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Confirming ultra-cool companions to Mdwarfs using low-resolution near-infrared-spectra

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Abstract. To confirm ultra-cool dwarf companions to M dwarfs, we present a method using low-resolution near-infrared spectra. Observing the candidate spectra along with known colour-similar "control" M dwarf spectra we discuss a method in which to confirm or reject a candidate based on a residual spectral difference approach. Using simulations we validate this method and suggest tailored spectral bands. We suggest low-resolution near-infrared follow-up of these candidates and their control M dwarfs in order to reject M dwarfs with no companion and thus produce candidates for full confirmation via adaptive optics, radial velocities, and light curves (for transit) where appropriate.

Key words. Stars: Ultra-Cool dwarf Companions – Stars: M dwarfs – Method: Low-Resolution Near-infrared Follow-up

1. Introduction

Presented in Cook et al. (2013) and (Cook et al. 2014, *in prep.)*, henceforth papers 1 and 2, are a set of candidates for ultra-cool dwarf (UCD) companions to M dwarfs. Using near-minus-mid infrared excess in colour the M dwarfs were selected as good candidates for further follow-up and confirmation. However as stated in Paper 1 there is high contamination and this method will only work for primaries of spectral type M3 or later and for companions of spectral type L1 to L5 (Paper 2).

Before full confirmation via adaptive optics, radial velocities, and light curves (for transit) is possible, contamination must be reduced. Using the cuts mentioned in Papers 1 and 2 there is no way to remove certain forms of contamination, such as very dusty M dwarfs or short term variability.

To resolve this we suggest that low-resolution near-infrared spectra would be ideal for reducing contamination for these and other sources by specifically picking out UCD spectroscopic features. Using simulations we validate this method and suggest tailored spectral bands. We suggest low-resolution near-infrared follow-up of these candidates and their control M dwarfs in order to reject M dwarfs with no observable signature of a companion. In this proceedings we briefly describe the method and use simulations to verify the suitability of this method.

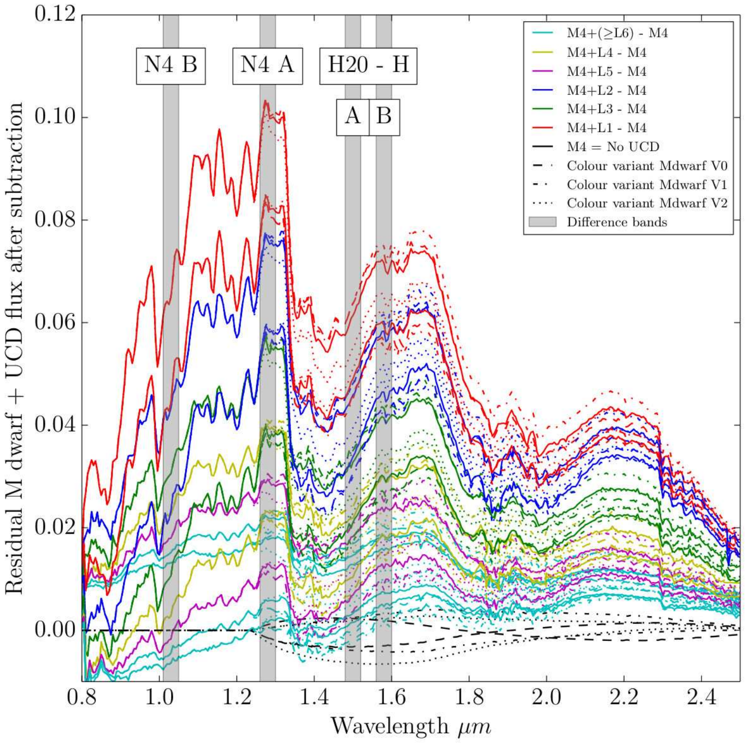

Fig. 1. Using M dwarf spectra from Burgasser et al. (2004) and the NASA Infrared Telescope Facility Spectral Library. We simulated small colour variations in the M dwarfs (Black broken curves, different variations shown with varying line style) and combined these with UCD spectra from the SpeX 'L Dwarf Optical Standards' (Burgasser et al. 2004; Burgasser & McElwain 2006; Burgasser et al. 2007, 2010) (Different subtype UCD spectra shown in different colours, from top to bottom L1, L2, L3, L4, L5, L6 and no UCD). The residual M dwarf + UCD spectra are shown after subtraction. Plotted in grey are the two sets of bands chosen to identify the UCDs from the residual spectra; ($H_20 - H$ and $N4$) *Band A* − *Band B*, see section 2.2.

