Outlier benchmark ultra-cool dwarfs with *Gaia* primaries

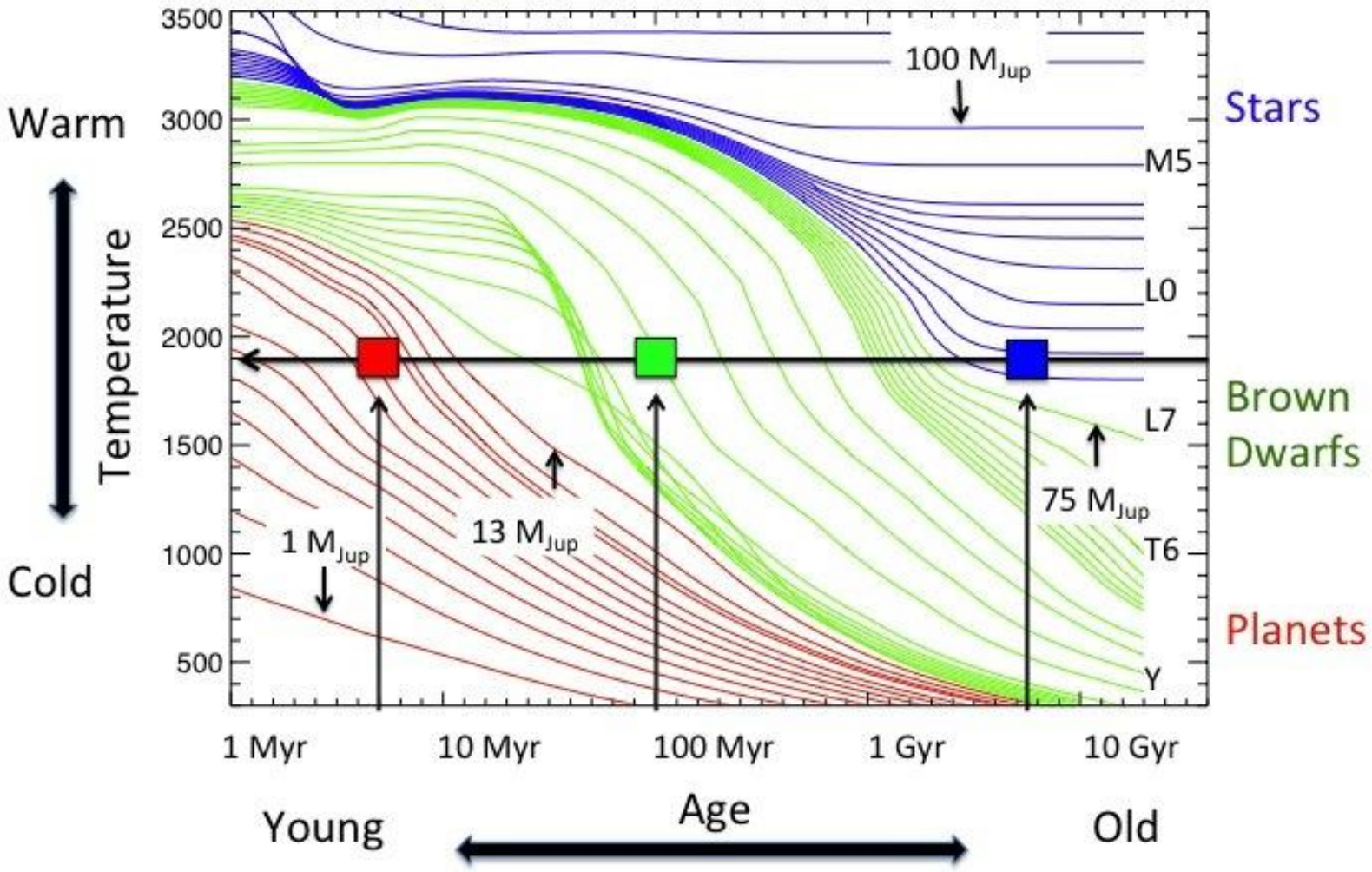
Federico Marocco

David Pinfield (UH), Hugh Jones (UH), Phil Lucas (UH), Neil Cook (UH), Niall Deacon (UH), ZhaoXiang Qi (SHAO), Ben Burningham (NASA/Ames), Richard Smart (OATo), Jose Caballero (CAB), Maricruz Galvez-Ortiz (CAB), Mariusz Gromadzki (UV), James Jenkins (U. Chile), Radostin Kurtev (UV), David Montes Gutierrez (UCM), Maria Teresa Ruiz (U. Chile), ZengHua Zhang (IAC).

University of Hertfordshire

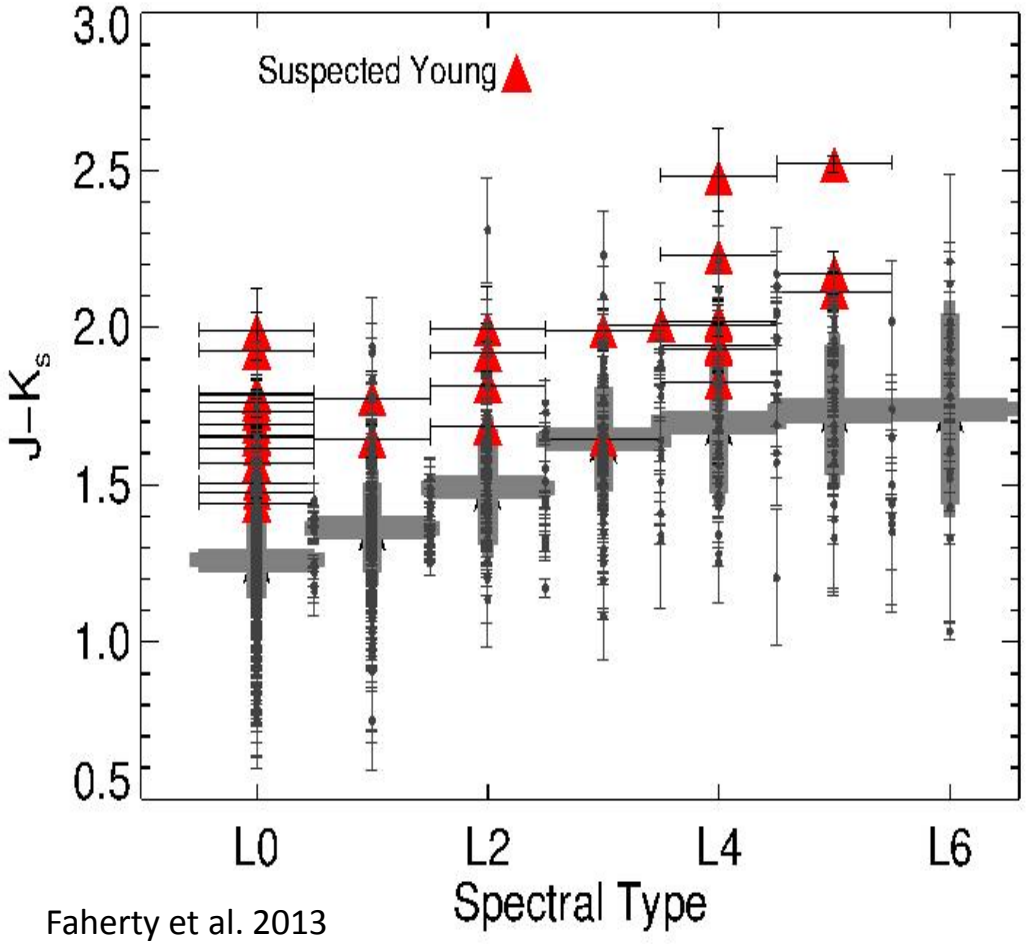
Introduction

Ultra-cool dwarfs are a mixture of sub-stellar objects and very low-mass hydrogen-burning stars

