Brown dwarfs & white dwarfs as wide faint companions – implications for exoplanet systems ?

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Wide companions and exoplanets

- Wide binary companions to exoplanet systems may/may not have affected the formation/evolution of these systems;
  - “invasive” companions - a<100AU or high e
  - “non-invasive” companions – a>100AU
- Non-invasive companions (e.g. WDs) can be age calibrators for primary stars and their planetary systems
- Previously un-discovered potentially invasive companions (e.g. LMS, BDs, WDs) could have implications for formation studies
- Non-invasive low-mass companions as targets for future RV planet hunting
  - If primary stars have planets, then LMS/BD companions could be fertile grounds for NIR planet hunting

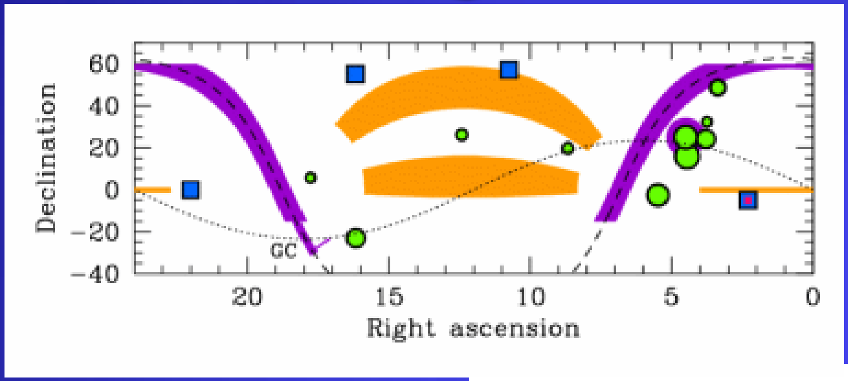
Wide companions and brown dwarfs

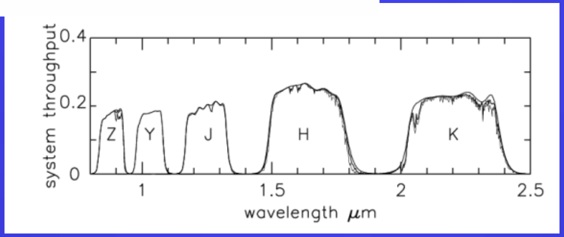
- Ongoing UH programme to identify wide binary systems with brown dwarfs as the focus
  - Exploiting a significant fraction of stars that have BD companions at wide separation (maybe as high as ~20%)
- Shared techniques
  - Common proper motion
  - Common distance – parallax/spectroscopic/photometric
- Shared motivation – calibration tools
  - In this case, ultra-cool atmospheres need calibration
  - Calibrating BD age & composition

    -> Teff, mass, log g, [M/H]

- 2 recent discoveries from UKIDSS have yielded some exciting results

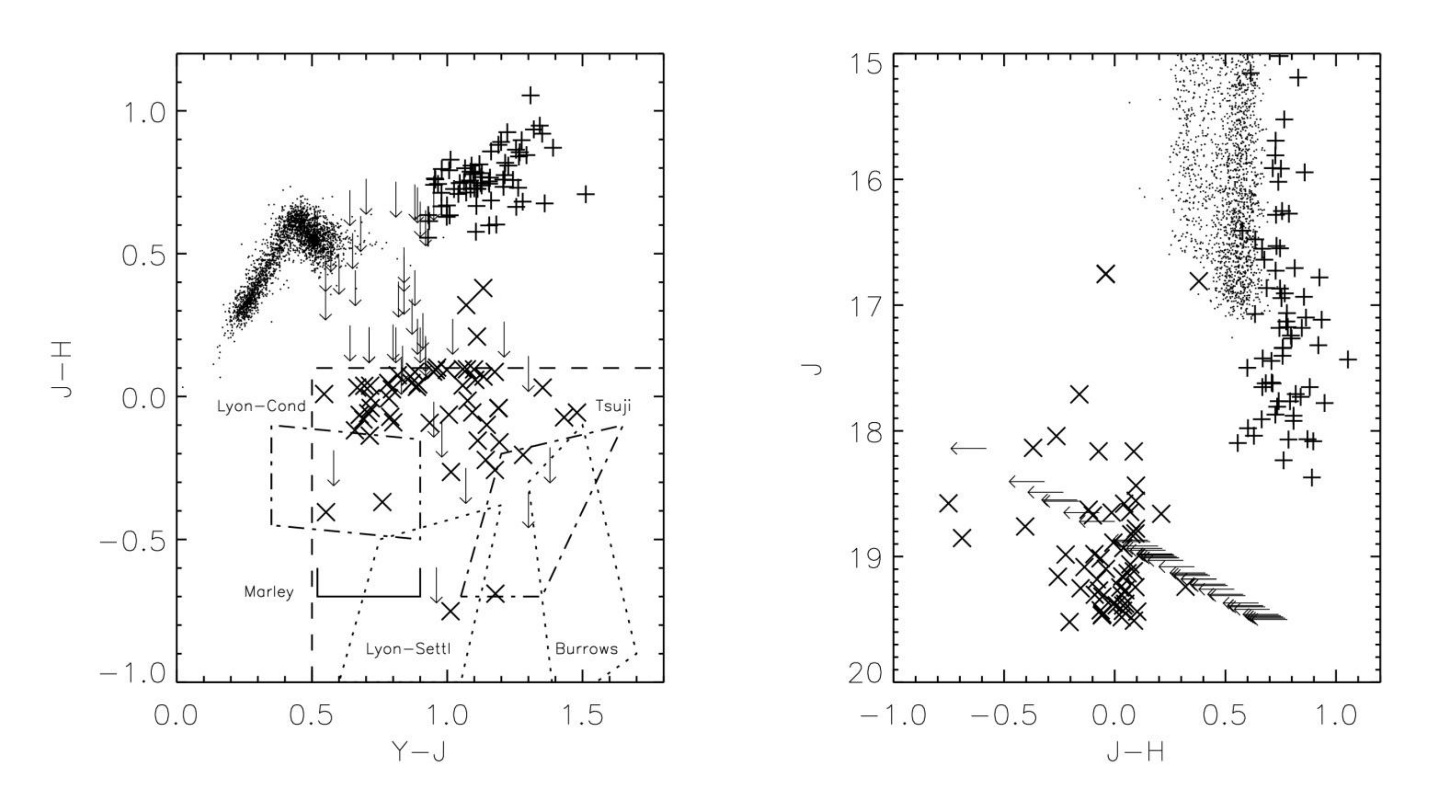
Searching for T and cooler dwarfs in the UKIDSS Large Area Survey (LAS)





