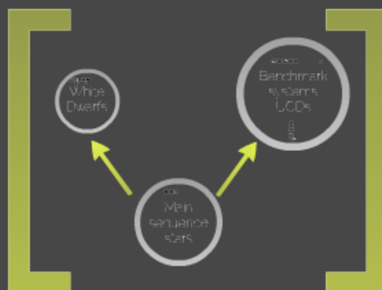
Searching for benchmark systems containing ultra-cool dwarfs and white dwarfs

Joana Gomes

Munich 2012

David Pinfield, Hugh Jones, Ben Burningham, Avril Day-Jones, James Jenkins, Silvia Catalan, Yakiv Pavlenko, Oleksiy Ivanyuk



Other projects

Extend our sample of benchmark systems

WISE - good for late T and Y dwarfs

UKIDSS - good for L dwarfs as it goes deeper than 2MASS and further (L dwarfs up to 100pc)

VISTA - up to 4 mags deeper than 2MASS

List of publications

- Two new ultracool benchmark systems from WISE+2MASS - Gomes et al (submitted)

- A WISE search for very late objects detected only in the W2 band - Pinfield, Gomes et al 2012 (to be submitted)

- The brightest pure-H ultracool white dwarf - Catalan et al 2012

- The sub-stellar birth rate from UKIDSS - Avril et al 2012 (submitted)

- Discovery of the benchmark metal-poor T8 dwarf BD +01° 2920B - Pinfield et al 2012

- The properties of the T8.5p dwarf Ross 458C - Burningham et al 2011
- The discovery of the T8.5 dwarf UGPS J0521+3640 - Burningham et al 2011
- Discovery of a T dwarf + white dwarf binary system - Day-Jones et al 2011

Summary

- New benchmark objects found with 2MASS/WISE and Hipparcos/Gliese

- WD+MS sample and its applications in
  - age calibration of the systems
  - age-activity relationship
  - correlation between G2s and metallicity of WD progenitors

- Sample of c.p.m benchmark binaries candidates;
- Y dwarfs in benchmark systems;
- Underluminous L dwarfs

Future Work

Finish the catalog paper of the MS stars + WD binaries

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Thank you!

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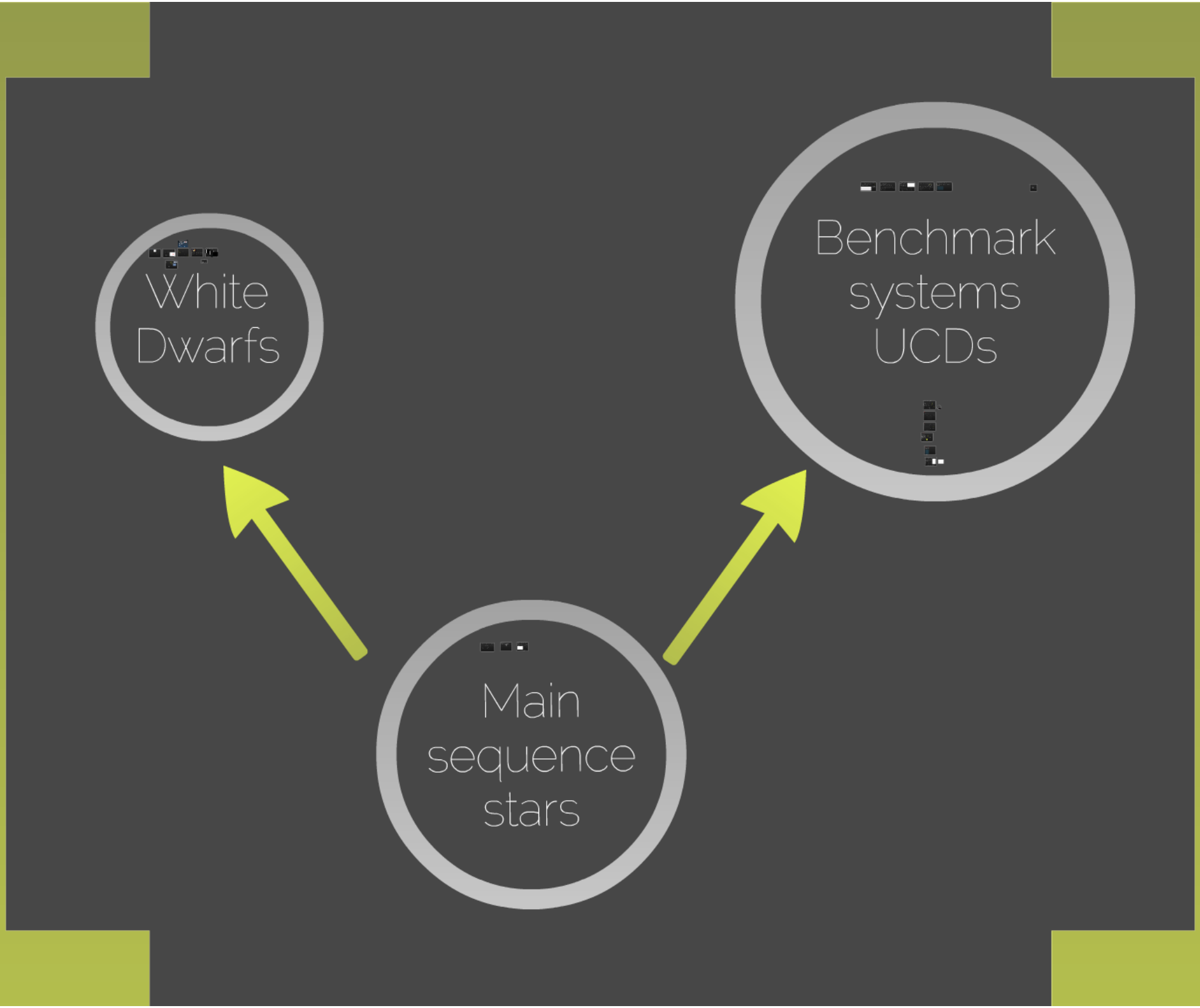
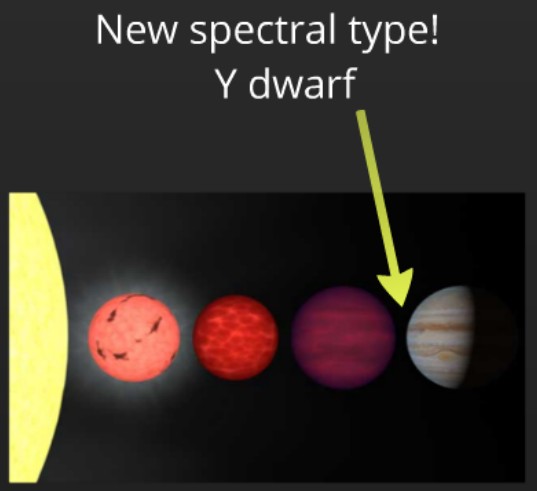