2. Spectroscopic signatures of unresolved companions

2.1. Spectral simulation

We developed a method that required only low-resolution spectra that could be used on all the candidates with infrared excess. To achieve this we decided to compare the normalised spectra (between 0.8 μm and 2.5 μm) of the excess candidates to that of the normalised spectra of known M dwarfs (initially from the Gliese Catalogue; Gliese & Jahreiß 1991) with very similar near-infrared colours (here after the control spectra), observed at a similar time and similar airmass.

To investigate the feasibility we used spectra from the SpeX Prism Spectral Libraries (Mdwarf spectra from Burgasser et al. 2004) and the NASA Infrared Telescope Facility Spectral Library (M dwarf spectra from Rayner et al. 2003, 2009; Cushing et al. 2005).

The original spectra were then modified by a slight colour difference in $V-J$, $J-H$ and $H-K$ such that the original and modified M dwarfs are colour-similar, using the same definition of colour-similar to that defined by Paper 1. The

Table 1. Table of bands used for UCD identification, difference spectra is the constructed from $f_{tot}(A)$ - $f_{tot}(B)$, where $f_{tot}(X)$ is the integrated flux between X_0 to X_1. [1] From Burgasser et al. (2010). [2] Custom bands based on those of Burgasser et al. (2010). The band starting and ending points were then modified to optimise the difference in UCD features while avoiding known telluric features (see figure 1).

Band	A_0	A_1	B_0	B_1
$H_20 - J^1$	1.140	1.165	1.260	1.285
$CH_4 - J^1$	1.315	1.340	1.260	1.285
$H_20 - H^1$	1.480	1.520	1.560	1.600
$CH_4 - H^1$	1.635	1.675	1.560	1.600
$H_20 - K^1$	1.975	1.995	2.080	2.100
$CH_4 - K^1$	2.215	2.255	2.080	2.120
N1^2	1.260	1.285	1.480	1.520
N2^2	1.635	1.675	1.480	1.520
N3^2	1.260	1.300	1.450	1.520
N4^2	1.260	1.300	1.010	1.050

modified and original (Spex) spectra became our simulated control spectra.

Adding UCDs (UCD spectra from SpeX ‘L Dwarf Optical Standards’; Burgasser et al. 2004; Burgasser & McElwain 2006; Burgasser et al. 2007, 2010) to these control spectra gave our simulated excess candidates.

We then subtracted our excess candidates from the control spectra and the left-over ‘noise’ was analysed for a possible companion signature (see Figure 1). These were then compared to our control spectra subtracted from other control spectra (to identify the contribution due to the colour differences between control spectra).

This assumes that the control spectra themselves do not have companions and given a binary (M dwarf - UCD) fraction of no higher than 10% it was decided that as long as each excess candidate was matched with ~3 or more control spectra that the chances of all three control spectra M dwarfs with UCD companions was small. Note that a normalised M dwarf-M dwarf spectra would for our purposes look very similar to a isolated M dwarf given the similar colour required and that near-infrared colours to not vary substantially for M dwarf-UCD systems (see Paper 1).

2.2. Band selection

One may be able to identify a companion UCD better from our “noisy” subtraction, however in many cases a UCD will be hard to identify. The intrinsic scatter in colour of M dwarfs in addition to other sources of excess contamination leads our observed subtractions to have a considerable amount of noise over that of our simulations. Spectral ratios have been used to identify binaries such as brown dwarf binaries (Burgasser et al. 2010). However because we are analysing subtractions, with non-detections having little-to-no flux at certain wavelengths (and hence extremely small denominators leading to very large indices) we chose to use the difference in scale height between a peak and trough of a UCD’s spectral features. Using our simulated M dwarf-UCD systems, bands were chosen using various combinations of near-infrared features, using the Burgasser et al. (2010) bands as a starting point, see table 1.

