Y dwarfs

Empirical and Theoretical Expectations

Daniel Stack

PHY 698

5/1/09

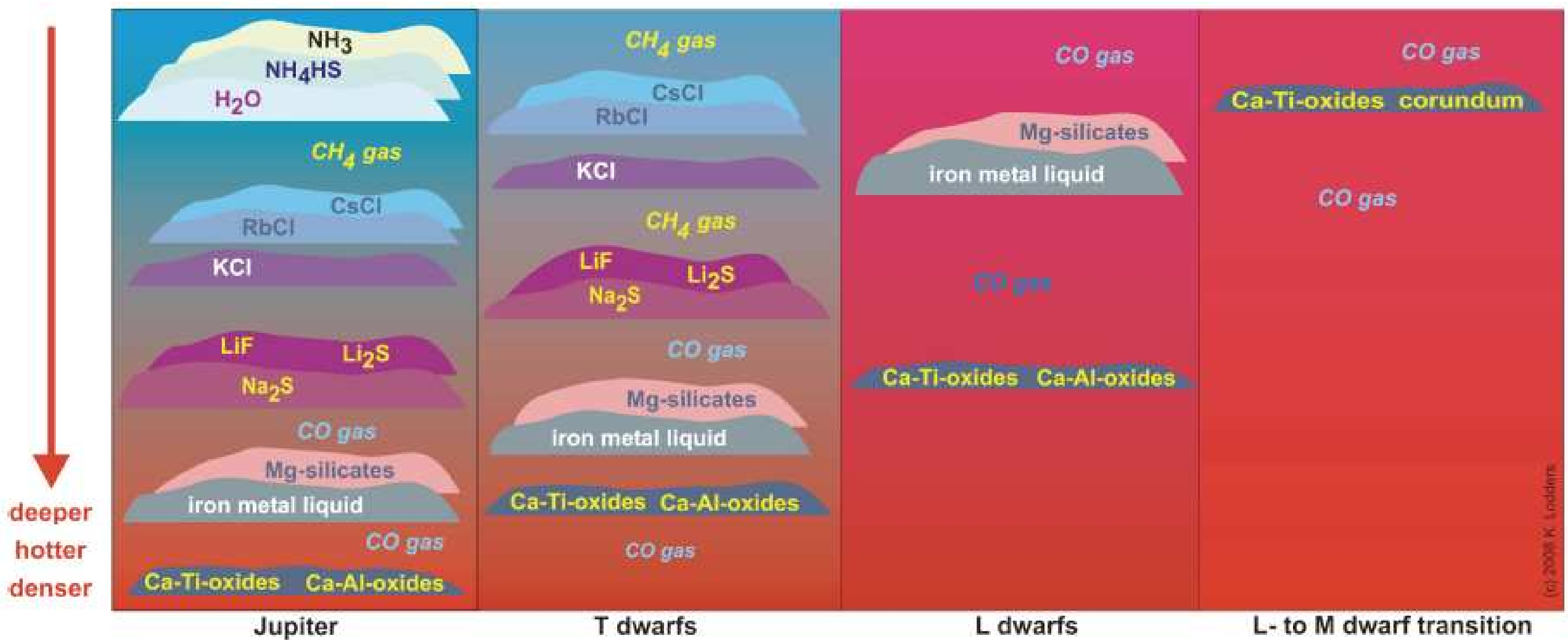
Outline

I. Theoretical Expectations
- Overview of BD Characteristics
- Late T Dwarf characteristics
- Beyond T

II. Possible Observed Y Dwarfs

III. Future for Y Dwarf discoveries.

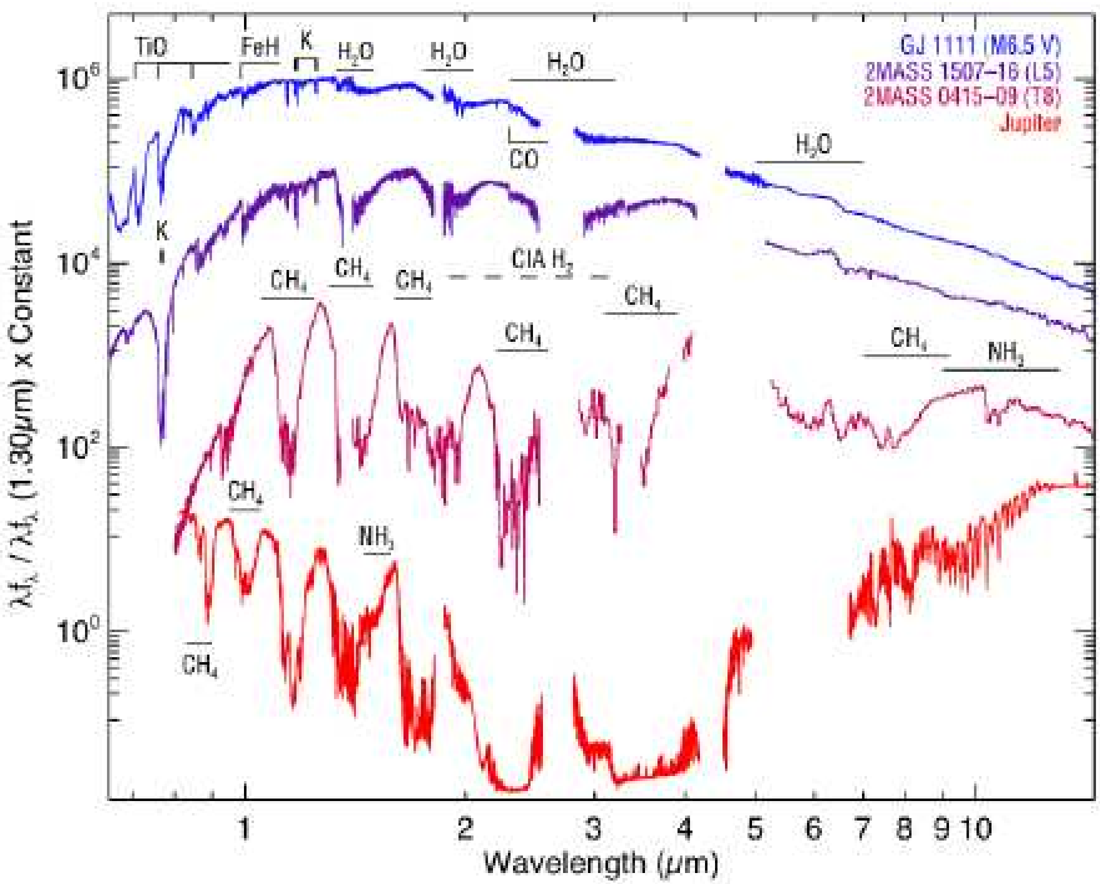
Clouds in Brown Dwarfs



Signatures of Y Dwarfs

- At around 700K NH_3 NIR bands become prominent
- At around 400 K, H_2O is depleted from gas phase and water clouds form.

Spectra of Brown Dwarfs



Late T Dwarfs

- Only 16 Late T Dwarfs (T7>) have been found (only 2 are companions).
- Mass and age can only be constrained by model spectra for field dwarfs.
- Blackbody spectra peak around 4-5 μm.
- Use a grid of solar metallicity cool brown dwarfs to calibrate two spectral ratios, H_2O-*J* and *K*/*H*, to Teff and log *g*.

