Discovery of the first white dwarf + T dwarf binary system and the use of white dwarfs as age calibrators.

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White dwarfs in binaries with UCDs

Binary systems containing a white dwarf and an ultracool dwarf are rare, only a handful containing late M dwarfs (>M7) or L dwarfs have so far been identified.

WD + late M binaries

* 2MASSJ0030-3739 (M9) ~4000AU. (Day-Jones et al. 2008).
* WD2151-015 (M8)~23AU. (Farihi, Becklin & Zuckerman et al.2005).
* WD2351-335 (M8) ~2054AU. (Farihi, Becklin & Zuckerman et al.2005).
* WD1241-010 (M9) ~284AU. (Farihi, Becklin & Zuckerman et al.2005).
* LHS4039/4040 (M8.5)~2200AU. (Scholtz et al. 2004).

WD + L dwarf binaries

* GD 165B (L4) ~150AU. (Zuckerman & Becklin, 1992).
* GD 1400B (L6/7)~ Unresolved (Farihi & Christopher, 2004; Dobbie et al. 2005).
* WD 0137-349 (L8) ~ v. close 1 hr orbit. (Maxted et al. 2006; Burleigh et al. 2006).
* PG 1234+482 (L0) ~ Unresolved (Steele et al. 2007).
* PHL 5038B (L8) ~55AU. (Steele et al. 2009).

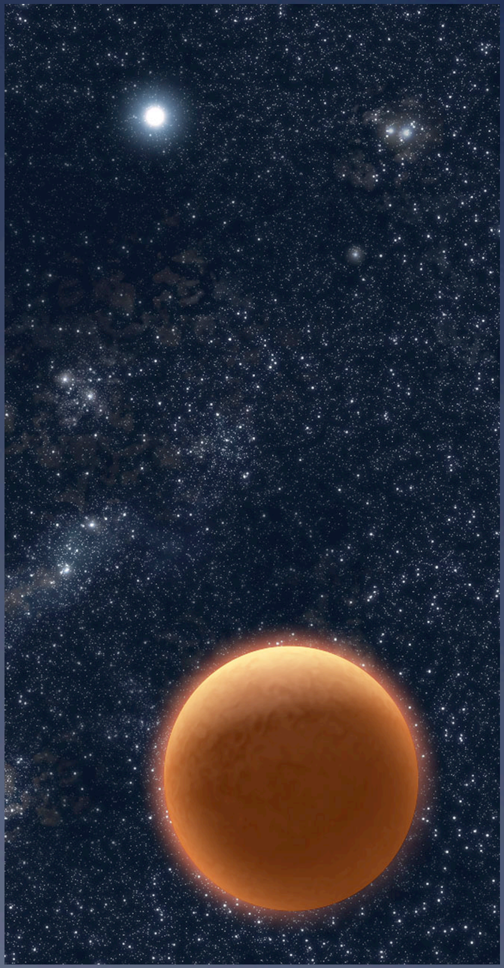
White dwarf + UCD binary fraction

- Farihi, Zuckerman & Becklin (2008) showed a low binary fraction (0.6%) for L and T dwarf companions to WDs at separations of up to a few hundred AU.

- However it is quite common to find UCD companions to main-sequence stars at very wide separations (1000-5000AU), where studies of common proper motion pairs have suggested the binary fraction is likely larger at very large separations 18±14% (Gizis et al. 2001), $34^{+9}_{-6}\%$, (Pinfield et al. 2006).

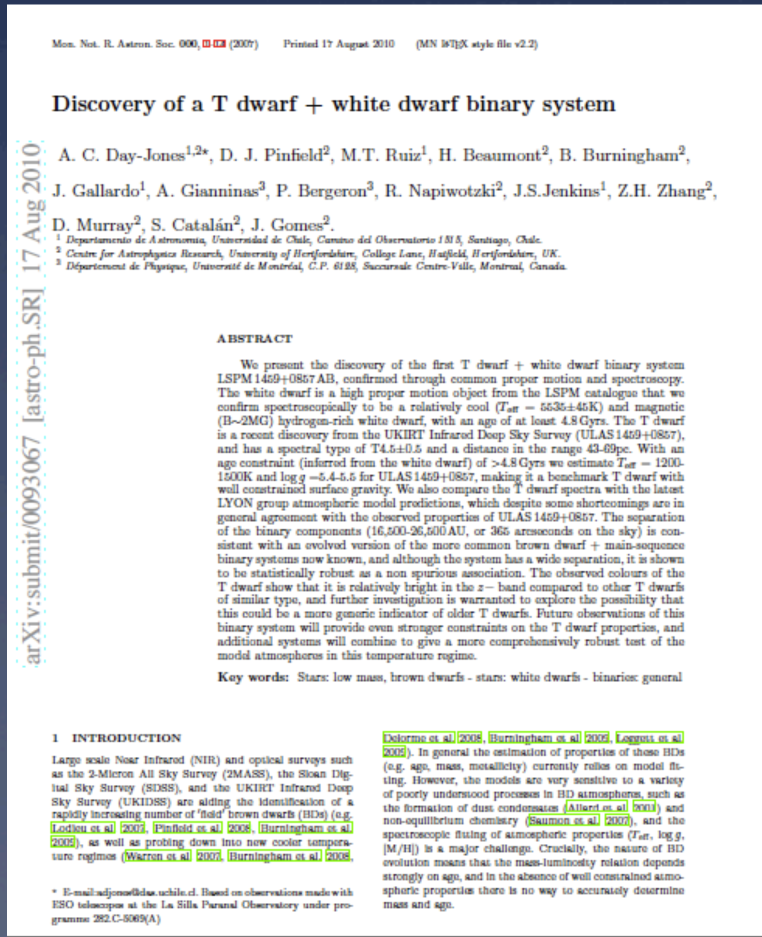
- In addition the mass loss phase of a white dwarf means that companions at initial separations >5AU are likely to migrate outwards (Burleigh, Clarke & Hodgekin 2002), such that WD + UCD binaries could have separations up to a few tens of thousands of AU.

