameson 1995), we estimate the contamination of $\sim 0.2$ field star in our BD candidates. Thus, the level of contamination of the BD candidates by non-members is negligibly low.

4.4 The cluster luminosity function and mass function

We have derived the cluster luminosity function for $J$ magnitudes between 15.5 to 20.0, which correspond to the BD limit of Zapatero Osorio et al. (1997b) and the 90 per cent completeness limit of our survey (almost the same as the 10σ detection limit), respectively. In our calculation we assume that the interstellar extinction towards the Pleiades in our survey area is spatially uniform with the value of 1.5 mag at $V$ or 0.4 mag at $J$, we subdivided this magnitude range into 2-mag bins, given in Table 4.

Using the DUSTY model, we have calculated the masses corresponding to each of our luminosity bins. We estimated the total number, $N_{\text{annul}}$, of members of the whole cluster from the number of our sample. First, we calculate the number, $N_{\text{annul}}$, of members inside an annulus. Our survey area covers 7.7 per cent of the area of the annulus of an inner and an outer radius of $r_i = 0.26$ and $r_o = 0.64$, respectively (Fig. 1). $N_{\text{annul}}$ is calculated simply from the area ratio. Next, we calculate $N_{\text{total}}$. Pinfield et al. (1998) and Raboud & Mermilliod (1998) show that the surface density distribution of the Pleiades members can be well fitted by a King distribution (King 1962), for which the core radius increases as the stellar mass decreases. The following equation, which is obtained by integrating the function of the King distribution, provides the number of cluster members inside the circle of a radius $r$, $n(r) = \pi r^2 k \left[ \ln (1 + x) - 4 \sqrt{1 + x} - 1 \right]$, where $x = r/r_c^2$, $r_c = (r_c/\sigma) x$, $k$ is the surface density of the cluster, $r$ is the radius from the cluster centre, $r_c$ is the core radius at

Table 4. $N_{\text{total}}$ per unit mass (in the case of $A_V = 1.5$ mag).

| $J$ magnitude bin | Mass bin (M$_\odot$) | Mid-mass (M$_\odot$) | $N_{\text{obs}}$ | $N_{\text{annul}}$ | $N_{\text{total}}$ | $N_{\text{total}}$ per unit mass |
|------------------|---------------------|---------------------|-----------------|-----------------|-----------------|----------------------------------|
| 15.1–17.1        | 0.095–0.037         | 0.066               | 2               | 26              | 330             | 5700 ± 4000                     |
| 17.1–19.6        | 0.037–0.025         | 0.031               | 2               | 26              | 330             | 28000 ± 19000                   |
Brown dwarf search in Pleiades

5 CONCLUSIONS

We have undertaken an optical ($i'$, $z$) and near-infrared ($J$, $H$, $Ks$) survey of a $14 \times 23$ arcmin$^2$ area near the centre of the Pleiades cluster to search for brown dwarf members. We have unearthed four BD candidates (PL$-1$, $-2$, $-3$ and $-4$), out of 853 sources. PL$-1$ is likely to be an M-type BD, PL$-2$ and $-3$ are likely to be late-M or early-L type BDs, while PL$-4$ is probably an L-type BD. The estimated mass of our faintest candidate, PL$-4$, is in the range 0.028–0.033$M_{\odot}$, lower than that of Roque25 (Martín et al. 1998) and can be lower than that of int-pl-IZ-69 (Dobbie et al. 2002b), possibly making it lowest-mass Pleiad identified to date.

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