ULAS J222711-004547
Dominated by dust

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IPERCOOL

Interpretation and Parameterization of Extremely Red COOL dwarfs

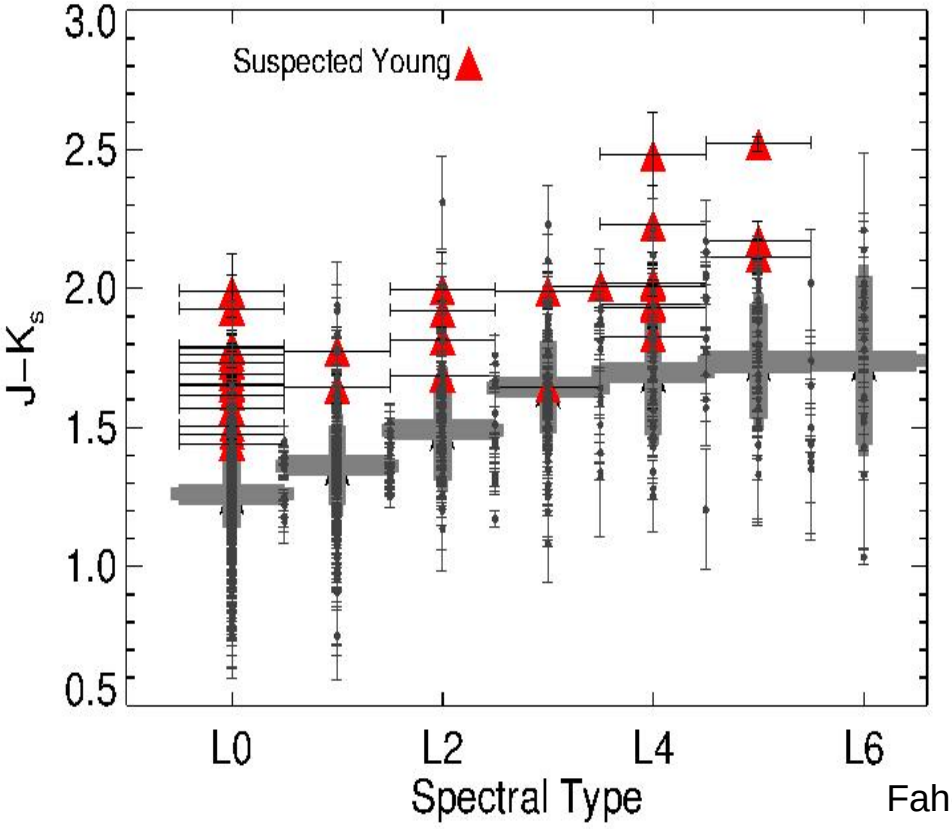
University of Hertfordshire

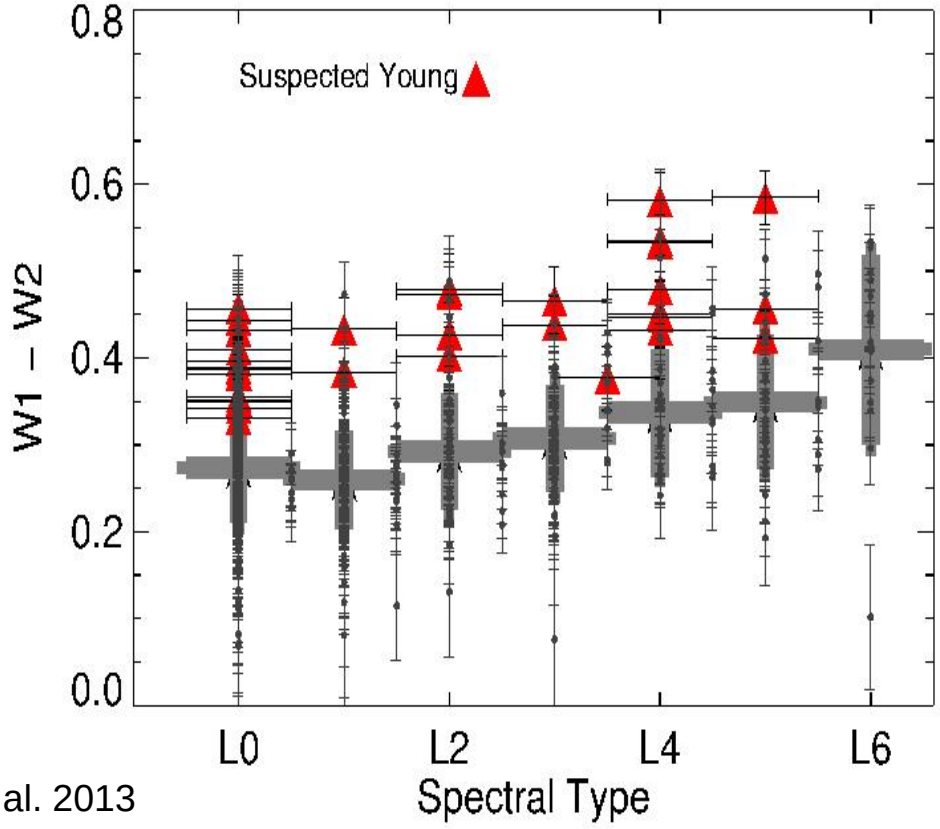
Introduction

Brown dwarfs do not form a “Main Sequence”.

Because of the mass-age-luminosity degeneracy objects of similar spectral type can have very different physical properties (e.g. age, mass, metallicity, surface gravity)

The wide range of parameters covered is reflected by the NIR colours.





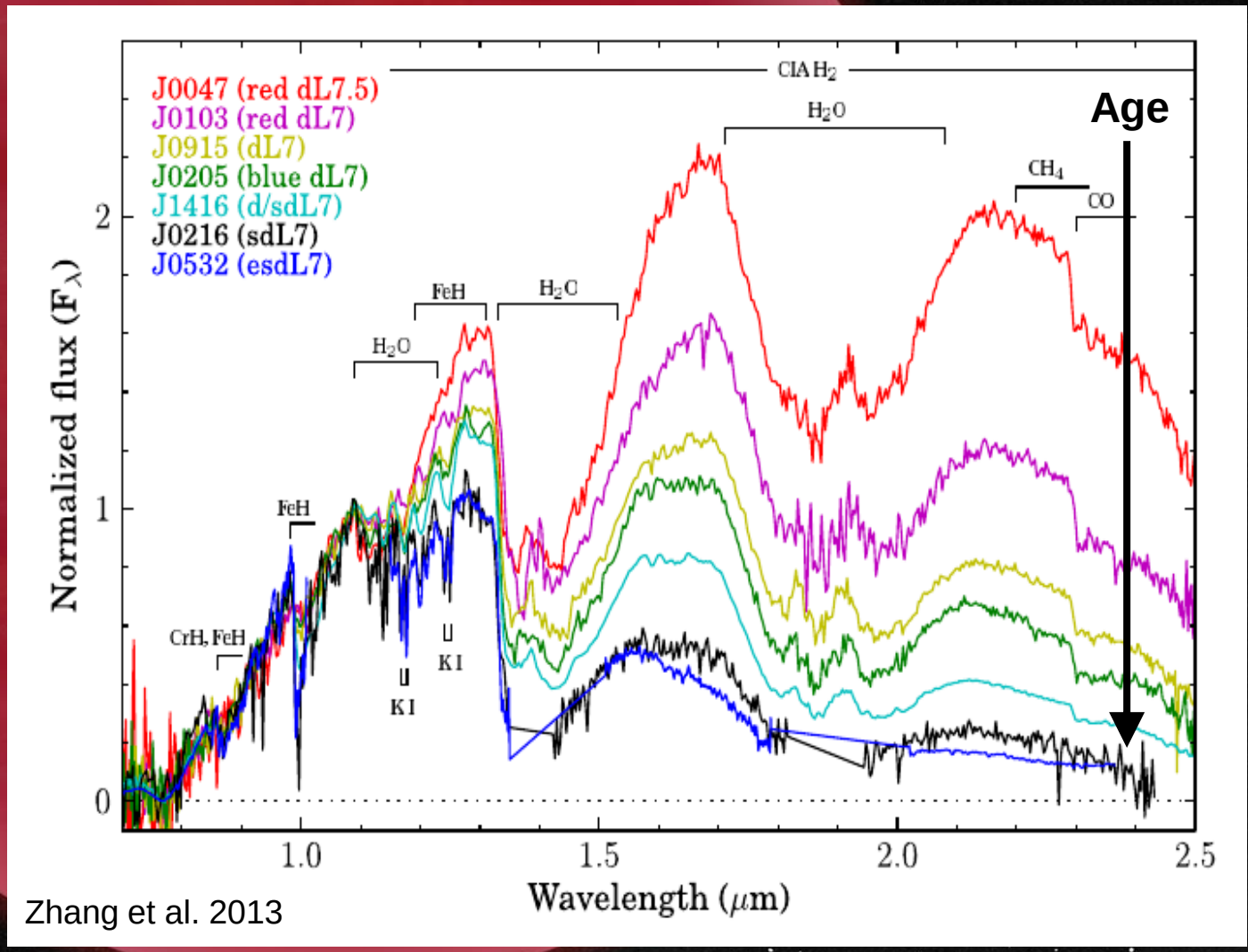
Faherty et al. 2013

Introduction

The same effect can be seen in the spectra.

