# Very Low Mass Brown Dwarfs With Disks

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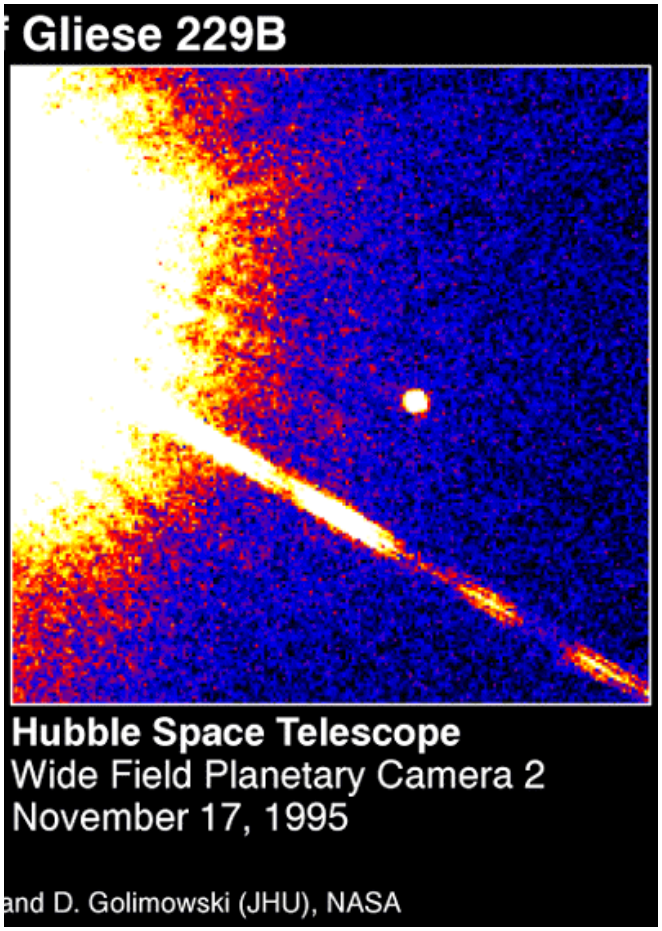
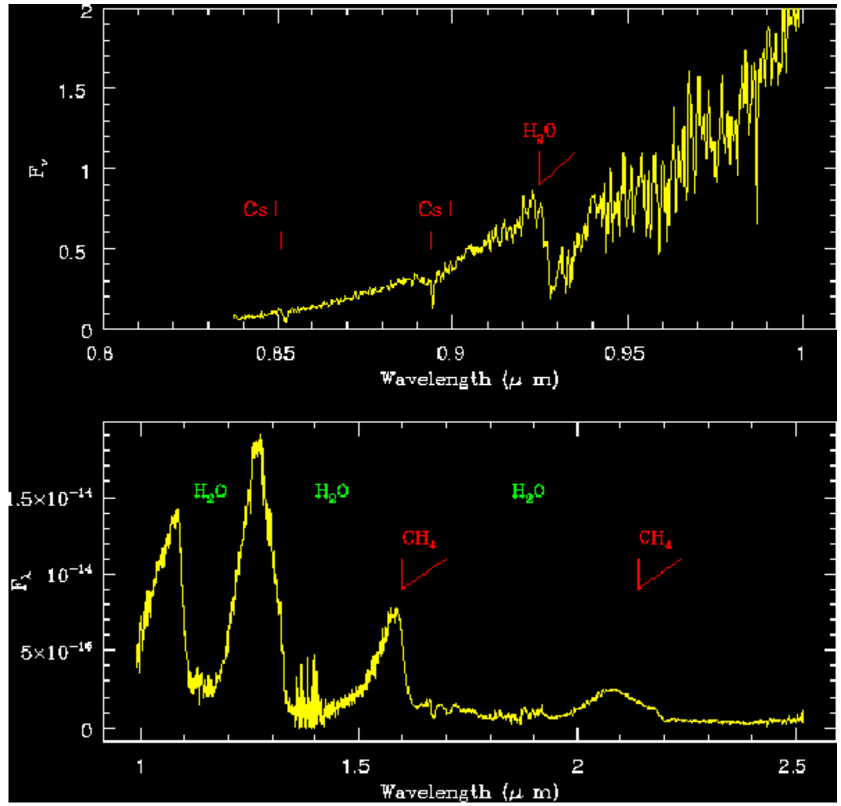
**Paul Harvey** (leads effort to find faintest candidates)

# c2d group

The discovery of GL229B in 1995 led to tremendous excitement.