- While some of the widest binaries may be dynamically broken apart quite rapidly by gravitational interactions with neighbouring stars, some systems may survive, offering a significant number of WD + UCD systems.



The first WD + T dwarf binary system

Hot off the press! On astro_ph today!



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Discovery of a T dwarf + white dwarf binary system

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ABSTRACT

We present the discovery of the first T dwarf + white dwarf binary system LSPM 1459+0857 AB, confirmed through common proper motion and spectroscopy. The white dwarf is a high proper motion object from the LSPM catalogue that we confirm spectroscopically to be a relatively cool (T_{eff} = 5535±45K) and magnetic (B∼2MG) hydrogen-rich white dwarf, with an age of at least 4.8 Gyrs. The T dwarf is a recent discovery from the UKIRT Infrared Deep Sky Survey (ULAS 1459+0857), and has a spectral type of T4.5±0.5 and a distance in the range 43-69pc. With an age constraint (inferred from the white dwarf) of >4.8 Gyrs we estimate T_{eff} = 1200-1500K and log g =5.4-5.5 for ULAS 1459+0857, making it a benchmark T dwarf with well constrained surface gravity. We also compare the T dwarf spectra with the latest LYON group atmospheric model predictions, which despite some shortcomings are in general agreement with the observed properties of ULAS 1459+0857. The separation of the binary components (16,500-26,500 AU, or 365 arcseconds on the sky) is consistent with an evolved version of the more common brown dwarf + main-sequence binary systems now known, and although the system has a wide separation, it is shown to be statistically robust as a non spurious association. The observed colours of the T dwarf show that it is relatively bright in the $z-$ band compared to other T dwarfs of similar type, and further investigation is warranted to explore the possibility that this could be a more generic indicator of older T dwarfs. Future observations of this binary system will provide even stronger constraints on the T dwarf properties, and additional systems will combine to give a more comprehensively robust test of the model atmospheres in this temperature regime.

Key words: Stars: low mass, brown dwarfs - stars: white dwarfs - binaries: general

1 INTRODUCTION

Large scale Near Infrared (NIR) and optical surveys such as the 2-Micron All Sky Survey (2MASS), the Sloan Digital Sky Survey (SDSS), and the UKIRT Infrared Deep Sky Survey (UKIDSS) are aiding the identification of a rapidly increasing number of 'field' brown dwarfs (BDs) (e.g. Lodieu et al. 2007, Pinfield et al. 2008, Burningham et al. 2009), as well as probing down into new cooler temperature regimes (Warren et al. 2007, Burningham et al. 2008, Delorme et al. 2008, Burningham et al. 2009, Leggett et al. 2009). In general the estimation of properties of these BDs (e.g. age, mass, metallicity) currently relies on model fitting. However, the models are very sensitive to a variety of poorly understood processes in BD atmospheres, such as the formation of dust condensates (Allard et al. 2001) and non-equilibrium chemistry (Saumon et al. 2007), and the spectroscopic fitting of atmospheric properties (T_{eff}, log g, [M/H]) is a major challenge. Crucially, the nature of BD evolution means that the mass-luminosity relation depends strongly on age, and in the absence of well constrained atmospheric properties there is no way to accurately determine mass and age.

* E-mail:adjones@das.uchile.cl. Based on observations made with ESO telescopes at the La Silla Paranal Observatory under programme 282.C-5069(A)