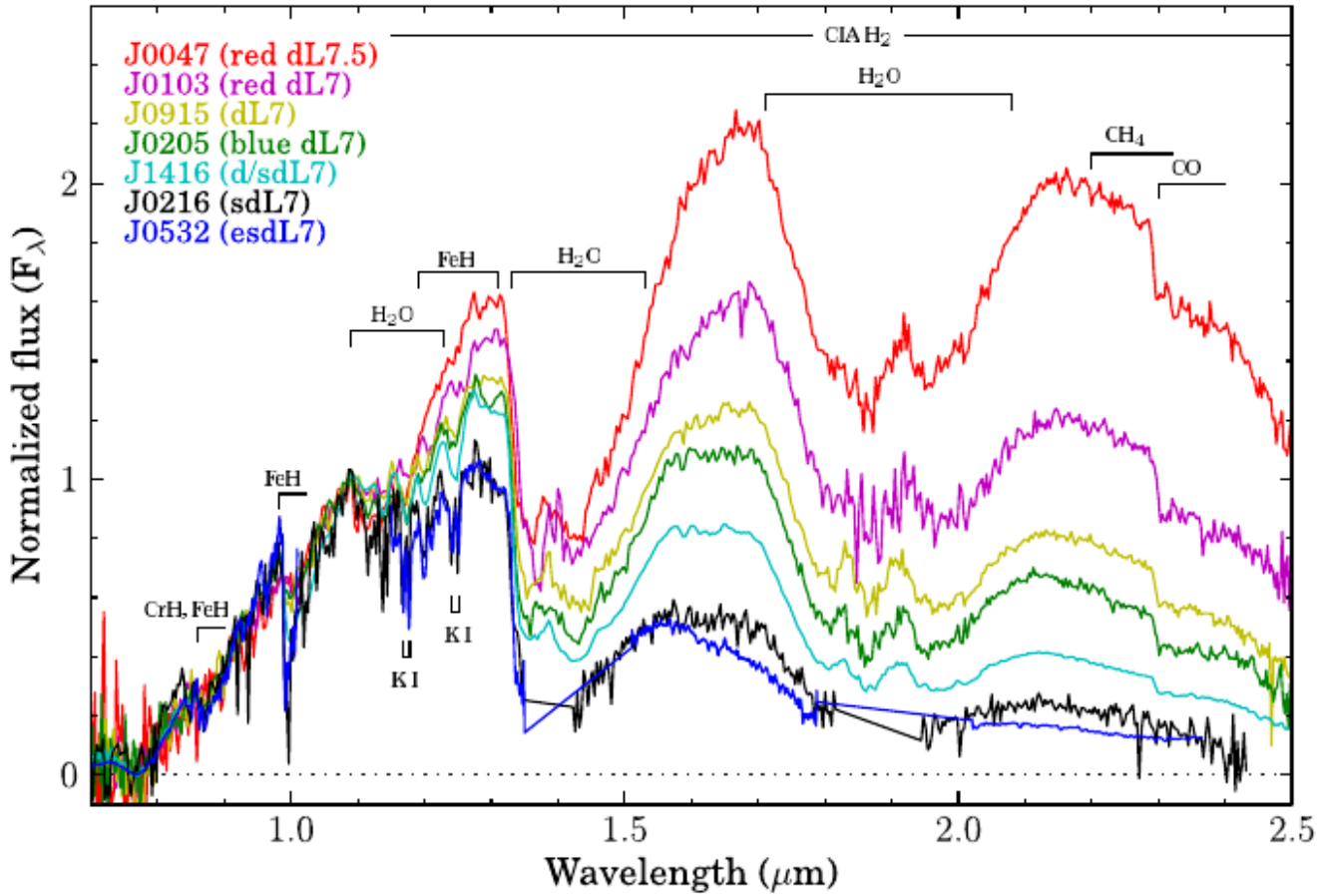


Introduction

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



Faherty et al. 2013



Zhang et al. 2013

Introduction

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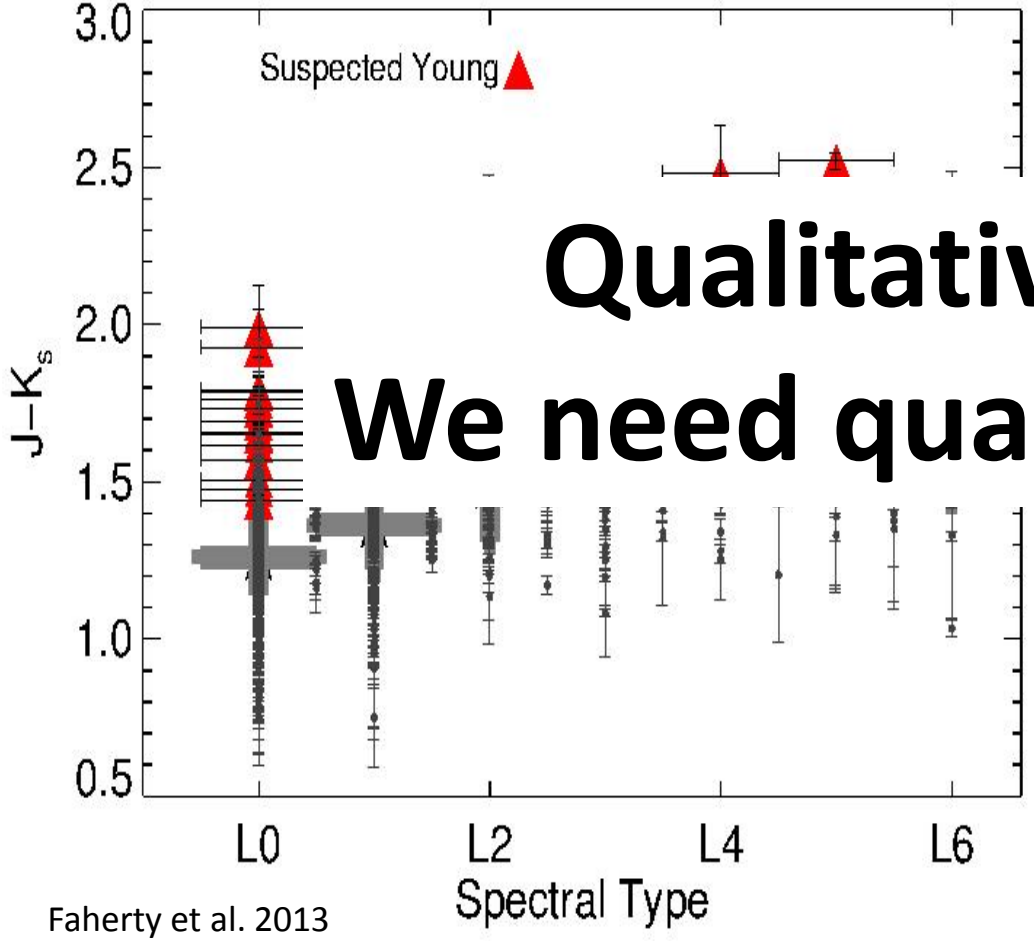
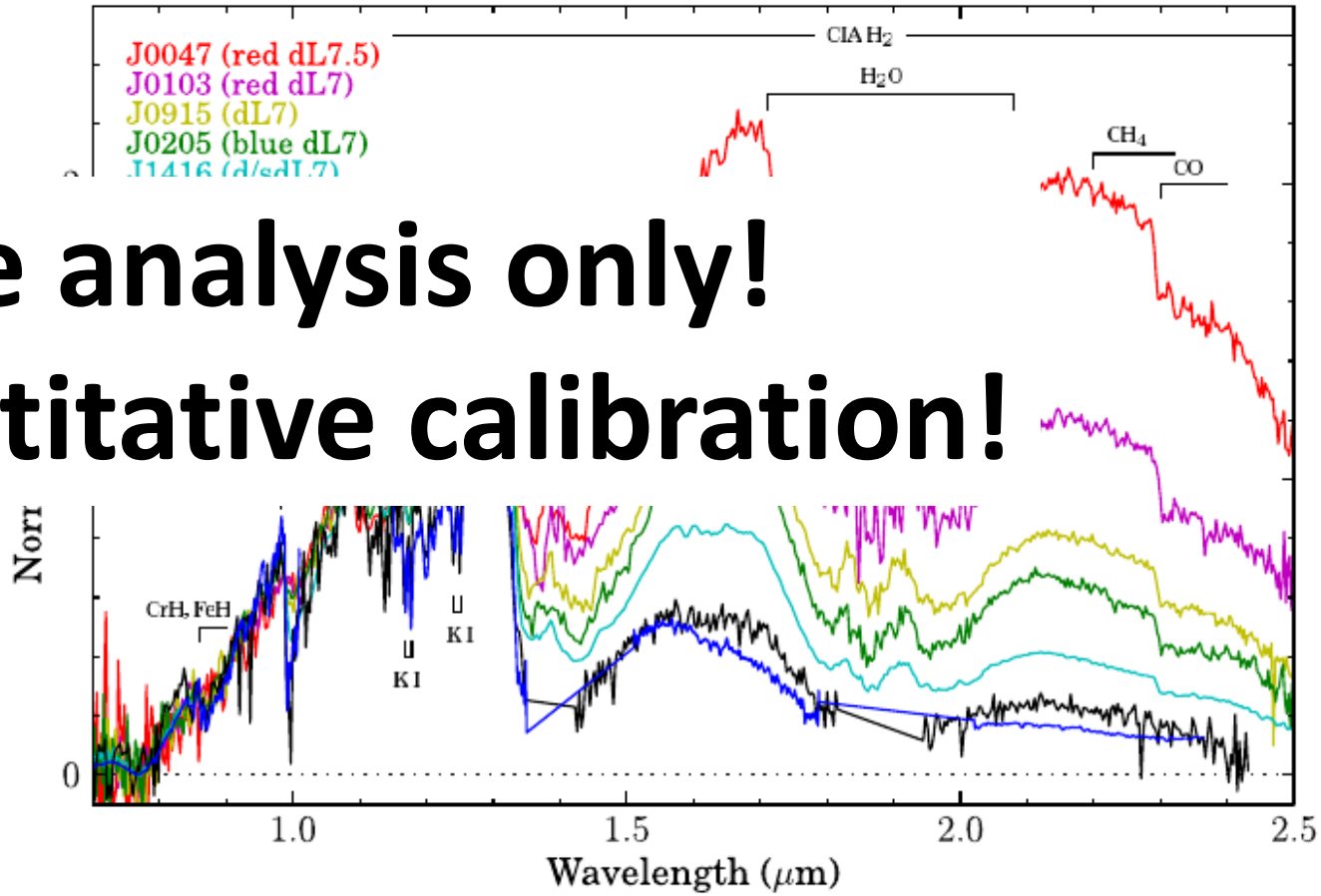


Faherty et al. 2013

Qualitative analysis only!

