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The discovery of the peculiar L dwarf ULAS J222711−004547

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Abstract. We present the discovery of a very peculiar L dwarf from the UKIDSS Large Area Survey (LAS), ULAS J222711−004547. Its very red infrared colours (MKO $J - K$ = 2.79) make it the reddest brown dwarf discovered so far. The object was discovered as part of a large spectroscopic campaign aimed at constraining the sub-stellar birth rate. We obtained a moderate resolution spectrum of this target using the echelle spectrograph XSHOOTER on VLT/UT2, and classified it as L7pec, confirming its very red nature. We show that applying a simple de-reddening curve to the spectrum of ULAS J222711−004547, this becomes very similar to the spectrum of a L7 spectroscopic standard. Therefore we conclude that the reddening of the spectrum is mostly due to an excess of dust in the photosphere of the object. This new discovery joins the list of unusually red L dwarfs, whose nature is not yet fully understood, and poses a new important challenge to atmospheric modeling of substellar objects.

Key words. brown dwarfs - stars: individual (ULAS J222711-004547)

1. Introduction

Young brown dwarfs have low surface gravity, as they have not contracted yet to their final radii. This results in peaked H-band infrared spectra and a general flux excess towards longer wavelengths (e.g. Lucas et al. 2001). Young brown dwarfs therefore appear very red in terms of infra-red colours. However recent kinematic studies (e.g. Kirkpatrick et al. 2010; Faherty et al. 2012) have suggested that field objects showing signs of youth in their spectra could instead be relatively old. Their peculiarity could be caused by an excess of dust in their photospheres due to a higher than average metallicity (Cushing et al. 2008). These objects are referred to as "unusually red L dwarfs" (URLs; e.g. Gizis et al. 2012).

Here we present the discovery of the unusually red L dwarf ULAS J222711-004547 (hereafter ULAS2227). This object is the reddest brown dwarf observed to date, with MKO $J - K$ = 2.79 corresponding to 2MASS $J - K \sim$ 3.04 (Figure 1). This object was identified as part of a large spectroscopic campaign to determine the sub-stellar birth rate (Day-Jones et al. 2013).

2. Spectroscopy

We obtained an optical + near-infrared spectrum of ULAS2227 using VLT/Xshooter and

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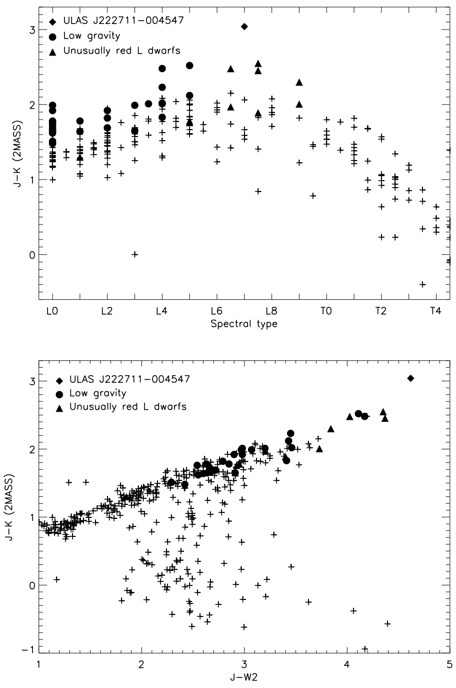

Fig. 1. *Top:* Colour – spectral type diagram. ULAS2227 is almost 0.5 mags redder than any other know late-L dwarf. *Bottom:* Colour – colour diagram. ULAS2227 represents the most extreme turning point of the spectral sequence.

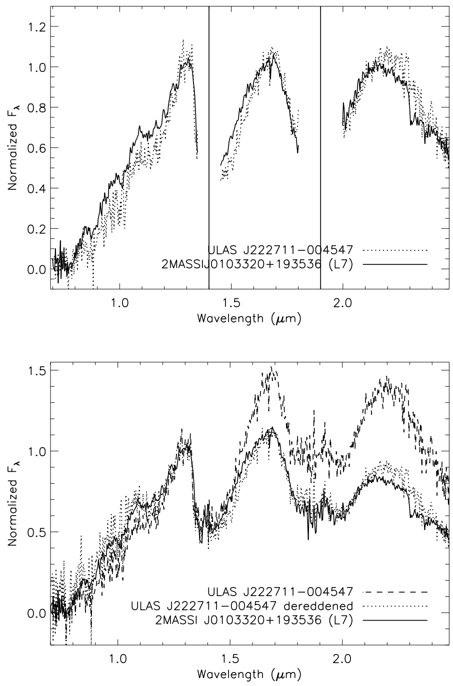

Fig. 2. *Top:* The spectrum of ULAS2227 compared to the L7 standard 2MASSI J0103320+193536. Both spectra are normalized to 1 in each part. *Bottom:* The spectrum of ULAS2227 de-reddened using the parameterization from Fitzpatrick (1999) compared to the L7 standard 2MASSI J0103320+193536. The best fit is given by a reddening of E(B-V) = 1.1.

