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A DEEP WISE SEARCH FOR VERY LATE TYPE OBJECTS

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RESUMEN

En este trabajo hemos explorado la base de datos WISE en todo el cielo, aplicando varios criterios de selección para obtener una muestra de objetos detectados únicamente en la banda W2 con baja señal a ruido (S/N≥8), candidatos a ser enanas tardías T y Y. Fuentes espurias fueron removidas usando los criterios de selección definidos a través de una muestra de control conformada por fuentes aisladas puntuales no-variables y sin movimiento del SDSS. Realizamos un seguimiento fotométrico en la banda J en telescopios de 4 a 8 metros, para confirmar el alto movimiento propio y baja temperatura de estos objetos. Espectroscopía de baja resolución en el cercano IR de las mejores candidatas ha confirmado unas pocas enanas tardías T (>T8) y una enana Y. Acá presentamos un resumen del seguimiento fotométrico y espectroscópico de las candidatas.

ABSTRACT

We have explored the WISE All-Sky database applying various selection criteria to obtain sample of $W2$-only detected and low signal-to-noise (S/N≥8) late T and Y dwarf candidates. Spurious sources were removed using database selection criteria defined through analysis of a control sample comprising isolated point-like non-variable non-moving sources from the SDSS. We perform J-band photometric follow-up on 4- to 8-m class telescopes to prove the high proper motion and low temperature of these objects. The low resolution near-IR spectroscopy of the best candidates has confirmed a few late T dwarfs (>T8) and one Y dwarf. Here we will present a summary of ground based photometric and spectroscopic follow-up of the candidates.

Key Words: brown dwarfs — stars: low-mass — surveys

1. INTRODUCTION

Brown dwarfs (BDs) are substellar mass objects ($\lesssim 0.75$ M$_\odot$) with very low surface temperatures (300 $\lesssim T_{\rm eff} \lesssim$ 2200 K) that are unable to sustain hydrogen fusion in their interiors and radiate gravitional contraction energy mostly in near- and mid-IR. Their spectra are dominated by H_2O, CO and CH_4 molecular bands absorbtion and rapidly change with decreasing temperature. Their standard spectral classsification now includes three additional classes L, T, and more recently Y. Very low luminosity (10^{-8}–$10^{-4} L_\odot$) makes BDs extremely difficult to detect. The first two unamiguous BDs were found almost simultaneusly by Rebolo et al. (1995) and Nakajima et al. (1995), 32 years after their theoretical prediction (Kumar 1963). Nowadays, thanks to near-IR detector development and large scale near-, mid-IR surveys (e.g. DENIS, 2MASS, UKIDSS and WISE) almost 1600 L-,T-,Y-type brown dwarfs have been confirmed (e.g. Mace 2014). The first Y dwarfs (e.g. Cushing et al. 2011; Kirkpatrick et al. 2011; Tinney et al. 2012) were identified quite recently with WISE, which is optimized to detect cool brown dwarfs. In particular $W1$ covers a deep CH_4 absorption band in the spectra of cool brown dwarfs, while $W2$ covers a spectral region of relatively low opacity. They present extremely red colours ($J - W2 > 4$) and $J - H$ indicates a reverse of the previously known colour trend of dwarfs (for bluer $J - H$).

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2. SEARCH METHOD

The search method identified WISE All-Sky sources detected in the $W2$-band only, and probed down to low signal-to-noise levels S/N $\gtrsim$ 8, targeting objects with faint $W2$ magnitudes and red $W1-W2$ colour. Spurious sources were removed using database selection criteria defined through analysis of a control sample comprising isolated point-like, non-variable, non-moving sources from the SDSS. A brief summary of the selection and rejection criteria is given below (more details see Pinfield et al. 2014a):

• Select sources detected only in the W2 band with S/N≥8. Require at least 8 individual exposures (in all bands) covering the sky position.

- The line of sight extinction must be $A_V < 0.8$ to remove reddened contamination.
- Reject non-point-like sources for which the reduced χ^2 of the $W2$ profile fit photometry was larger than 1.2.
- Reject sources for which the scatter in the multiple mea- surement photometry was higher than expected from the integrated flux uncertainty.
- Reject sources for which the number of detections in the individual $W2$ frames was less than expected.
- Reject faint sources ($W2$ signal-to-noise from 8-10) within extended bright star halo regions, by comparing with 2MASS point-source-catalogue positions (see figure 2 of Pinfield et al. 2014a).
- Select final candidates by visual inspection, rejecting artifacts, resolved extended structures (e.g. nebulosity and galaxies), badly blended sources, and sources with visual $W1$, $W3$ or $W4$ detections.