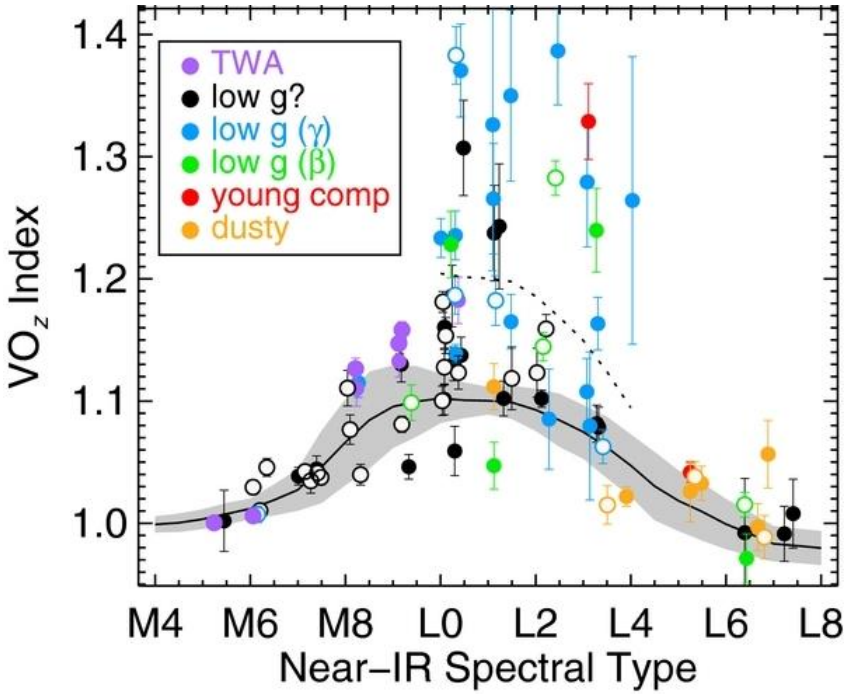
We need quantitative calibration!



Zhang et al. 2013

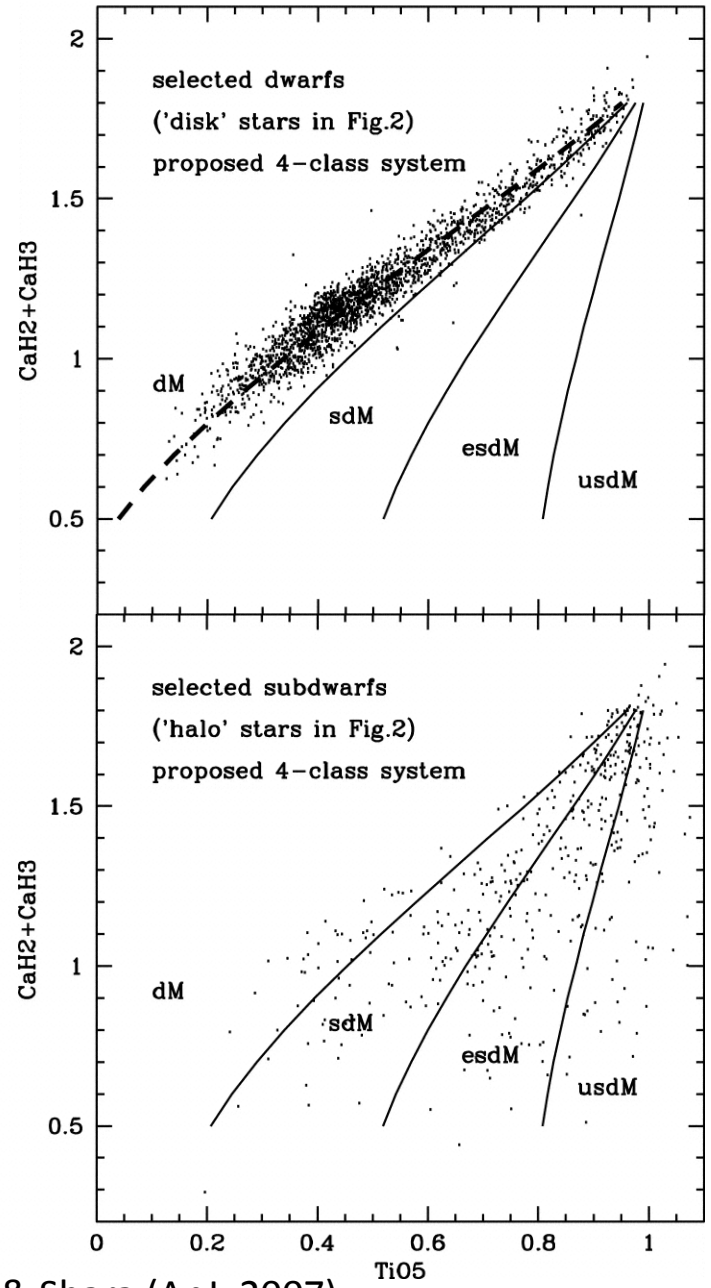
Benchmark systems

A direct way to overcome this challenge is to identify ultra-cool dwarfs (UCDs) whose physical properties can be inferred indirectly – so-called "benchmark systems" (e.g. Pinfield et al. 2006).



Allers & Liu (ApJ, 2013)

A number of atomic (KI and NaI) and molecular (FeH, VO, TiO, CaH) features have been shown to be sensitive to surface gravity and metallicity, but **the current calibrations suffer from limited sample size**.



Lepine, Rich & Shara (ApJ, 2007)

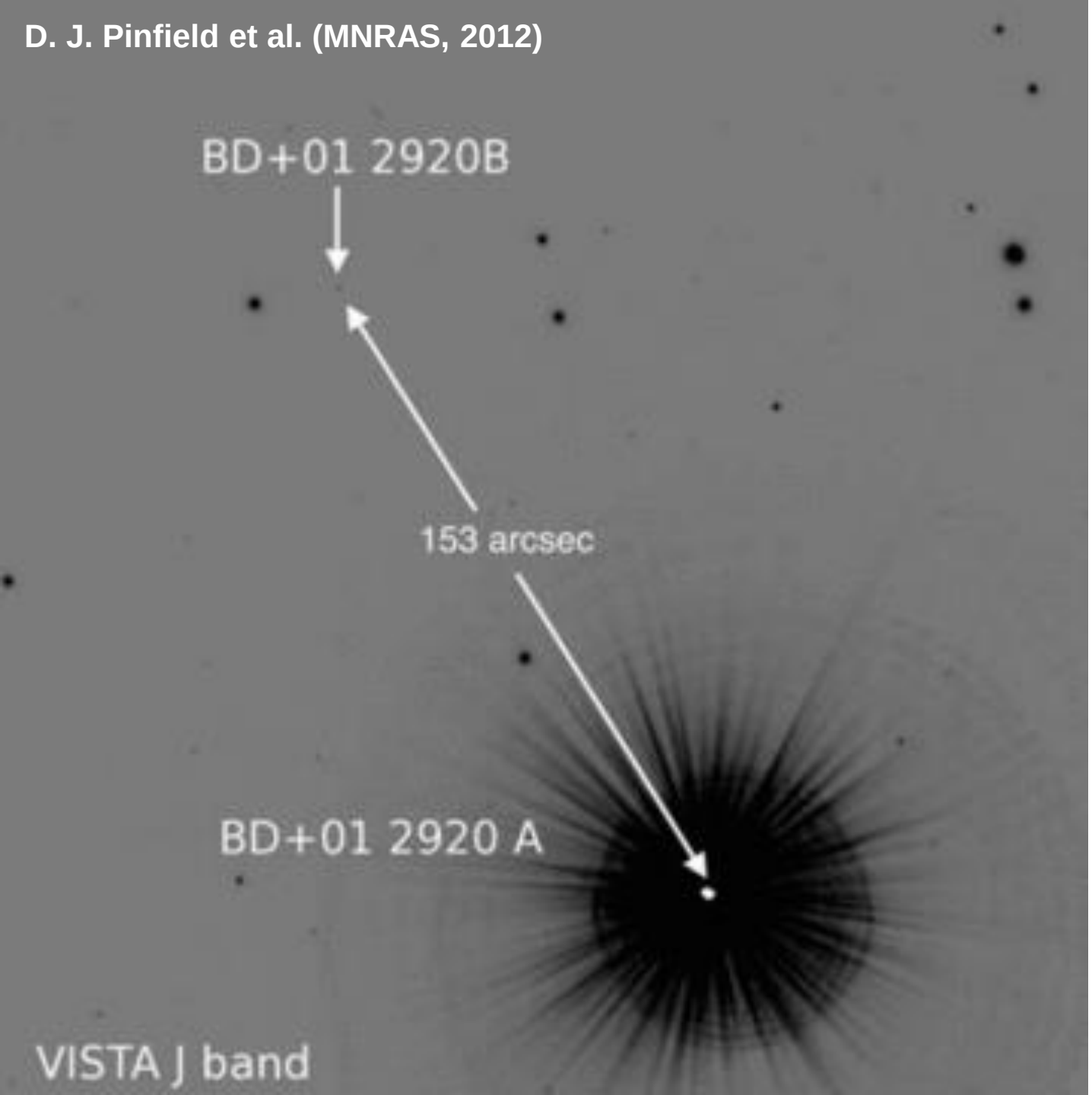
Benchmark systems

UCDs as wide companions to stars or stellar remnants of various type are a particularly crucial source of benchmarks, for which common age and compositional constraints can be determined from studies of the primaries.