The huge differences in the NIR spectra of these late Ls are due to the large spread in ages sampled, from the very blue esdL7 to the very red dL7.5.

However, as usual there are exceptions...



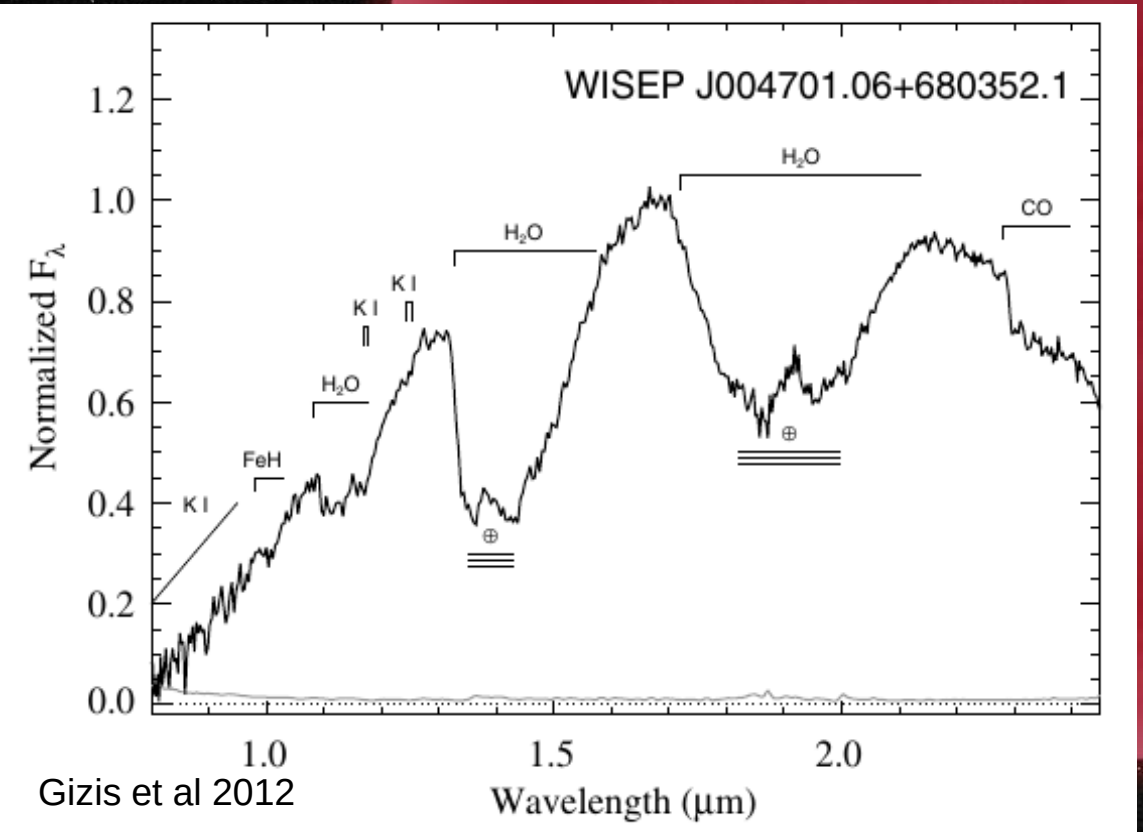
Zhang et al. 2013

Unusually red L dwarfs

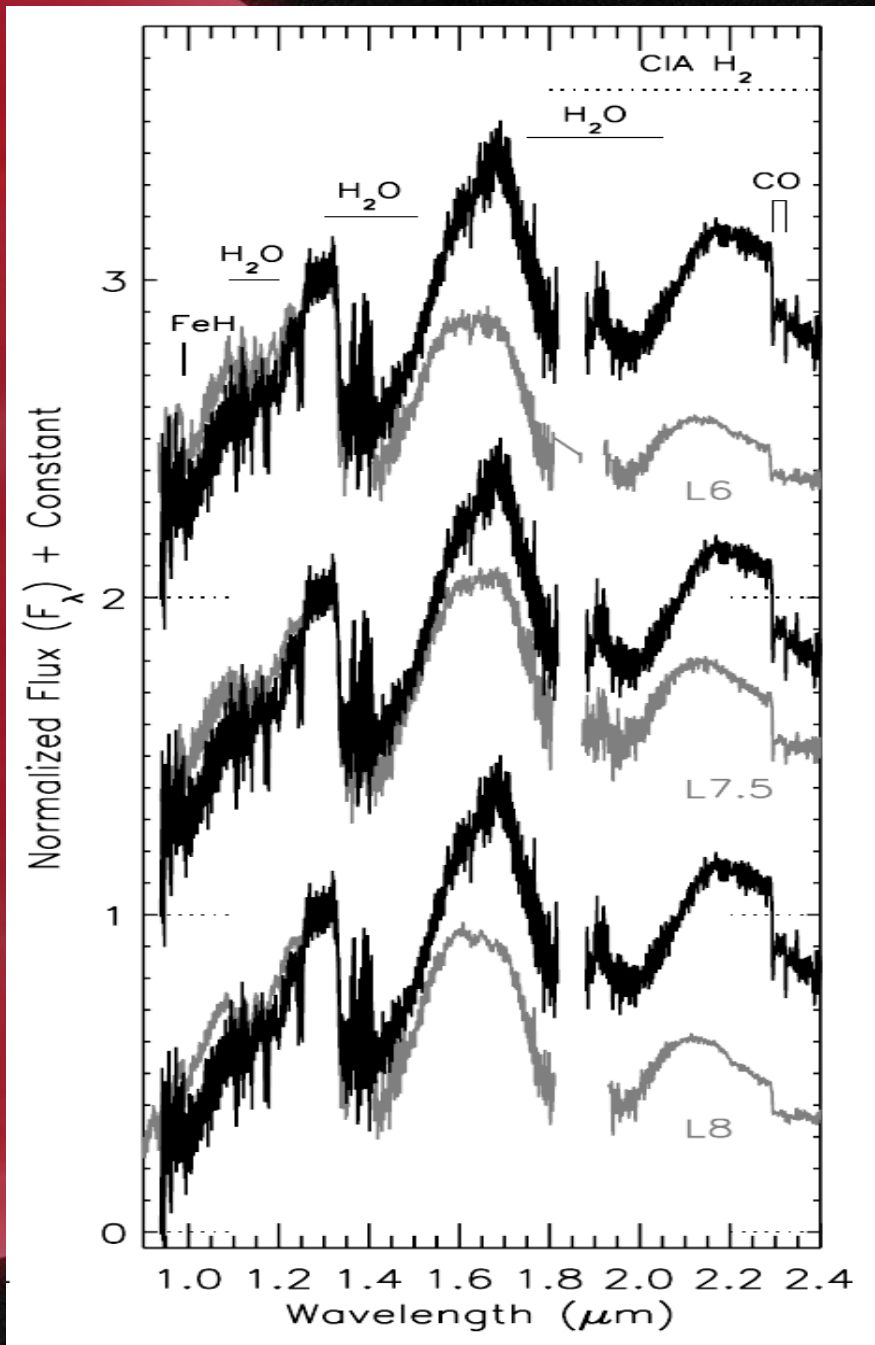
Looper et al 2008

There is infact a category of L dwarfs with very red NIR colours and spectra, that do not appear to be particularly young (e.g. Kirkpatrick et al. 2010).

Low gravity is not sufficient to explain their peculiar colours (e.g. Allers & Liu 2013).