White Dwarfs
Benchmark systems UCDs
Main sequence stars

Benchmark systems UCDs

Brown dwarfs

- Ultracool dwarfs: spectral type later than M7
- Not enough mass for nuclear reactions to occur
- Masses < 0.075 solar masses

Spectral types	T_{eff}	Properties
L	2300 – 1400 K	Dusty upper atmospheres; Red colours.
T	1400 – 650 K	Spectra dominated by strong water vapour and methane bands. Blue in the NIR.
Y	> 650 K	Absorption bands of ammonia in NIR



Comparison between stars, brown dwarfs and planets (dwarfarchive.org)

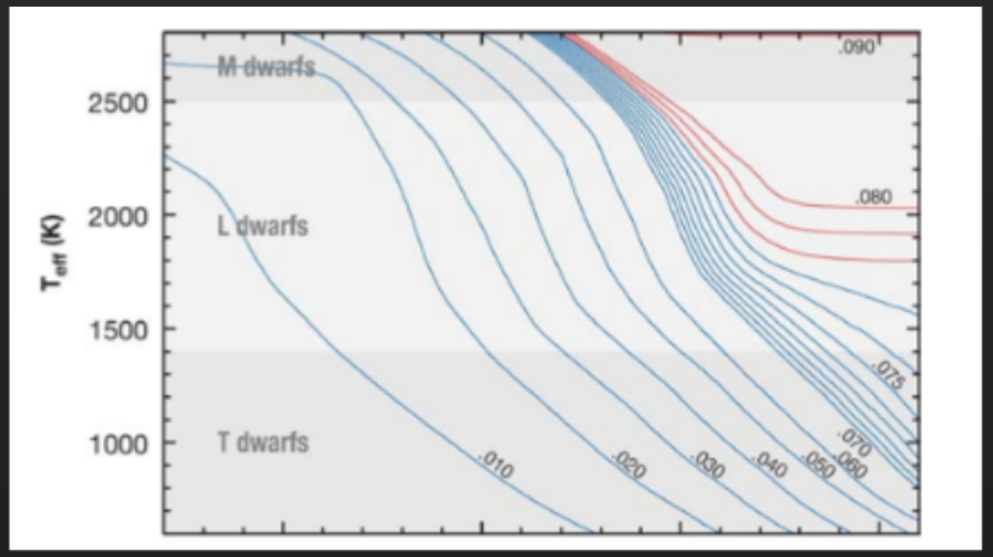
Brown dwarfs - Why so interesting:

- They are the lowest mass products of star formation
- Temperatures in the range of those of giant exoplanets
- Good calibrators for the atmospheric physics of exoplanets
- They represent a fossilized record of star formation during the Galaxy's evolution

(Burgasser 2008, Kirkpatrick 2011)

- Problem: Degeneracy between temperature and luminosity for these extremely cool objects

- Brown dwarfs whose properties can be estimated independently



Age

BENCHMARK OBJECTS

MS star companion → AGE, DISTANCE, COMPOSITION

- Improve the atmoshperic models
- Understand how SED of BD is affected by dust and molecular opacities

Benchmark brown dwarfs in wide binaries

- Test bed for prevailing theories and models
- Wide companions meaning there is no interaction expected between the components
- MS stars are numerous, covering a wide range of ages and compositions

Wide-field surveys to search for MS stars and ultracool binaries

- LSPM (best for high p.m.)
- Tycho stars
- Hipparcos and Gliese
- PPMXL (2MASS + USNO-B1)