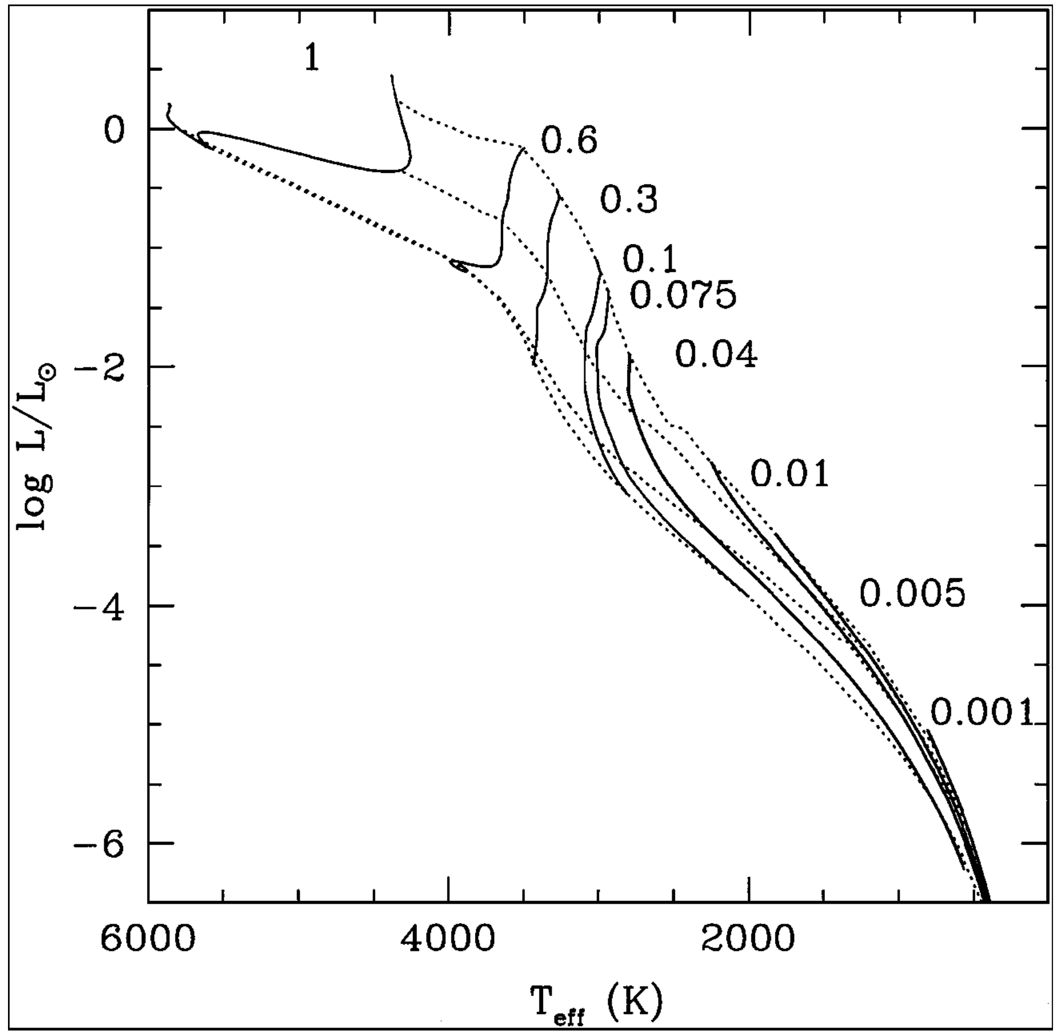



Oppenheimer et al. 1995

The luminosities of BD's drop precipitously with age, but theoretical models imply Jupiter-mass objects should be observable at 1 Myr Very exciting- but led to a number of dubious detections.

Chabrier and Baraffe 2000, ARAA



**The formation mechanism for brown dwarfs is still controversial. They may form...**

...like more massive stars: by fragmentation and collapse of a parent cloud.

...by ejection of incomplete stars from multiple systems (Reipurth & Clarke 2001, Kroupa & Bouvier 2003, Bate 2005).

...via photo-evaporation of a collapsing core. (Whitworth & Zinnecker 2004).

If they form like stars, and that seems increasingly likely, then the low mass end of the initial mass function then tells us about this process.

Inability to cool leads to an ultimate cutoff:

Jeans Mass $M_J \sim (T^{3/2}/\rho^{1/2})$

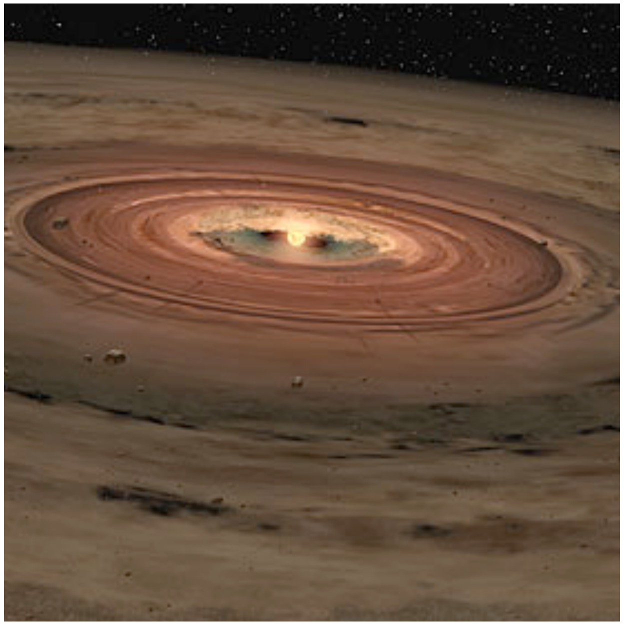
"Jeans Extinction" $A_J \sim (4/3)R_J\, \rho \sim \rho^{1/2}$

$\sim 1/M_J$

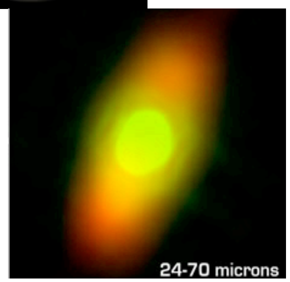
This leads to the "opacity limit", a size scale below which isothermal collapse is not possible.

~2-4 Jupiter masses

Disks around these very low mass objects allow
us to test disk physics and planet formation in an
extreme regime.