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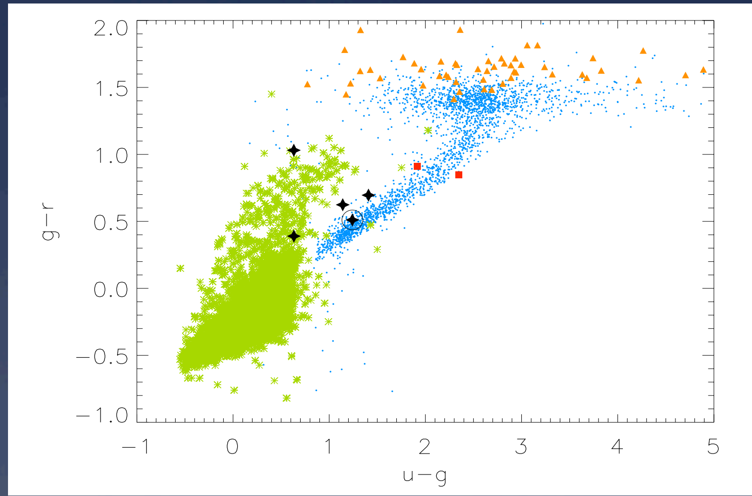
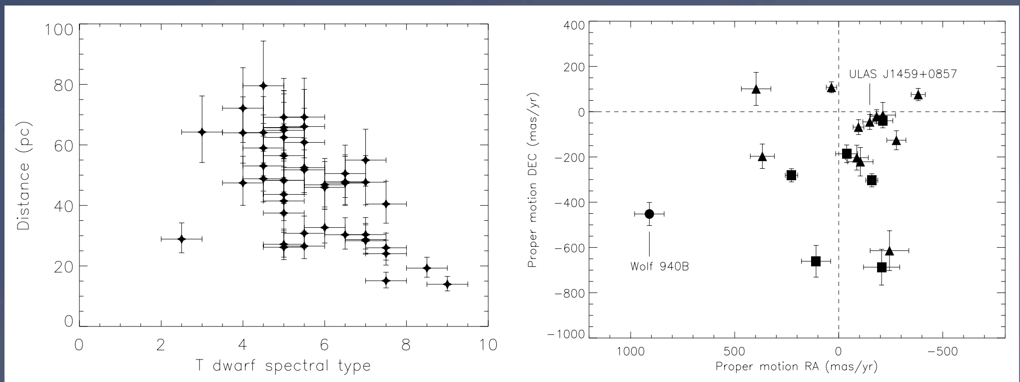
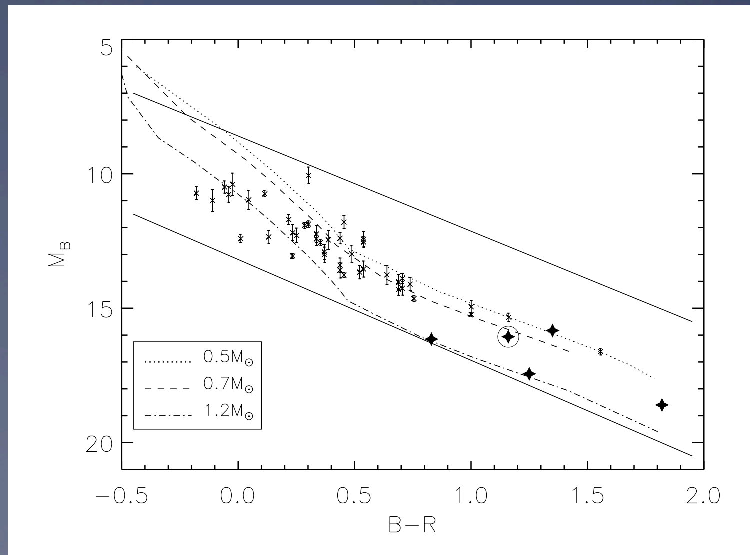
The first WD + T dwarf binary system

- We searched around spectroscopically identified T dwarfs from UKIDSS DR5, published in Burningham et al. (2010) for common proper motion companions in SuperCOSMOS.
- Identified 6 common proper motion systems.
- 1 was identified as a T8.5 dwarf companion to a M4 star, Wolf 940A, Burningham et al. (2009).
- We also identified 5 other common proper motion companions whose colours are consistent with being WDs.



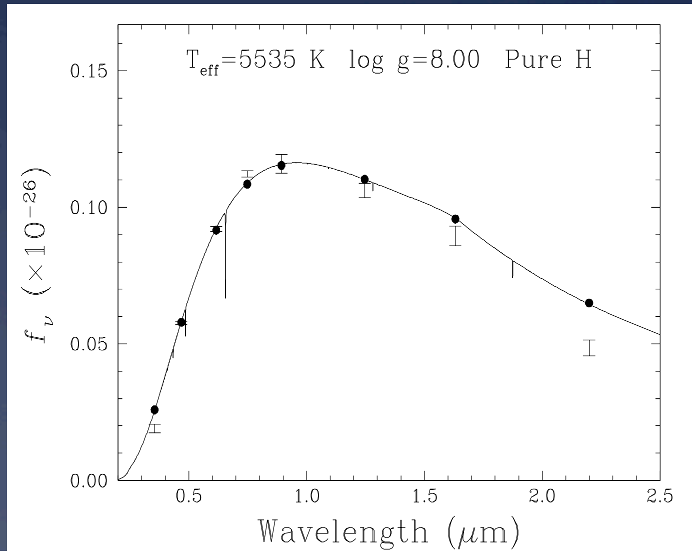
Green=WDs, Red=cool subdwarfs, Blue=MS stars, Orange=M dwarfs