Near infrared surveys - 2MASS, UKIDSS, WISE, VISTA

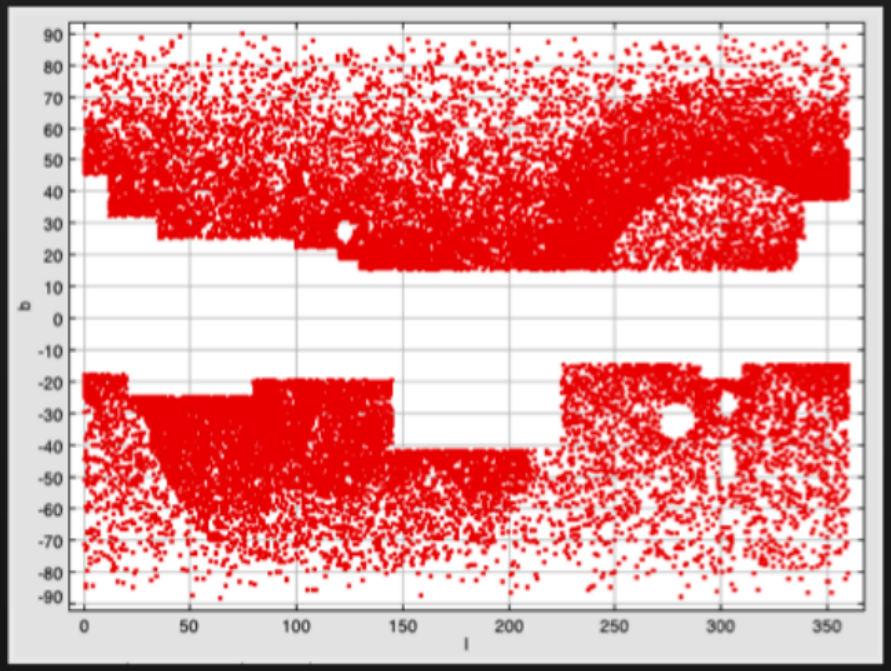
- Find the coldest brown dwarfs.
- Sky survey in four infrared wavelengths - 3.4, 4.6, 12 and 22 micron.
- Band W1 and W2 designed to optimize sensitivity to the coolest BDs - objects cooler than 1500K have strong absorption due to methane centered at 3.3 micron.
- W1 - spans the deep water and methane absorption features
- W2 - centers on the window near 5 micron where much of the flux of cool BDs is emitted.

Method

Hipparcos/Gliese + 2MASS/WISE

1 - Select L dwarfs from 2MASS with color cuts and quality flags 28 000

2 - Cross match with FGK stars. Separations 10' 570



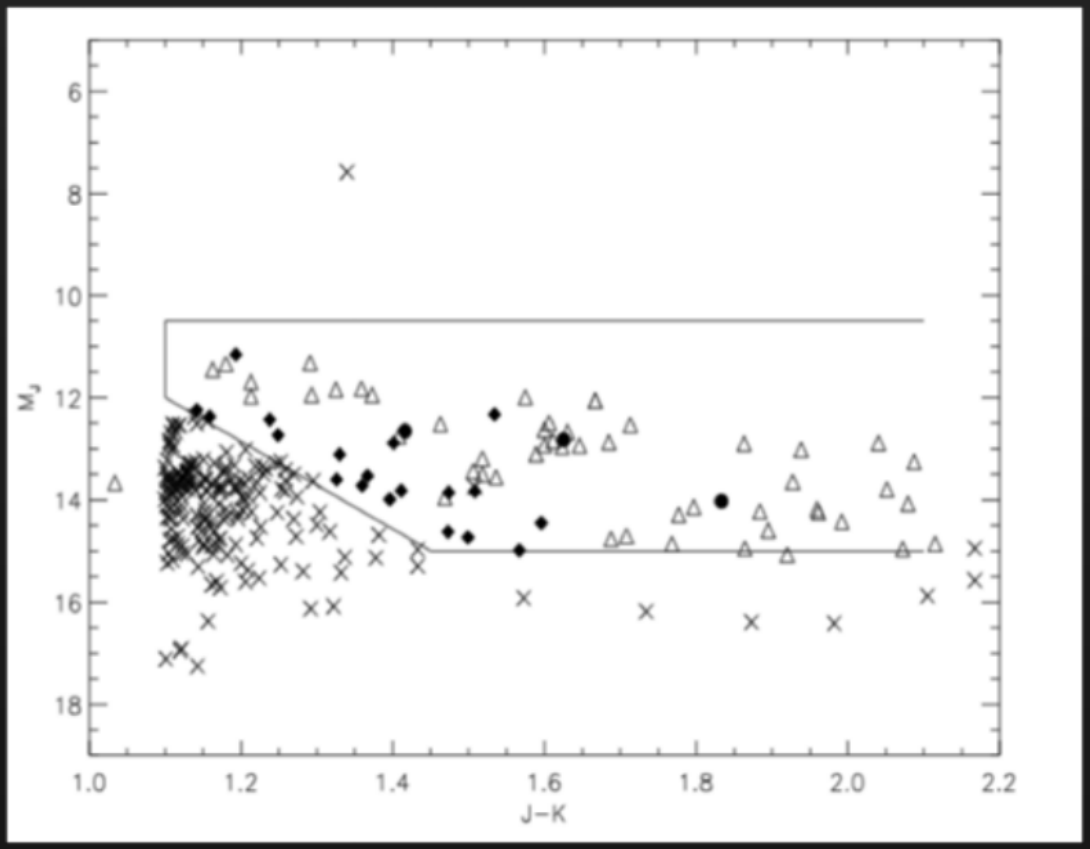
Method

3 - Assess photometry and separation on sky

4 - Assess proper motion - 2MASS + WISE

25

2



Gomes et al (2012)

Two new common proper motion systems!

