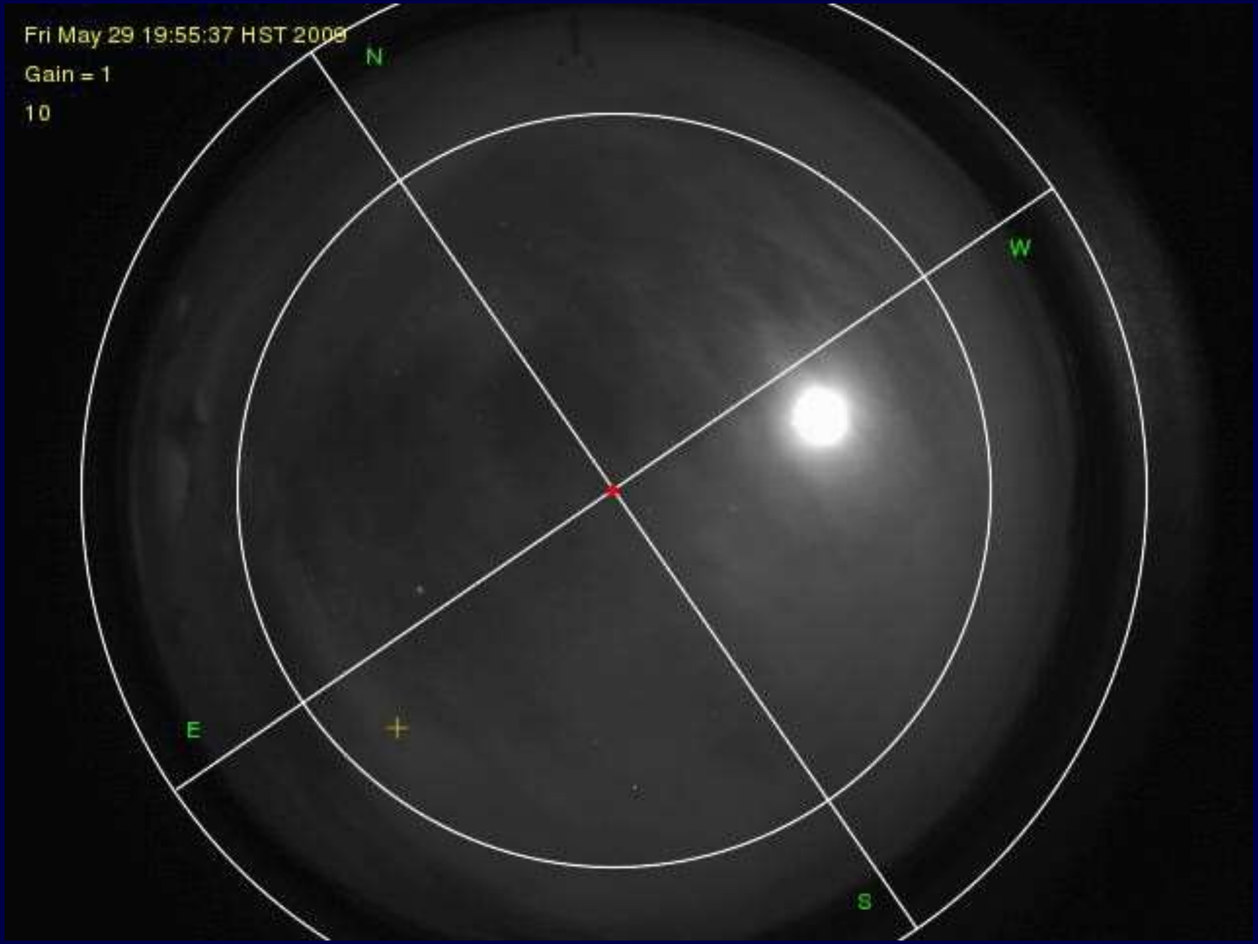
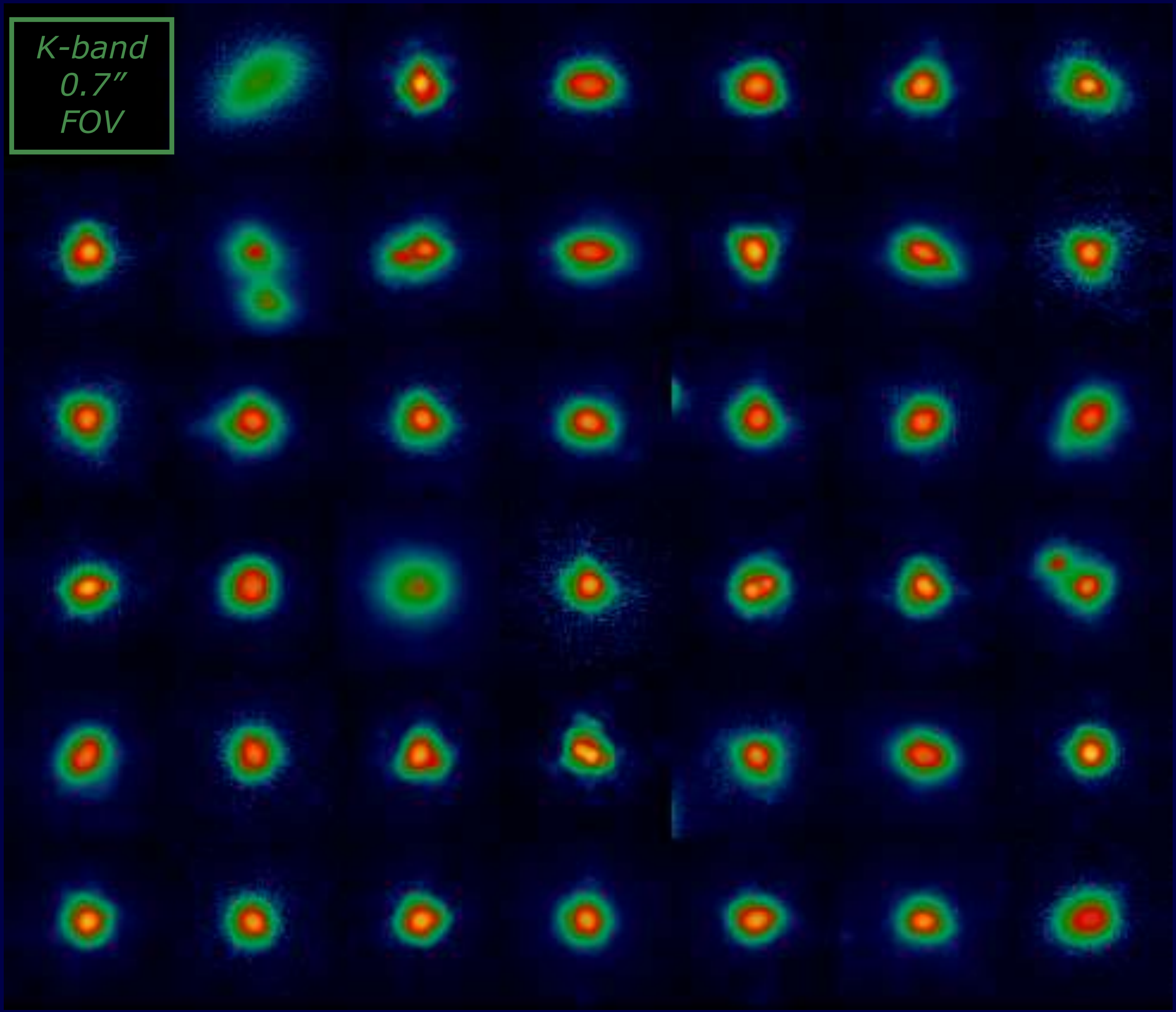
Testing Substellar Models with Keck LGS AO Dynamical Masses