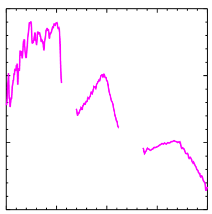


# Our initial work has five phases:




a survey for free-floating sub-brown dwarfs

a study of circumstellar disks around Brown Dwarfs

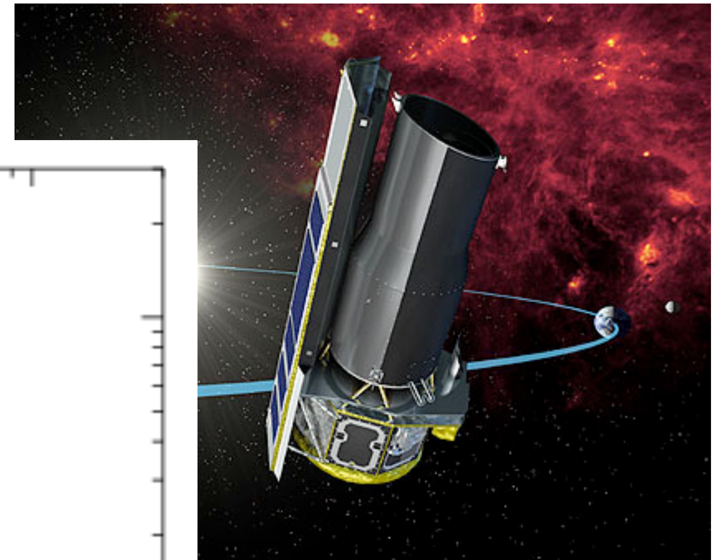


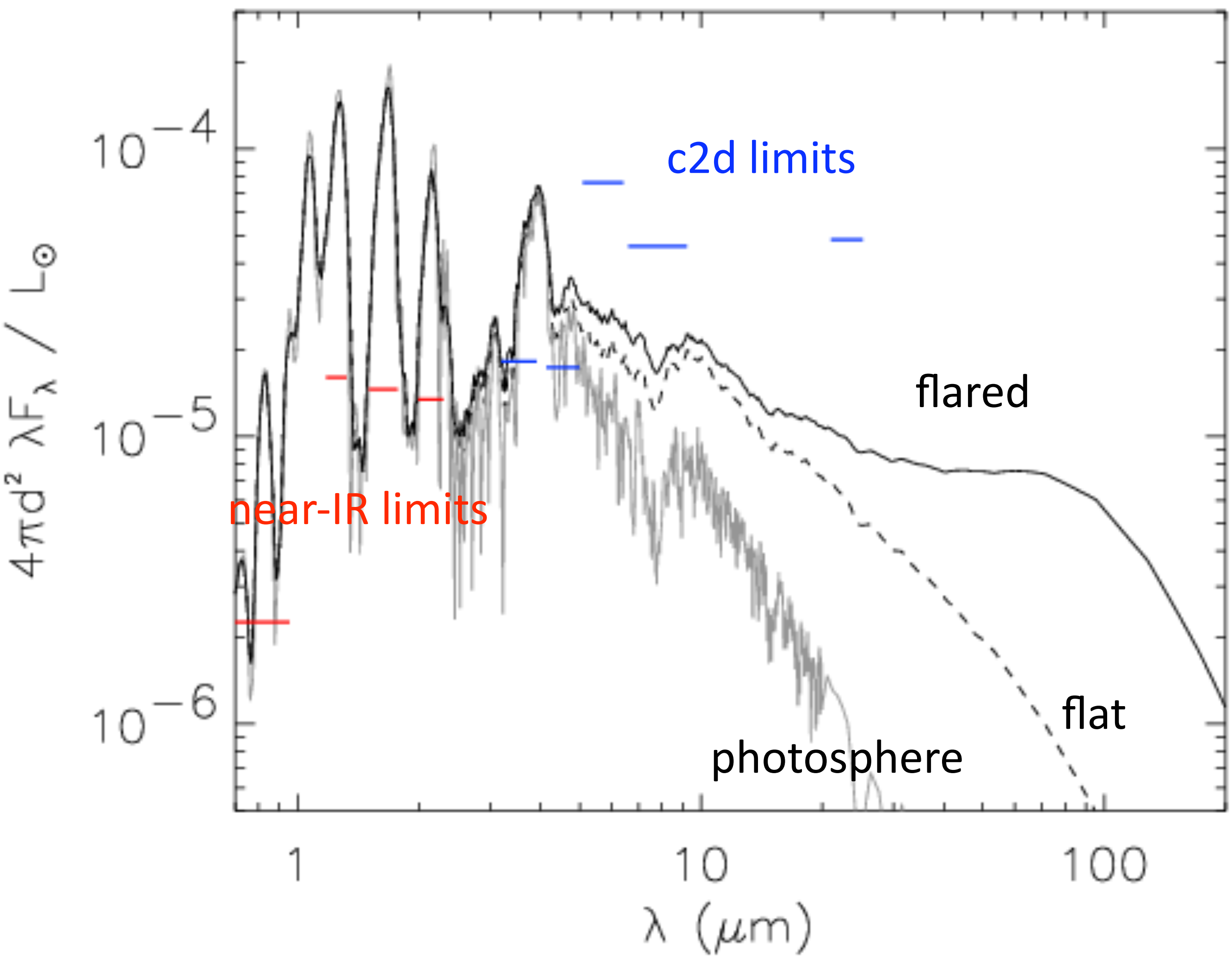
spectroscopic confirmation of our sample and tests of models

detailed spectra of sources and disks

a search for even lower mass objects

Neal Evan's Spitzer Legacy Program, From Cores to Disks (c2d) provides a fabulous opportunity for brown dwarf studies