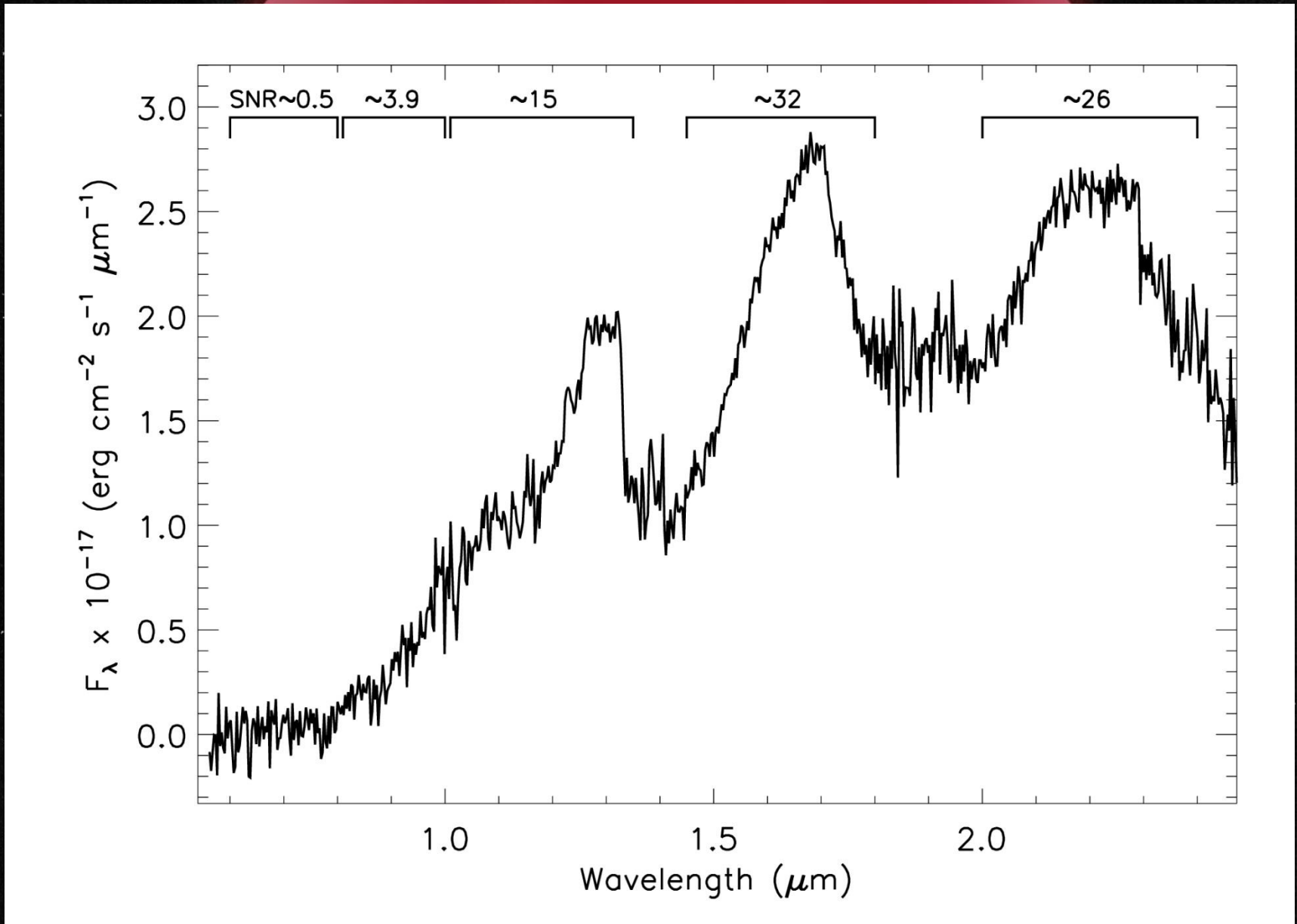


Gizis et al 2012



ULAS J2227-0045

One of the most extreme URLs is ULAS J2227-0045, with MKO J-K= 2.79.

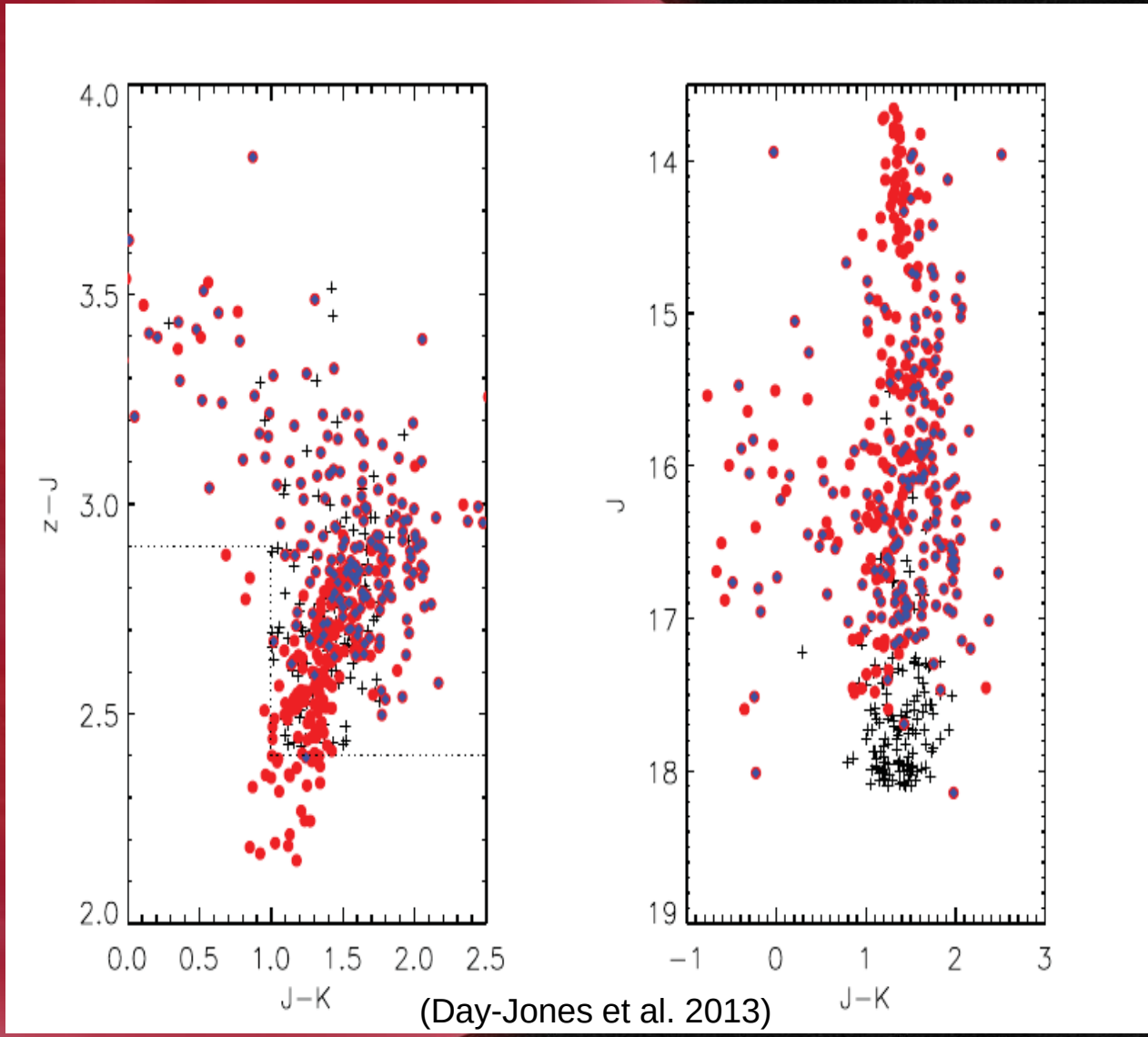


Candidates Selection

ULAS J2227-0045 comes out of a Large sample of L and T dwarf candidates, selected from the UKIDSS LAS DR7 (Day-Jones et al. 2013).

Criteria:
- J <= 18.1
- Y-J >= 0.8
- z-J >= 2.4 and J-K >= 1.0
  OR
  z-J >= 2.9 and J-K < 1.0
- i-z > 2.0
- i-J > 4.7
- z-K > 3.5 and J-K < 1.0

Final candidates list: 263 objects, to be followed-up with X-shooter



(Day-Jones et al. 2013)

Spectroscopic follow-up

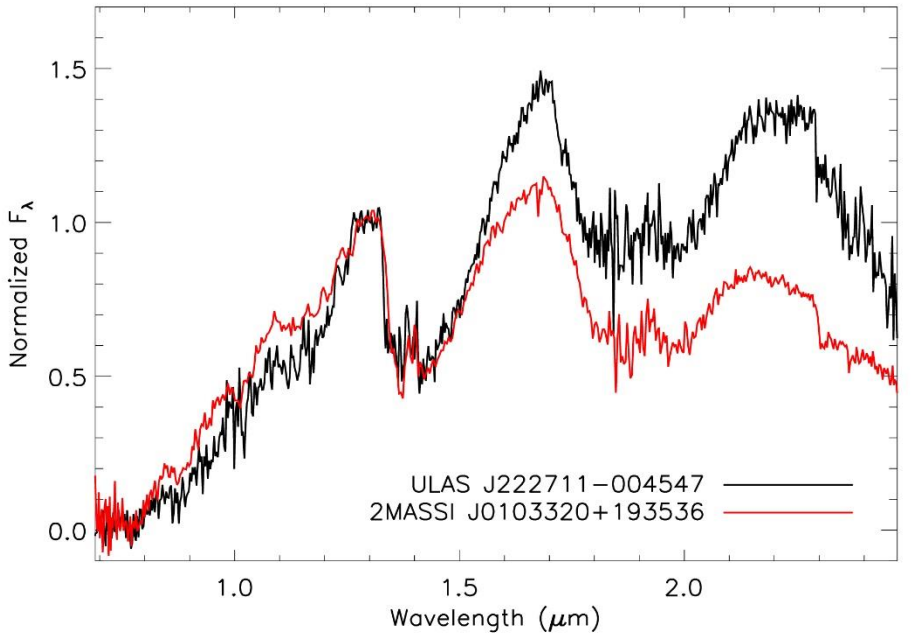
We obtained a optical+NIR spectrum using VLT/Xshooter.