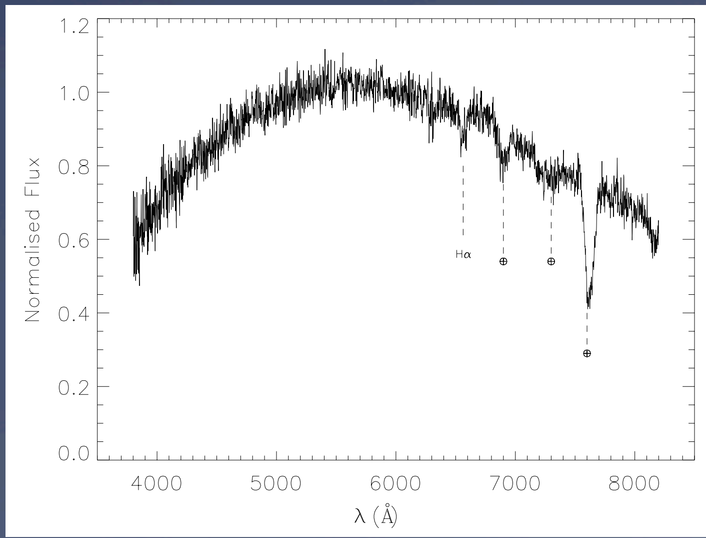


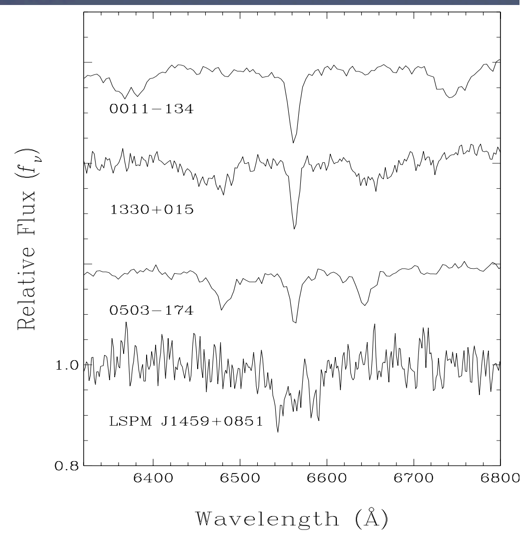


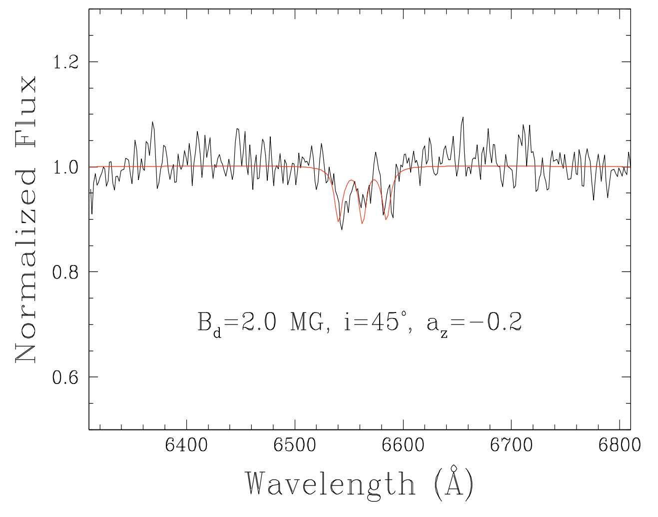
The first WD + T dwarf binary system

- We followed up the brightest of our WD components (LSPMJ1459+0851) with spectroscopy on the VLT with FORS2 in DDT.
- The spectra revealed a very cool hydrogen rich WD, with evidence of Zeeman splitting.
- Using the model fits of Bergeron we calculate its temperature as 5535 ±45K and to have a strong magnetic field of B~2MG.