Wide companions can be identified via common proper motion (e.g. Gomes et al., MNRAS, 2013; Burningham et al., MNRAS, 2013; Deacon et al., ApJ, 2014) or common radial velocity (cf. Dithal et al., AJ, 2012).

To date 98 >M7 dwarfs in 92 multiple systems

0.33 % of main sequence stars should host L dwarf companions



BD+01 2920 AB

BD+01 2920 A

G1V

D = 17.2 ± 0.2 pc

V_r= 19.6 ± 0.3 km s^{-1}

Space motion UVW= 22, 15, 39 → thin disk

T_{eff} = 5750 ± 100 K

log *g* = 4.45 ± 0.05 dex

Mass = 0.87 ± 0.07 $M_\odot$

[Fe/H] = −0.38 ± 0.06 dex

Age = 2.3–14.4 Gyr

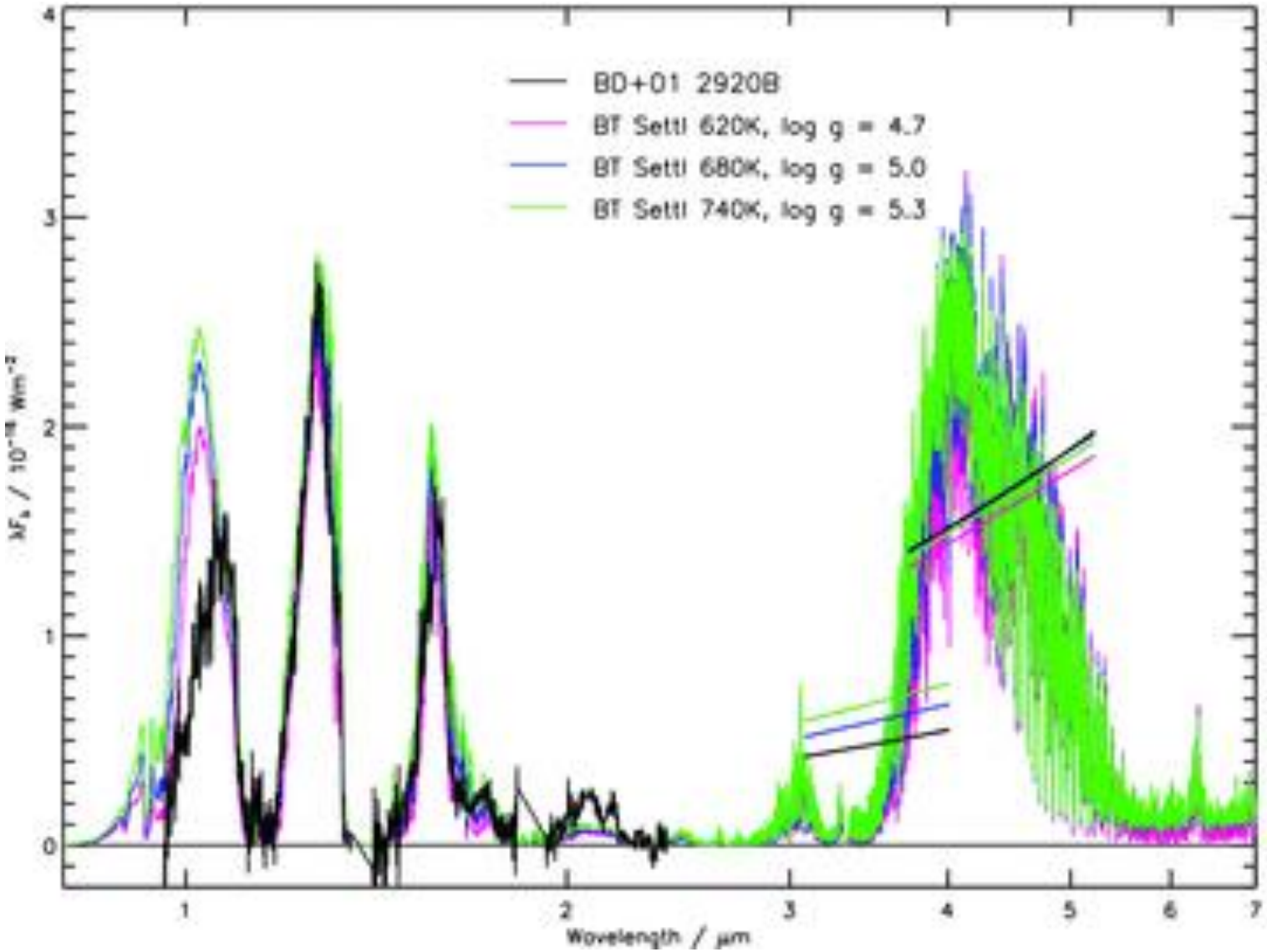
v sin(i)= 1–2 km s^{-1}

Low-activity star

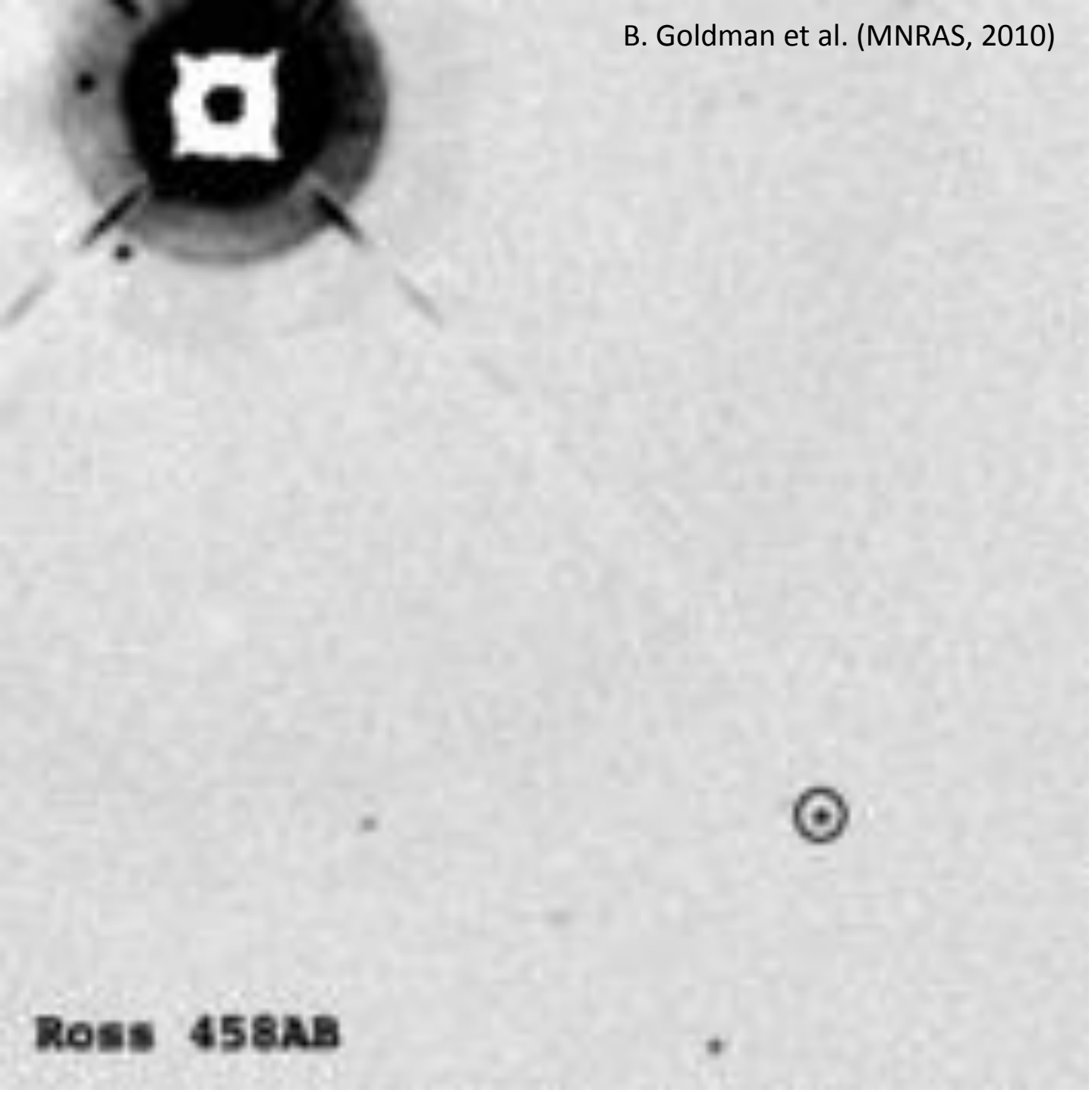
BD+01 2920 AB

BD+01 2920 B
T8p
log $L/L_{\odot}$= −5.83 ± 0.05
Mass = 20–50M_{Jup}
Radius = 0.80–0.99 R_{Jup}
log *g* = 4.68–5.30 dex
T_{eff} = 680 ± 55 K

Discrepancy with model atmospheres in both NIR and MIR!