Non-Chemical Equilibrium in T/Y

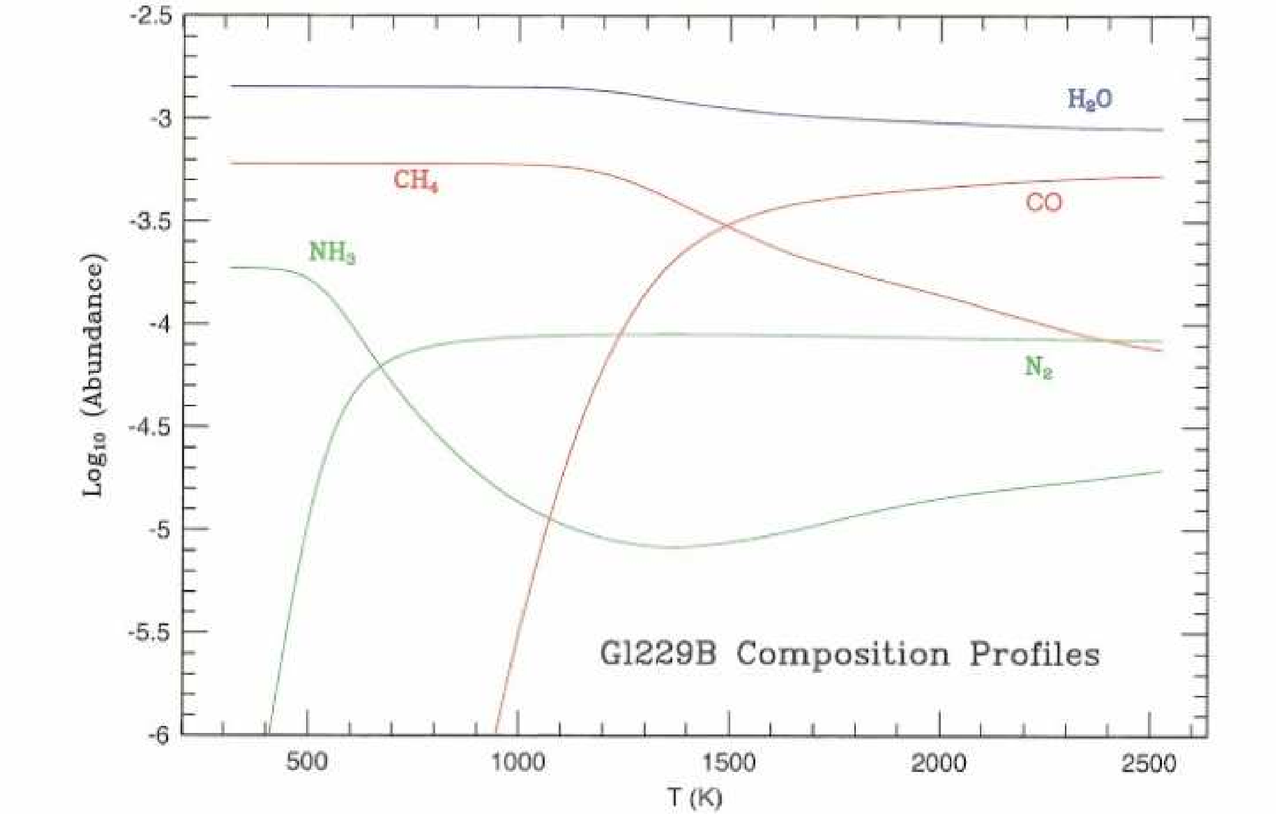
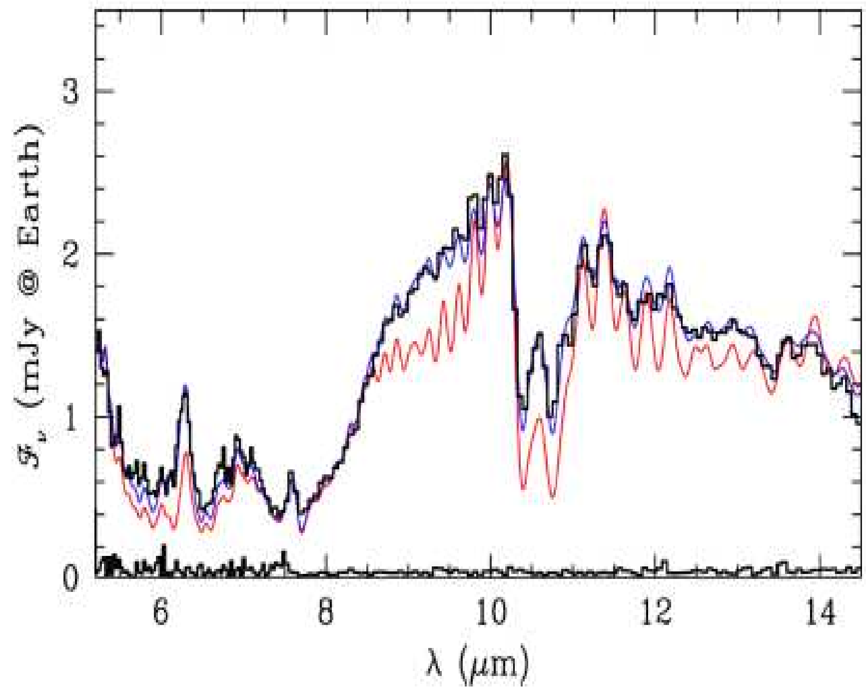


FIG. 11. Depicted are the abundances of the major O, C, and N compounds vs layer temperature for a representative Gliese 229B model. N_2 and NH_3 are in green, CO and CH_4 are in red, and water is in blue. The transition from N_2 to NH_3 occurs near ~700 K, while that from CO to CH_4 occurs from near 1200 to near 1800 K, depending upon the actual pressure/temperature profile. This model is for T_{eff}=950 K and a gravity of 10^5 cm s^{-2}. See Sec. V for details [Color].

NCE in T/Y

- Due to convection, CO and N_2 are found in T Dwarf spectra.

- CH_4 and NH_3 are suppressed.

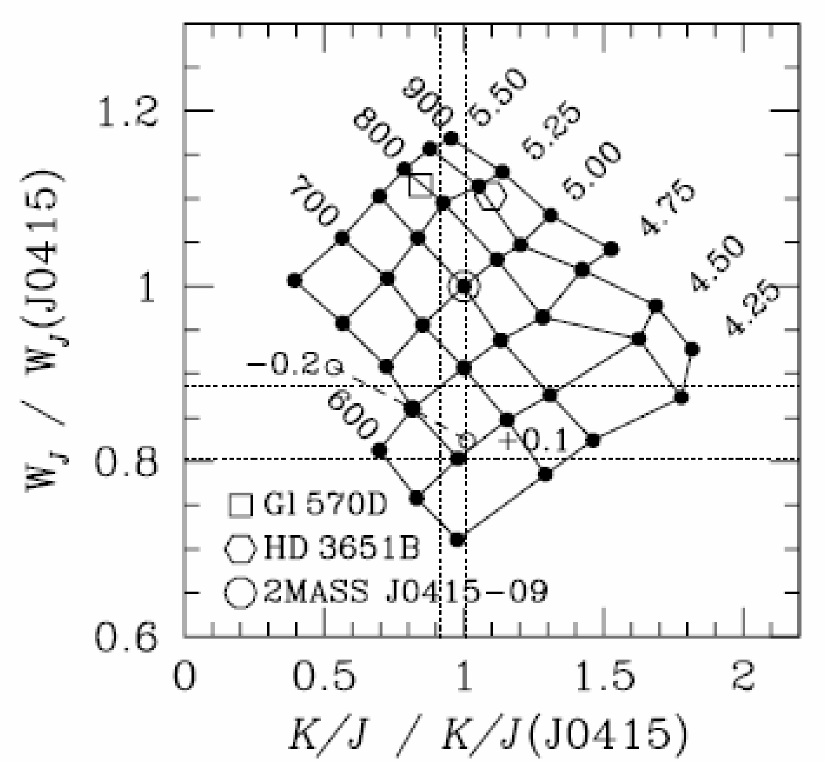


Atmospheric models

- Create a BD spectra from a model atmosphere (disagreement over CNO abundances)
- Cloud layers retreat as T_{eff} decreases
- Nonchemical equilibrium taken into account, less NH_3 and more CO.