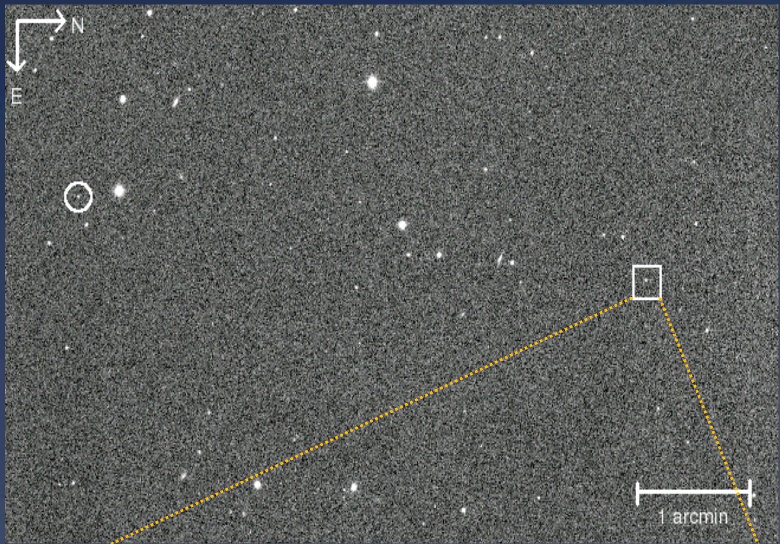


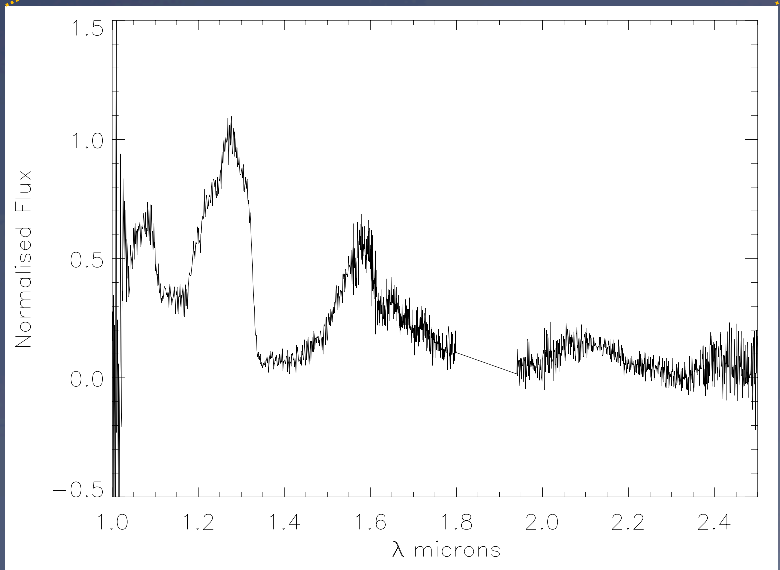






The first WD + T dwarf binary system





- The WD (LSPM1459+0857) is a companion to the T4.5 dwarf ULAS J1459+0857.
- The system is very widely separated at 6 arc minutes on the sky, or ~16,500AU at the estimated distance of the T dwarf.
- As the binary is very widely separated, we calculated the statistical likely hood of finding such a white dwarf and T dwarf, with photometry and common proper motion to be a spurious line-of-sight association is 1/3000. We thus conclude that this is a genuinely bound binary system.

Properties of the new binary system

Mass and Distance

- The mass and age of the WD was calculated from standard cooling models from Fontaine et al. (2001) as $0.585M_{\odot}$ and 3.0Gyrs, assuming a log_{g}=8.0, which is consistent with the estimated distance of the system, obtained from the T dwarf (~43pc; Liu et al. 2006).

Age

- The As the total age of the system is both the cooling age of the WD and its progenitor's main-sequence lifetime.
- Estimate that mass of the progenitor would have been 1.5-$1.75M_{\odot}$ (IFMR's from Ferrario et al.2005, Catalan et al. 2008 and kalirai et al. 2008).
- The MS lifetime of the progenitor was calculated as 1.8-3.0 Gyrs (Lachaume et al. 1999). Giving the binary age as 4.8-6.0 Gyrs.

Properties of the new binary system

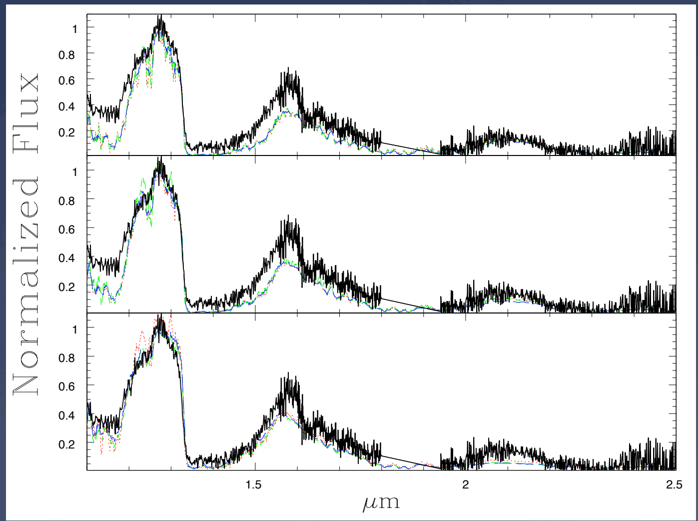
However…

- The WD is magnetic, this may affect the evolution on the MS.
- The origins for the highly magnetic component is still somewhat uncertain (favoured scenarios are from single Ap or Bp stars, or from the merger of 2 stellar cores).
- It has been suggested that this could cause the WD to have a higher mass (Kawka et al. 2007), increasing the cooling time (~6Gyrs; Fontaine et al. 2001).
- As it is not possible to measure more accurately the mass or the effect this has had on the MS evolution, which would likely only lengthen the age, we conservatively suggest that the system is >4.8Gyrs.