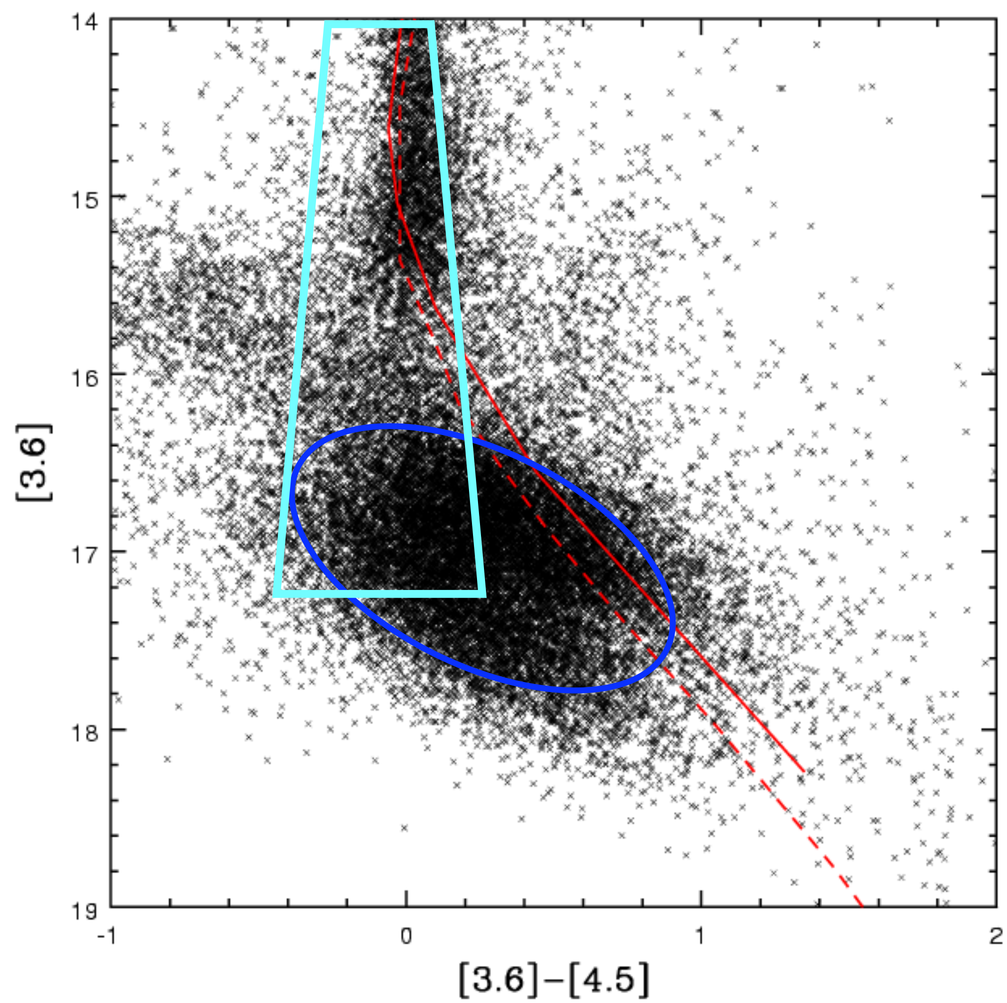


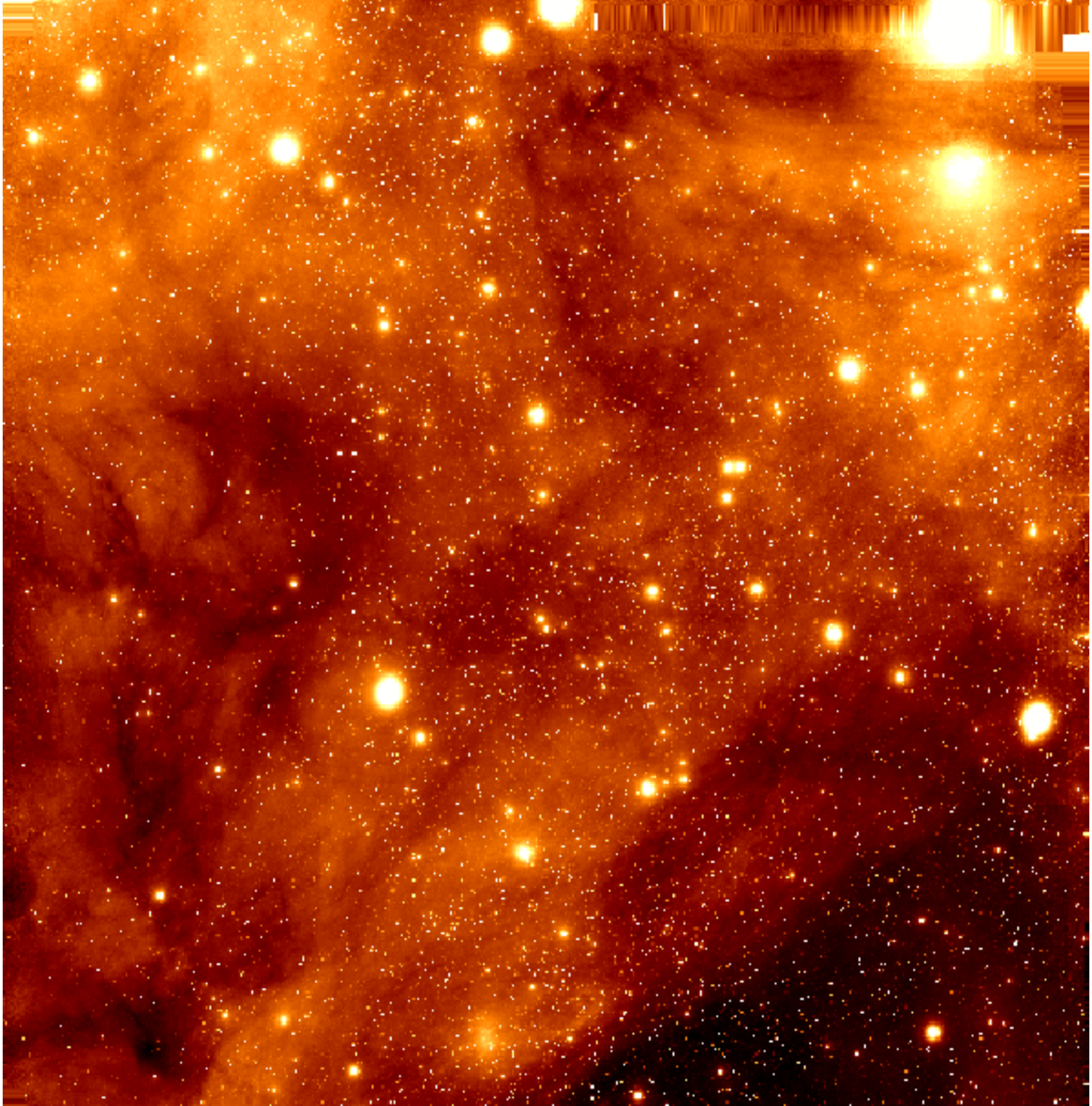

We do fine to 4.5 $\mu$m, but cannot see 2 $M_{Jupiter}$ objects with disks at longer wavelengths, => limit around 5 $M_J$