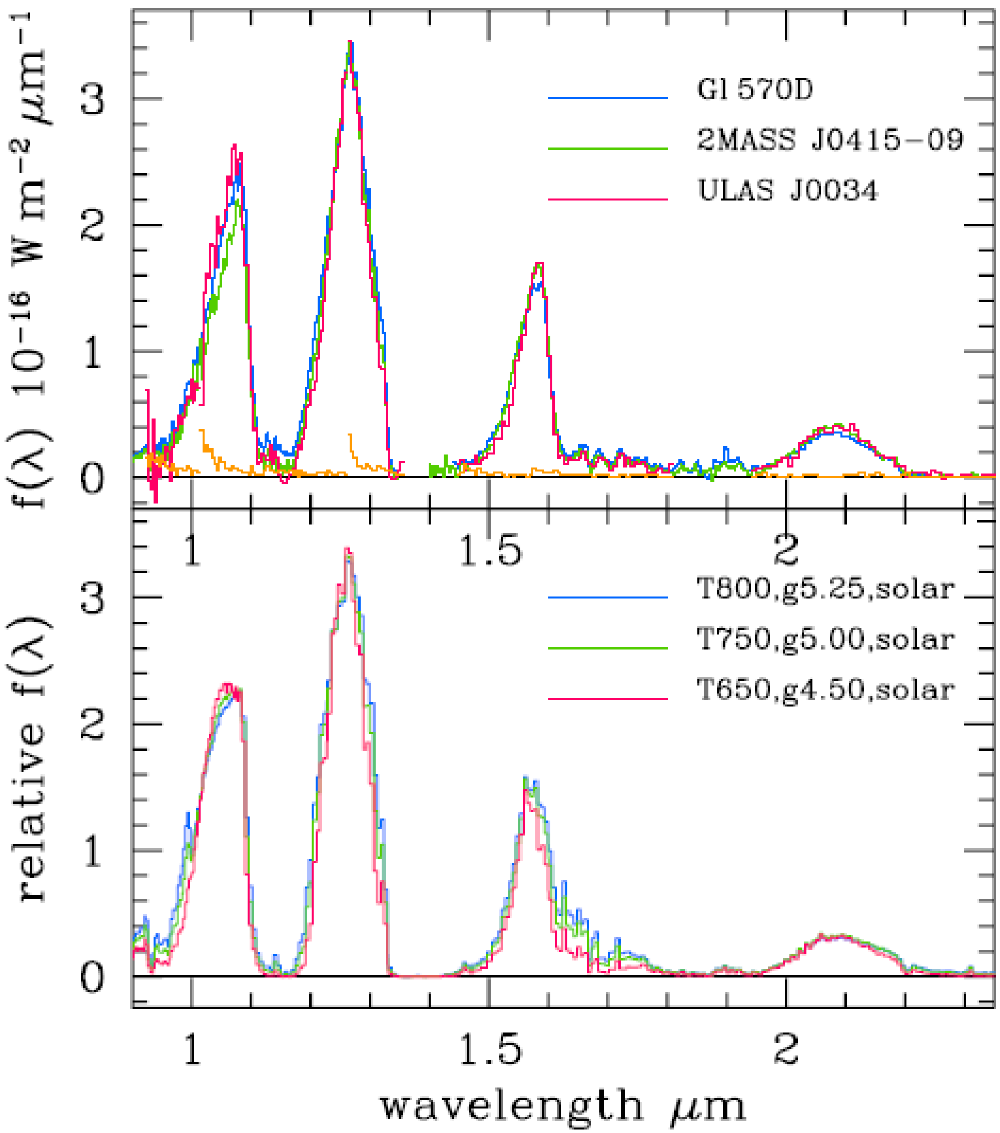
Fitting T_{eff} and log g

- Generate model spectra for various T_{eff} and log g.
- Assume solar metallicity.
- Plot observed spectra on grid.

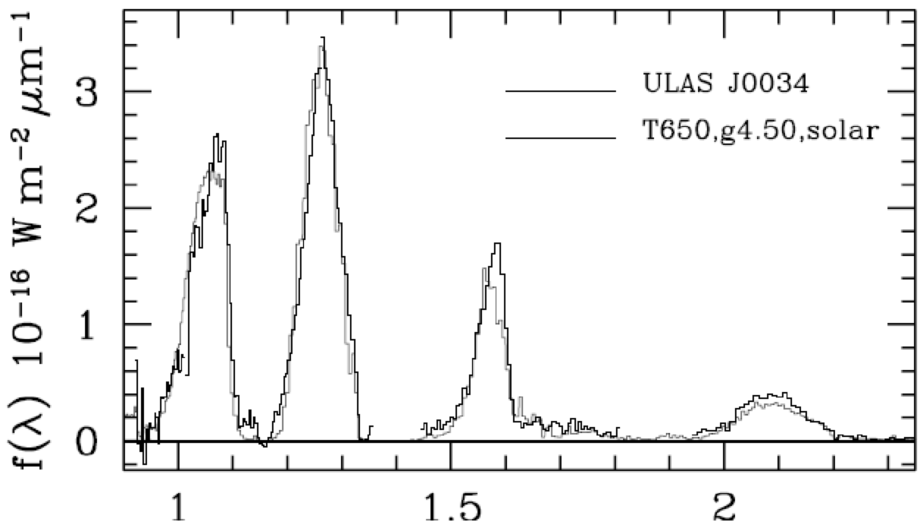


$$W_J = \frac{\int F_{1.18-1.23}}{2\int F_{1.26-1.285}}, \quad K/J = \frac{\int F_{2.06-2.10}}{\int F_{1.25-1.29}}$$

Actual Versus Models



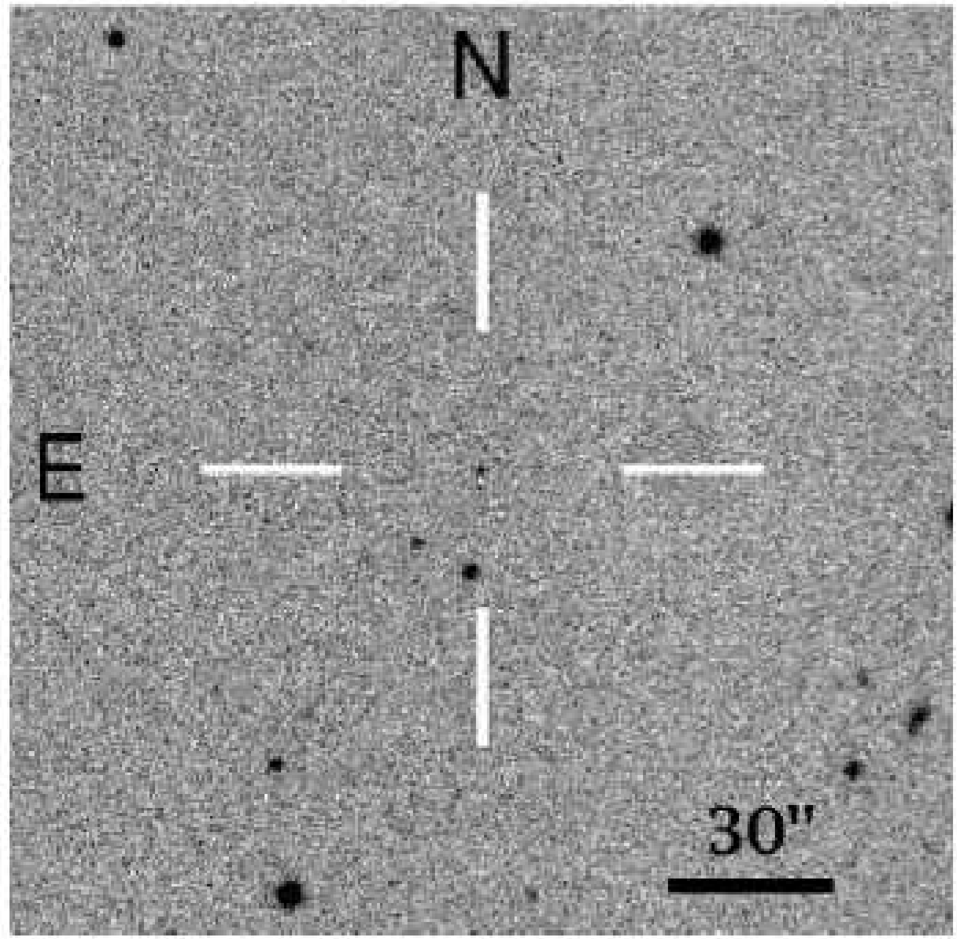
Not a Perfect Match



- Departure from model at 1.1-1.15 μm and 1.6-1.7 μm.