Trent Dupuy
IfA/Hawaii

Michael Liu
IfA/Hawaii

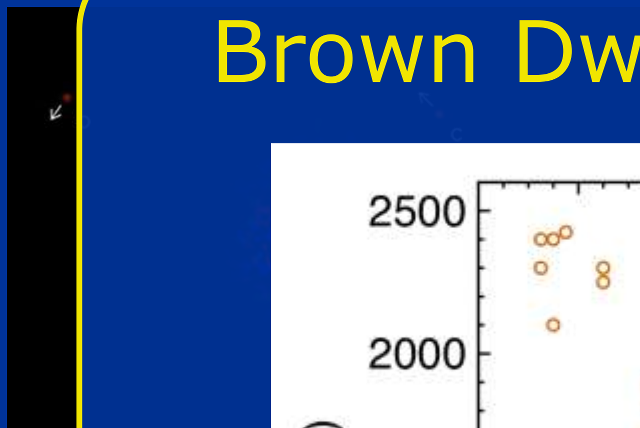
Michael Ireland
U. Sydney



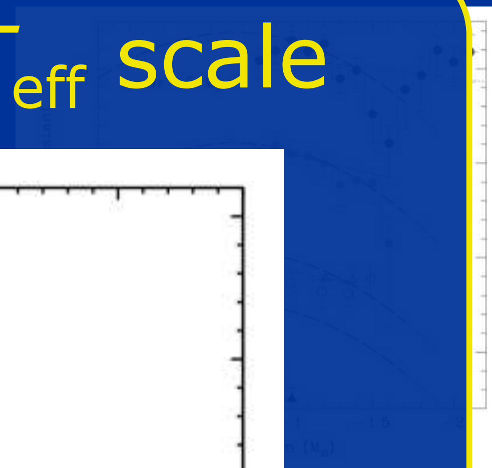
Liu et al., Allers et al., Biller et al., in prep.

It is very important to test substellar theoretical models.