- 4000 square degrees in YJHK
- 5σ limit of Y=20.2, J = 19.5, H=18.8, K=18.2
- Science drivers include the coolest dwarfs, and high z quasars
- With a ~2yr baseline, 2 epochs in J => proper motions

Methodology for finding T and possible Y dwarfs



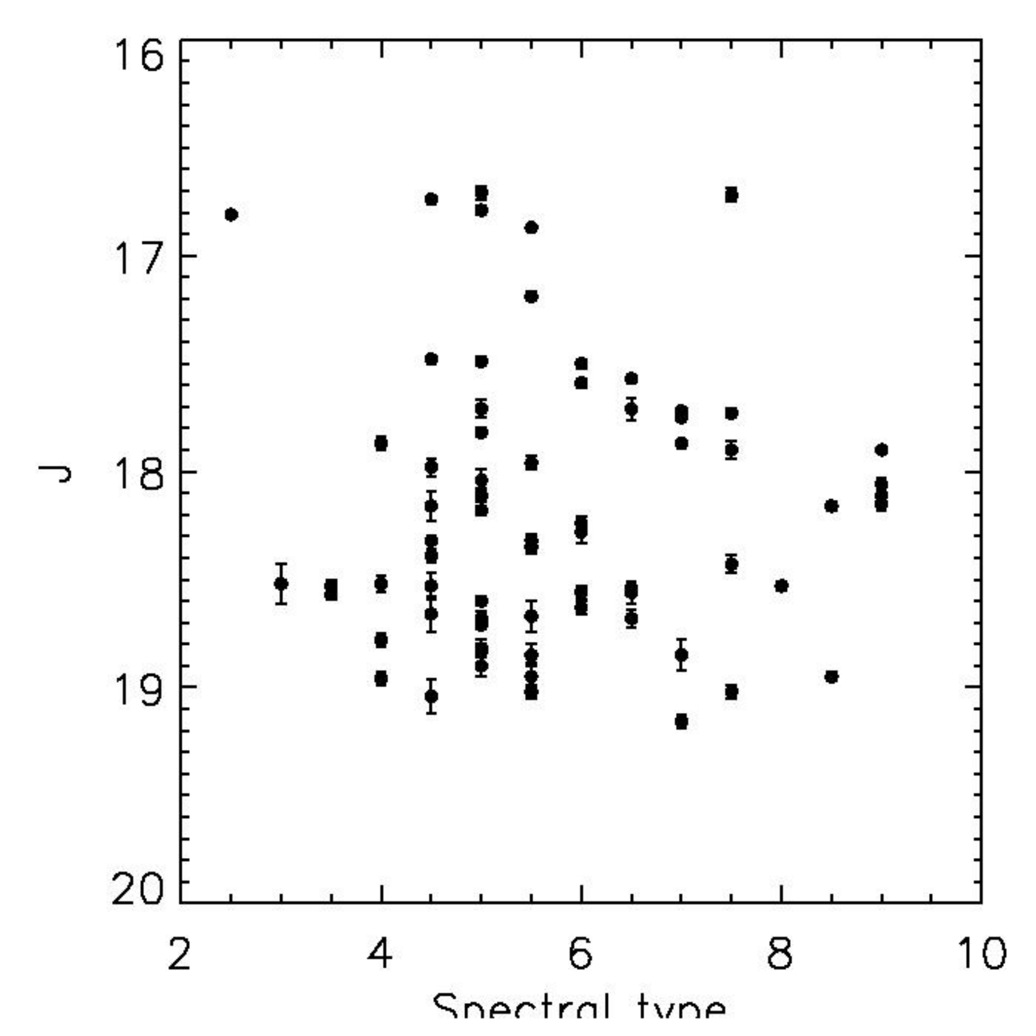
Datamine UKIDSS LAS + SDSS:
- **near-IR colours (see box)**
- **optical near-IR colours/limits**