ULAS 0034

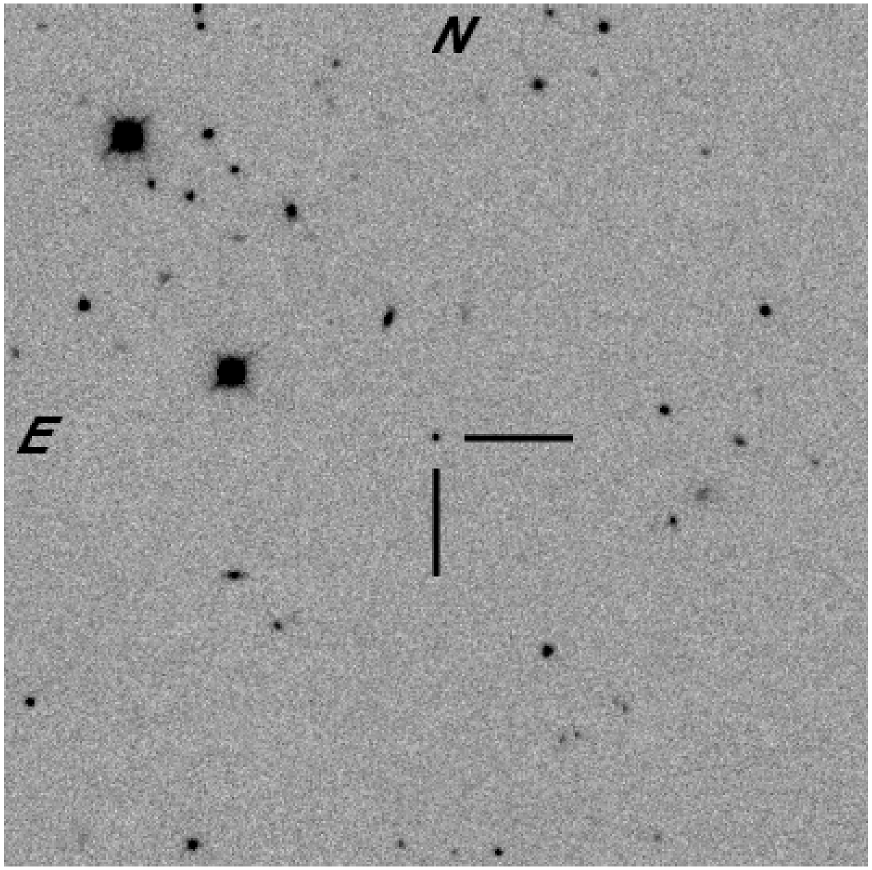
- UKIDSS DR1
- Mass of 15–36 M_J
- Age of 0.5 – 8 Gyr
- 14 – 22 pc



Y-Band Image

CFBDS0059

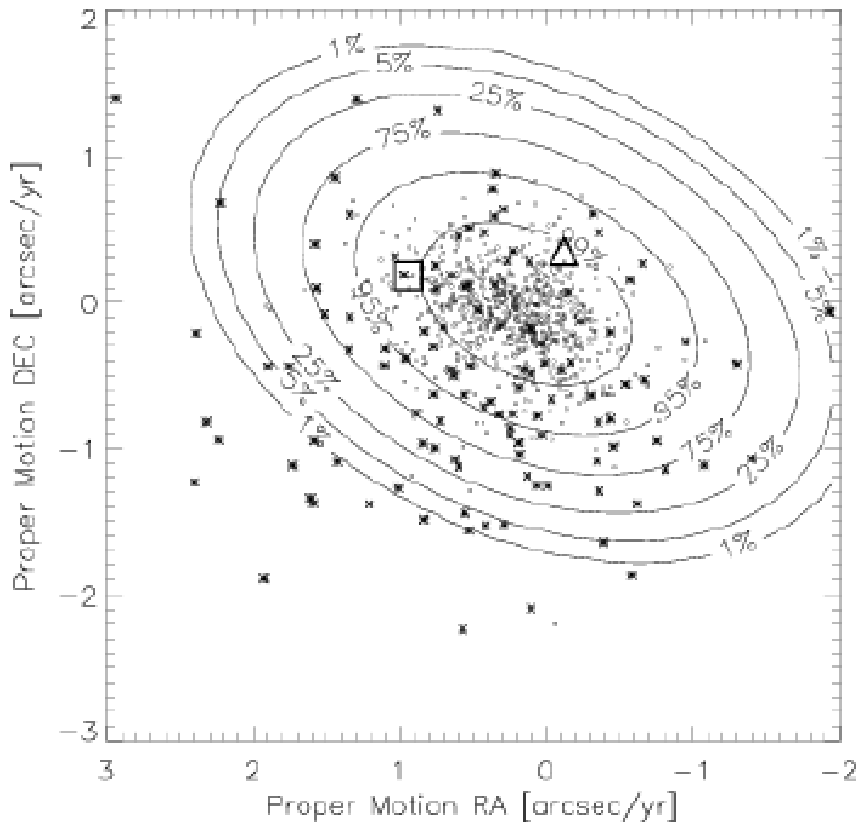
- Detected by comparing i' and z' on 3.6m CFHT.
- Age of 1-5 Gyr
- Mass of ~ 15-30 M_J
- log *g* ~ 4.75
- ~ 13 pc