D. J. Pinfield et al. (MNRAS, 2012)



B. Goldman et al. (MNRAS, 2010)

Ross 458 ABC

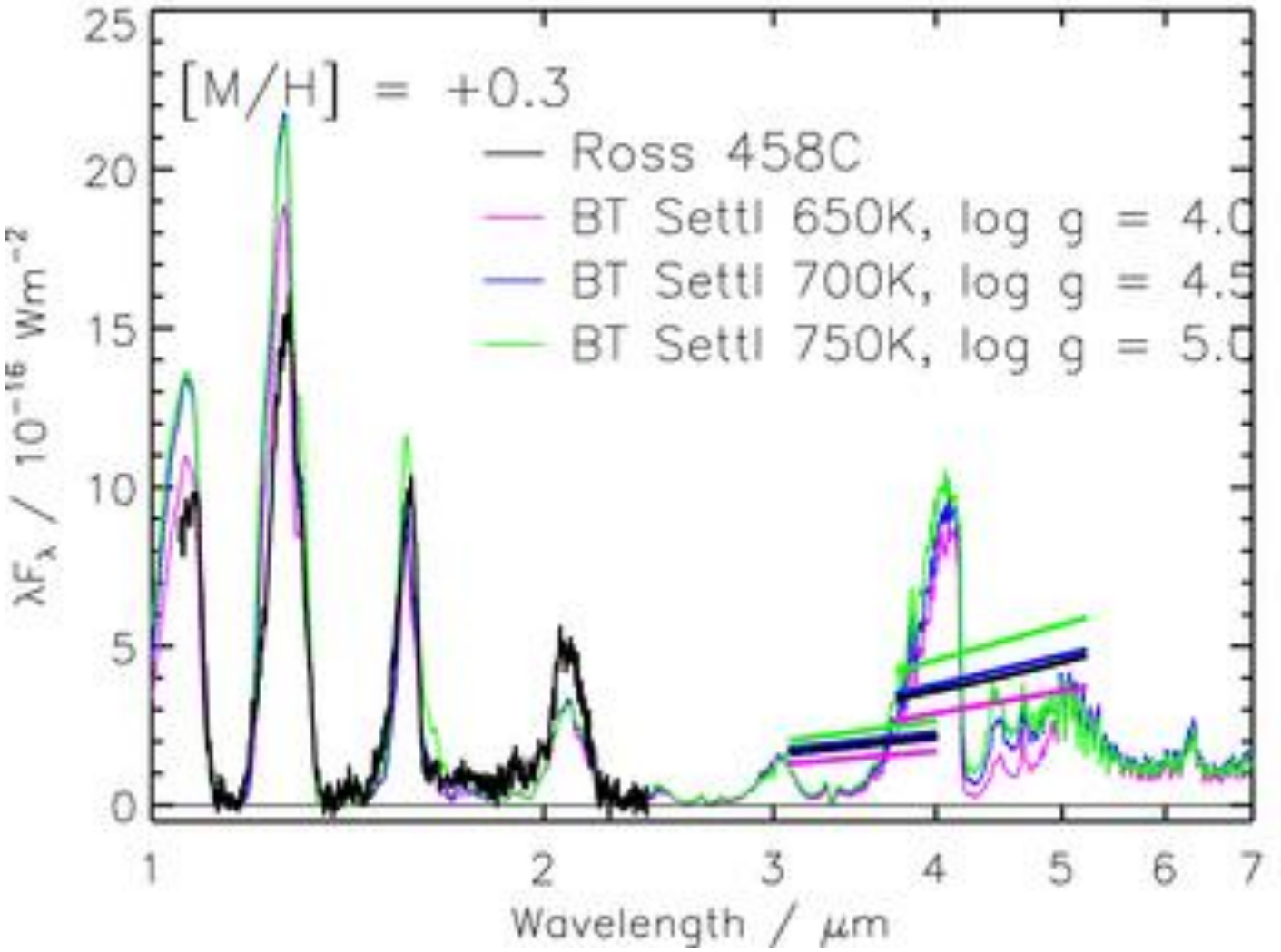
Ross 458AB
M0.5 + M7
Age ≤1 Gyr
D = 11.4 ± 0.2 pc
[Fe/H] = 0.20–0.31 dex
Member of the Hyades?

Ross 458 ABC

Burningham et al. (MNRAS, 2011)

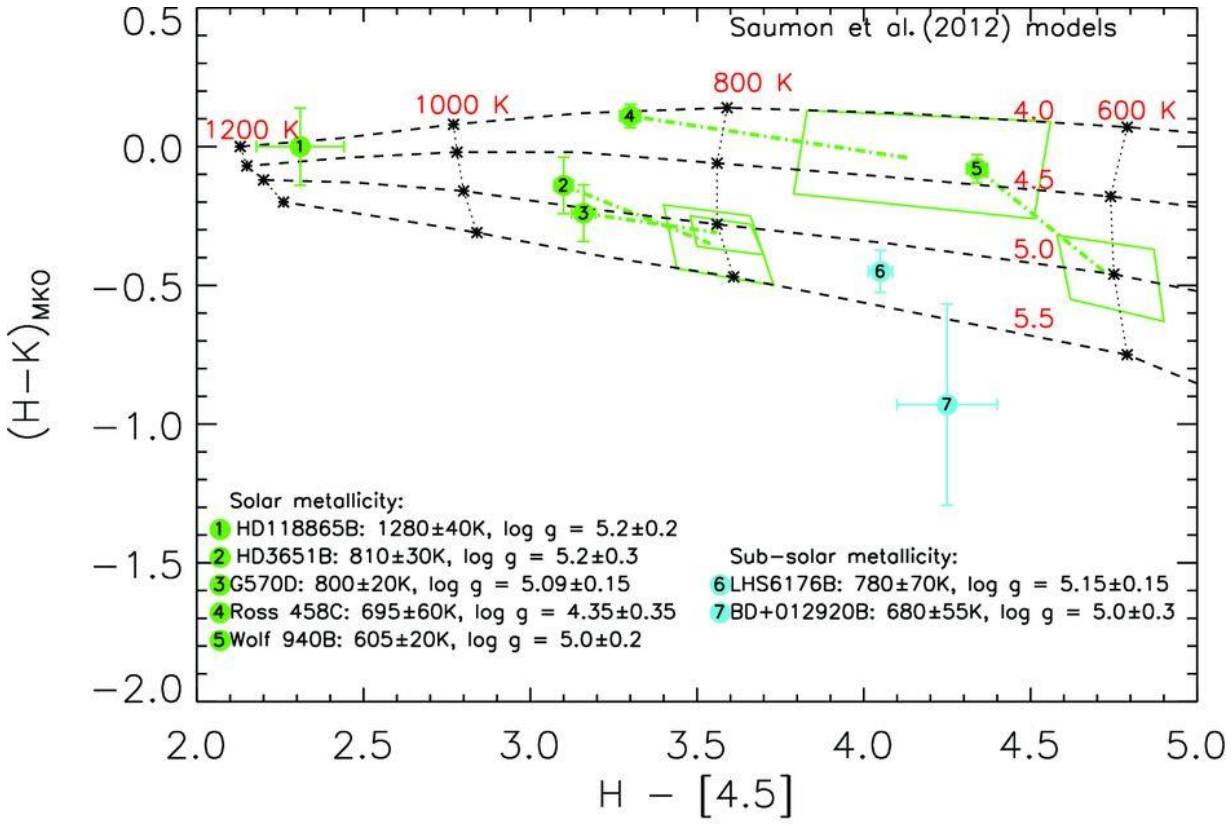
Ross 458C
T8.5
T_{eff} = 695 ± 60 K
log *g* = 4.0–4.7 dex

Discrepancy with model atmospheres in both NIR and MIR!