Follow-up 1:
Photometry to deal with YJ-only objects and improve colours

Prioritise

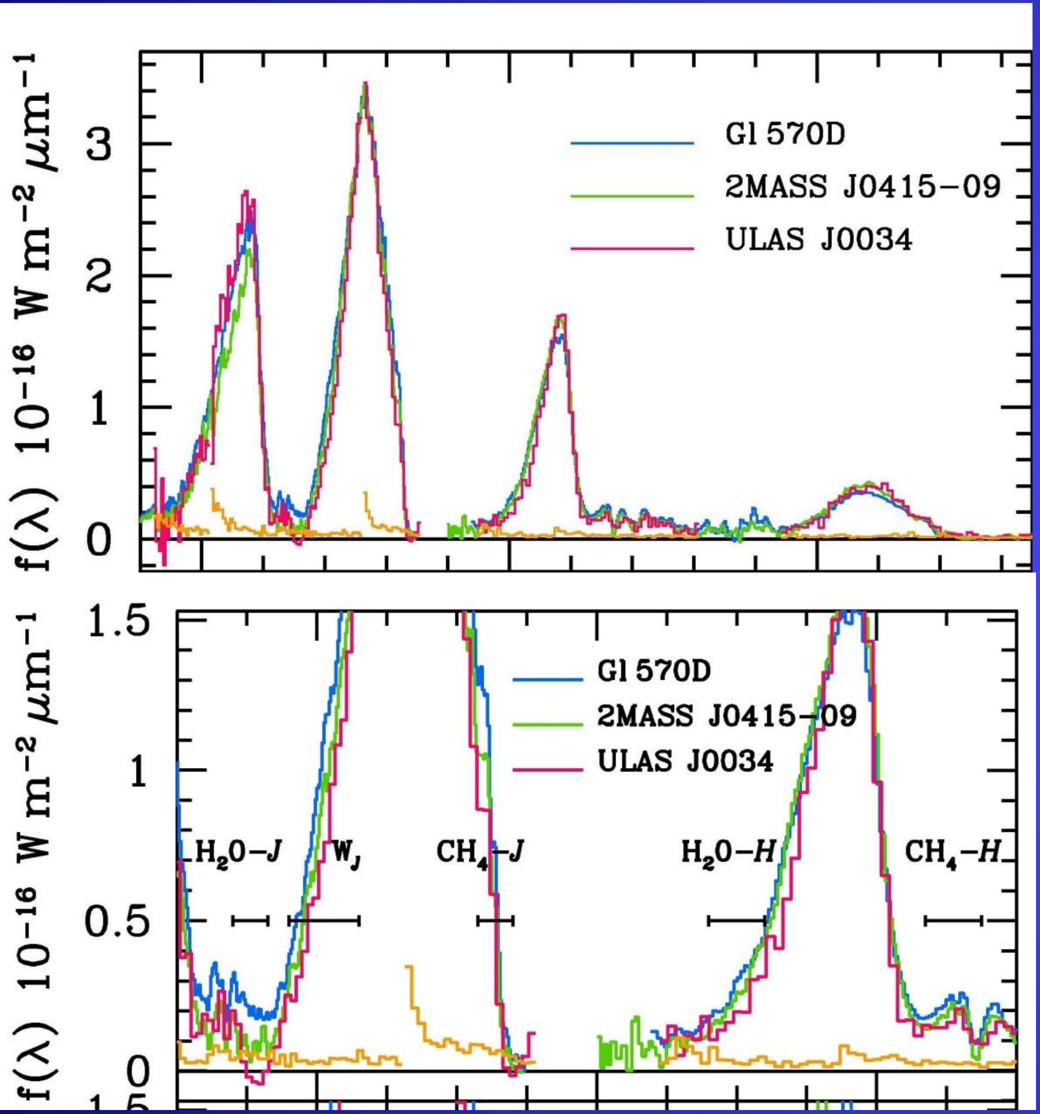
Follow-up 2:
8m spectroscopy (NIRI/IRCS/GNIRS)