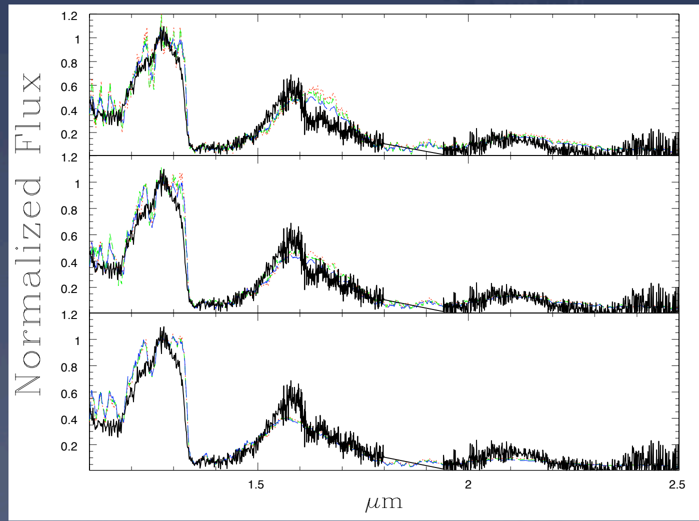
LSPM J1459+0851B: An evolved age benchmark T dwarf

* Model spectra from the Lyon group COND models with comparison to the T dwarf spectra.

* The models suggest high gravity, solar to slightly sub-solar metallicity. However there are many areas where the model doesn't fit the spectra well.



1200 K model

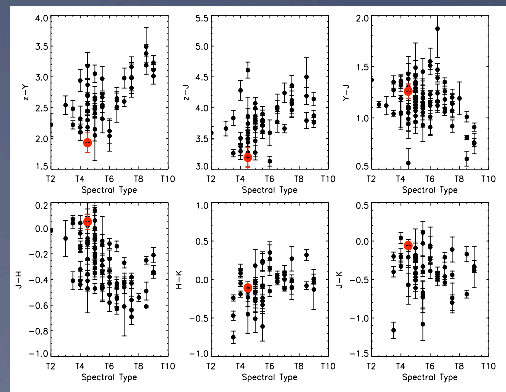


1500 K model

Top=[M/H]=+0.3
Middle=[M/H]=0.0
Bottom=[M/H]=-0.5

Blue=$\log_g$=5.0
Green=$\log_g$=5.25
Red=$\log_g$=5.5

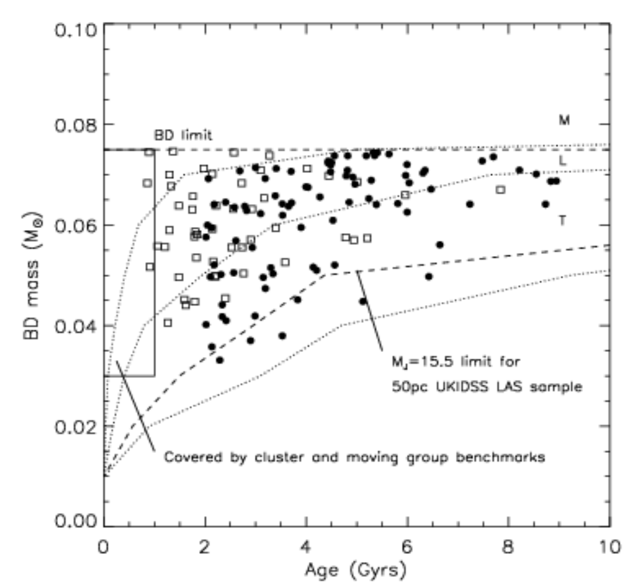
Could the older age be the reason for some of the 'extreme' colours we see in the T dwarf?

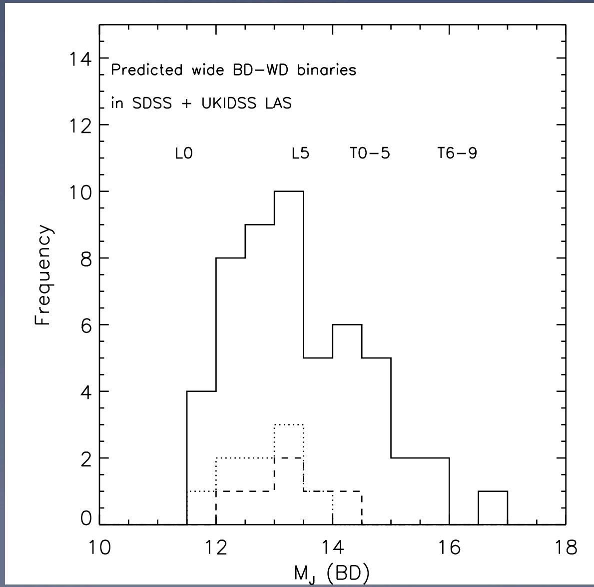


WDs as age calibrators for UCD models

- It is currently not possible to calculate the age of a UCD from models alone, as the models can not, as yet reliably reproduce the spectral and physical properties seen across the population of UCDs identified.
- WDs in binary systems with a UCD can thus be used as benchmarks and provide an age constraint to help calibrate UCD models and investigate the relationship between the observable properties with age.
- WD models are more robust than the ages calculated for MS stars and thus it should be available to calculate the age of a WD to accurate levels, providing good benchmark systems with tight constraints.