**Spitzer c2d can *detect* the brown dwarfs, but it cannot *identify them.***

**37,000 objects!**

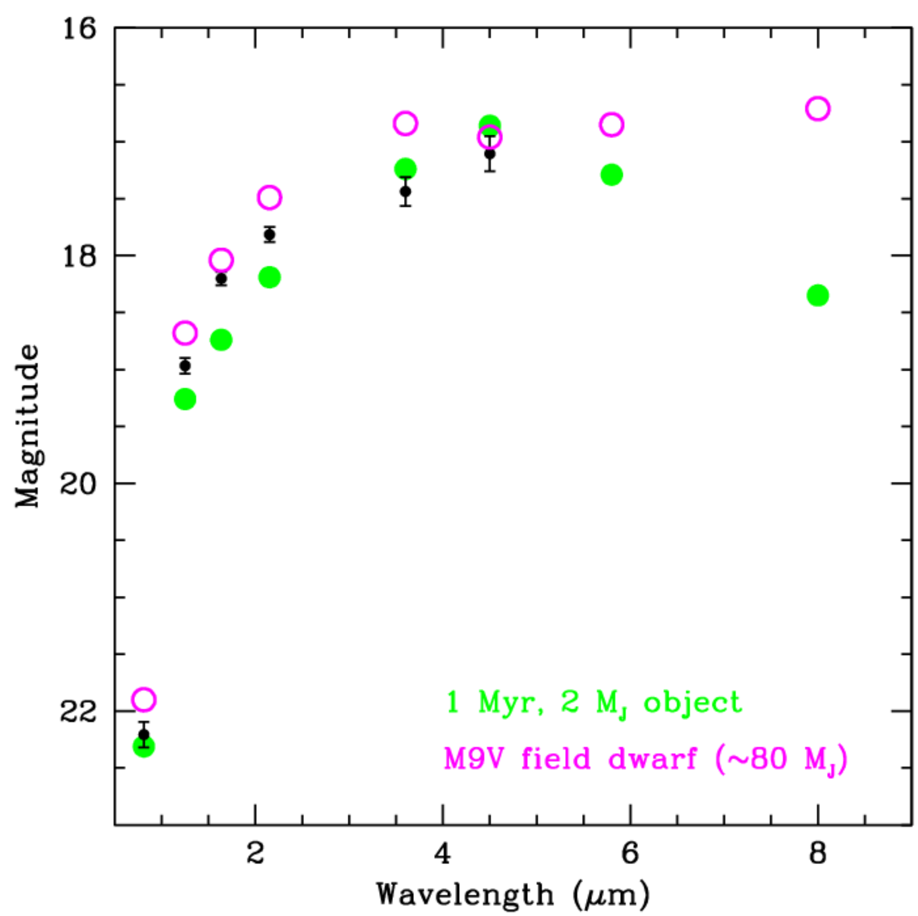
**Blue: Galaxies (SWIRE)**
**Cyan: Background Stars**
**Red: Model Isochrones**





**Having the near-IR data does not eliminate every ambiguity.**

We detected 120,000 objects in all 4 near-IR bands. 3800 of these have appropriate colors for sub-brown dwarfs. The space density of field brown dwarfs is high- we should have 1200-9000 later than M9 in our survey.



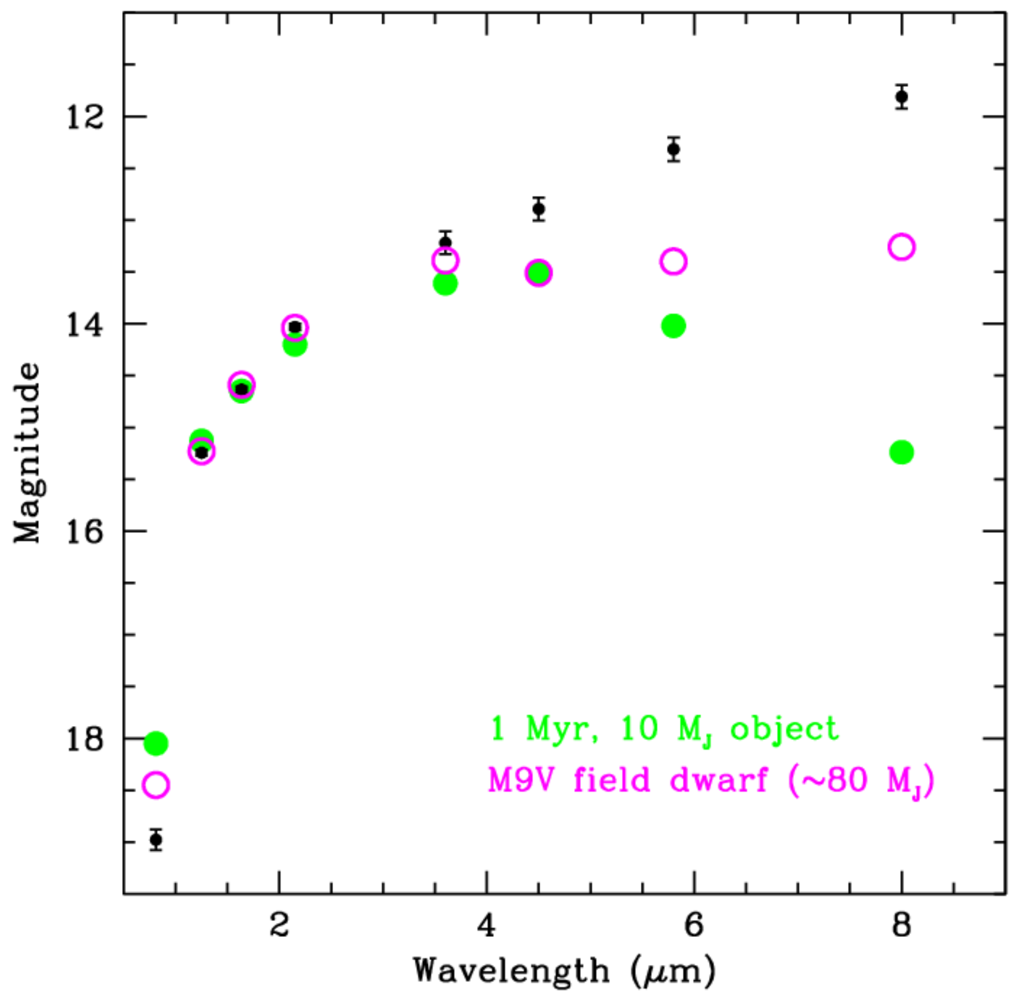
## From 120,000 to 19: mid-IR excesses

Presence of mid-IR excess emission ensures youth (< 6 Myr)