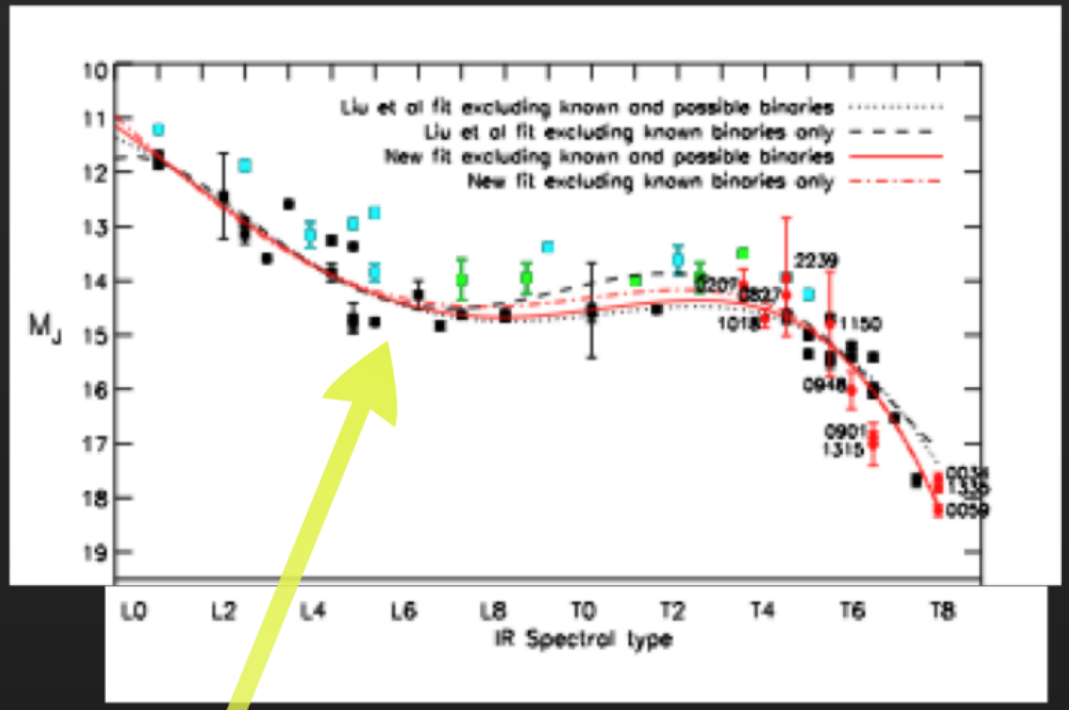
G499AB - J1305+2046

GJ 499 ABC - Triple system

L dwarf + K8 + M0

L dwarf classified as an L4± 2 (Cruz et al 2003) and proper motions available in Jameson et al (2008)

Use parallax of primary and place the L dwarf at 18 pc.