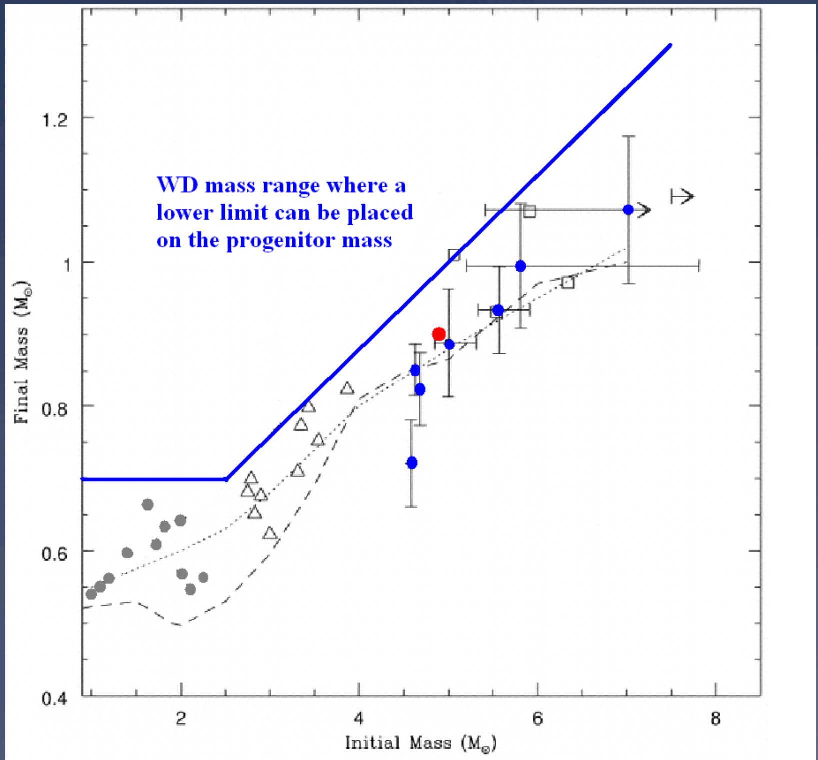
Simulated number of benchmarks that could be provided by WDs (Pinfield et al. 2006).



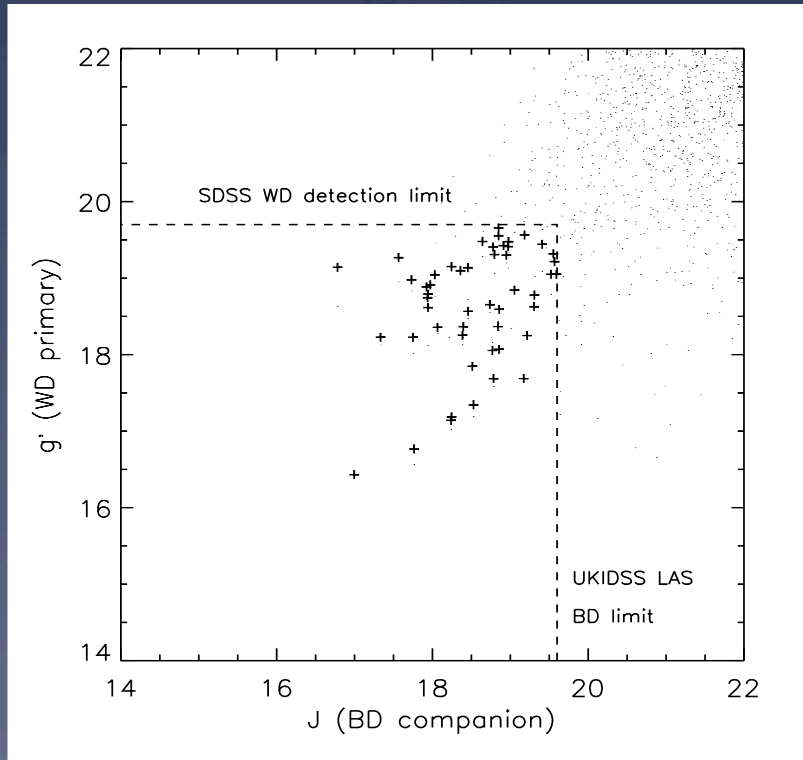


WDs as age calibrators for UCD models

The best benchmark systems will come from higher mass WDs ($M>0.7M_{\odot}$), where the ages can be constrained to ~10%.