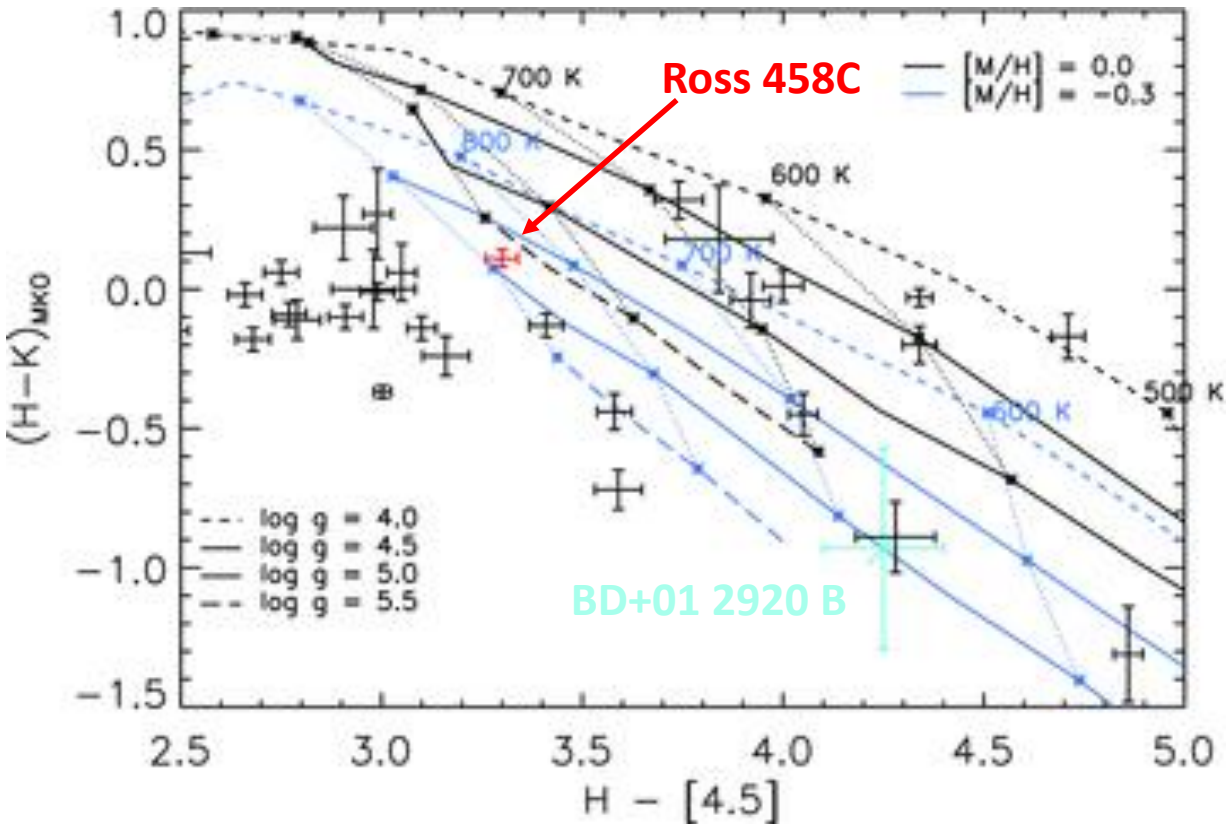


Benchmark systems

Burningham et al. (MNRAS, 2013)



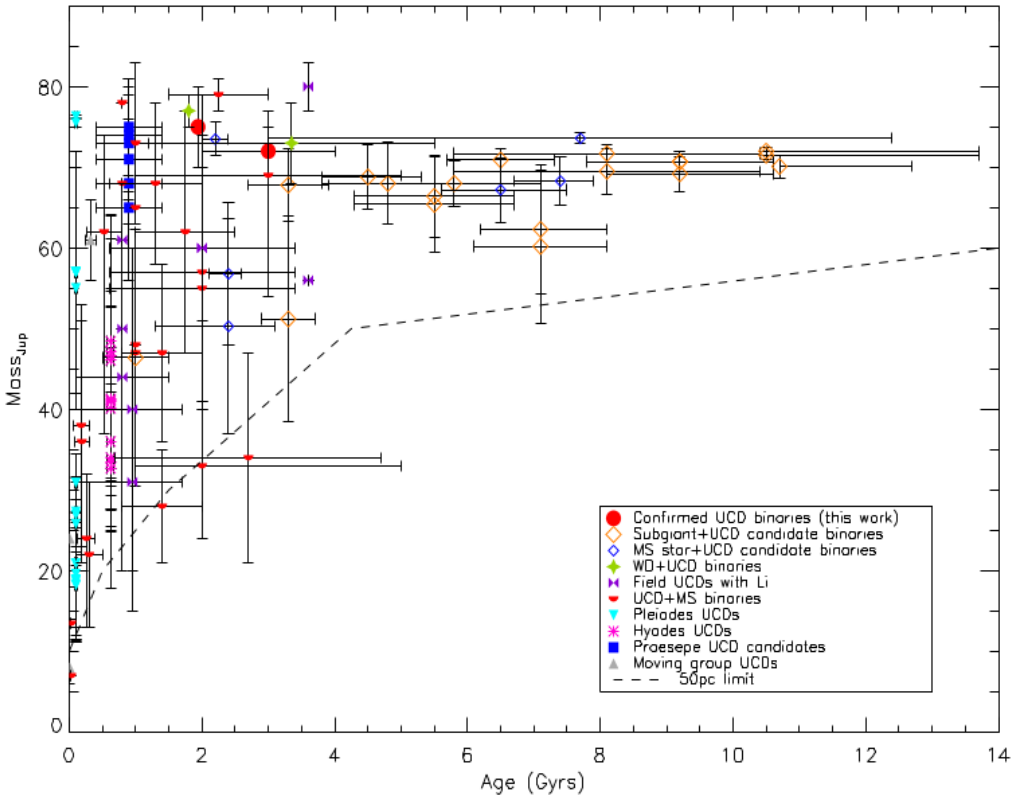
Pinfield et al. (MNRAS, 2012)

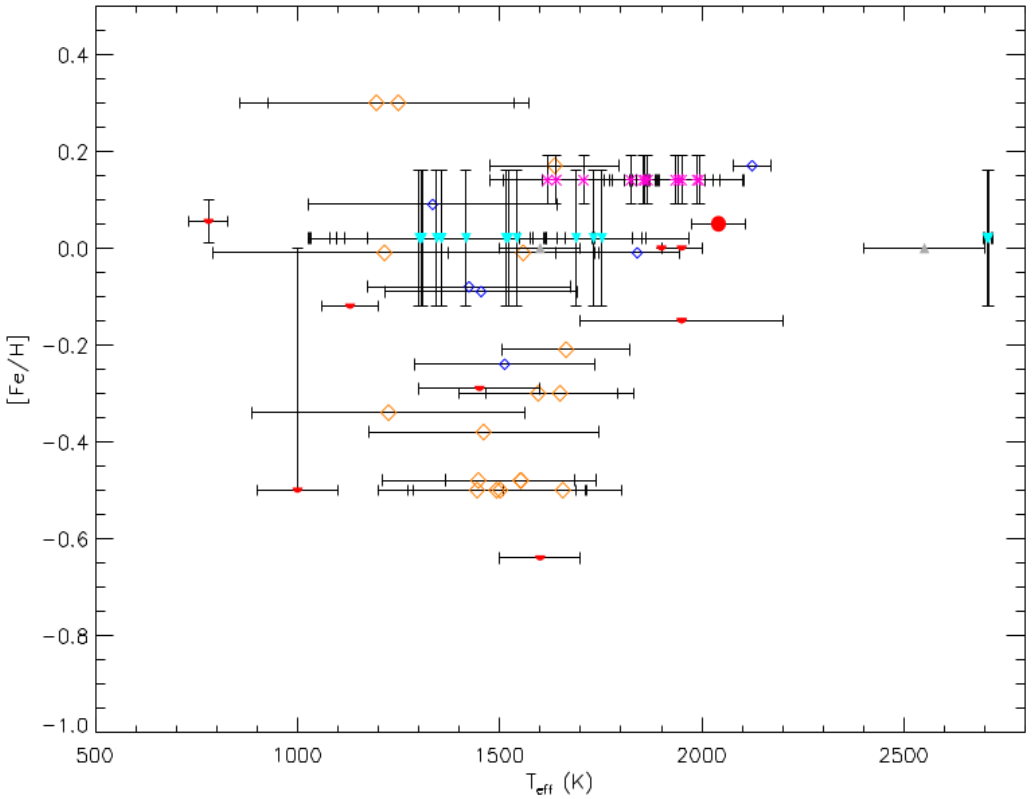


Models fail to reproduce properly the NIR and MIR colours of benchmark systems!

Benchmark systems

A. Day-Jones (UHRA, 2009)





Vast regions of the parameter space are unexplored/under-sampled!

Benchmark systems

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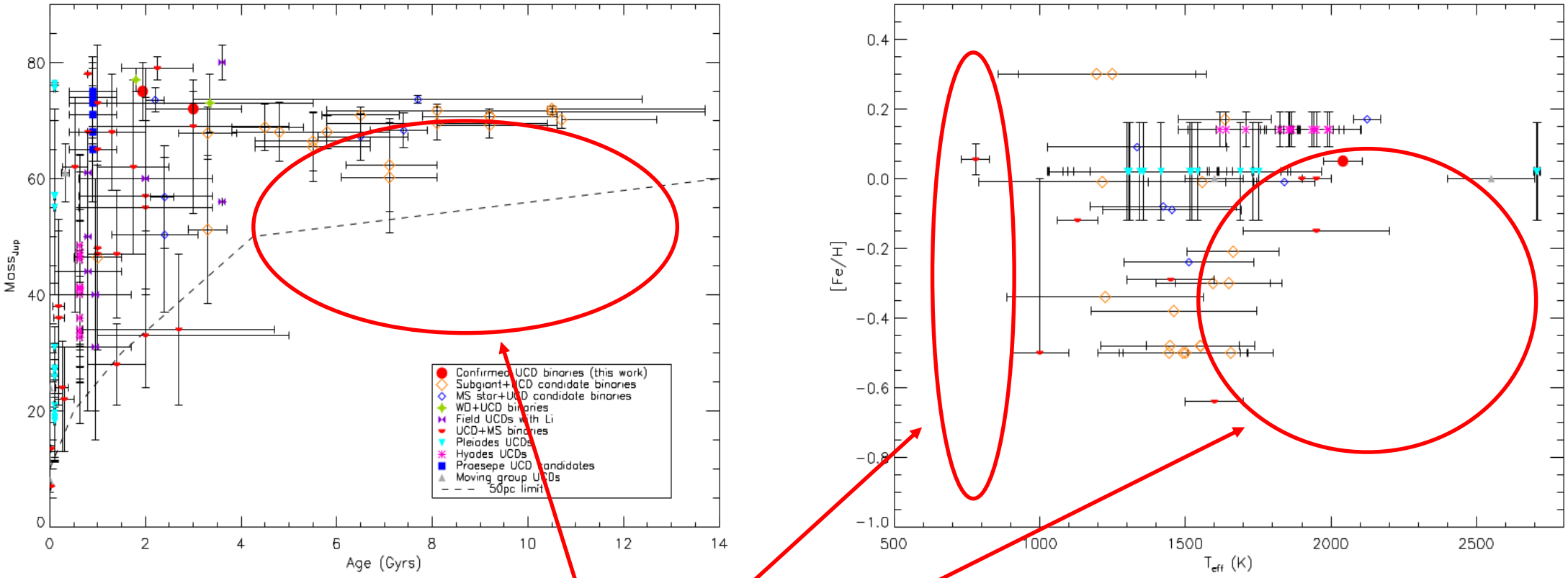
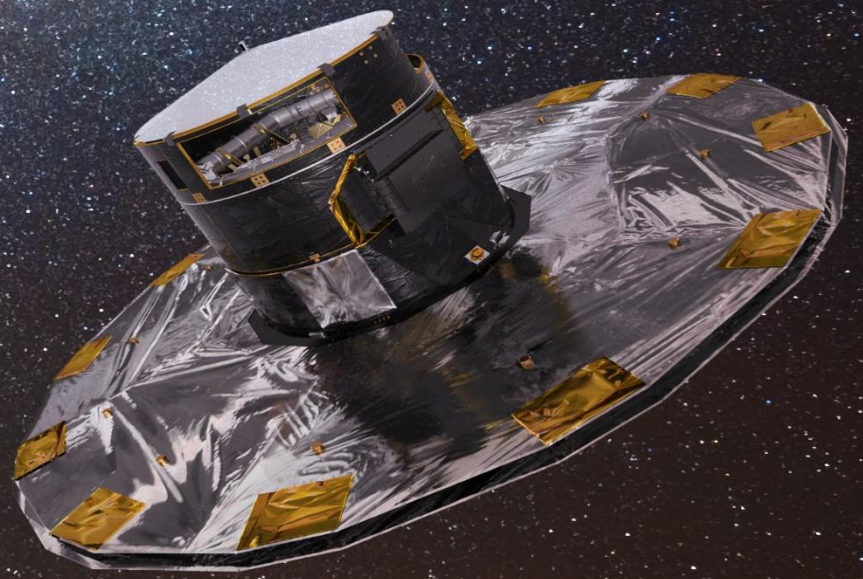