We identify 158 candidate late objects. Twenty eight of these sources are previously identified T5-Y dwarfs from the literature (Burningham et al. 2010; Kirkpatrick et al. 2012; Lodieu et al. 2012). The dominant magnitude range for the new sample is $W2 = 15 - 16$, where we find 116 sources. Our sample also contains 25 sources fainter than $W2 = 16$.

3. FOLLOW-UP

We initially followed-up our WISE candidates using J-band imaging from survey data (UKIDSS, UHS, VISTA) as well as targeted observations using Magellan, Gemini North and South, UKIRT and NTT. This allowed us to identify mid T dwarfs and spurious highly reddened sources with $J - W2 < 4$ (accounting for ∼20% of our sample). J-detected candidates $J - W2 > 4$ may be T8 or later or later (e.g. fig 7 of Kirkpatrick et al. 2011). For these we measured additional photometry in the H-band and/or $J3 + J2$-bands (Magellan filters designed to measure the strength of methane absorption in the J-band). We then assess $J - H$ colour which is blue for most Y dwarfs (e.g. fig. 7 of Kirkpatrick et al. 2012), and/or $J3 - J2$ which should be < -0.5 for late T and Y dwarfs (see Tinney et al. 2012). Proper motion measurements were also obtained where a suitable epoch difference was available (see Fig 1).

Contamination from galaxies and young stellar objects was thus identified (∼20% of sample), with good candidates fed through for spectroscopy (∼10% of sample) using FIRE/Magellan and GNIRS+FLAMINGOS2/Gemini. We could also obtain near-infrared spectroscopy to J∼22 or $J - [4.5] = 6 - 7$ (*i.e.* for typical early Y dwarfs). An example spectrum (of our first Y dwarf) is shown on Fig 2. We founnd that ∼ 50% of our sample were un-detected in the initial J-band imaging, and these (along with confirmed T8–Y dwarfs) are being targeted by our Spitzer follow-up.

4. SUMMARY

To date we have spectroscopically confirmed seven T8-Y0 dwarfs.

This includes one Y dwarf, which shows peculiar spectral morphology and could be the first Y0 dwarf that is a member of the old Disk (Pinfield et al. 2014b). We have also published a T8 and a T9 with Thick-Disk/Halo kinematics(Pinfield et al. 2014a), and have spectroscopically confirmed 3 additional T8-9 dwarfs, one of which is the most K-band suppressed late T dwarf yet found, and another also has Thick-Disk/Halo kinematics (Pinfield et al. and Gromadzki et al. in prep). In addition we have 3 strong photometric candidates waiting for spectroscopic follow-up.

We are also creating a new larger candidate sample using an improved version of our original selection method, which we now apply to the AllWISE database. This method is sensitive to moving as well as stationary objects, and reaches down to significantly fainter limits than have been previously attempted. As the WISE mission continues, and new data products emerge, the sensitivity of our new method will continue to improve.

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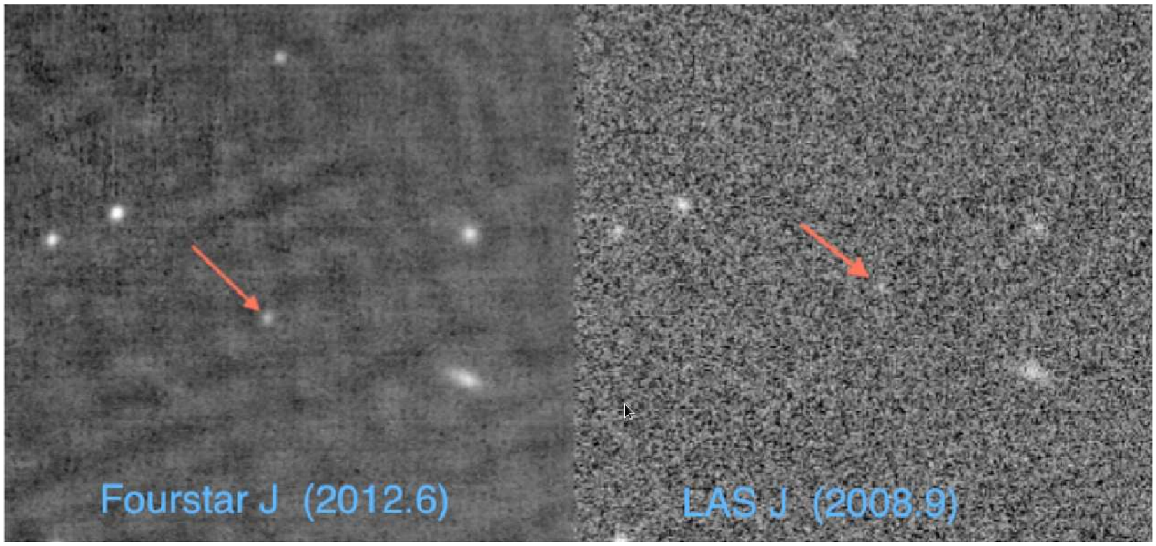