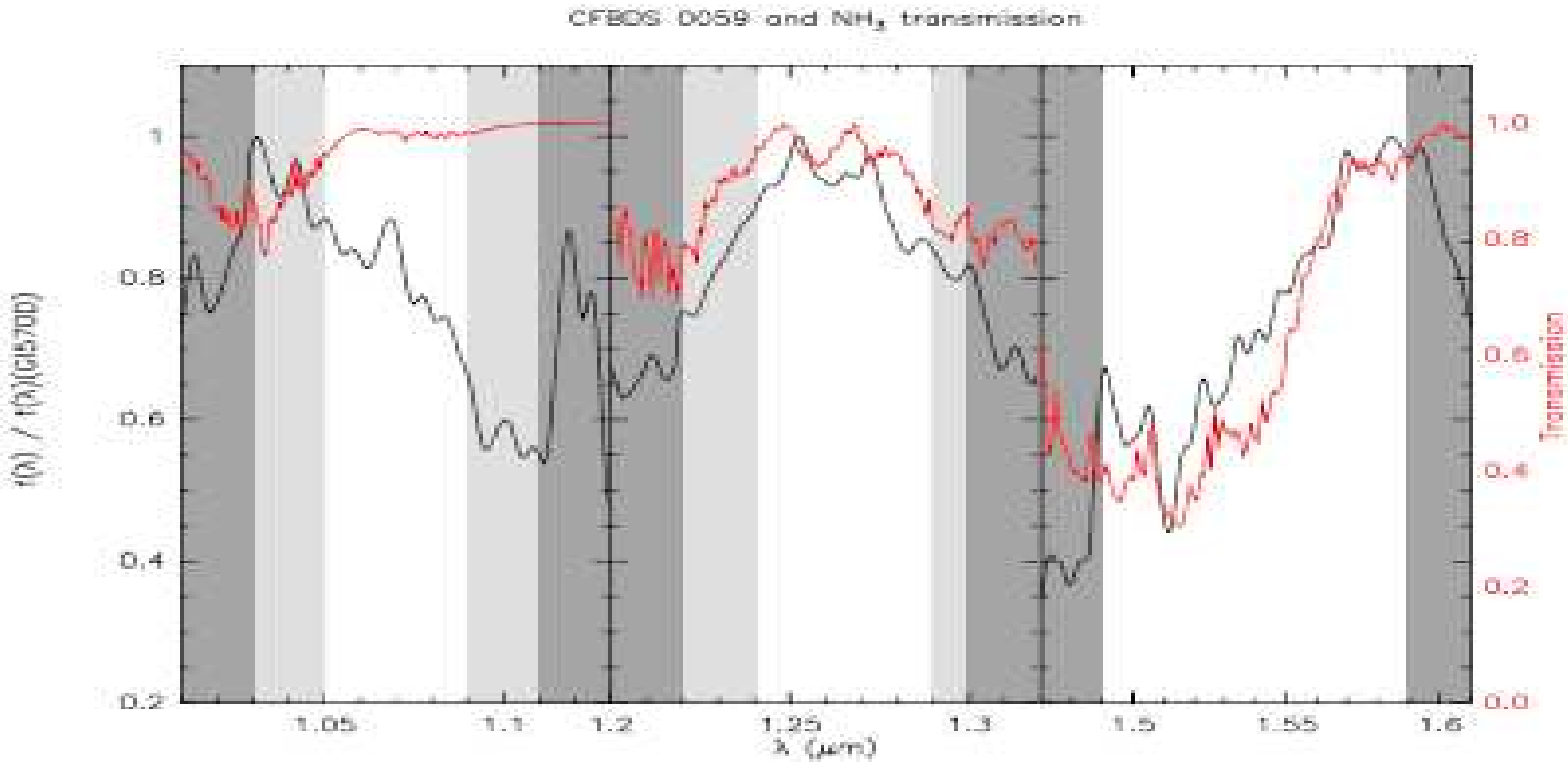
Ks (2.15 μm)

Proper Motion

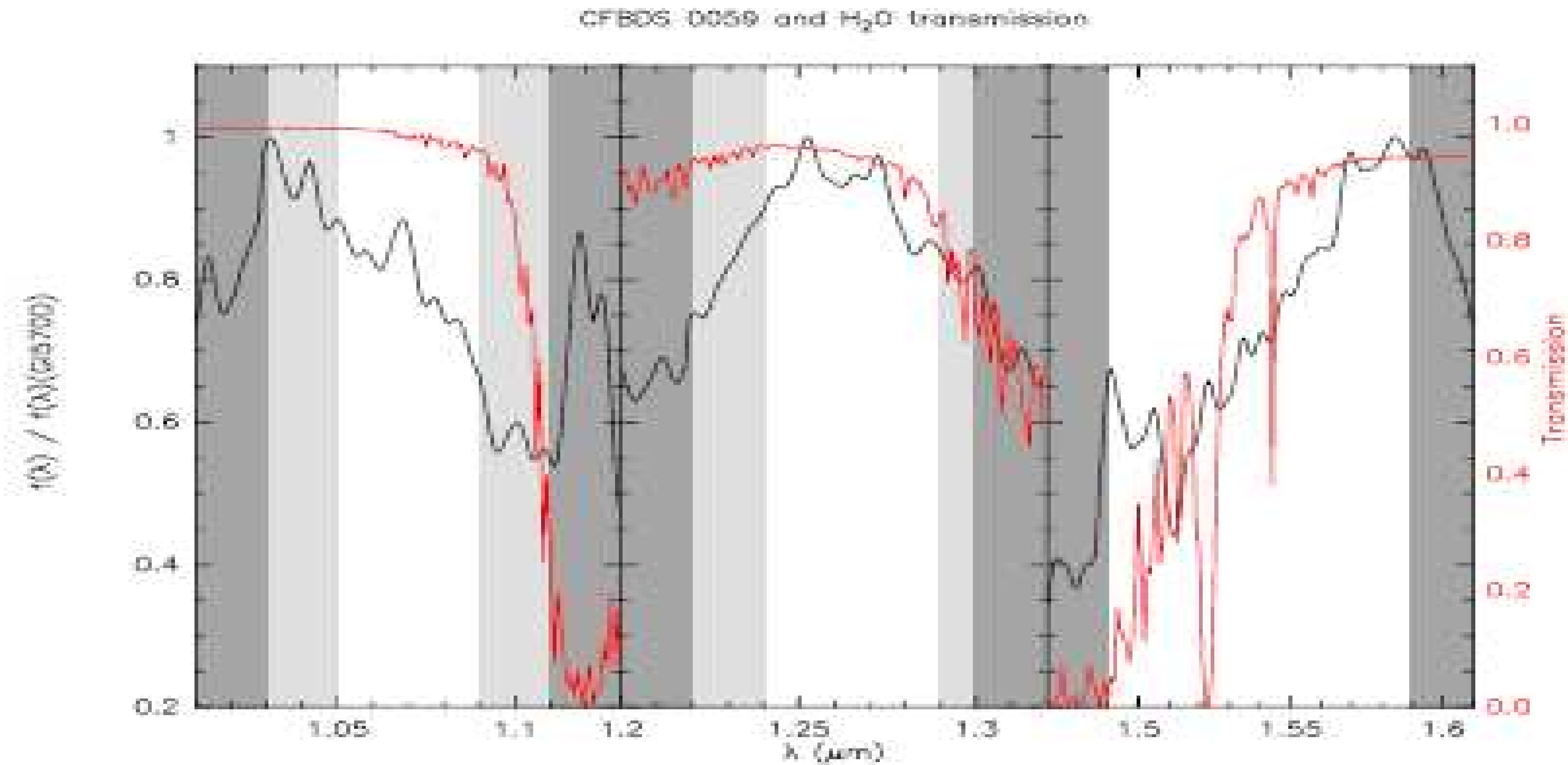
- Use Besancon stellar population model
- 95%, 99% thin disk for CFBDS0059, ULAS0034