From these bands $H_20 - H$ (1.48 - 1.52 μm and 1.56 - 1.6 μm) and $N4$ (1.26 - 1.3 and 1.01 - 1.05 μm) were selected as giving the best detection results, see Figures 2 and 3. From this it was possible to define a UCD detection limit, if after this process a candidate has a spectral difference dissimilar from the case where we have no UCD (black lines Figures 2 and 3, then the candidate is deemed a viable companion candidate for higher resolution follow-up.

3. Summary

The simulations in Section 2 show that if we can obtain low-resolution near-infrared spectra for an excess candidate with several “control” colour-similar M dwarfs it may be possible to greatly reduce contamination in the excess candidates presented by Paper 1. We suggest a full low-resolution follow-up campaign for those candidates in order to select the best candidates for higher resolution follow-up including adaptive optics, radial velocities, and light curves (for transit) where appropriate.

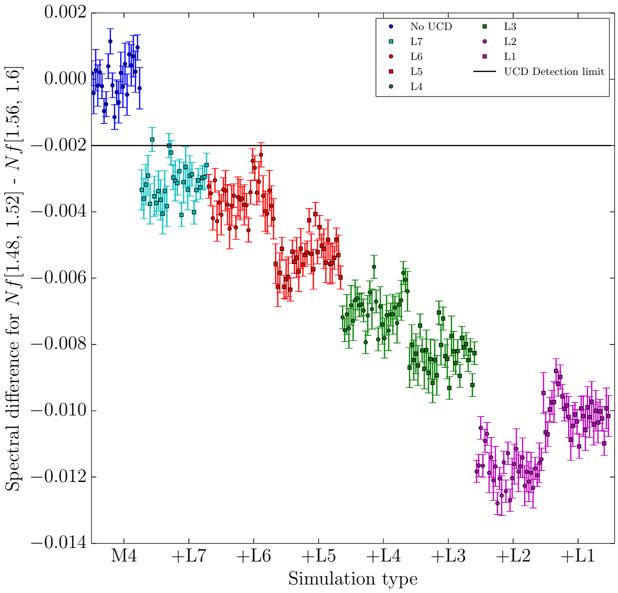

Fig. 2. The spectral difference obtained from taking the difference of the normalised flux, Nf, in band A and band B for H_20-H (1.48 - 1.52 μm and 1.56 - 1.6 μm), black line is the UCD detection limit, if after this process a candidate has a spectral difference dissimilar from the case where we have no UCD, then the candidate is deemed a viable companion candidate. M dwarfs with no UCD tend to scatter around zero, as expected. UCD's of increasing spectra type (L7 through to L1) add more on the earlier the spectral type is. For H_20-H the trend is negative due to a trough minus a peak selction and a candidate will fall below the black line.

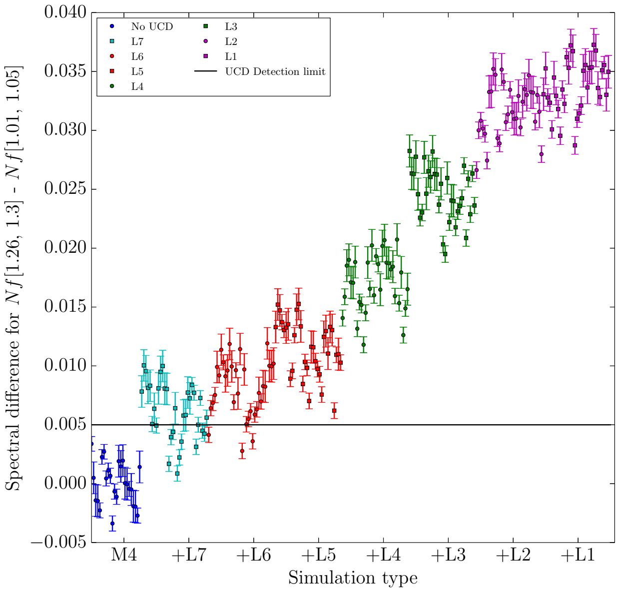

Fig. 3. Spectral difference obtained for $N4$ (1.26 - 1.3 and 1.01 - 1.05 μm), format the same as Figure 2. For $N4$ the trend is positive due to a peak minus trough selction and a candidate will fall above the black line.

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