The growing LAS T dwarf population



- Colour selection efficient for >T4
- Follow-up is close to complete for J<19

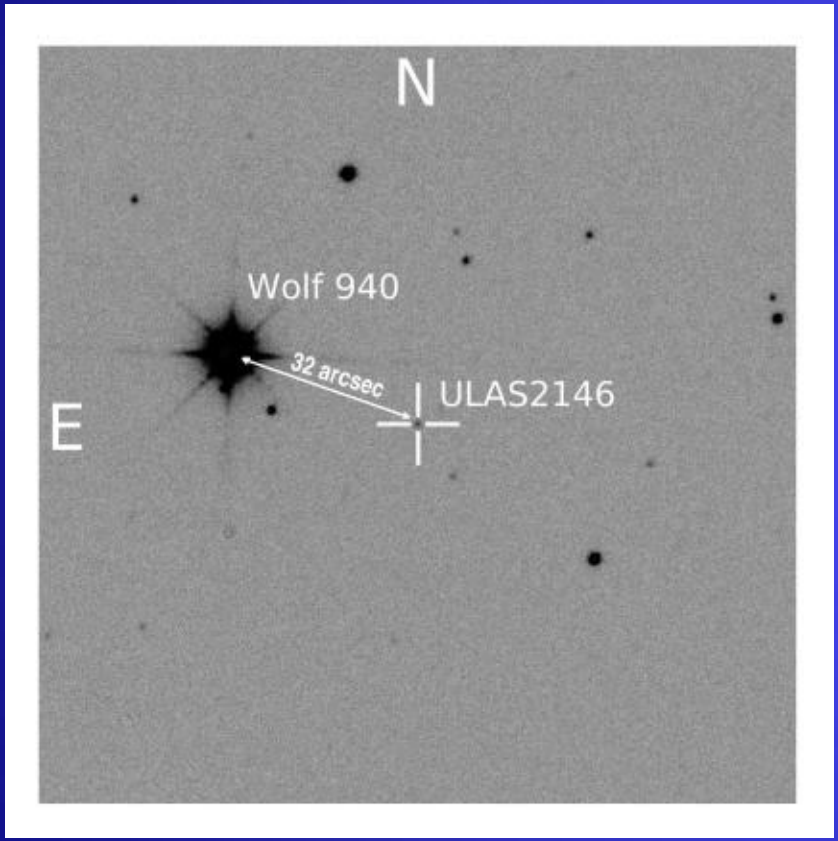
T8+ dwarfs



- DR1 yielded the first T8+ dwarf
- ULAS J0034 (Warren et al. 2007)
- Existing spectral ratios suggested T8+
- The J-band peak is narrower than for T8s
- We defined a new spectral index Wj – to describe the width of the J-band peak
- Estimated Teff~650-700K but significant uncertainty

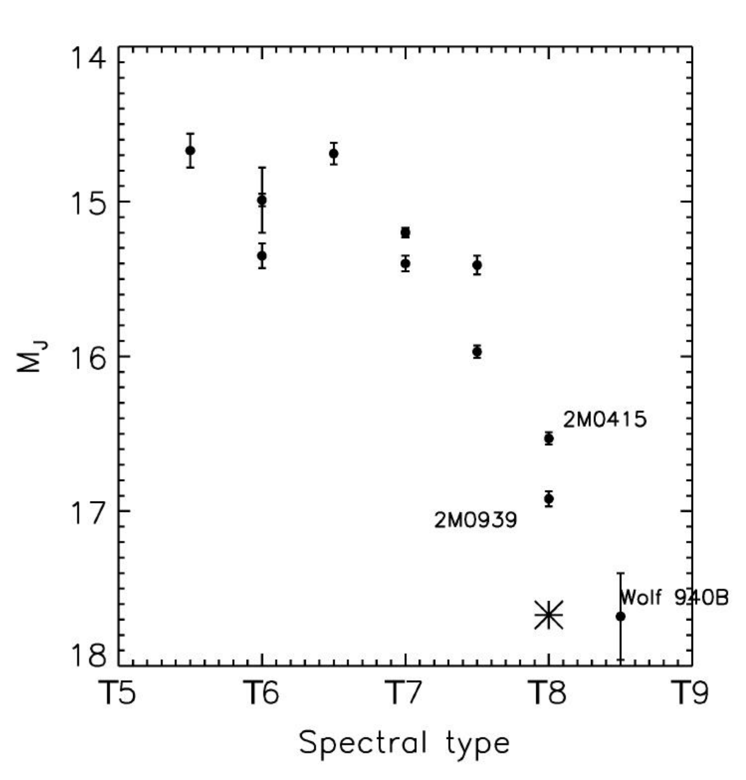
Warren et al. 2007

The coolest benchmark yet – Wolfe 940B



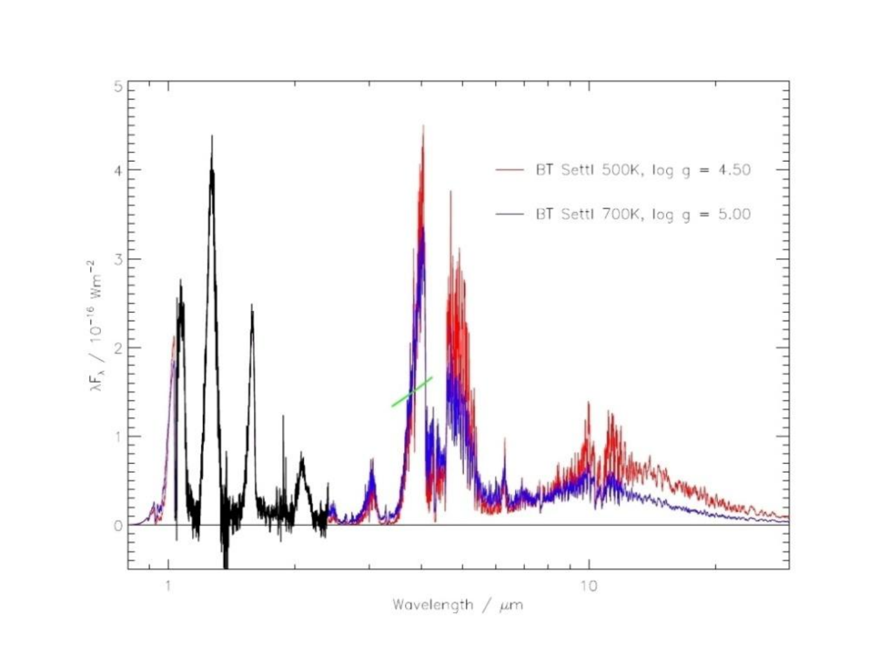
- ULAS2146 is another T8+ found in the LAS
- A visual comparison between LAS image and old Schmidt plate data showed the HPM star Wolf 940 just 32″ away
- Proper motion of T dwarf then measured, and CPM confirmed
- Statistical likelihood of a chance alignment (separation, distance, PM) is 10^{-5}
- Wolf 940A known for 90 years