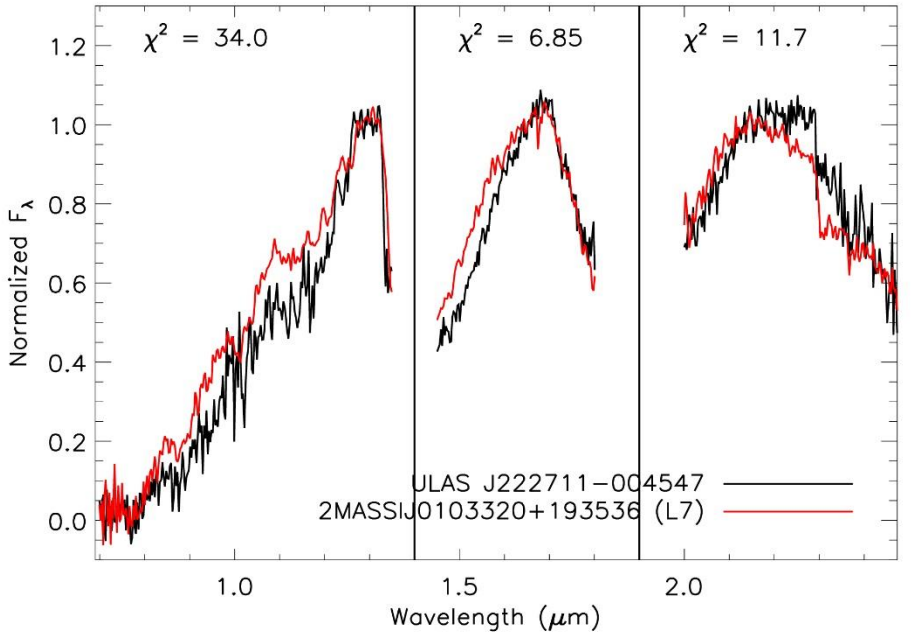
Very red spectrum, peaks in the H band.

We classify this object L7 via spectral fitting.

We split the spectrum in three parts (optical+J, H and K band) and separately normalize them to remove the “red excess”, then we fit it to the spectroscopic standards (Burgasser et al. 2006; Kirkpatrick et al. 2010).

When compared directly to the standard, ULAS J2227-0045 show a massive H and K band “excess”





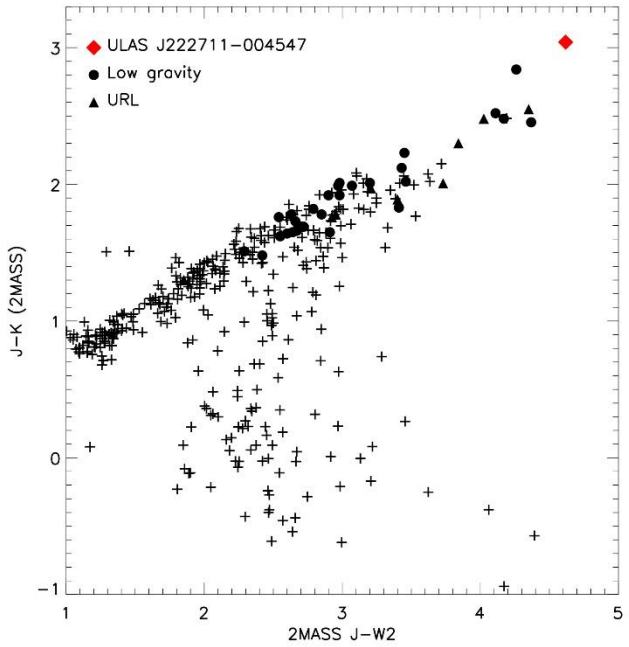
Photometry

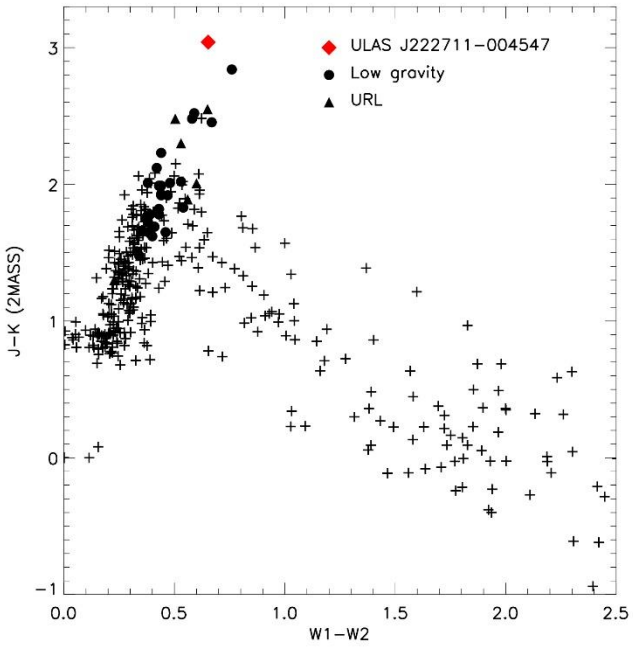
ULAS J2227-0045 is detected in UKIDSS, WISE and 2MASS (H and K band only):

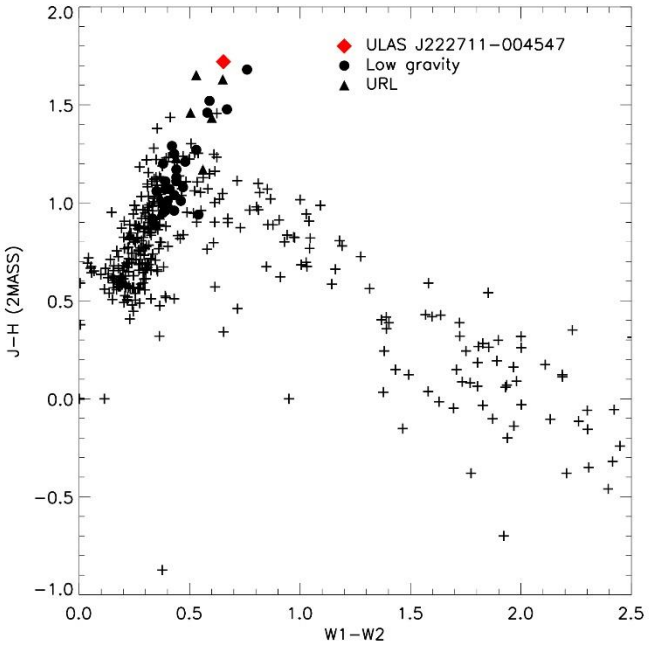
MKO J = 18.11
MKO J-K= 2.79
2MASS J-K= 3.04
J-W2= 4.47
W1-W2= 0.653

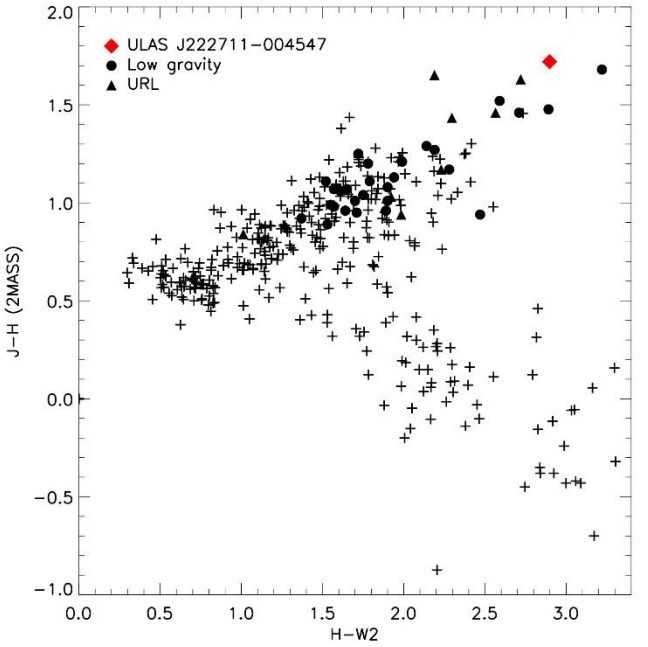
The object marks an extreme in the L-T sequence.

The peculiarity is more prominent in the NIR than in MIR.