Vast regions of the parameter space are unexplored/under-sampled!

Gaia

600,000 stars out to ~100 pc from *Gaia*
+
0.33% L dwarf companions fraction
=
more than 2000 benchmarks!

Combining *Gaia* capabilities (form primaries) with UKIDSS/VISTA/SDSS survey depth (for the companions), we can pre-select sizeable sub-samples with extreme (outlier) physical properties, that will provide a complete test of the spectral sensitivities across a broad parameter-space.



UCD candidates selection

We have begun a programme to identify outlier benchmark systems with *Gaia* primaries, with a focus on metal-rich and metal-poor systems.

UCD candidates were selected cross-matching **UKIDSS LAS + SDSS** and **UKIDSS GCS**.

The initial selection is VERY conservative. We select all the objects with typical colours of known L/T dwarfs from the literature:

Y – J > 0.85
and
J – H > 0.50
and
SDSS *z* – J > 2.1 (1.667 for GCS *z*)

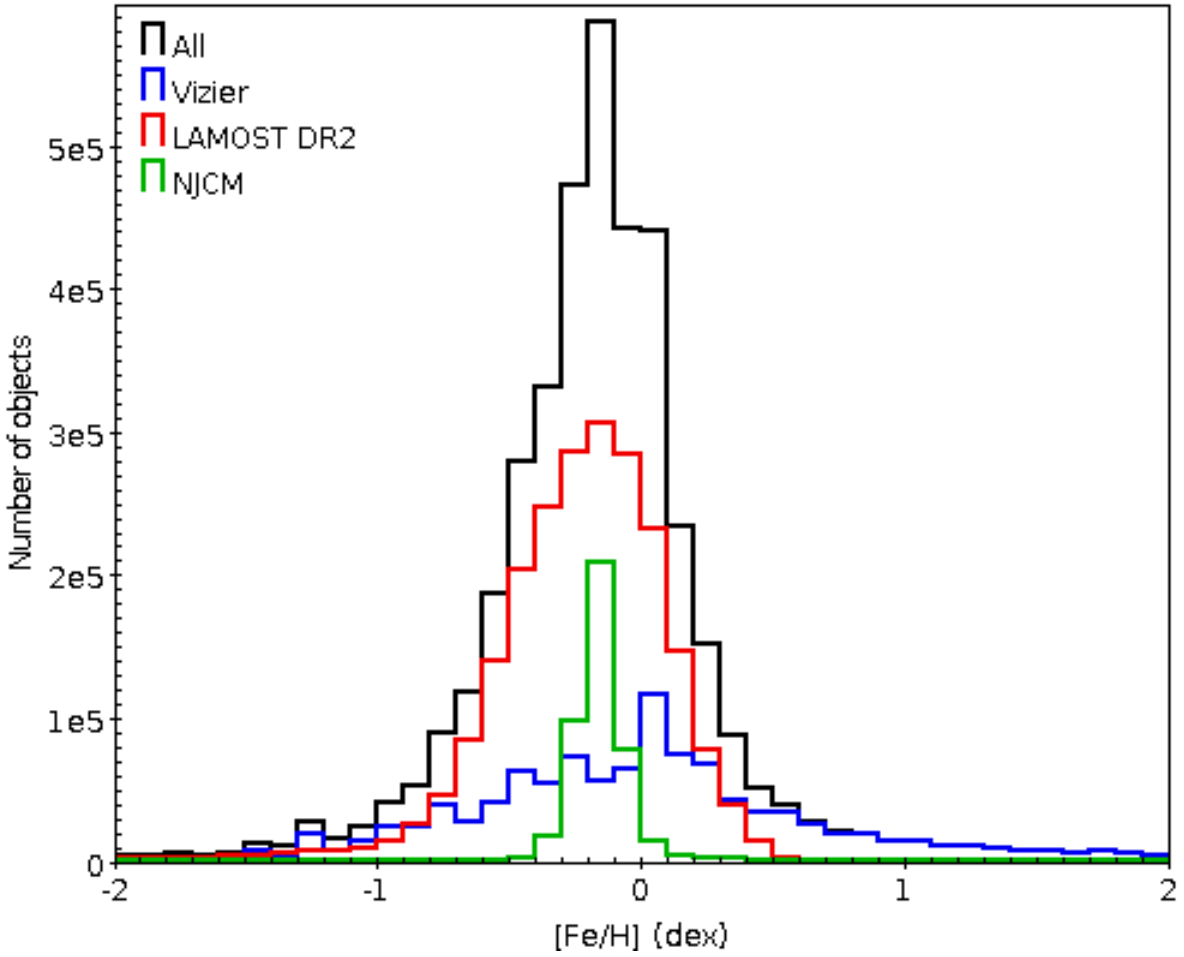
These criteria return a total of **82842 UCD candidates**.

Primaries selection

We have constructed a sample of outlier *Gaia* primaries with [Fe/H] < -0.3 or [Fe/H] > 0.3 dex using:

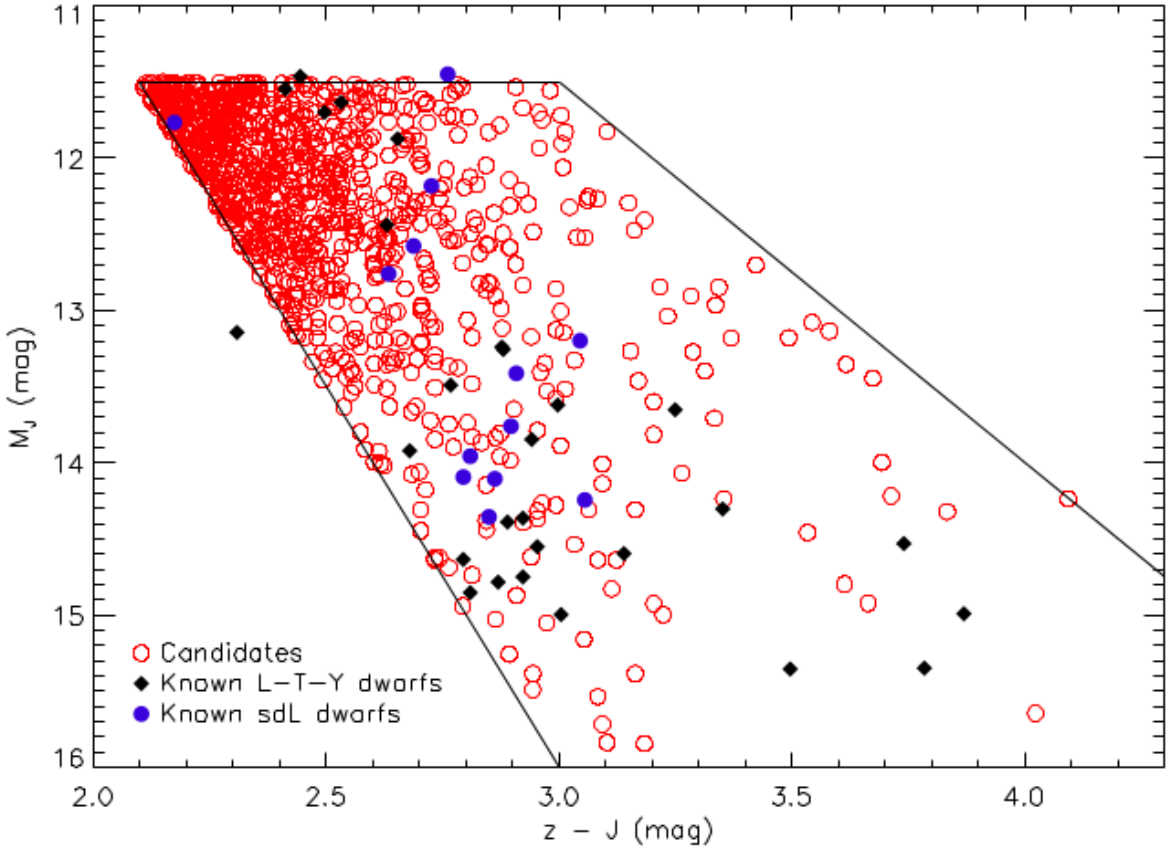
- published catalogues from *Vizier* (e.g. RAVE, Kordopatis et al. 2013; N2K, Ammons et al. 2006);
- the LAMOST DR2 (Yuan et al. 2015);
- the NJCM catalogue (Neil Cook's talk), with [Fe/H] estimated using the Neves et al. (2012) calibration.