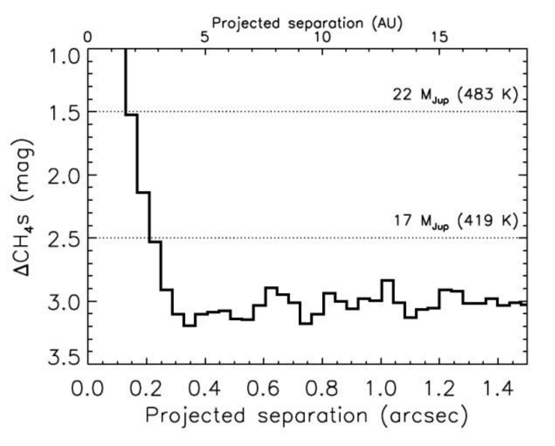
Wolf 940B - Distance and age



- Distance=$12.5^{+0.75}_{-0.67}$ pc (from parallax of primary)
- Age=3.5-6.0Gyrs
  - Lower limit – don't see H-alpha emission
  - Must be older than the activity life-time (for M4) of West et al. (2008) – who studied 38,000 Sloan M-dwarfs
- Upper limit from H-alpha in absorption
  - M dwarf atmospheres too cool to produce photospheric H-alpha absorption
  - So H-alpha absorption from chromospheric heating