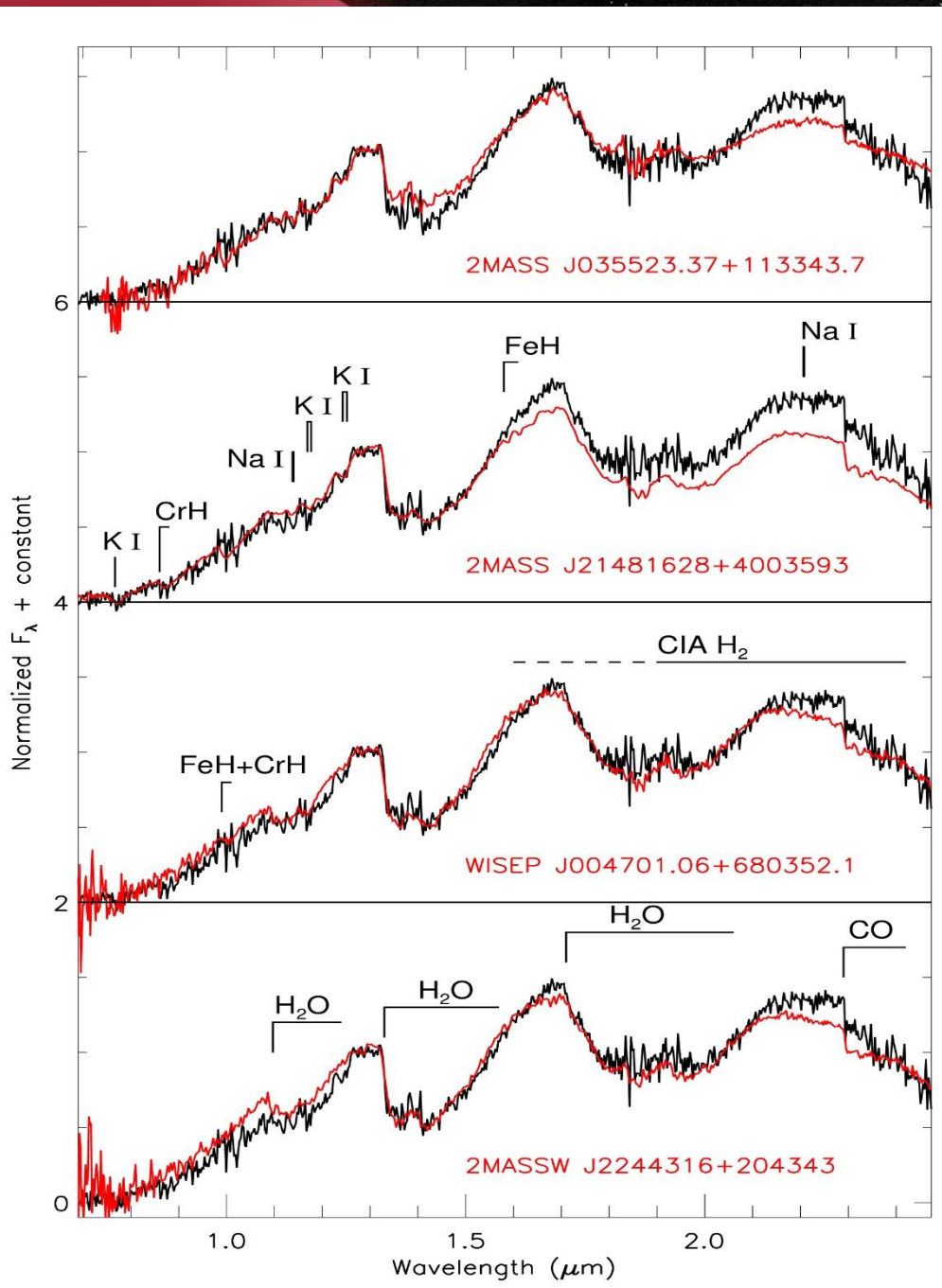


Spectroscopic follow-up

The spectrum looks very similar to other low-gravity dwarfs and URLs.

They all show smooth optical spectra and very red SEDs, peaking in the H band.

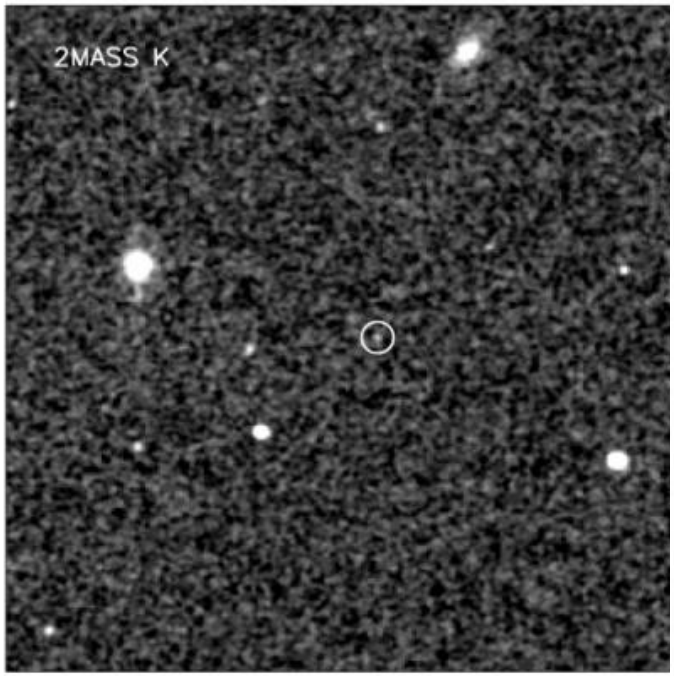
The spectral indices defined in Allers & Liu 2013 do not point towards low gravity for ULAS J2227-0045.

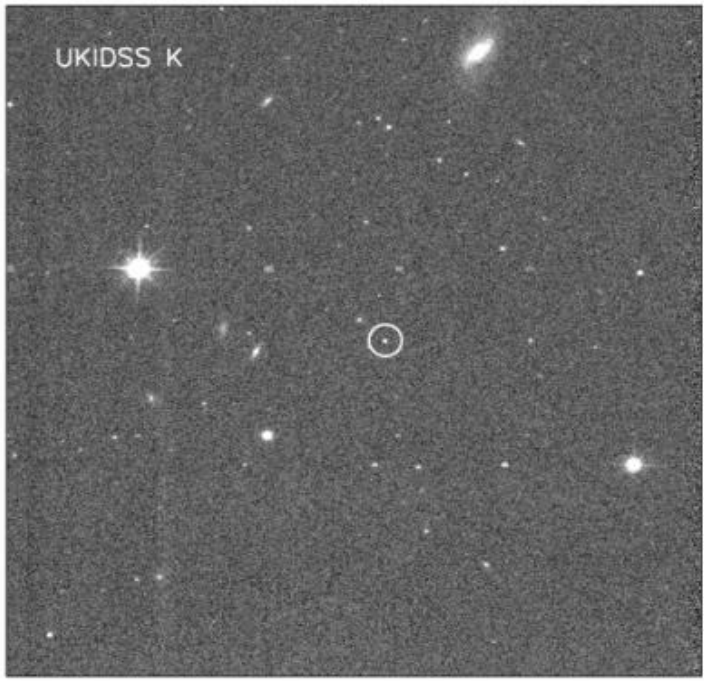


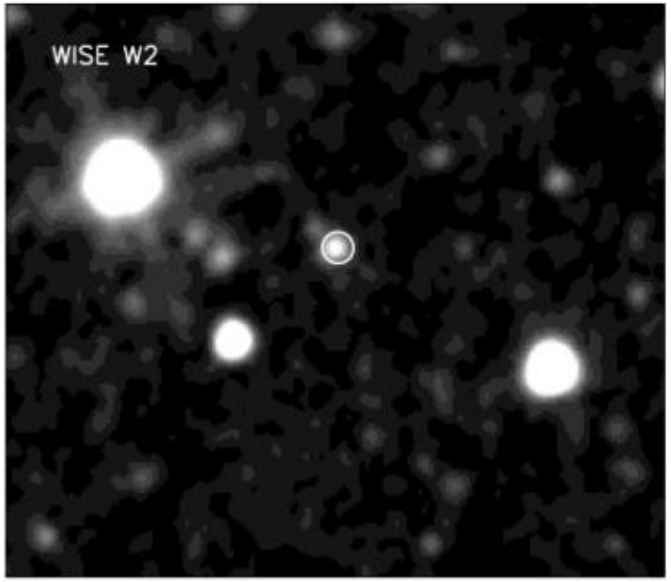
Astrometry

We have estimated the proper motion using 2MASS, UKIDSS and WISE

$\mu_\alpha \cos\delta = 100 \pm 16$ mas/yr $\mu_\delta = -30 \pm 16$ mas/yr







Not a member of any young moving group. So what causes the H and K band excess? Dust?