Marocco et al 2010

Estimating MJ places the L dwarf in the L5 spectral type

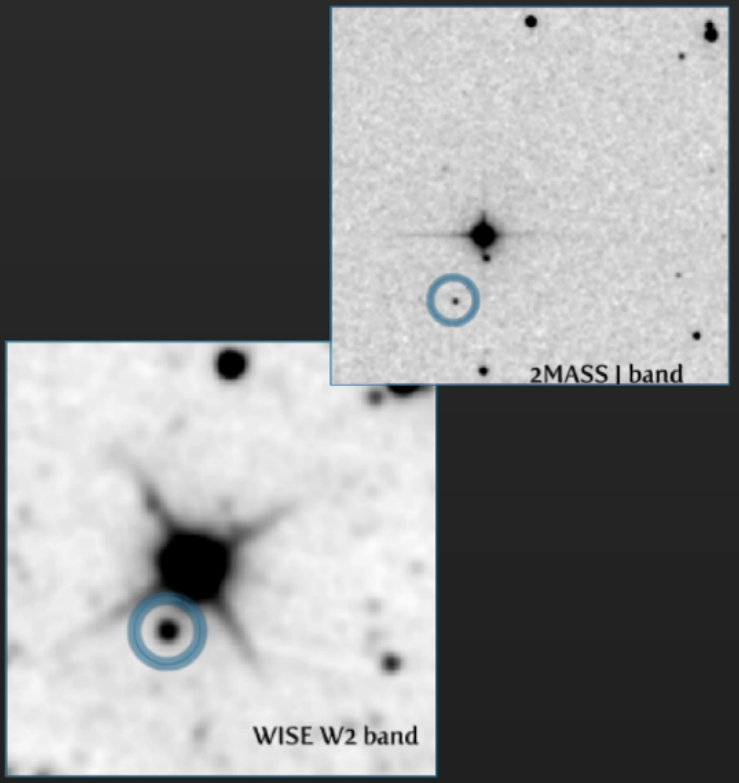
SDSS spectrum consistent with L5 +/- 1

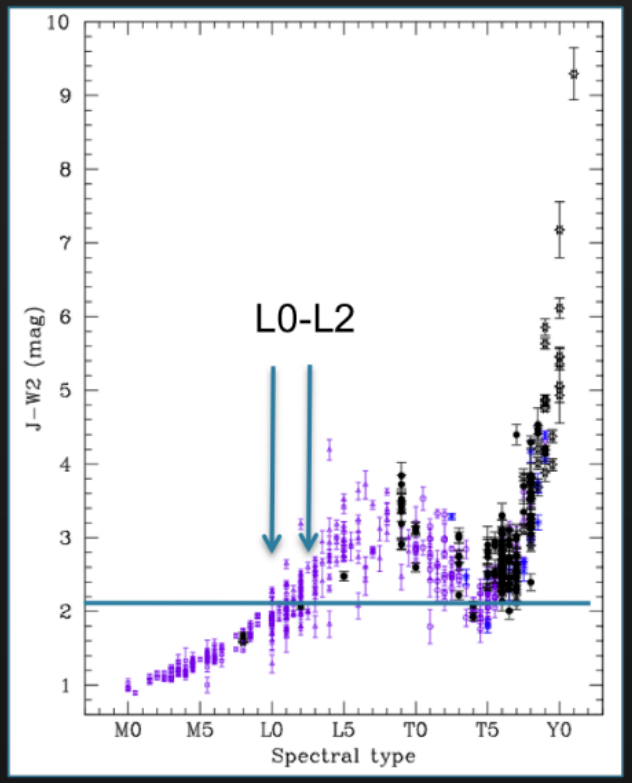
Agrees with Cruz paper classification

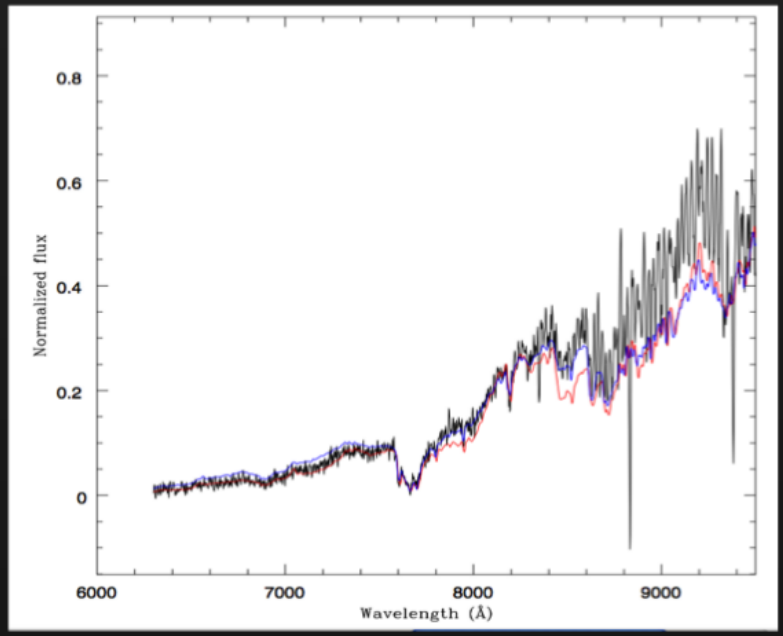
G255-34 - J1332+7459

G255-34 - K8 star + new L2 dwarf

- Confirmed spectroscopically
- Confirmed with WISE and 2MASS colors







Kirkpatrick 2011

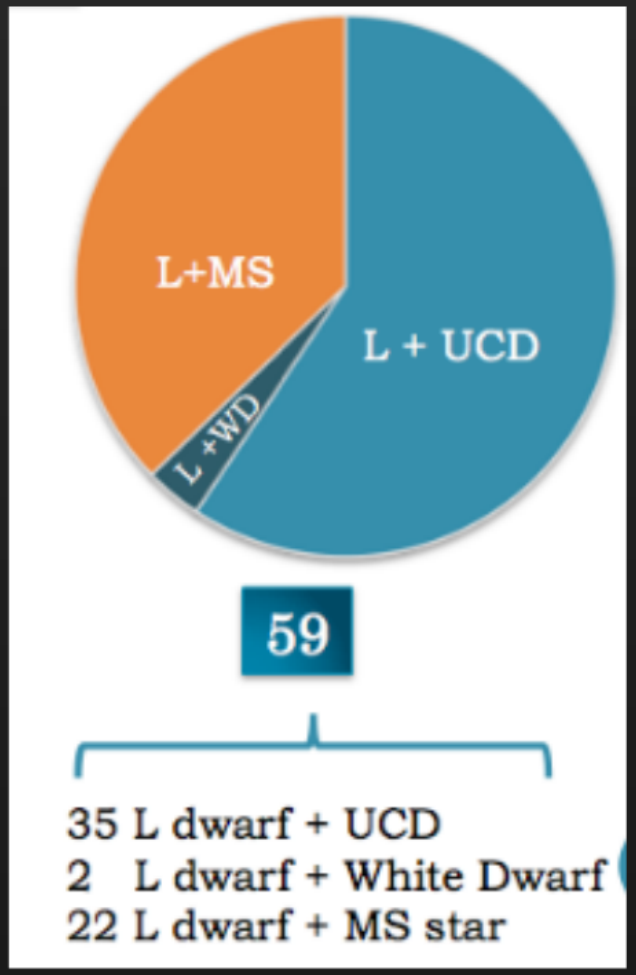
Known L dwarf + MS star binaries

Dupuy et al (2010), Faherty et al (2008,2009), many others

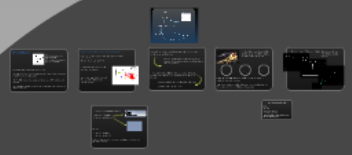
Using the L dwarf space density derived in Cruz et al (2003), we estimate 109 ±17 L dwarfs to be in the volume limited sample.

L dwarfs in multiple systems with MS stars ≈ 6%

For the MS stars, the binary fraction is ≈ 0.33%



We need more benchmark systems.