Fig. 1. J-band images of WISE 0013+0634. The left plot was taken by the Magellan Four Star and the right one by UKIDSS LAS. The epoch difference between these two images is 3.7 yr. The object is indicated in each image by a red arrow. Plot taken from (Pinfield et al. 2014a).

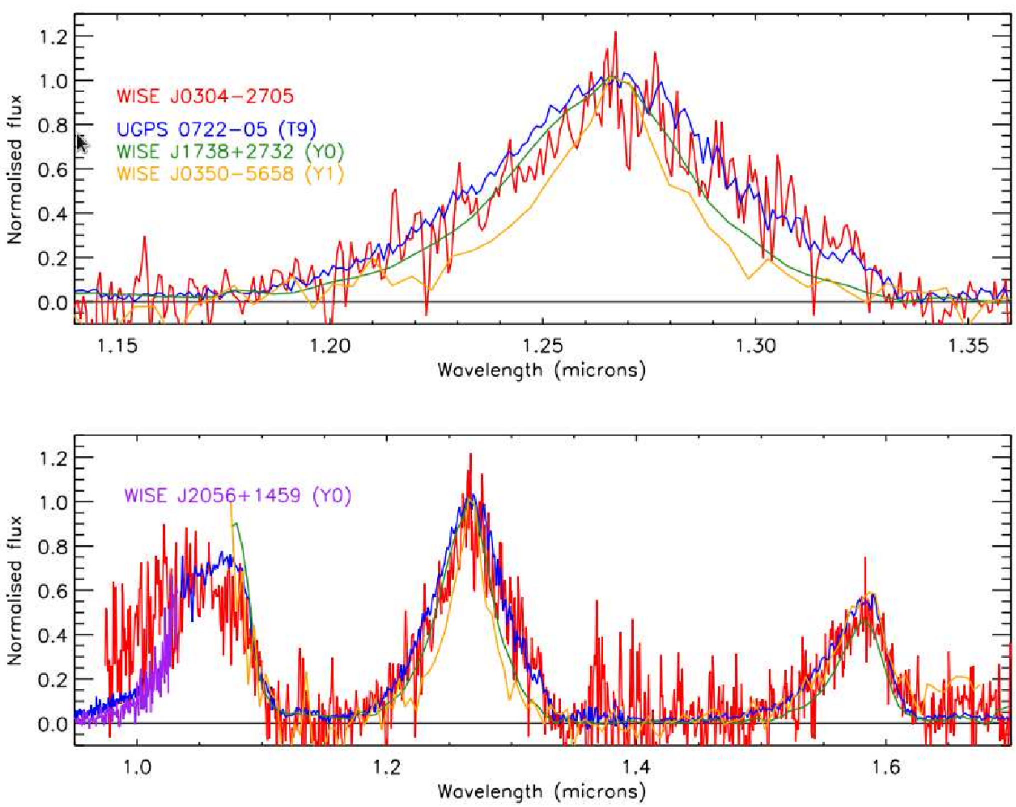

Fig. 2. The near-IR Gemini South Flamingos-2 spectrum of WISE J0304-2705. The top plot shows the J-band region, and the lower plot the full YJH range. Several spectra are over-plotted for comparison: UGPS 0722-05 (T9), WISE J1738+2732 (Y0), WISE J0350-5658 (Y1), and red-optical WISE J2056+1459 (Y0). All spectra are normalised to an average of unity from 1.265-1.270 μm. Plot taken from (Pinfield et al. 2014b).

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