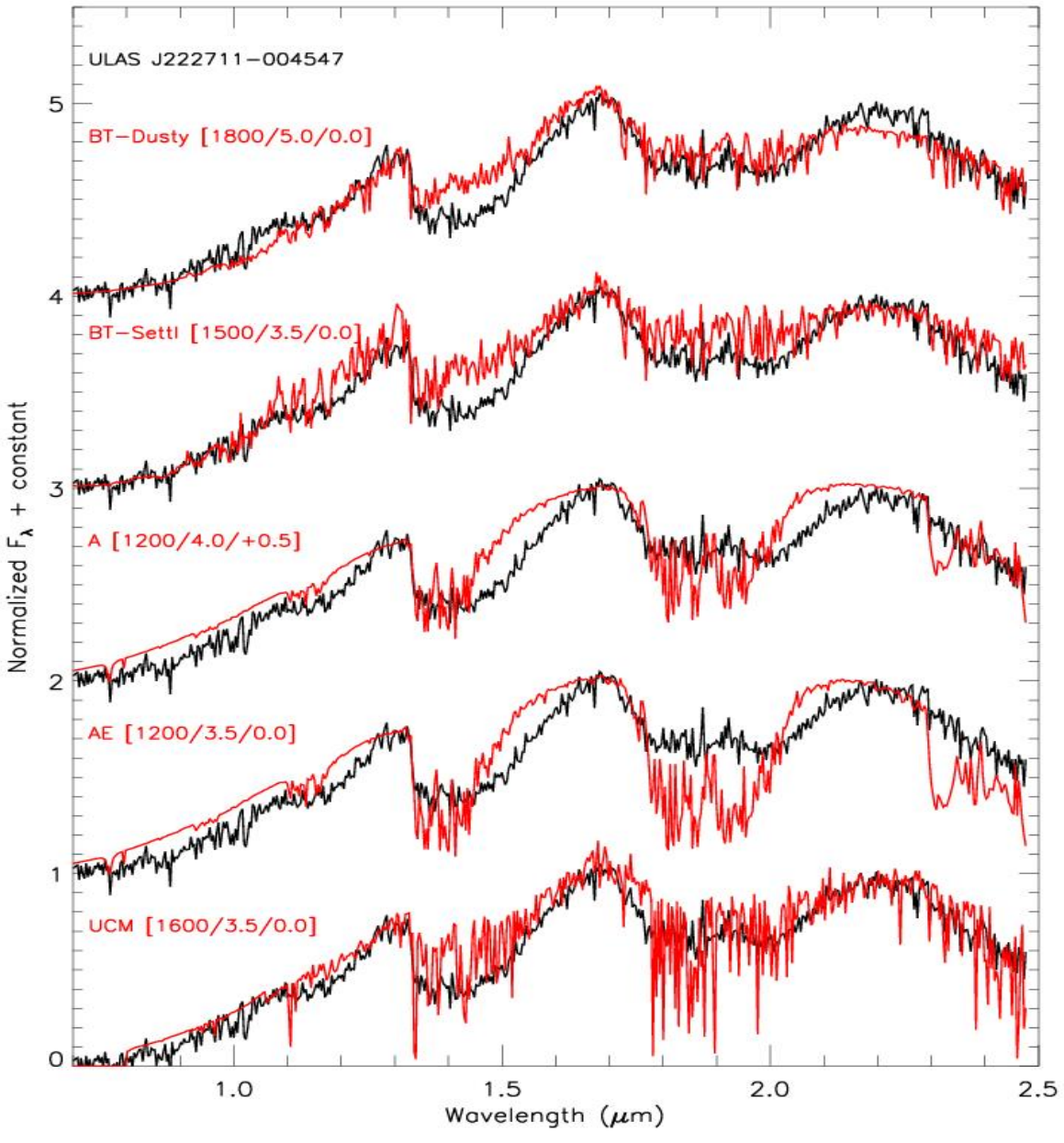
Model fitting

Models do not reproduce the spectrum properly.

H_2O and CO absorption bands, and the shape of the H band peak are the major issues.

NB: models do not include higher-than-solar metallicity

Ref:
Allard et al. 2011 (BT-Dusty & BT-Settl)
Madhusudhan et al. 2011 (A & AE)
Tsuji 2005 (UCM)

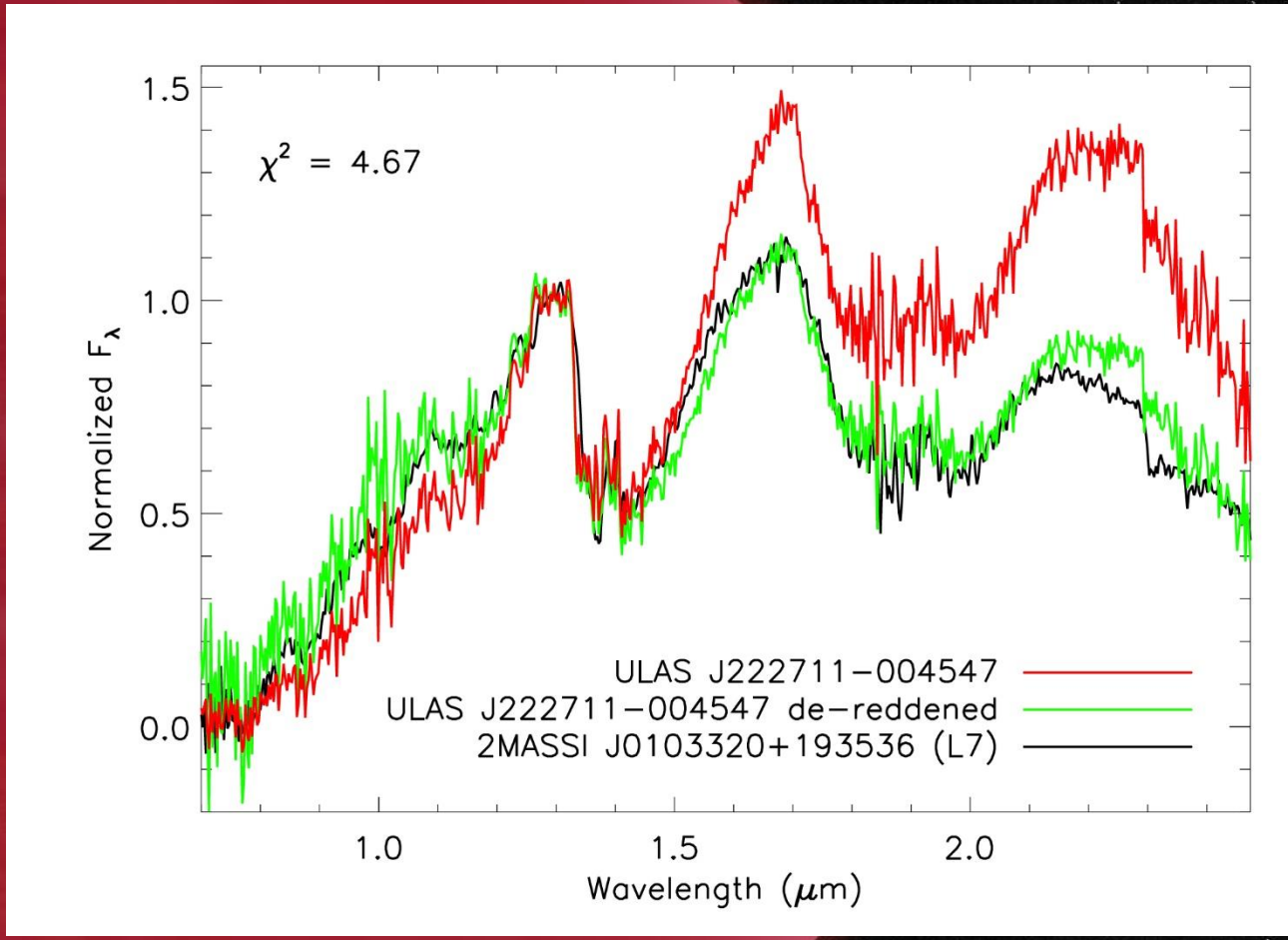


De-reddening

We have de-reddened the spectrum of ULAS J2227-045 using the Fitzpatrick 1999 extinction curve.

The spectrum fits quite well the L7 standard with an E(B-V) = 1.1.

The asymptotic reddening of the field is 0.07, i.e. the reddening of the spectrum is intrinsic.