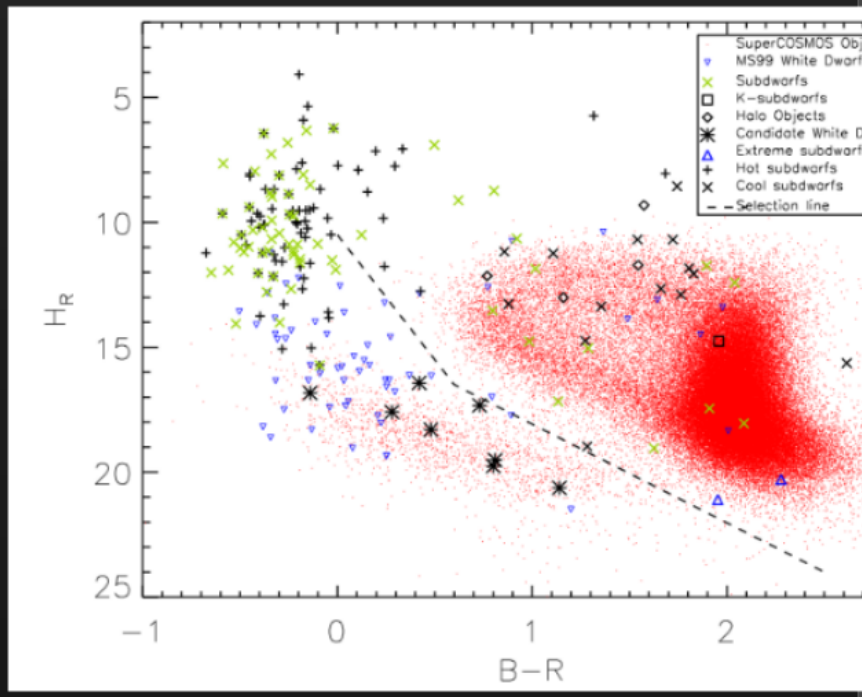
White Dwarfs

White dwarfs and Main sequence stars in wide binaries

WDs - selected from SuperCOSMOS (Day-Jones et al 2008)

MS stars - from Tycho with V < 12

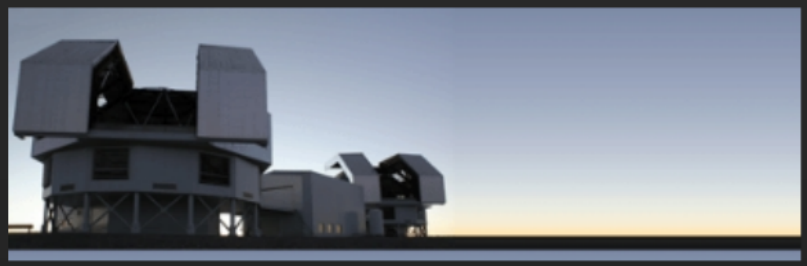
Sample of 160 WD candidates + MS star c.p.m. wide binaries



Garces et al 2011 - 30 M dwarf + WD
Zhao et al 2012 - 10 MS + WD
Silvestri et al 2005

Observed sample (brighter objects)

- 41 observed with IMACS
- 8 observed with Xshooter



MS stars

- 6 observed with FEROS
- 2 observed with the HET

High resolution spectra - determine metallicities and abundances (Pavlenko et al. 2012)

1 - Use the age derived from the DAs to infer the age for system and therefore for the MS star.

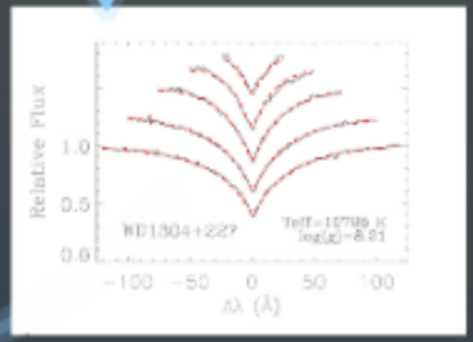
Measure Ca II K & H lines in MS stars spectra and improve chromospheric activity-age relationship for older ages (<1 Gyr)

2 - Use other methods (lithium abundances, X-ray luminosity, isochrones) to estimate an age for the MS star and therefore for the WD

Improve initial-final mass relationship for the WD

(Catalan et al 2008, Zhao 2012)

Use spectra to fit Balmer lines to models



Teff, log(g)

Cooling sequences

Mass white dwarf + Cooling Time

Initial-Final Mass Relationship

Mass progenitor

Stellar tracks

Progenitor time

AGE

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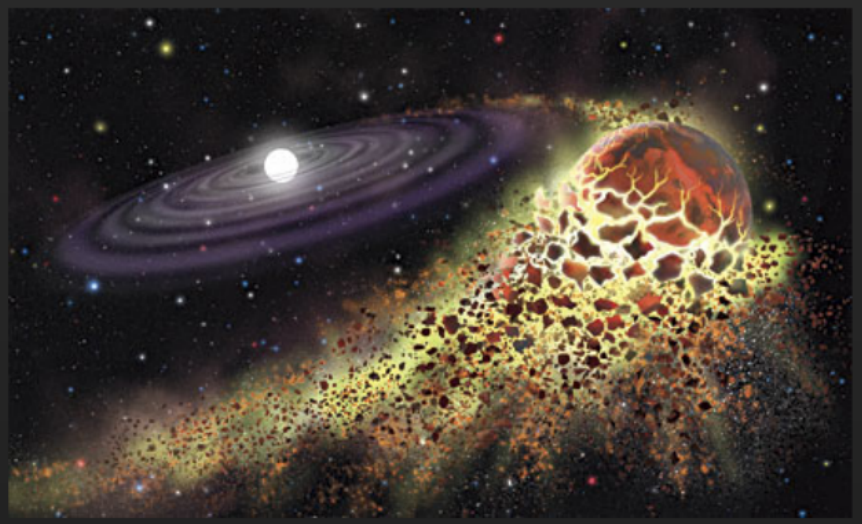


3 - DZs white dwarfs show metal lines in their spectra. Can this be explained by ISM accretion? Maybe not...