Wolf 940B – other properties

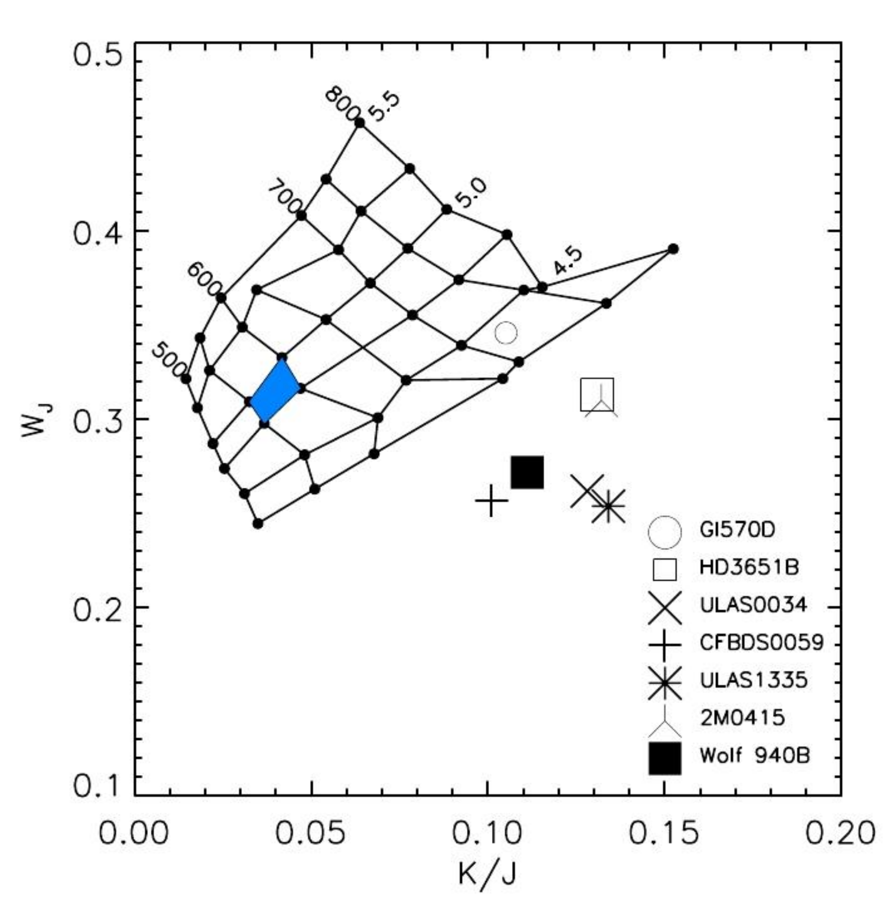


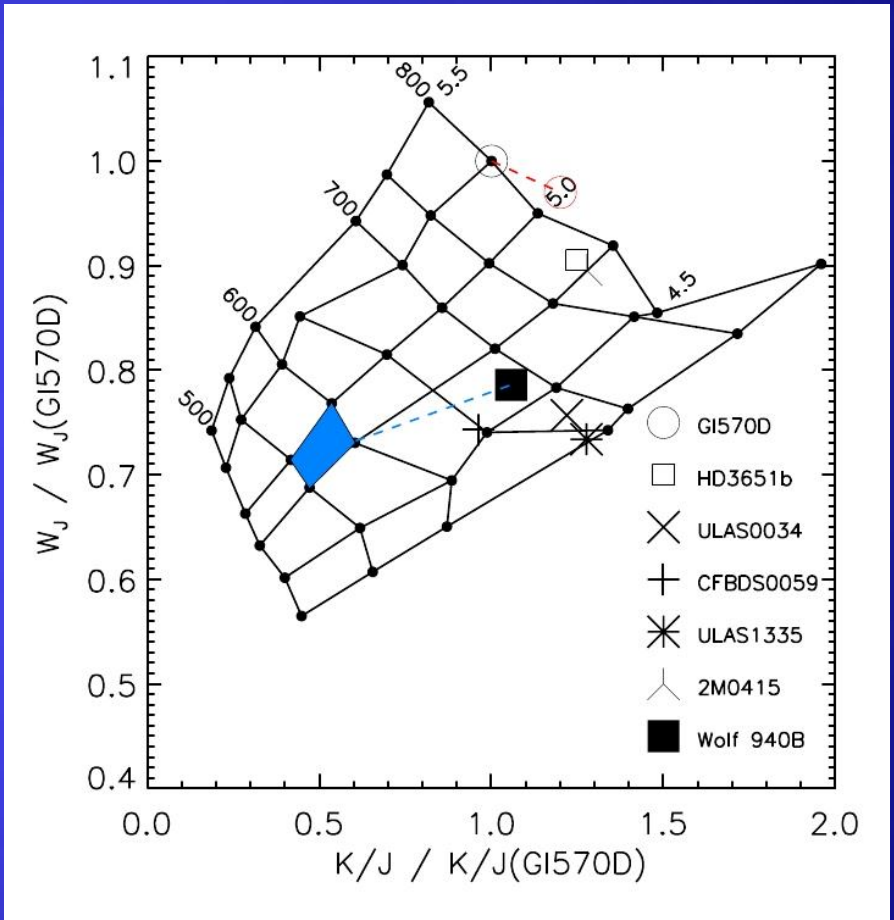


- Luminosity from Fbol (YJHK+L)
- Metallicity=-0.06+/-0.2

  from the primary (fit using Mk vs V-K and Bonfils 2005)
- Single or binary?
- Radius and mass (and logg) from evolutionary models
- log(g)=4.75-5.00
- Mass = 20-32 Mjup
- Teff from luminosity & radius
- Teff=570+/-25K

Wolfe 940B - benchmarking very cool NIR models atmospheres



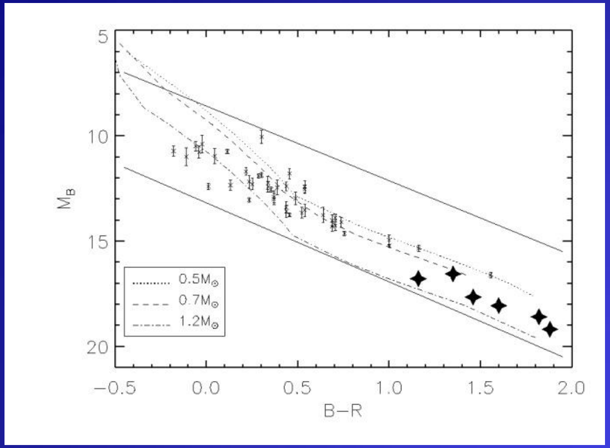


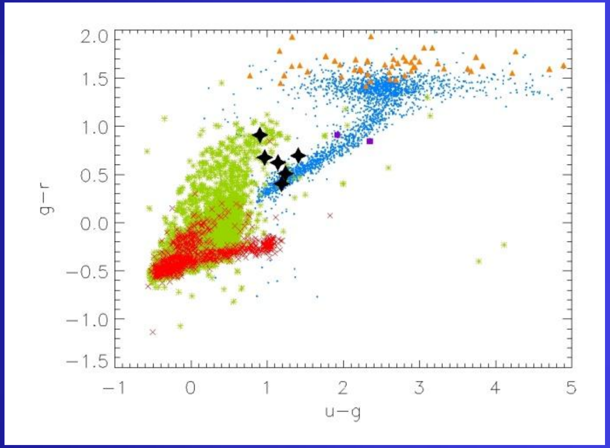
The first T dwarf – white dwarf benchmark

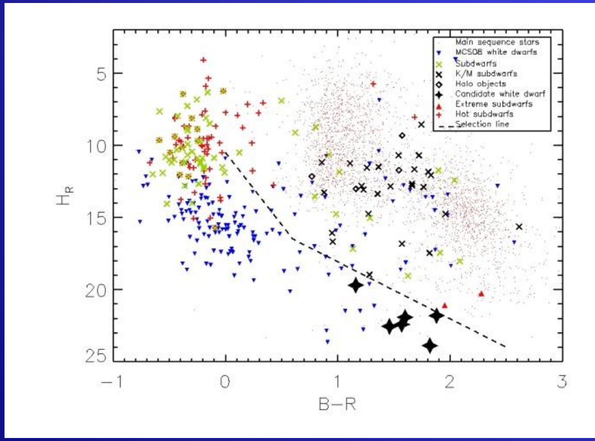
- White dwarf companions can give age constraints from their cooling age
- Relatively high mass DA white dwarfs would give the best constraints – high mass progenitor stars with short MS life-time
- White dwarf cooling age ~the same as system age
- Always get at-least a lower limit to the system age
- White dwarf companions will generally be at wider separation to MS companions (mass loss)
- cf. BD-MS binaries typically a~1000-5000AU
- Allowing for post-MS mass loss of ~75%, could expect BD-WD binaries with a<20,000AU

The first T dwarf – white dwarf benchmark

- Systematic proper motion measurements of T dwarfs (Summer 08)
- UKIDSS as first epoch and follow-up images (UFTI/SofI) as second
- Base-lines ~ 0.7-2yrs
- Proper motion quality depends on: number & distribution of reference stars, SNR on T dwarf (centroiding)
- Useful PMs determined for ~20 T dwarfs so far
- Used SuperCOSMOS to search for CPM companions out to 20,000AU at the estimated distance of each T dwarf