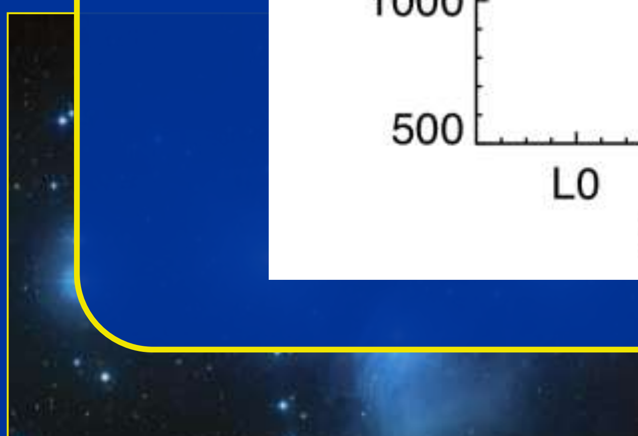
Directly imaged planets



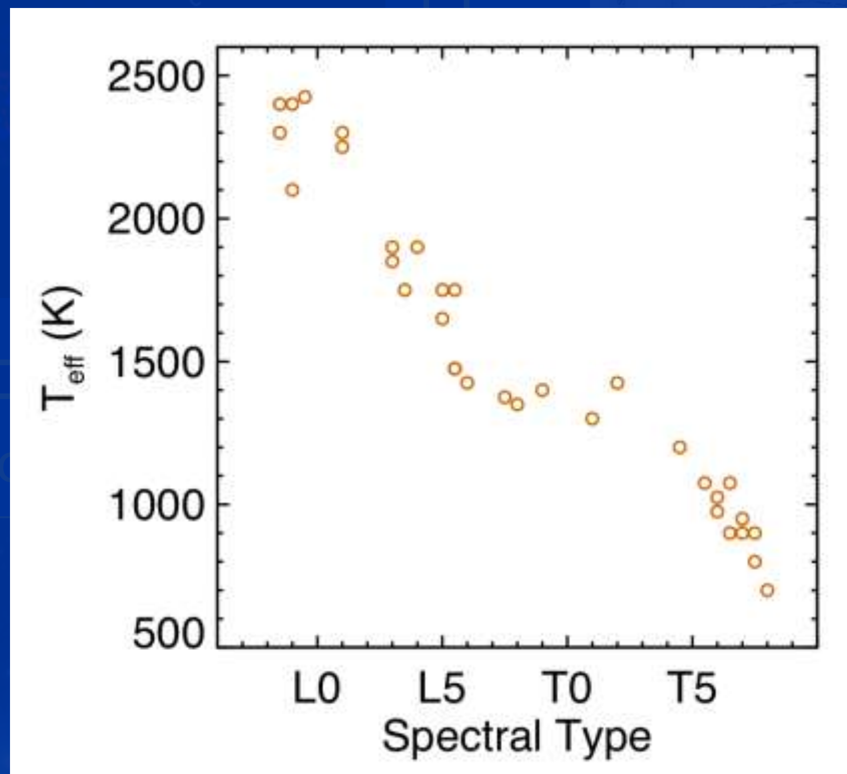
Initial Mass Function



Young c



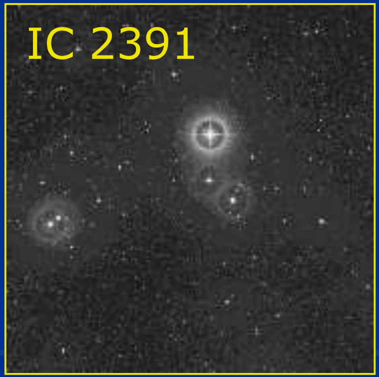
Brown Dwarf T_{eff} scale

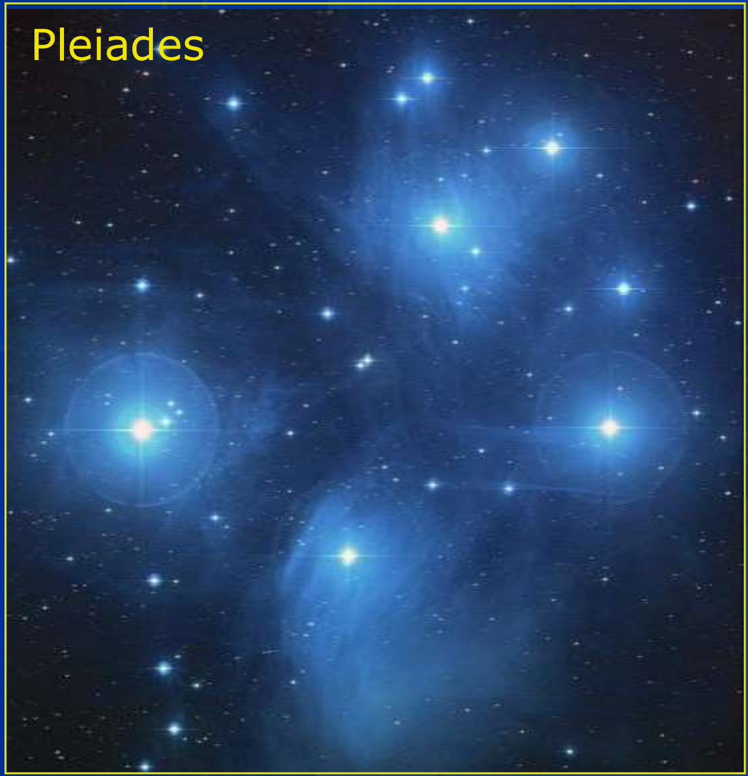