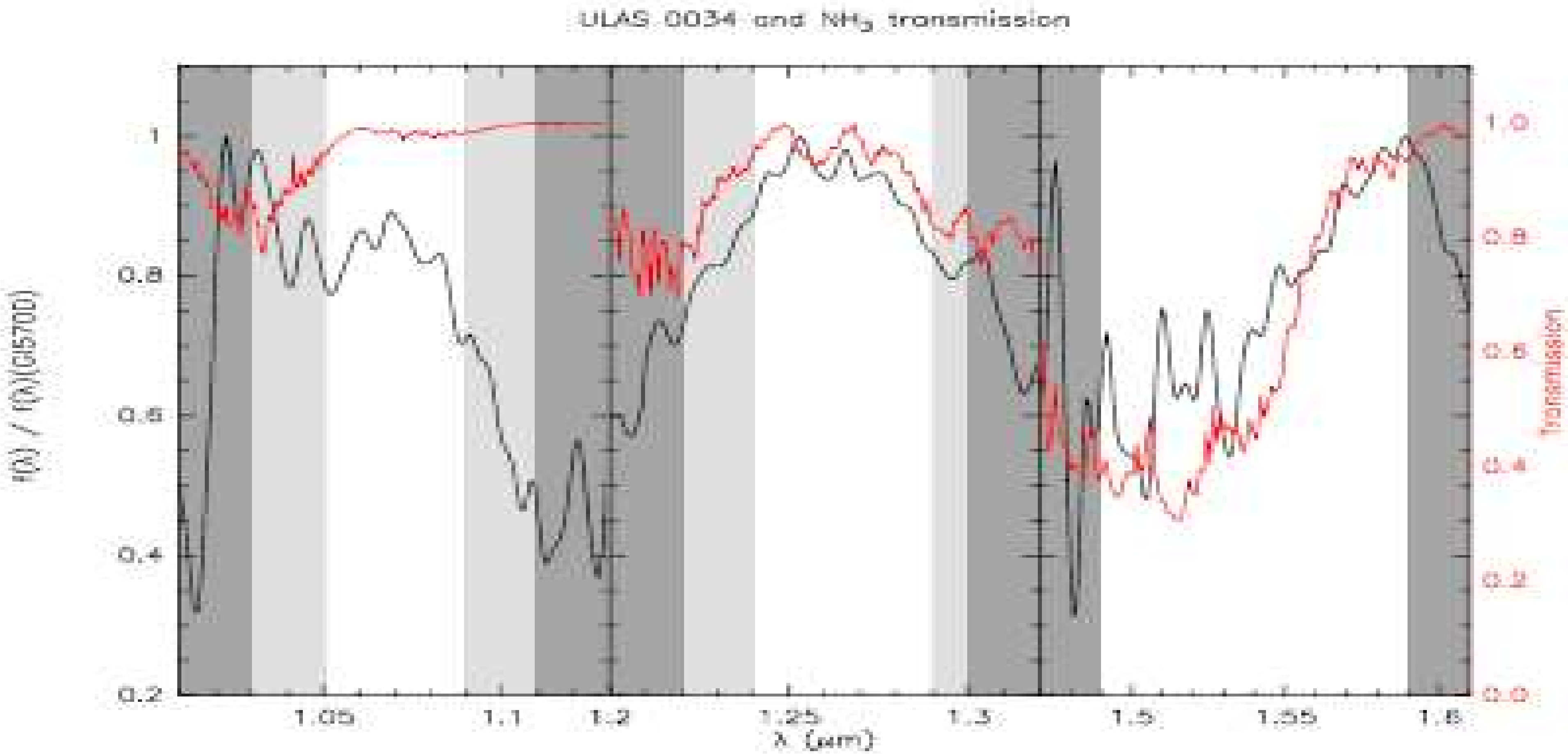
CFBDS0059 NIR Spectrum



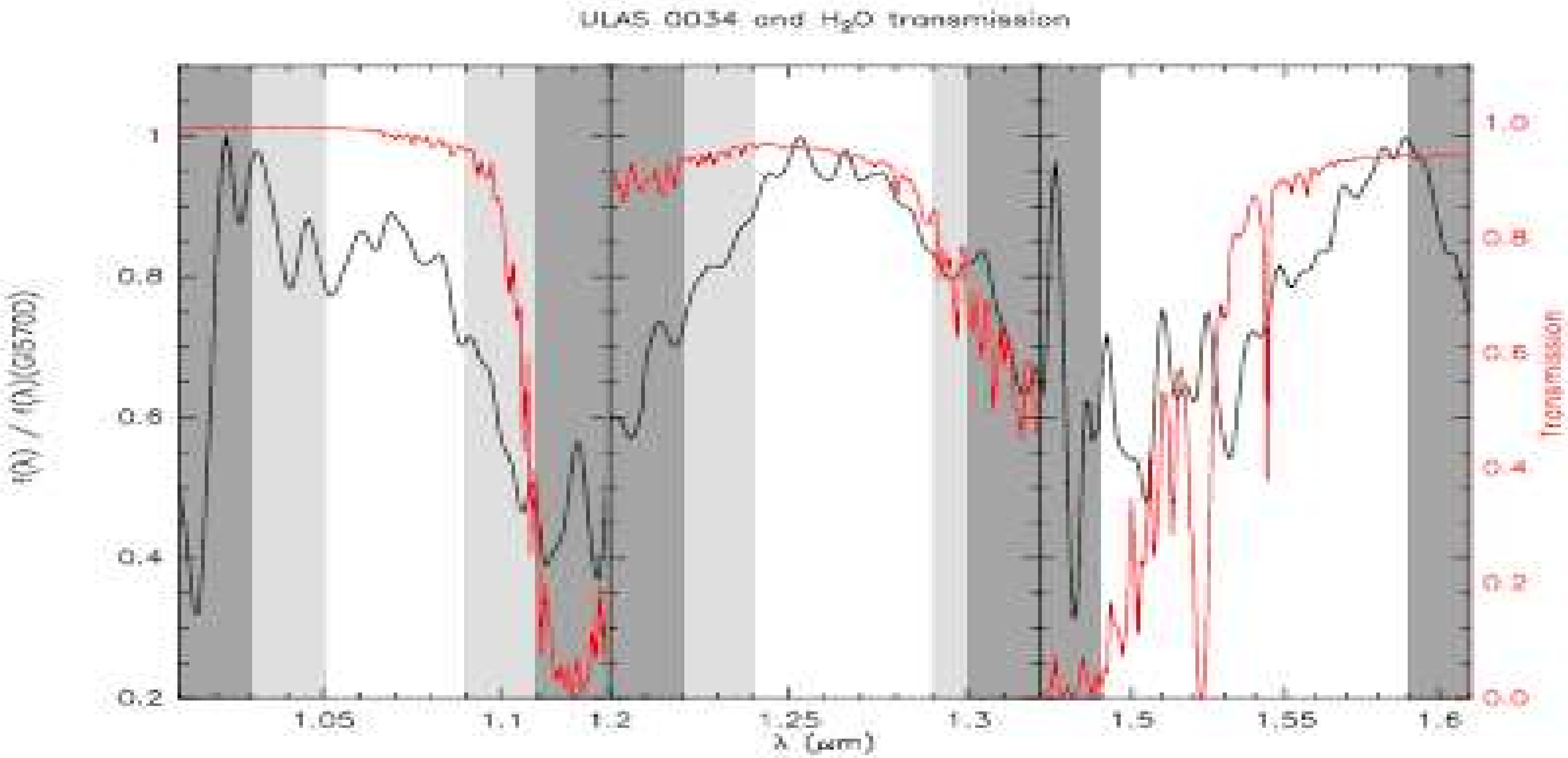
CFBDS0059 NIR Spectrum



ULAS 0034 NIR Spectrum

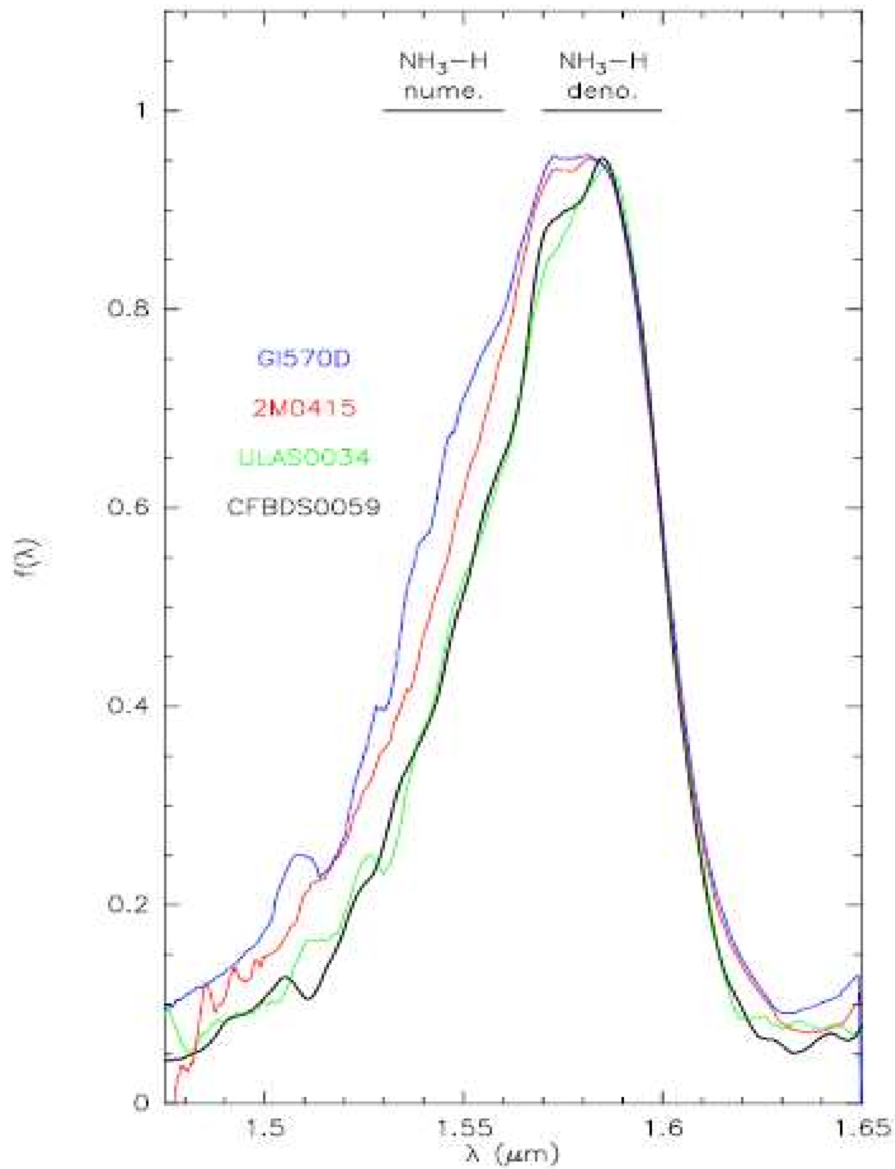


ULAS 0034 NIR Spectrum



Classification of Y Dwarfs

- NH_3 – H decreases as a function of spectral type
- Caused by stronger absorption of NH_3.

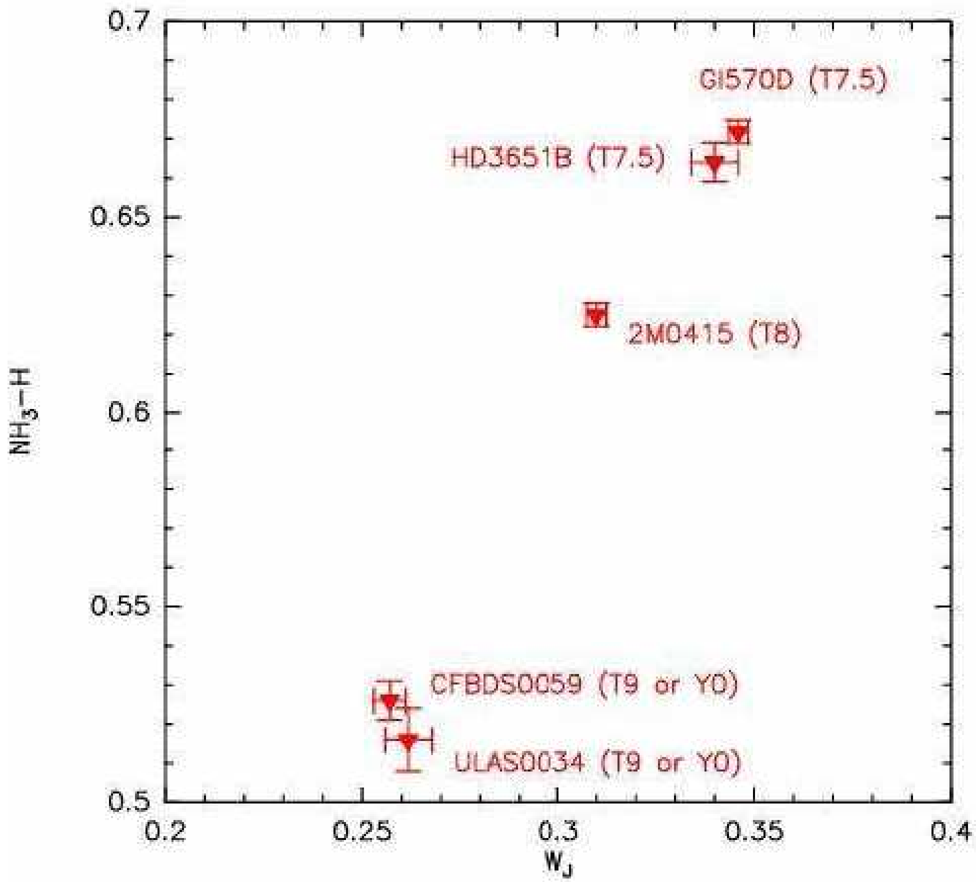


Y? Dwarfs

	Gl570D	HD3651B	2M0415	ULAS0034	CFBDS0059
NH_3-H	0.672±0.008	0.66±0.005	0.625±0.003	0.516±0.008	0.526±0.005