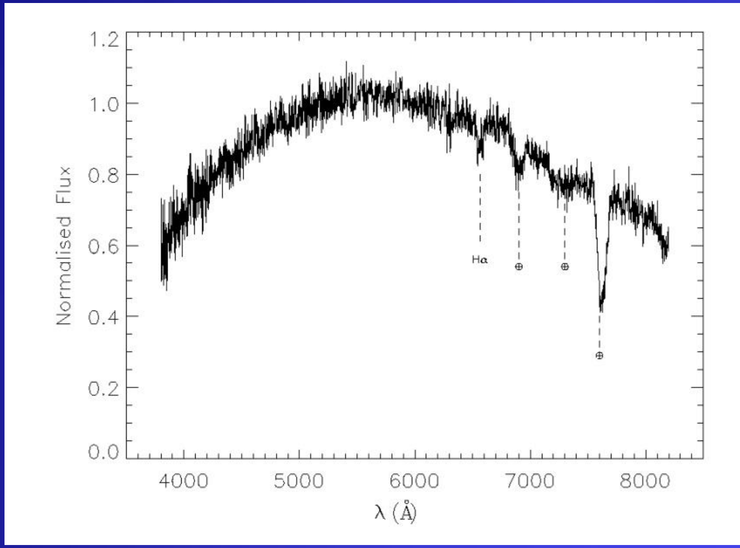


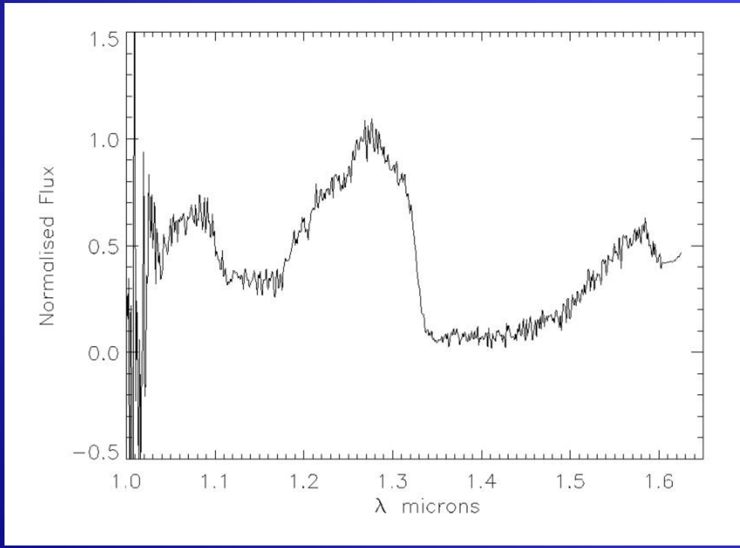


The first Tdwarf–WD benchmark

- WD candidates tested by assuming the same distance as their T dwarf neighbour
  - A test of colour mag consistency at a common distance
- Sloan colours examined, and some M dwarfs removed
- Reduced proper motions OK
- 6 WD companion candidates remained

The first Tdwarf–WD benchmark

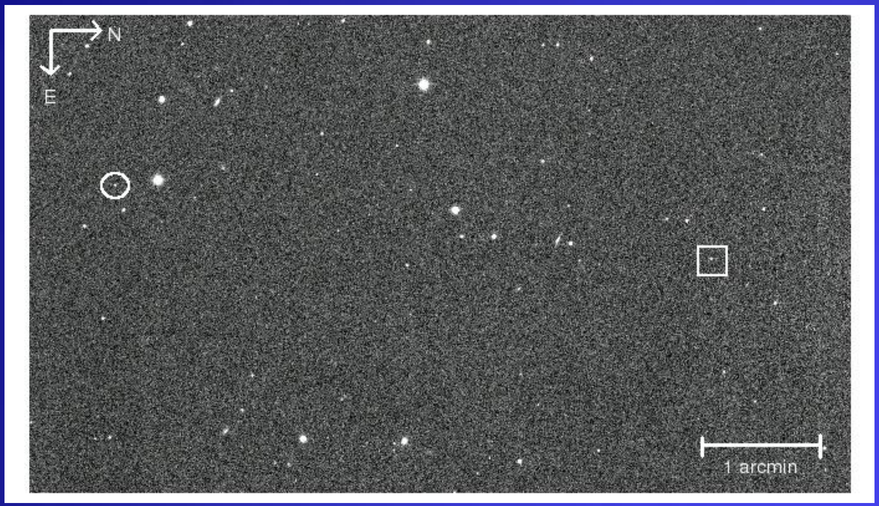


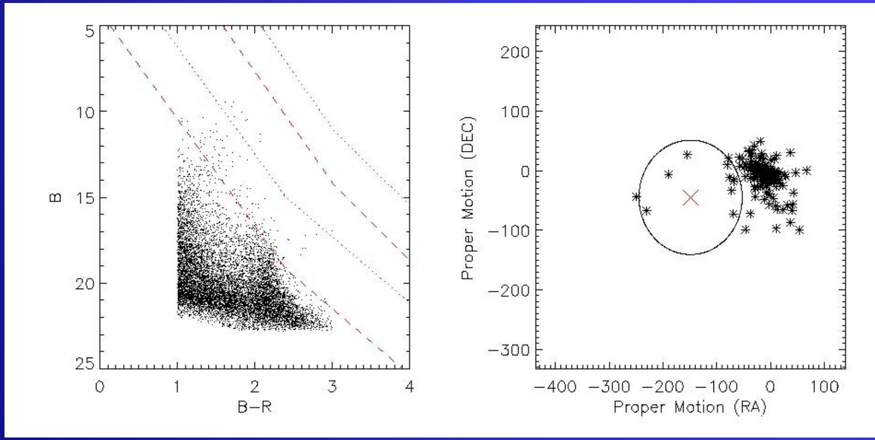


- DDT on VLT has so far confirmed one candidate as a DA WD
- Teff=5390K, logg~8.0
- Mass=0.55-0.95Mo
- Cooling age = 3-9Gyrs
- Progenitor MS age >1Gyr
- Age of system = 4-10Gyrs