Point source detected in all 4 IRAC bands

$A_V$'s by comparison to young brown dwarfs

Select sources with >3σ 5.8 and 8.0 μm excesses

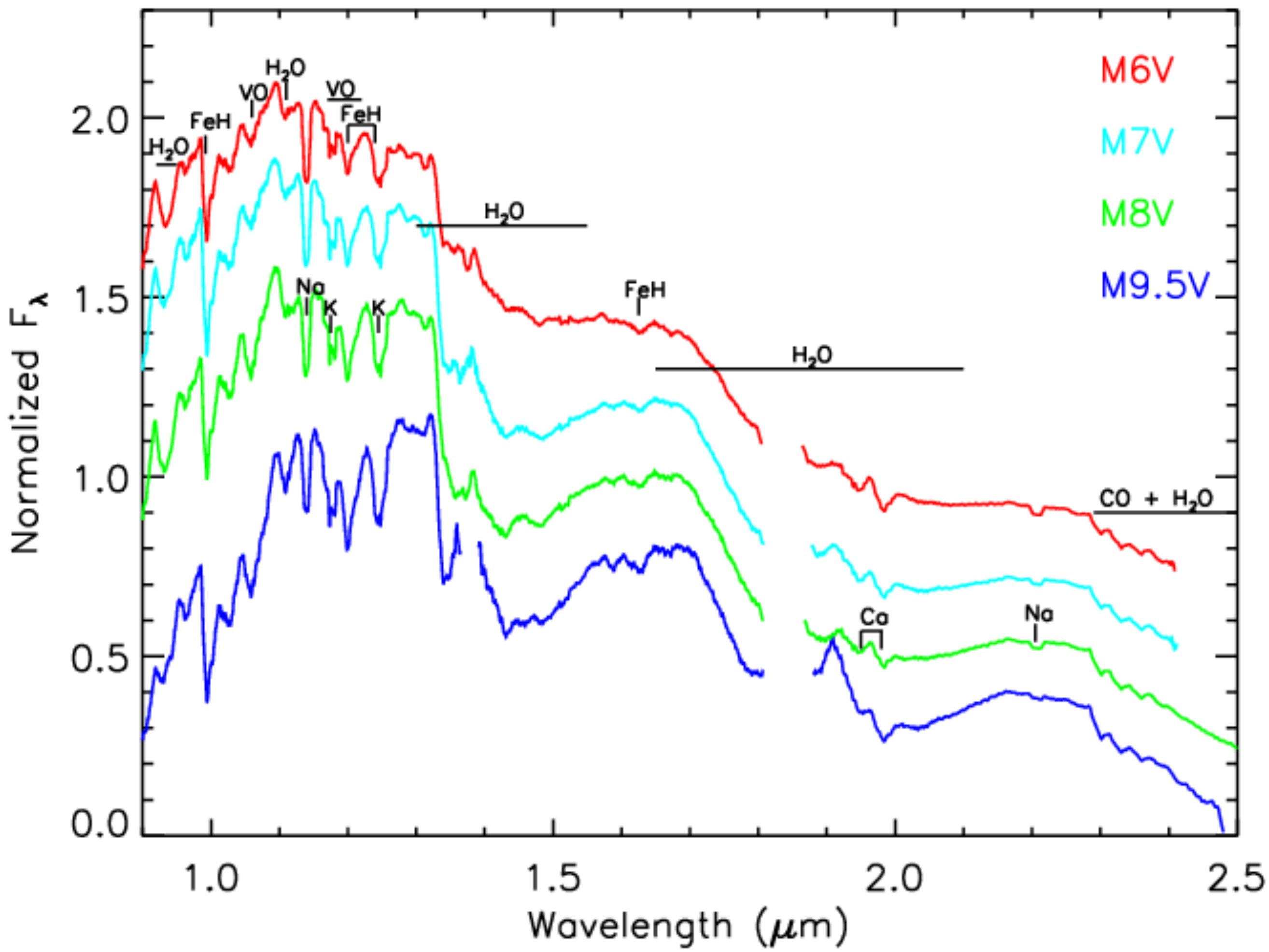


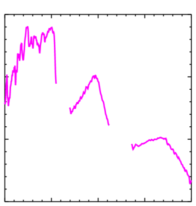
# A sample of 19 young stars, brown dwarfs and sub-brown dwarfs with disks

- Luminosities from 0.56 to -3.11 $\log(L_*/L_\odot)$
- Mass range from 6 to 350 $M_{Jupiter}$
- Four sources with $\log(L_*/L_\odot)<-2.89$
- Five sources with $M<12\ M_{Jupiter}$
- Six of the more massive found by other surveys