Spec. Type	T7.5[(1)]	T7.5[(1)]	T8[(1)]	T9 or Y0[(2)]	T9 or Y0[(2)]

- If NH_3 band at 1.55 μm deepens as T_{eff} decreases, this will provide a nice signature for Y Dwarfs.

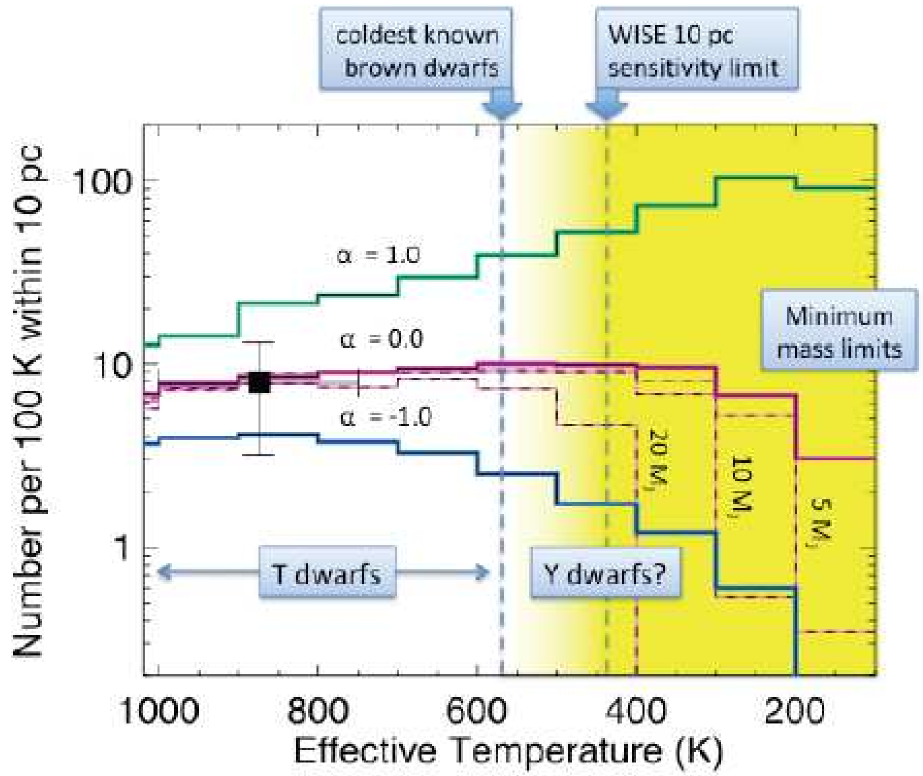
NH_3-H vs W_J



GI570D (T7.5)
HD3651B (T7.5)
2M0415 (T8)
CFBDS0059 (T9 or Y0)
ULAS0034 (T9 or Y0)
NH3−H
WJ
0.7
0.65
0.6
0.55
0.5
0.2
0.25
0.3
0.35
0.4

Number of Brown Dwarfs

- $dN/DM \sim M^{-\alpha}$
- WISE sensitive to 440K
- Most probable value $\alpha=0$
- Many more BD's still to be detected nearby.