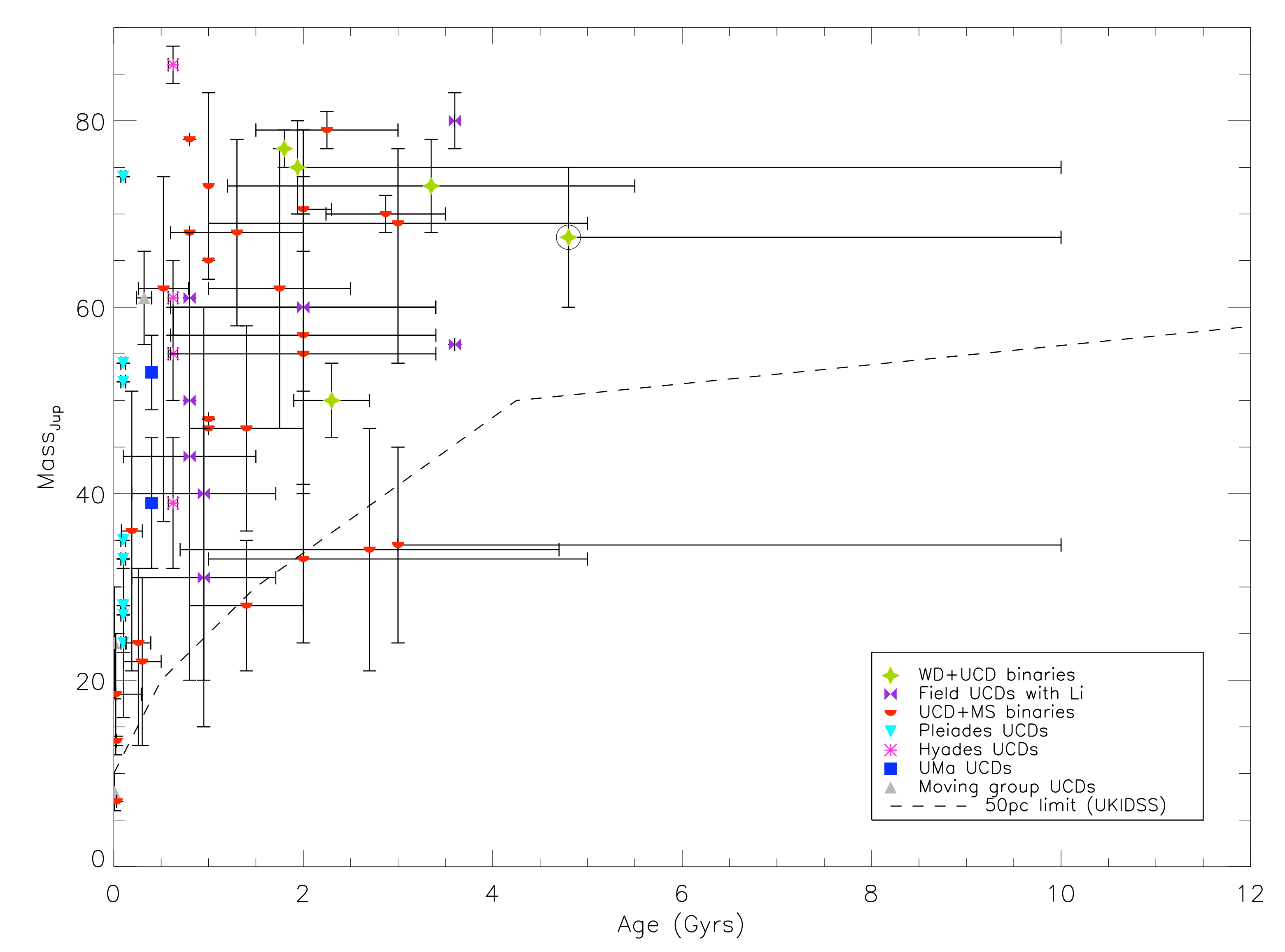


IFMR from Dobbie et al. (2006)



Simulation for 10% of the sky for age calibrating WD + UCD binary systems from SDSS and UKIDSS from Pinfield et al. (2006).

The current population of benchmark UCDs



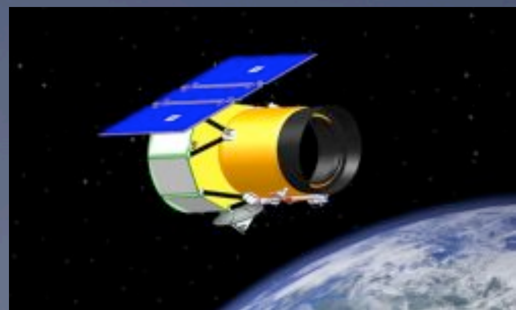
Day-Jones et al. (2010), in prep

Current and Future Surveys

Surveys currently underway and those with near-future data releases should provide more WD +UCD binary systems.

Vista – The coverage of VIKING & VHS will cover 3 times the area of the UKIDSS LAS at depths of 1.5 mags deeper than UKIDSS and ~5 mags deeper than 2MASS. It has been suggested it will provide up to ~20 times the number of late T dwarfs currently identified in the UKIDSS LAS.

WISE will also be able to provide accurate temperatures of binary component by providing complete spectral coverage, and thus provide good bolometric fluxes.



Conclusions

* Discovered the first T dwarf companion to a WD.
* The new WD + T dwarf binary provides the only robust old-disk T dwarf benchmark.
* WDs provide good benchmark UCDs, which can aid the calibration of currently struggling UCD models.
* Many more are likely to be identified in near-future surveys or those currently underway.