The fact that in DZs there is more calcium in the photosphere than hydrogen supports the idea that the accreted material was volatile depleted

(Dufour et al 2007)

Existence of DAZs with metal diffusion timescales as short as a few days and that have Galactic positions far from known interstellar clouds

(Koester et al 2005)

A large number of DZs show infrared excess and have rings of dust and gaseous debris orbiting them

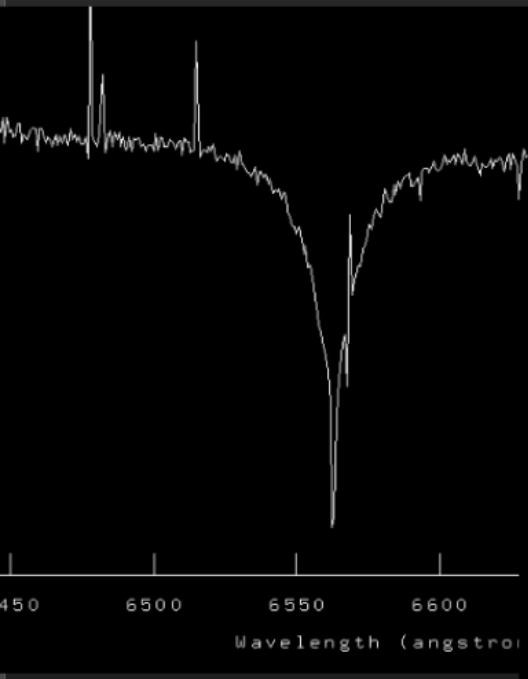
(Farihi et al 2009)

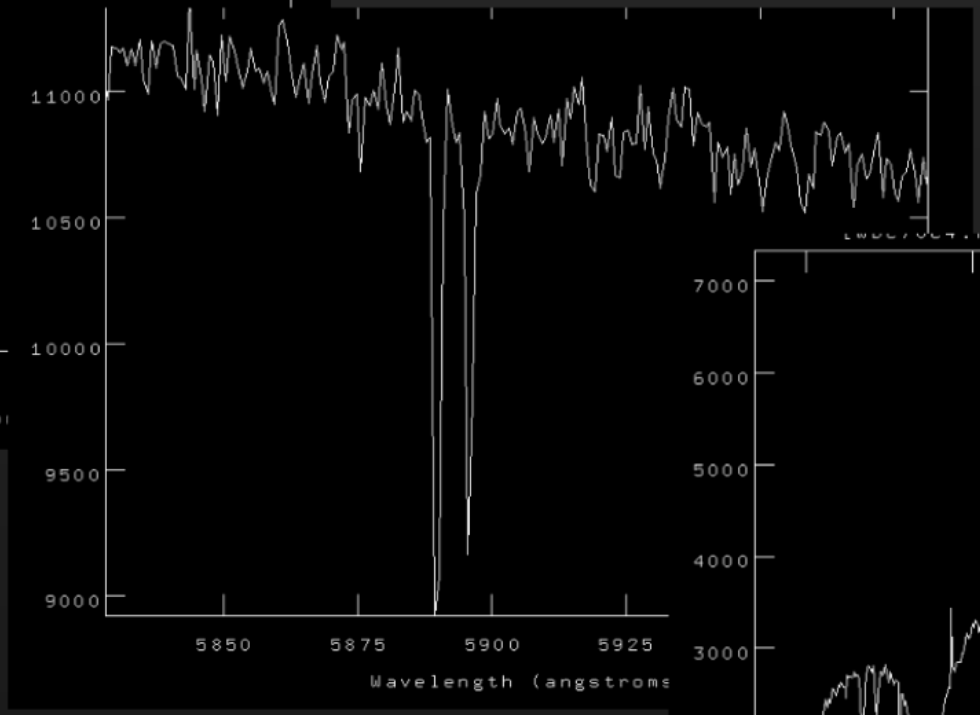
Explore the possibility that DZs metal lines are the indication of exoplanets remnants accretion

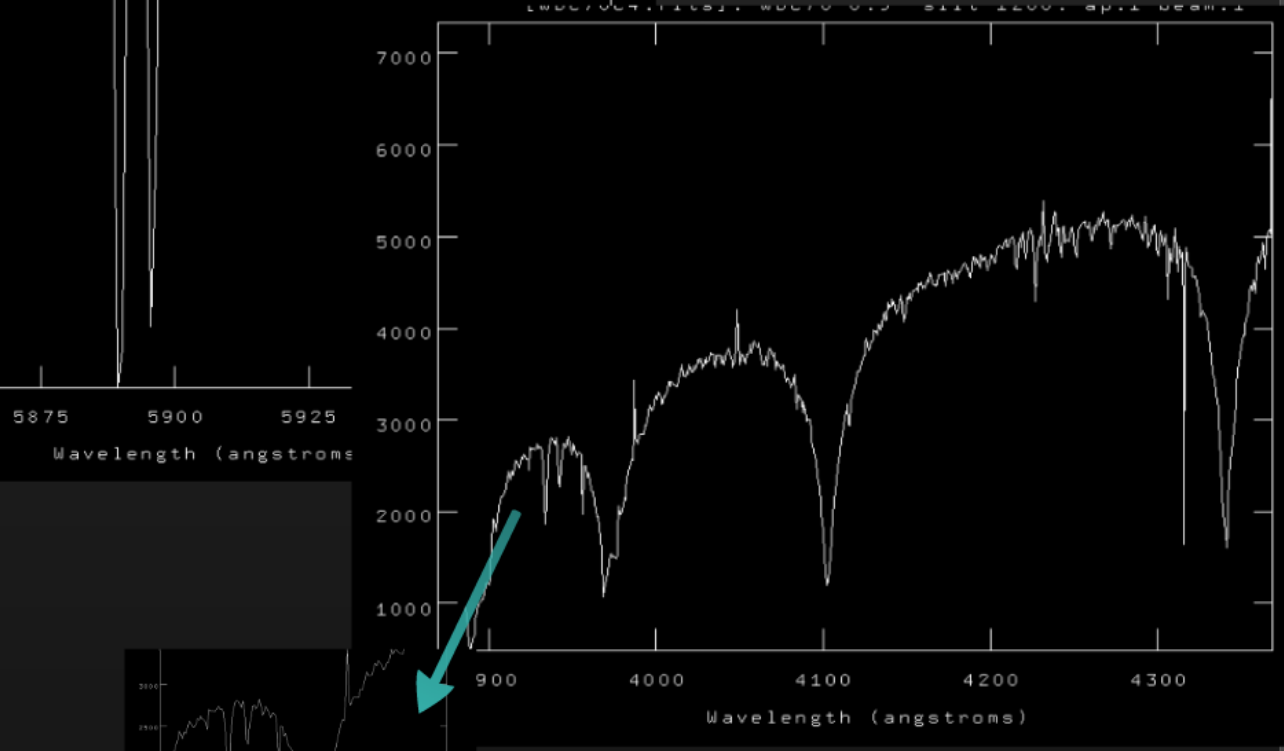
With a large sample, we will be able to study any correlation between the fraction of DZs and metallicity of its progenitor