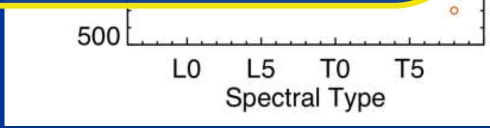
Directly imaged planets

Initial Mass Function

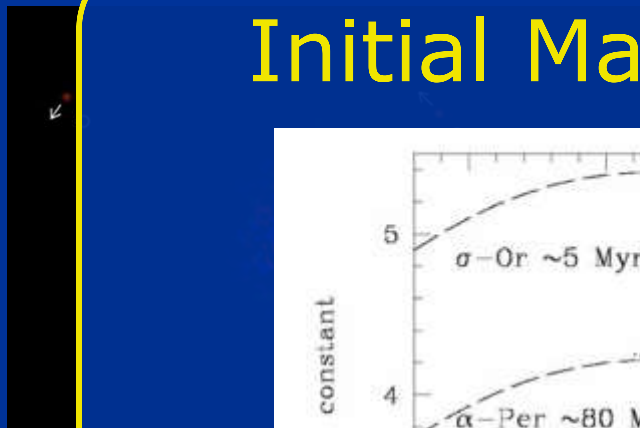
Young cluster ages



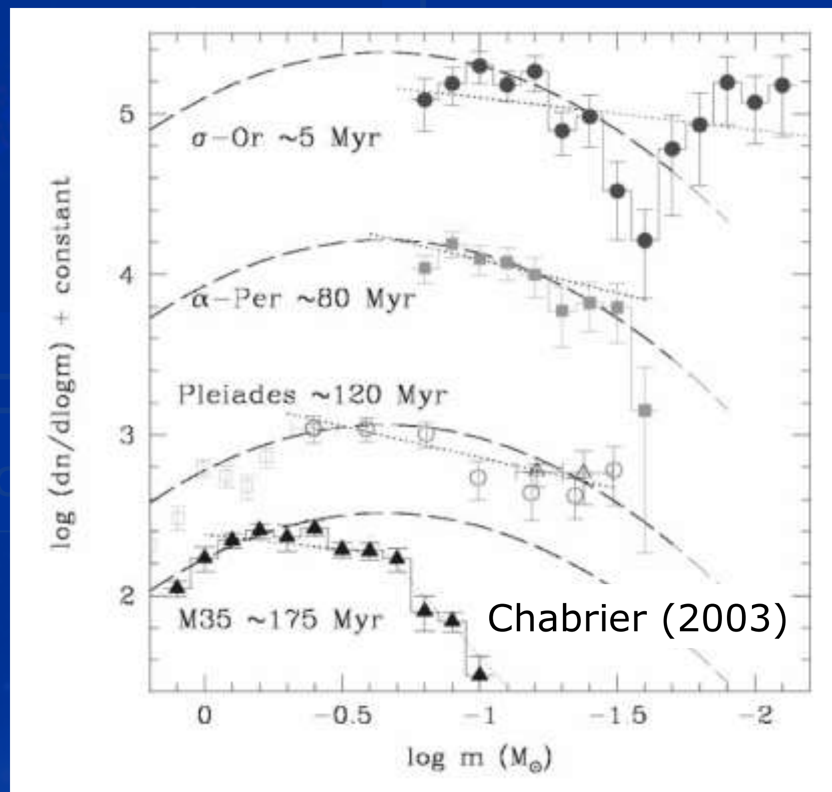


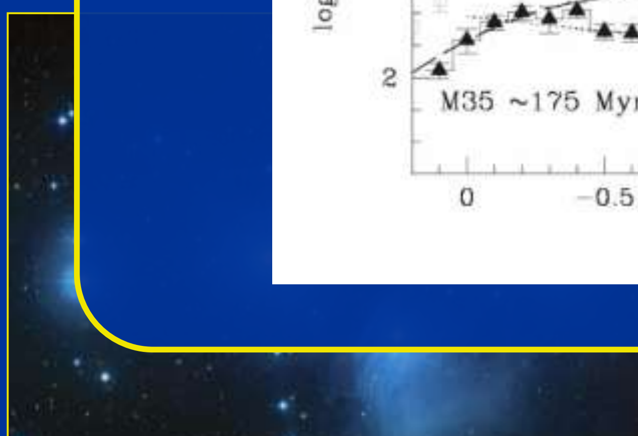