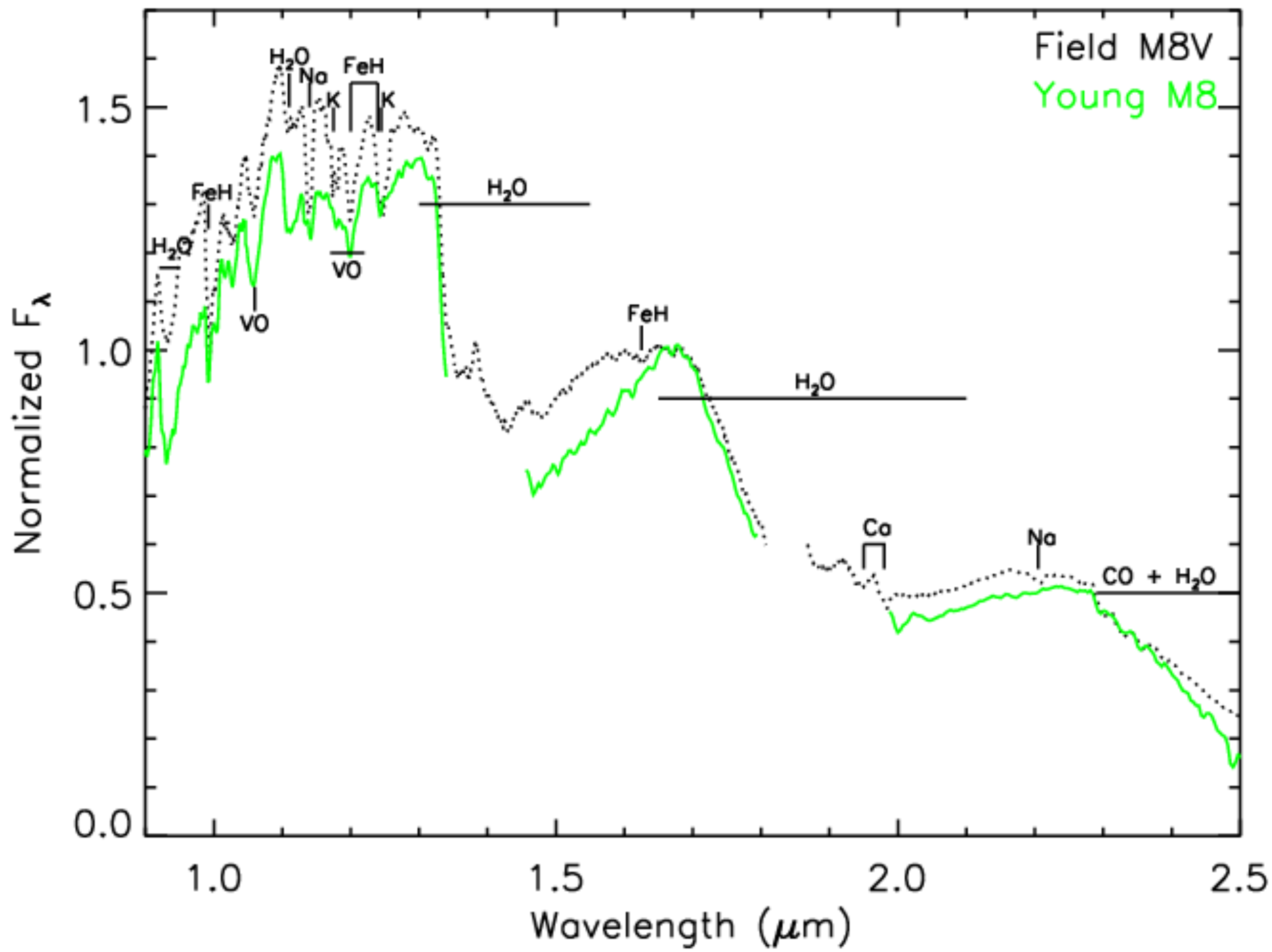
*All but one now confirmed by spectroscopy.*
*The last is a superposition.*

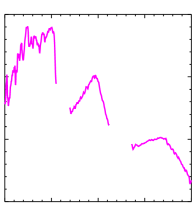
Near-IR spectra of field dwarfs allow us to determine spectral types that, in turn tell us the stellar temperature.