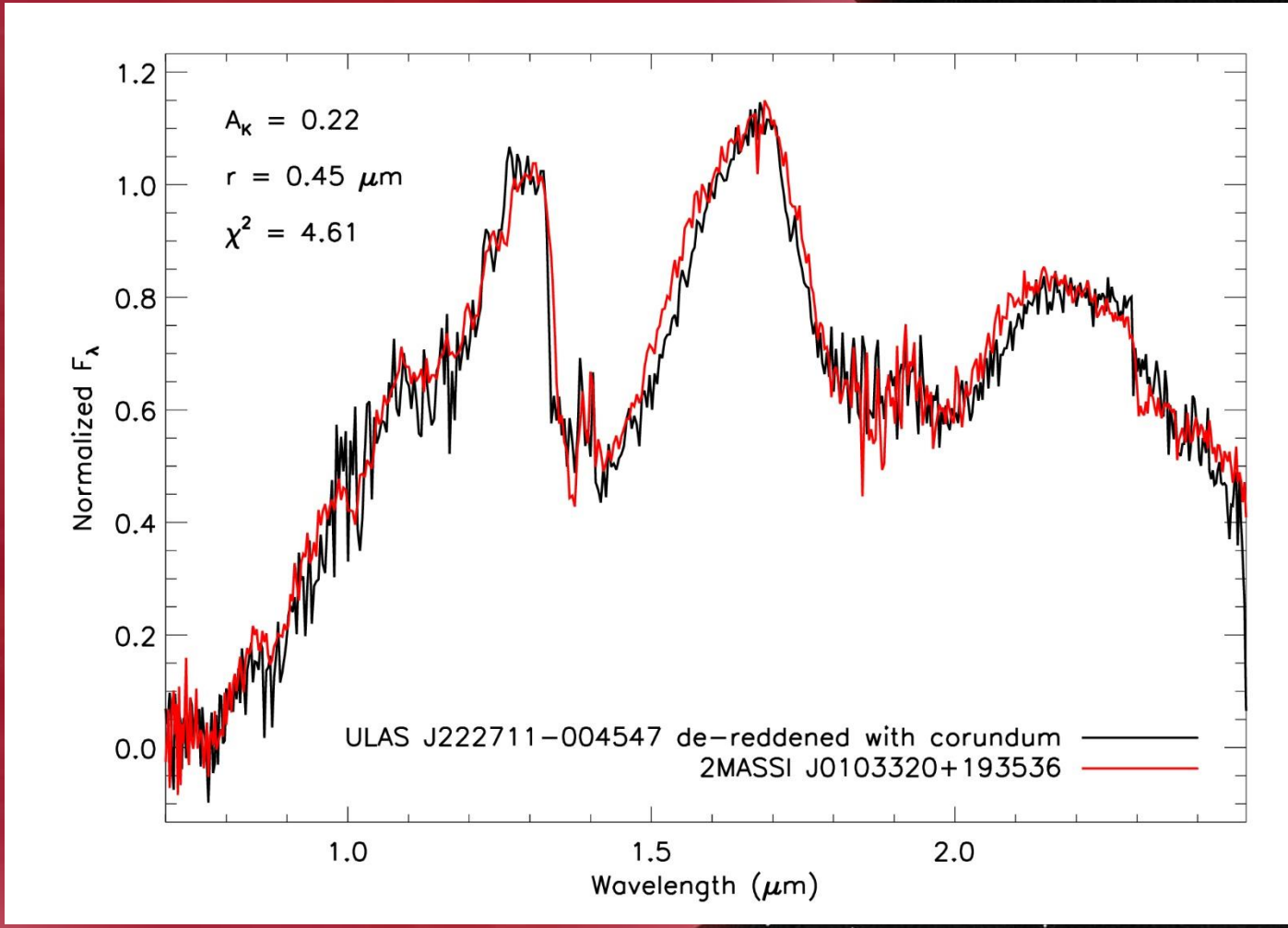


De-reddening

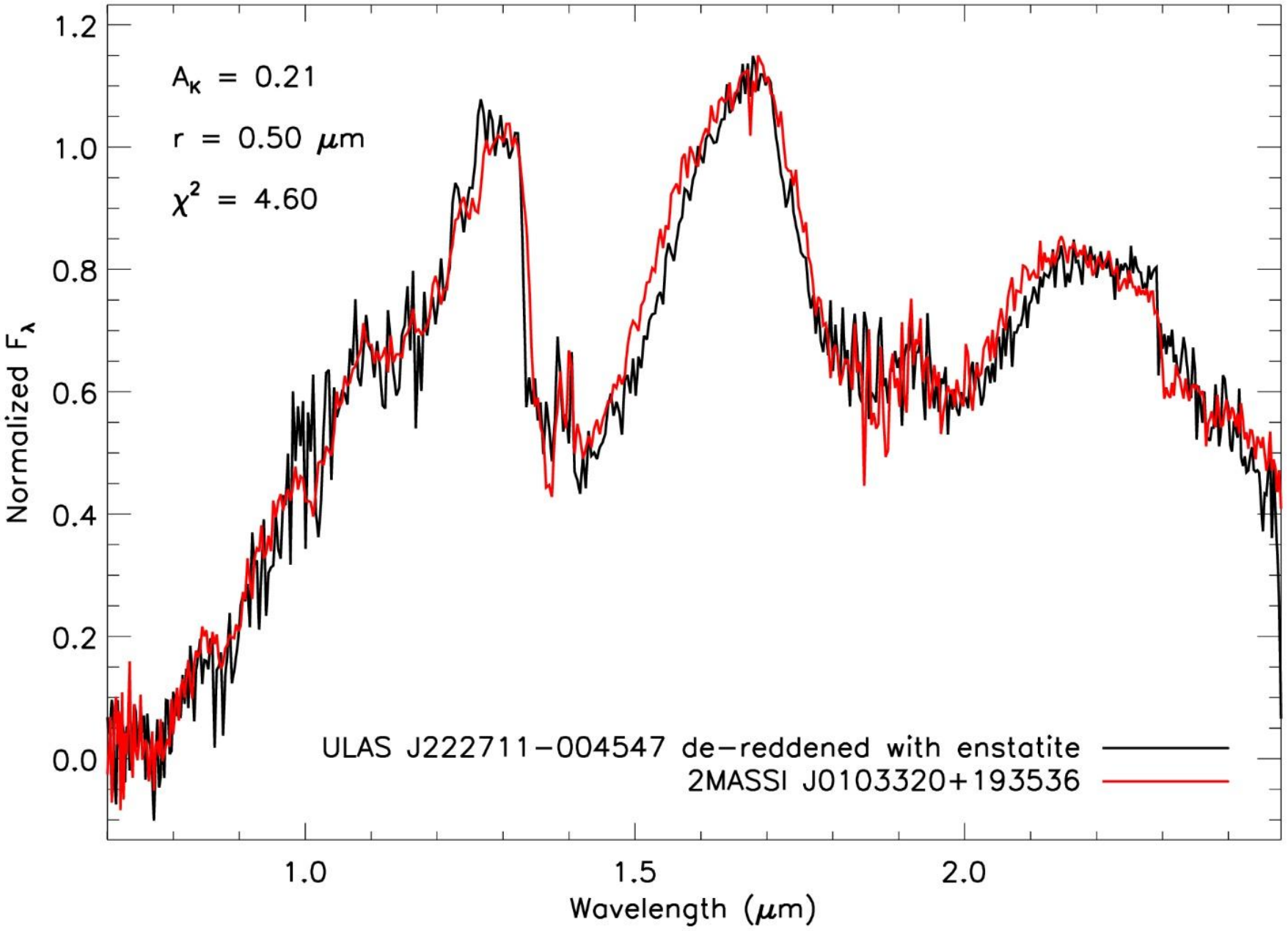
The main dust species in L dwarfs are thought to be corundum (Al_2O_3), enstatite ($MgSiO_3$) and iron (e.g. Morley et al. 2012).

We derived extinction curves for these 3 species for a range of grain sizes (r = 0.05 to 1.00 μm) and applied them to the spectrum of ULAS J2227-0045.

Corundum and enstatite give good fit for grain size of 0.40-0.55 μm.

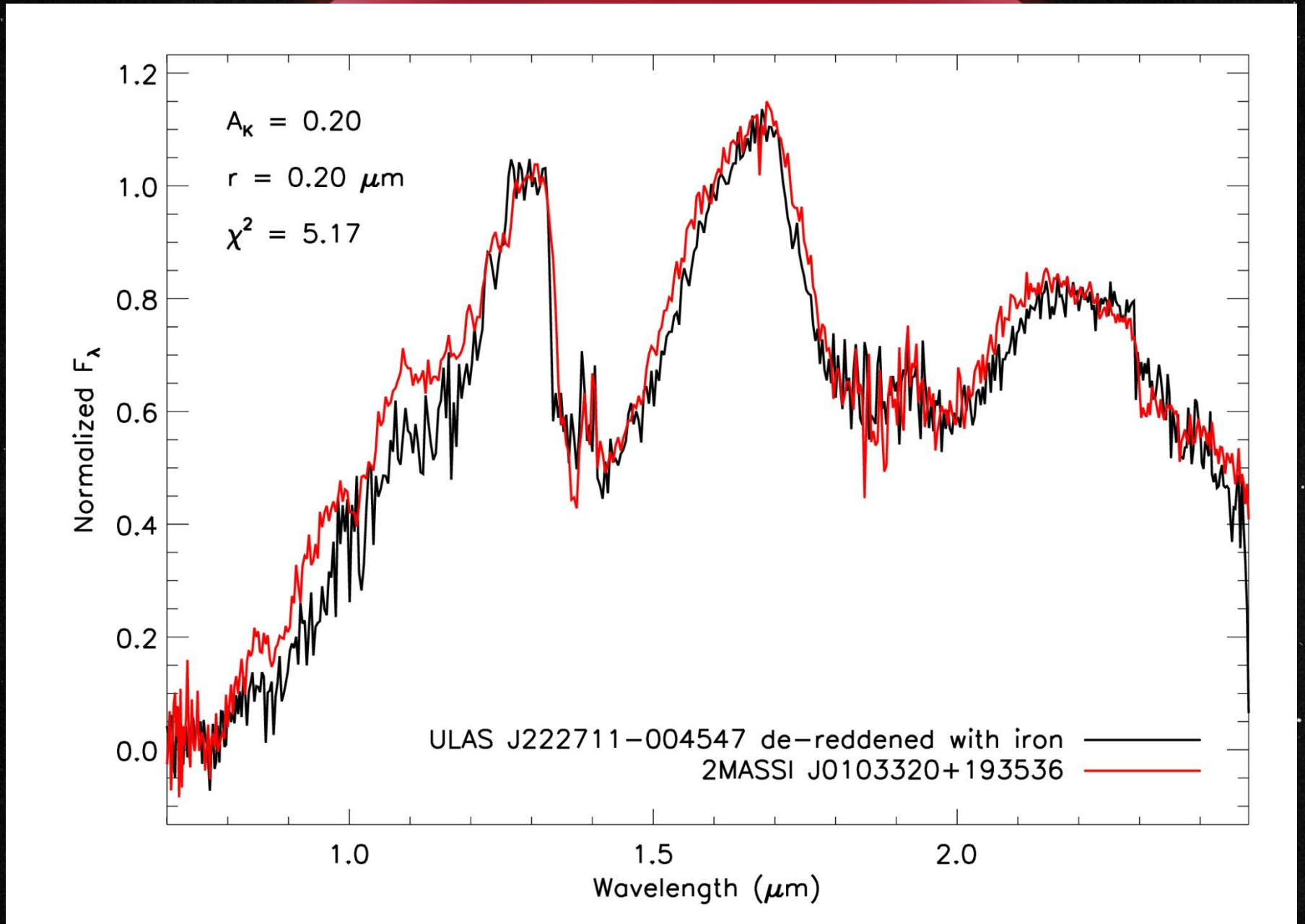


De-reddening



De-reddening

Iron requires smaller grains but does not give good results in the optical part of the spectrum.