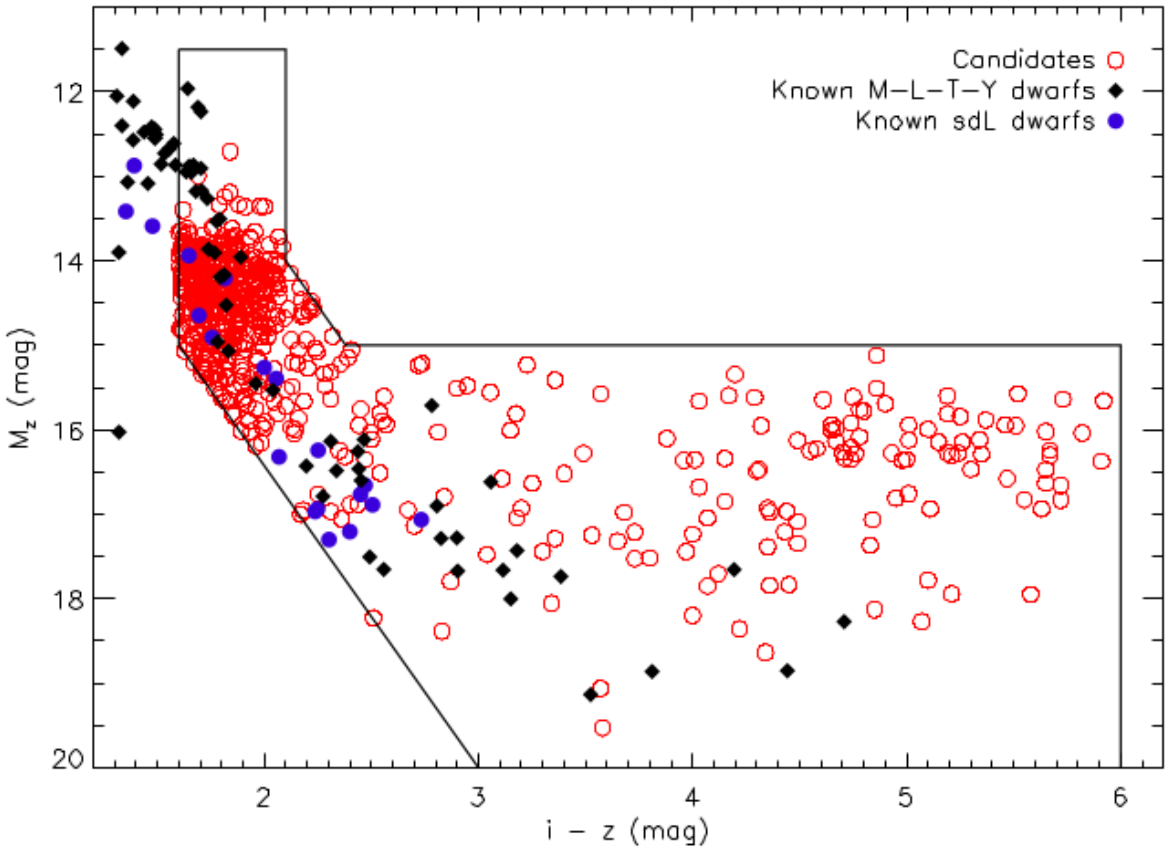
The final list includes ~**1.6 million FGKM stars**.



Benchmark system candidates selection

Our candidate benchmark systems were selected using primary-secondary separation limits of < 3 arcminutes. We employ distance constraints for the primaries, to apply a colour-magnitude test for the UCD companions.



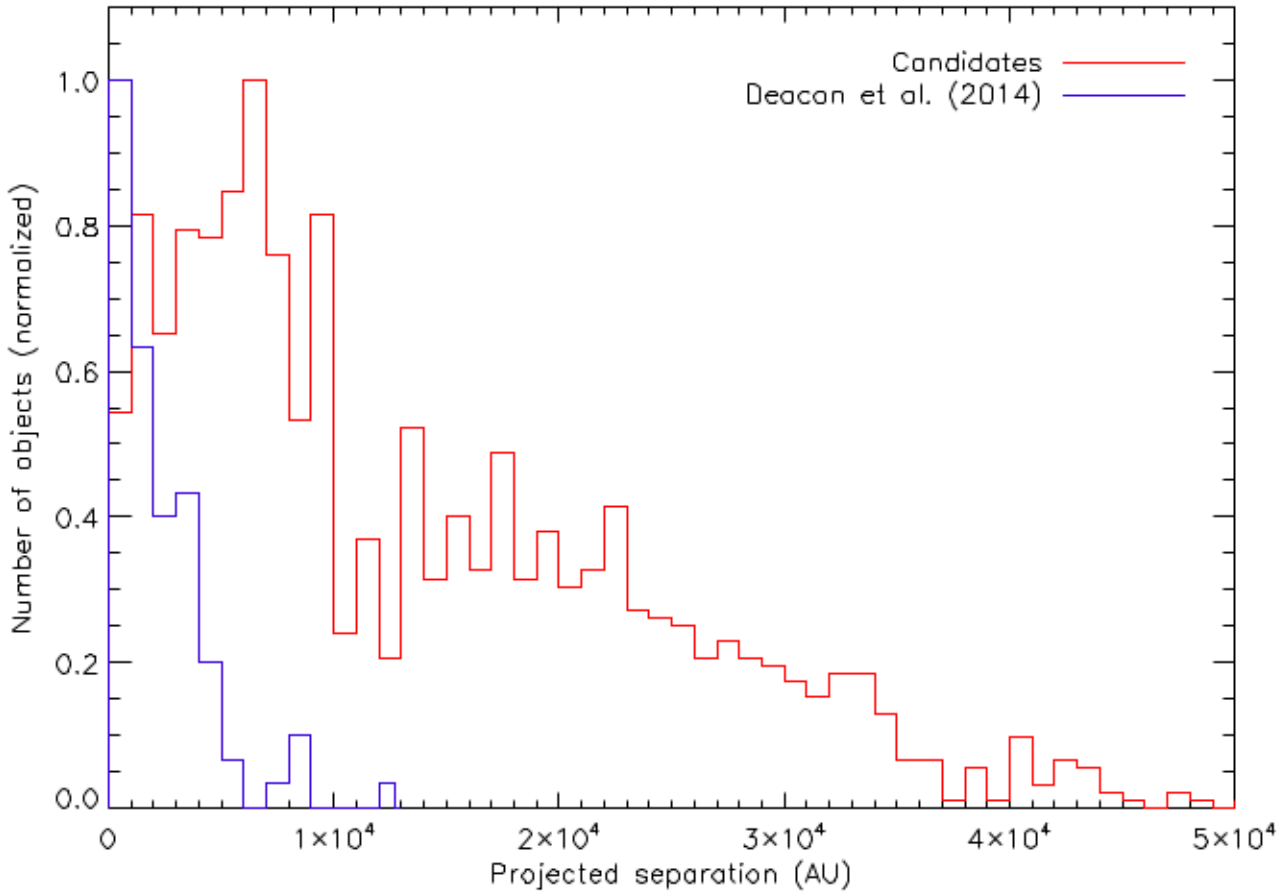


Benchmark system candidates selection

Our selection yields **1397 system candidates.**

- **330 high proper motion systems** (i.e. total PM ≥ 50 mas yr^{-1}), TBC via common PM
- **1067 low proper motion systems,** TBC via common RV

We do not expect to be dominated by contamination.



Future work

Statistical assessment of companionship via several criteria:

- Primary – secondary projected separation;
- CPM where the proper motion of the system is large enough (i.e. total PM ≥ 50 mas yr^{-1});
- CRV for low proper motion system where the UCD is bright enough (down to J ~ 18, see e.g. Marocco et al. 2015);
- Unambiguous property constraints between candidate pairings.

Characterization of the genuine systems via high-resolution spectroscopy for the primaries and mid-resolution spectroscopy of the UCDs to look for correlations between spectral signatures and atmospheric parameters in UCDs.

Population studies of the systems properties: separation distribution, mass-ratio distribution etc…