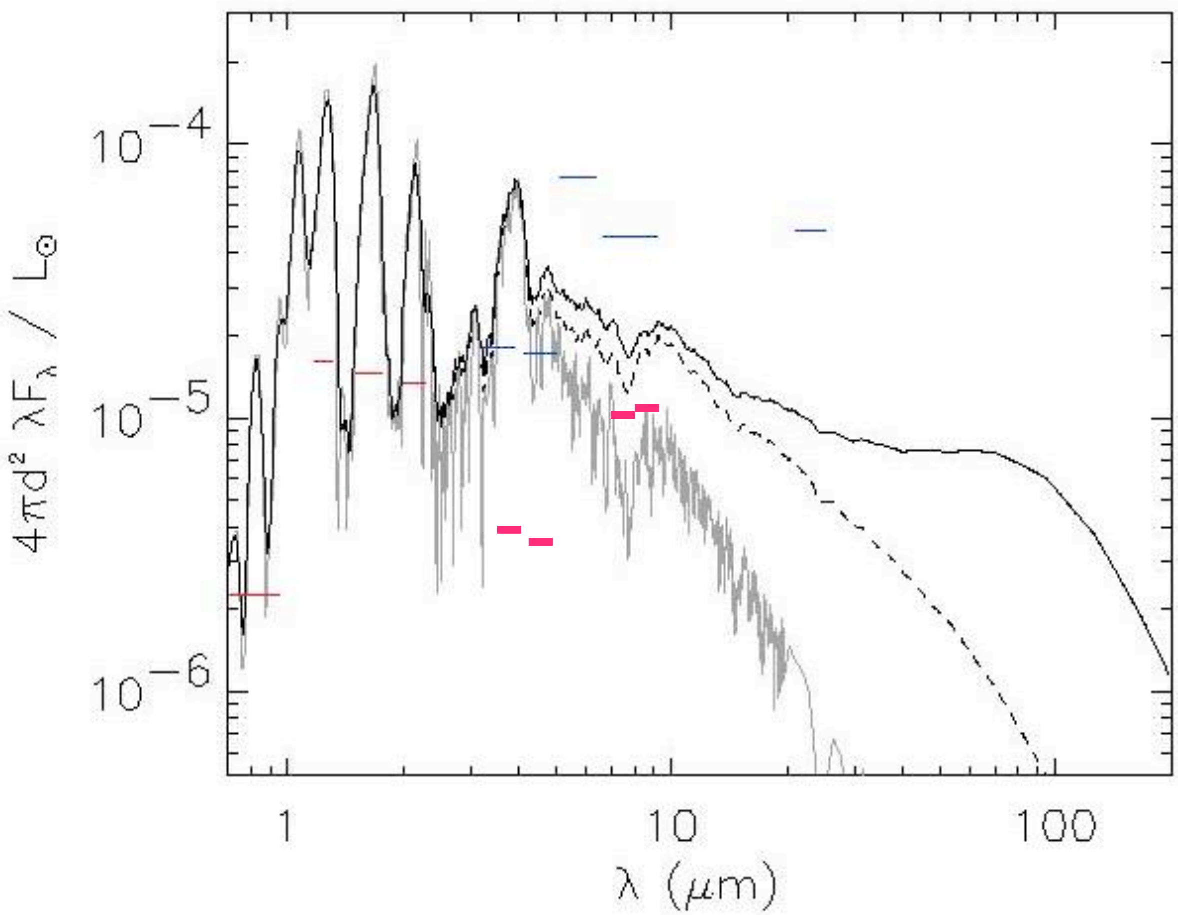



Surface gravity (stellar size) affects the near-IR spectrum allowing us to distinguish young objects from old ones.

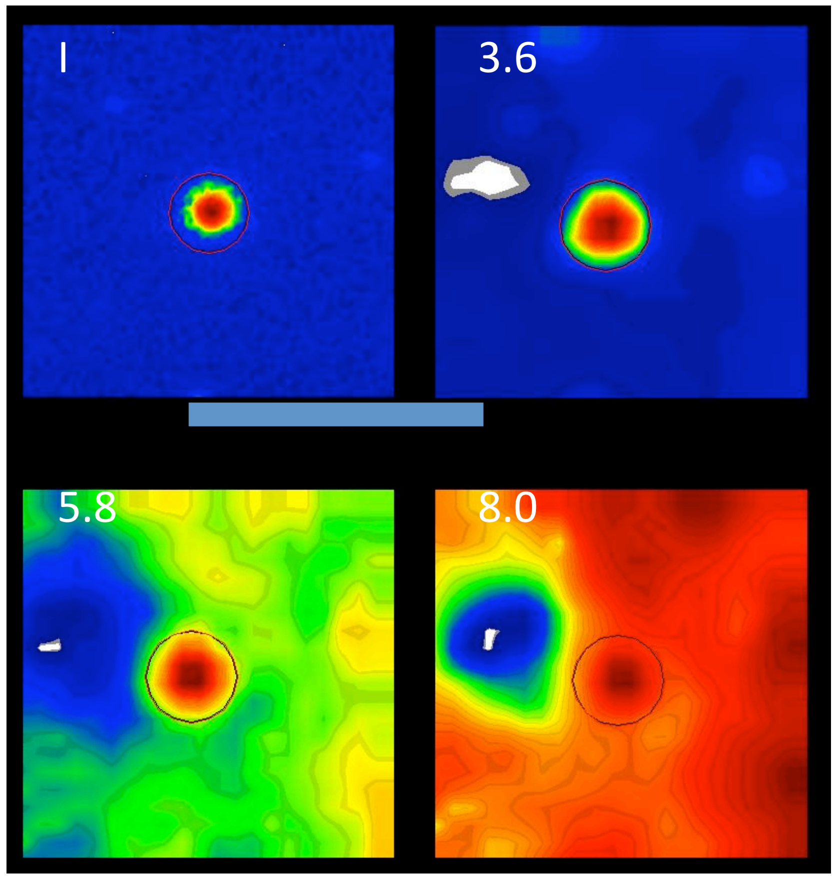


# New Sensitivity Limits



# Results – A High Probability Source



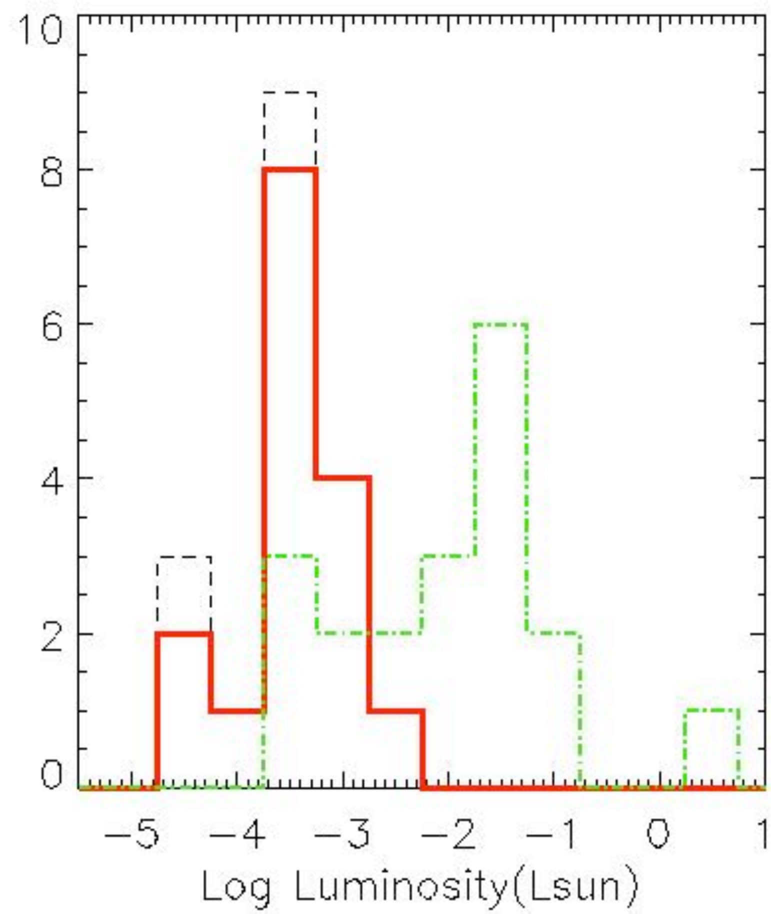

From Paul Harvey

# Luminosities of Candidates

Allers '06 objects

Likely New

Possible New




Harvey et al. in prep

Planetary systems may form with parent objects as low as 3-10 Jupiter masses making the process almost universal.

Tools to study such systems are becoming available.