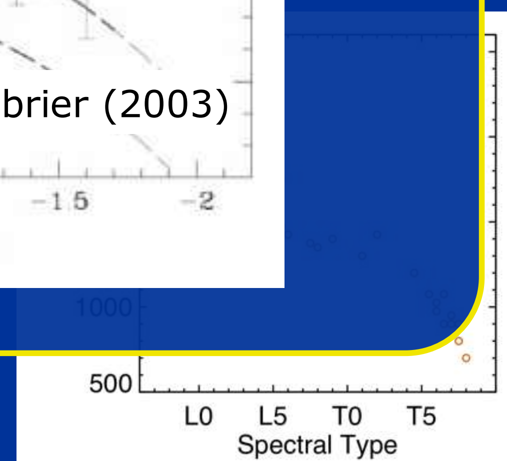
Directly imaged planets



Initial Mass Function

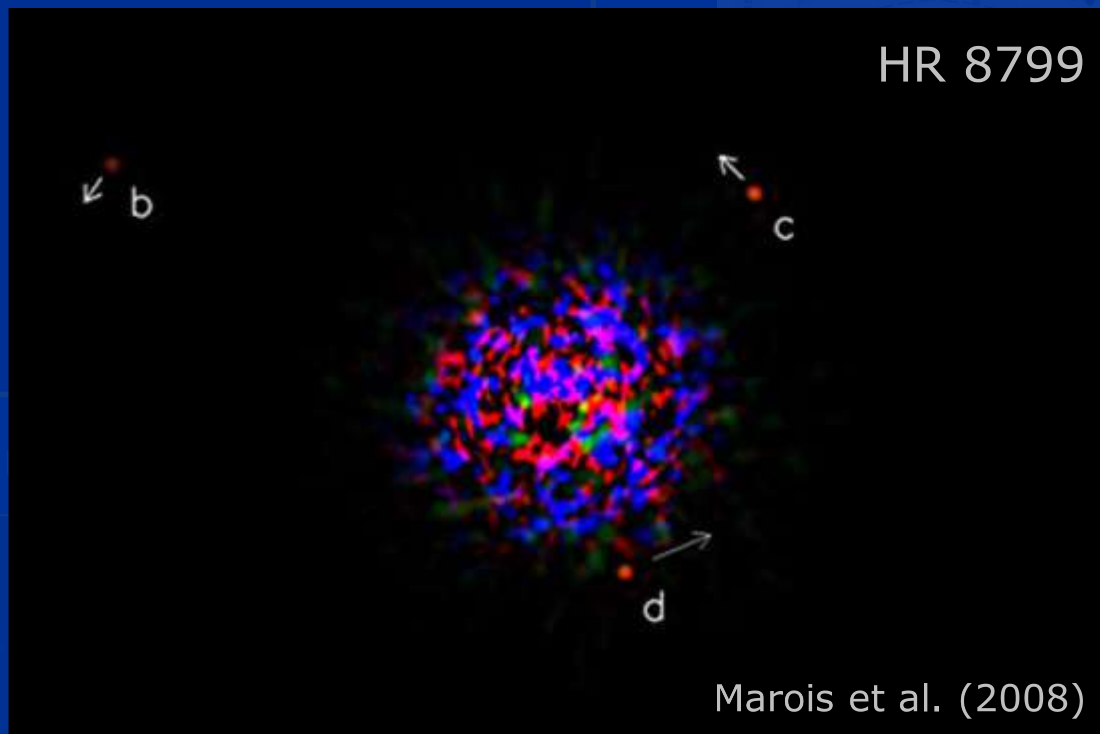


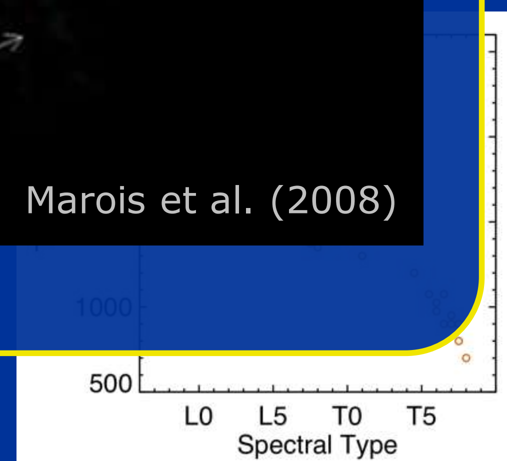




Initial Mass Function

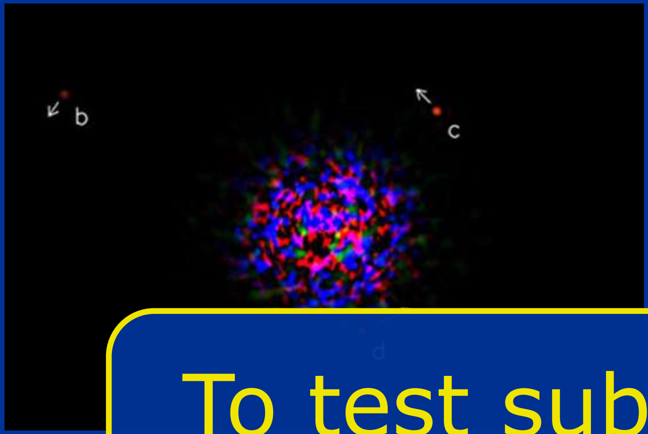
Directly imaged planets