classified it as L7pec based on spectral fitting. We split the spectrum of the target into three parts (optical + *J*-band, *H*-band, and *K*-band) and separately normalized them to one at their peaks. We then fit each part with the spectroscopic standard templates (taken from the SpeX Prism Spectral libraries) normalized in the same way. In each part the best-fit standard is the L7 dwarf 2MASSI J0103320+193536 (Figure 2, top panel). If we compare the entire spectra normalizing both of them in the *J*-band, we can see that ULAS2227 is much redder than the standard in the *H* and *K*-band, and its optical and *J*-band spectrum is much smoother than the standard (Figure 2, bottom panel).

We de-reddened the spectrum of ULAS2227 using the reddening curve from Fitzpatrick (1999). We find that with a colour excess of E(B-V) = 1.1 the spectrum of ULAS2227 matches well the spectrum of the L7 standard 2MASSI J0103320+193536 (Figure 2, bottom panel). However there still remain several discrepancies, such as the "peakiness" of the *H*-band and a flux excess at wavelengths longer than 2.2 μm.

3. Astrometry

We calculated the proper motion of ULAS2227 using its 2MASS *K*-band, UKIDSS *K*-band and *WISE* W2 images, measuring $\mu_\alpha cos\delta$ = 100 ± 16 mas yr^{-1} and μ_δ = -30 ± 16 mas yr^{-1}. We estimated the photometric distance to the target using the polynomial calibrations presented in Dupuy & Liu (2012) and obtained a distance range of 30 – 70 pc. Given these values and using the convergent point method (de Bruijne 1999), we find ULAS2227 is unlikely to be a member of any young moving group.

4. Model fitting

We fit the spectrum of ULAS2227 with different sets of atmospheric models (Figure 3). We used the BT-Dusty and BT-Settl models (Allard et al. 2011), the A and AE models (Madhusudhan et al. 2011), and the UCM models (Tsuji 2005). For each set of models we select the best-fit parameters via χ^2 fitting.

The BT-Dusty and BT-Settl models fail to reproduce properly the depth of the water absorption band at $1.4\,\mu$m, but fits appropriately the peakiness of the H-band and its flux level. The A and AE models overestimate the flux in the blue part of the spectrum and do not reproduce properly the shape of the H and K-band. The strength of the CO absorption is overestimated. The UCM models reproduce properly the shape and flux level of the near-infrared part of the spectrum. The optical part however is too smooth compared to ULAS2227.

All the models suggest a low gravity nature for ULAS2227, and the remaining discrepancies with the observed spectrum could be due to a higher than solar metallicity, causing an excess of dust in the photosphere of the target.

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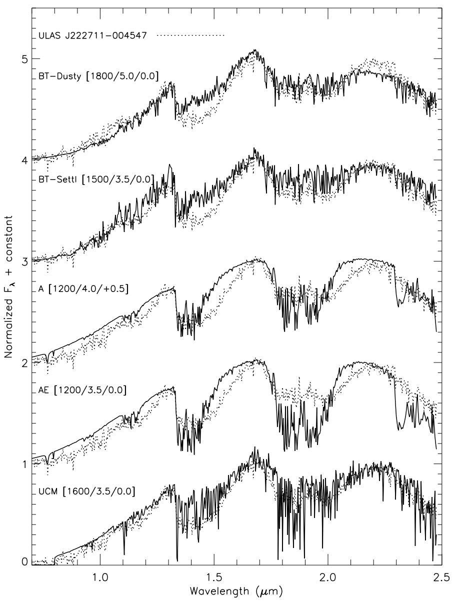

Fig. 3. The spectrum of ULAS2227 compared to atmospheric models. The models used are the BT-Dusty and BT-Settl (Allard et al. 2011), the A and AE models (Madhusudhan et al. 2011) and the UCM (Tsuji 2005).

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