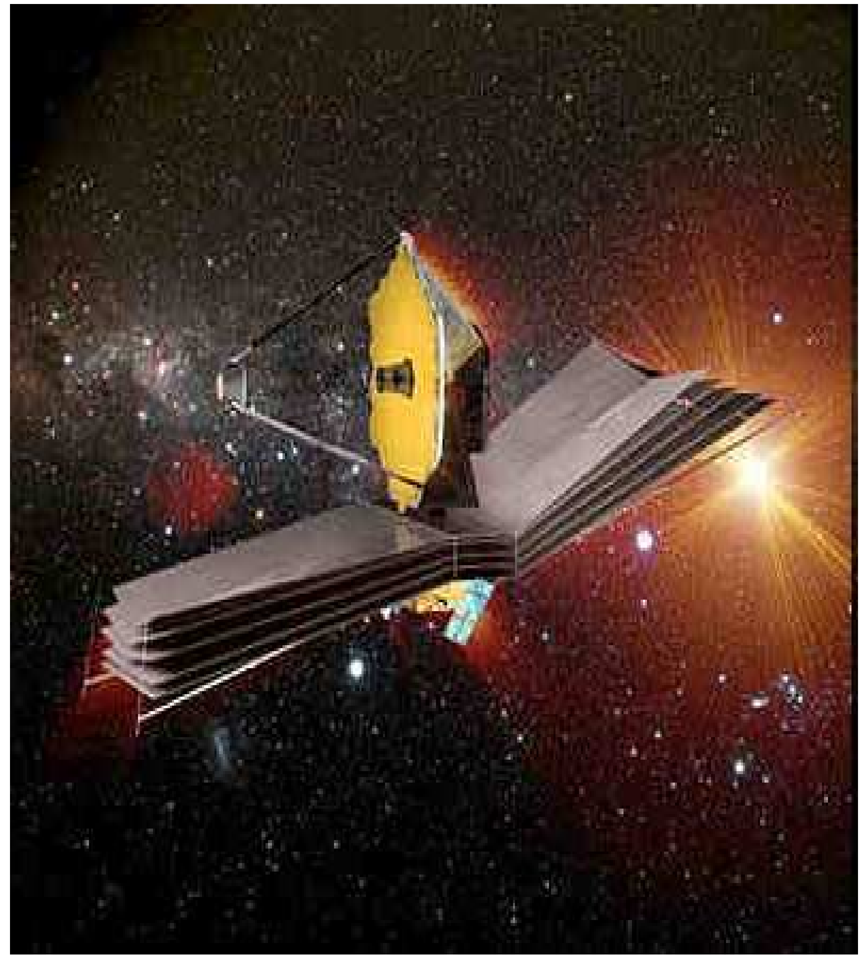
UKDISS/WISE

- 0.95–2.4 μm, 18% sky
- 3 m ground-based telescope
- 2005 – 2011

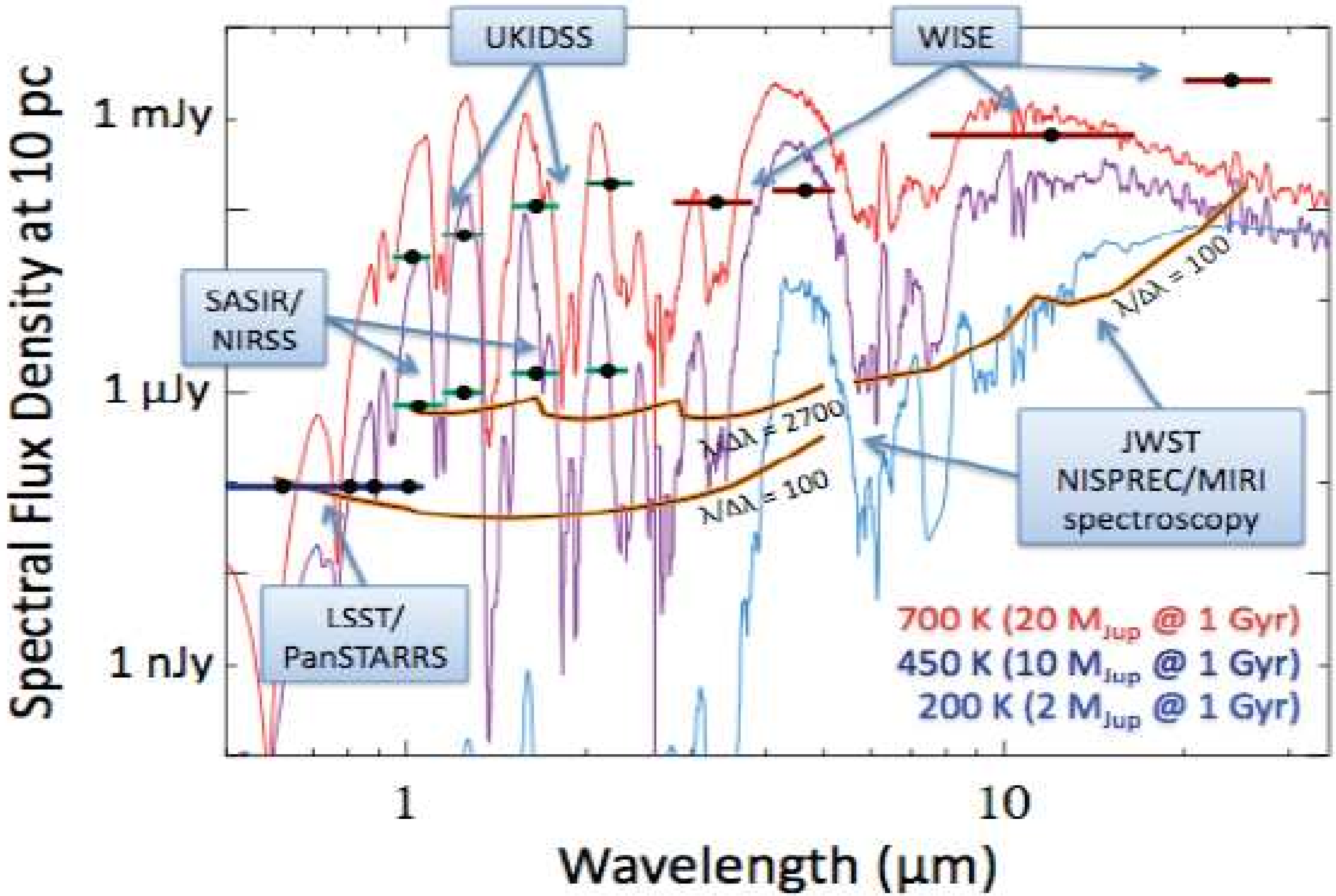
- 3–25 μm, 99% sky
- 0.4 m, space-based
- November 2009 launch

JWST

- Optical-MIR
- 6.5 m space-based telescope
- ~2.5 mag more sensitive than UKDIS/WISE
- Launch in 2013



Current/Future Searches



References

- Warren, S. J., Mortlock, D. J., Leggett, S. K., et al. 2007, MNRAS, 381, 1400
- Delorme, et al. 2008 arXiv:0802.4387v2.
- Burgasser, A. J., et al, “Toward the End of Stars: Discovering the Galaxy’s Coldest Brown Dwarfs.” Astro2010 Decadal Review Science White Paper
- Burrows, A., Sudarsky, D., & Hubeny, I. 2004, ApJ, 609, 407

J-Band Features

- NH_3 also has a strong absorption in spectra but its absorption lines are not well known.

- However, H_2O and CH_4 have strong absorption as well.

Motivation

- Large temperature gap between coolest BD's and Jupiter. What's in between?
- Help constrain atmospheric models which largely disagree at these temperatures.

How to find T_{eff} without spectra

1. Assign spectral type by comparing different spectral bands (H_2O, CH_4, J, H, K, etc.)

2. Apply bolometric correction, get the bolometric flux.

3. Use relation between BC and T_{eff} to find T_{eff}.

4. For late T dwarfs, W_J and NH_3-H most promising.