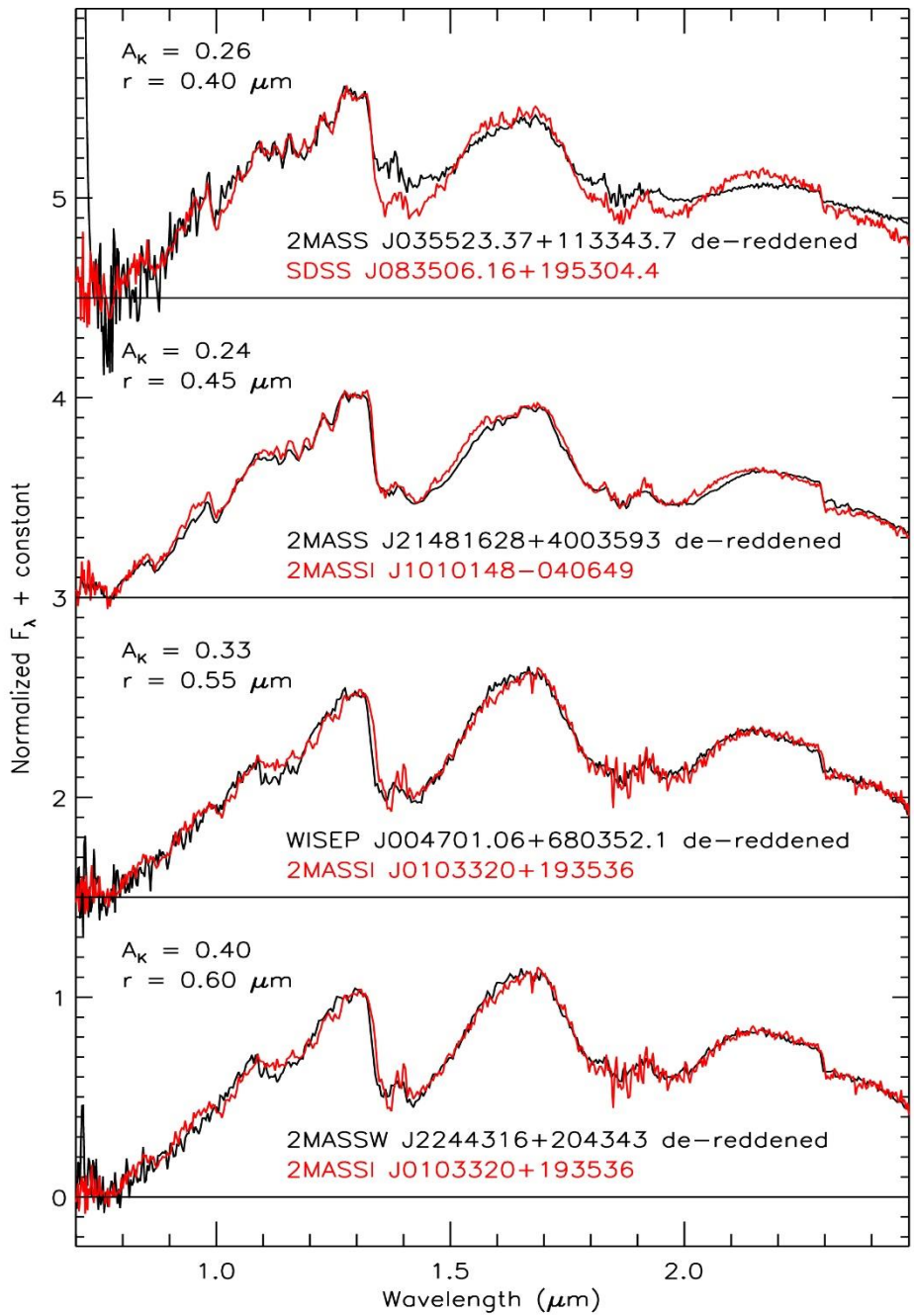


De-reddening

The de-reddening works for other URLs too.

The grain sizes obtained are consistent with those obtained for ULAS J2227-0045.

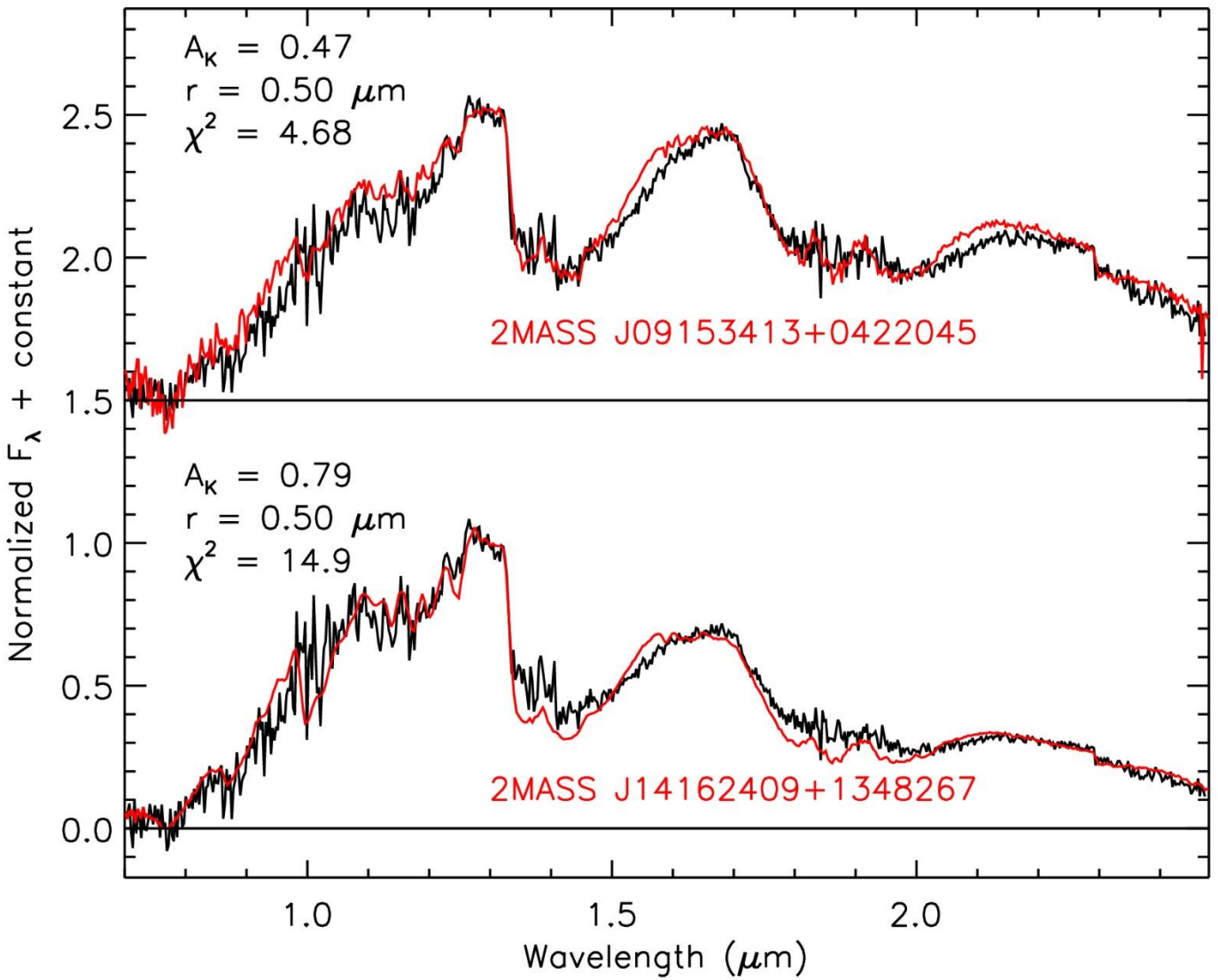
When going to earlier types (e.g. 2MASS J0355+1133, L5γ) the quality of the fit decreases.



De-reddening

You can push the de-reddening even further!

ULAS J2227-0045 de-reddened with **enstatite**



Summary & Conclusions

ULAS J2227-0045 is one of the reddest L-dwarfs known to date, and fits into the category of URLs.

Spectral indices and kinematic show that its extreme colours are not caused by low gravity.

An alternative explanation can be an excess of dust in the photosphere, maybe caused by unusual metallicity.

De-reddening the spectrum of URLs and young objects using extinction curves for different dust species gives surprisingly good results.

Dust opacity seems to be enough to explain the diversity of objects, at least in the mid-to-late L regime.


Thank you!