- CPM companion: T4.5 dwarf at ~45pc
- Teff=1200-1500K
- At the system age, COND isochrones give logg=5.42-5.49

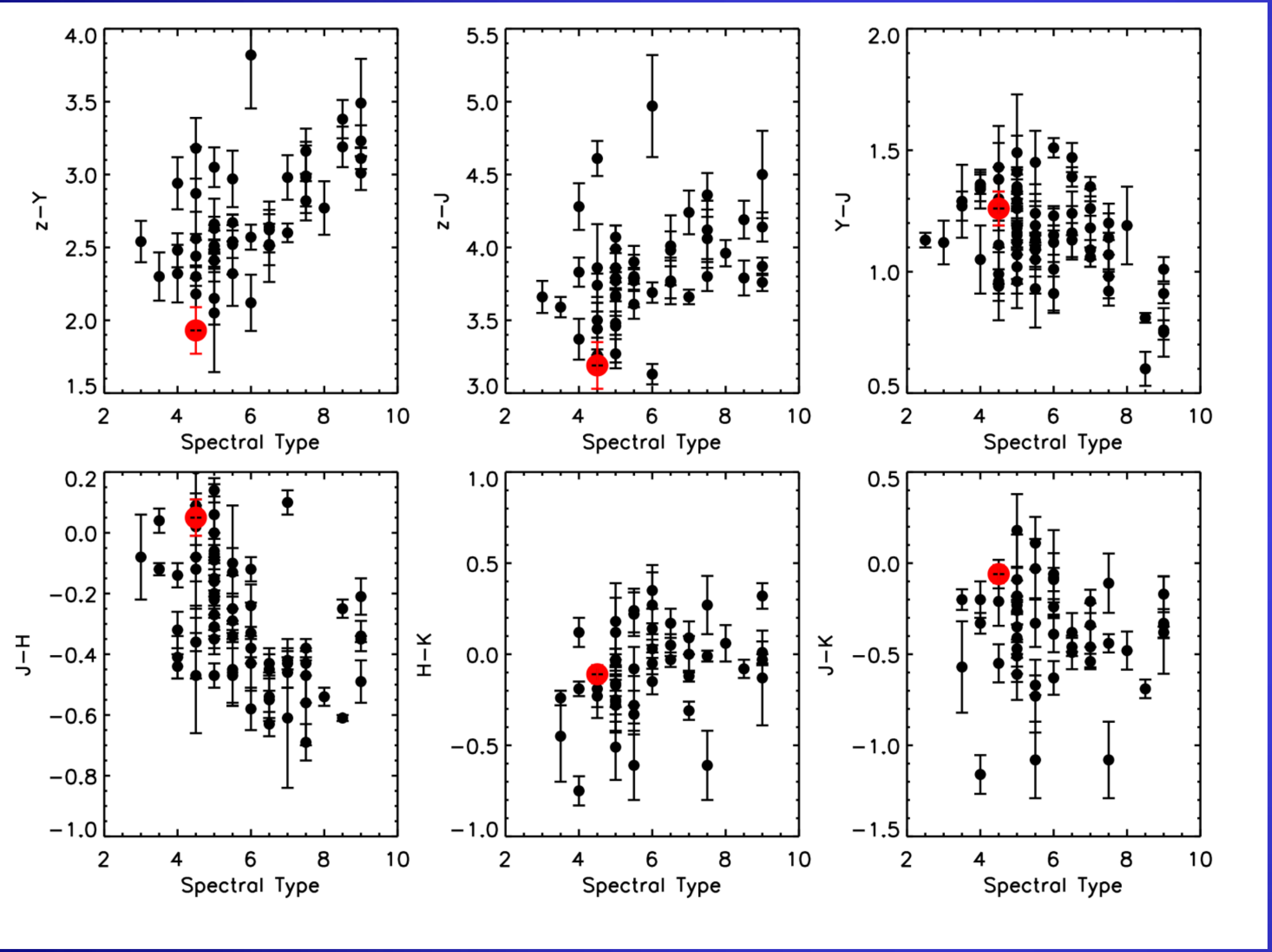
The first Tdwarf–WD benchmark





- This is a very wide system (396”, ~18000AU), although quite typical for what would be expected
- What is the probability that such a CPM pair could be observed this close by random chance?
  - Assuming D=45-70pc
  - A local space density for WDs
  - And a WD PM distribution similar to stars over 45-70pc
- Probability that these objects are unrelated ~ 0.00033 (1 in 3000)

The first Tdwarf–WD benchmark



- Compared to the other LAS T dwarfs
- Blue in z-Y and z-J
- ~Normal in other colours
- Model calibration for high gravity ultra-cool atmospheres?

Summary

- Wide binary systems can be powerful tools for calibrating sub-stellar brown dwarfs
- Showing up significant problems with ultra-cool model atmospheres
- Large scale NIR & optical surveys like UKIDSS, SuperCOSMOS and SDSS can provide great sensitivity to BD and WD populations
- Ranging potential for wide companions to exoplanet host stars

The end