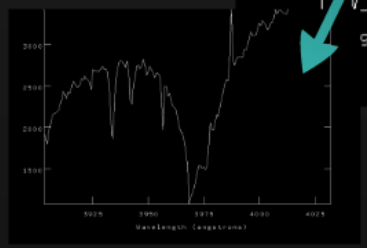
Metal lines in DZs and DAZs

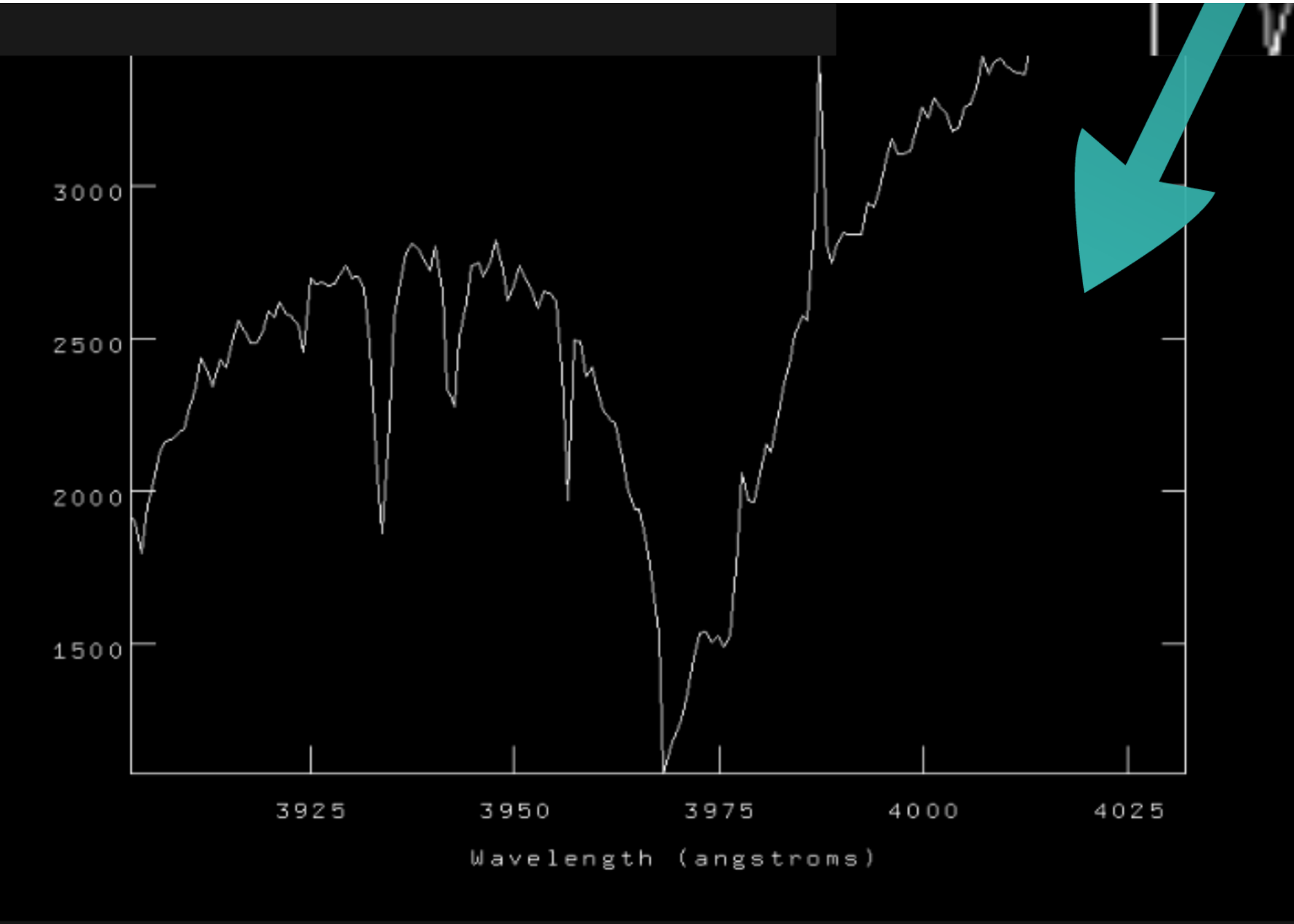
Most commonly found metals include Fe, Mg, Na, Ca, Ti









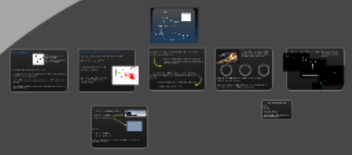

3000
2500
2000
1500
3925
3950
3975
4000
4025
Wavelength (angstroms)

Same early results from the sample

5 DAZs
5 DAZ(?)
20 DA or DB

Contamination - subdwarfs

4 pairs where both WD and MS star have spectra and can be fully characterized



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