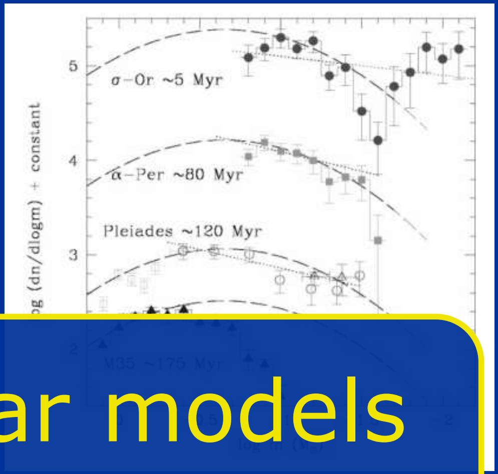


Trent Dupuy (IfA/Hawaii)

Directly imaged planets



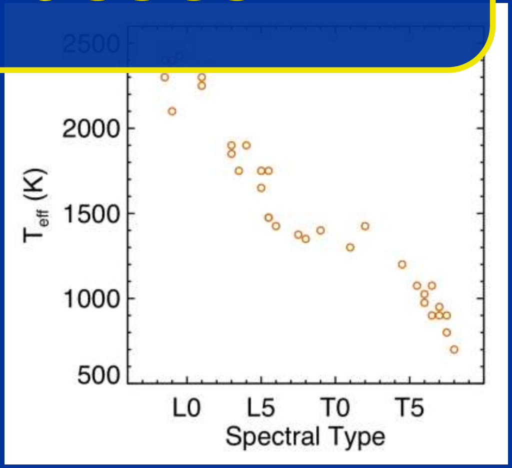
Initial Mass Function



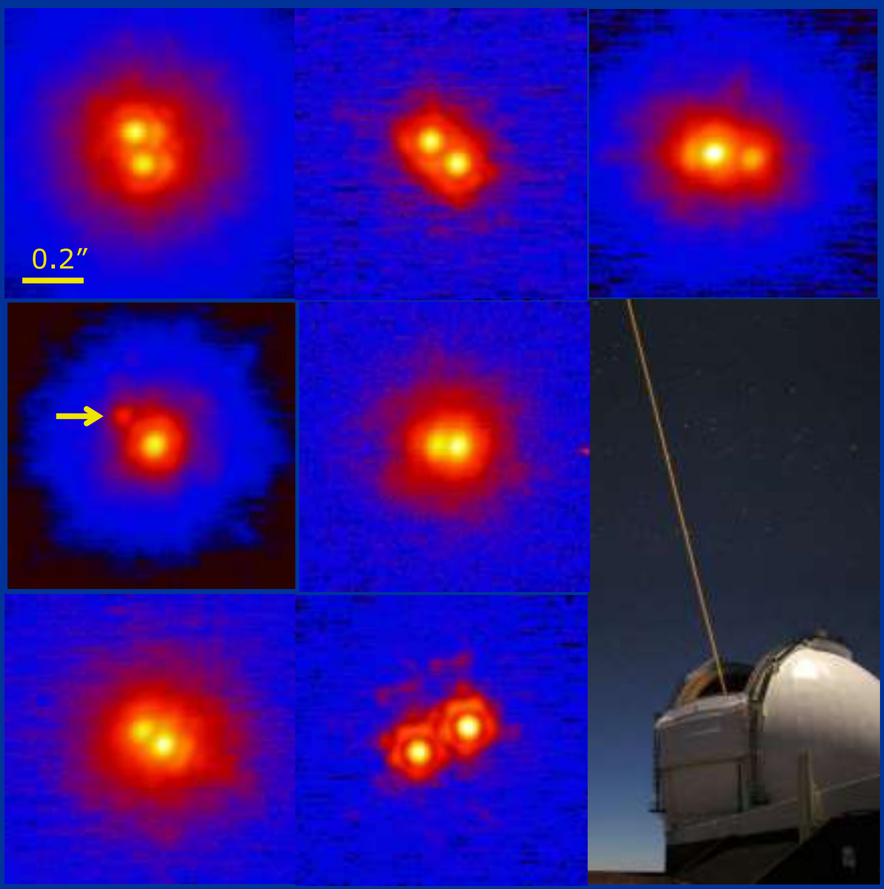
To test substellar models we are measuring dynamical masses.

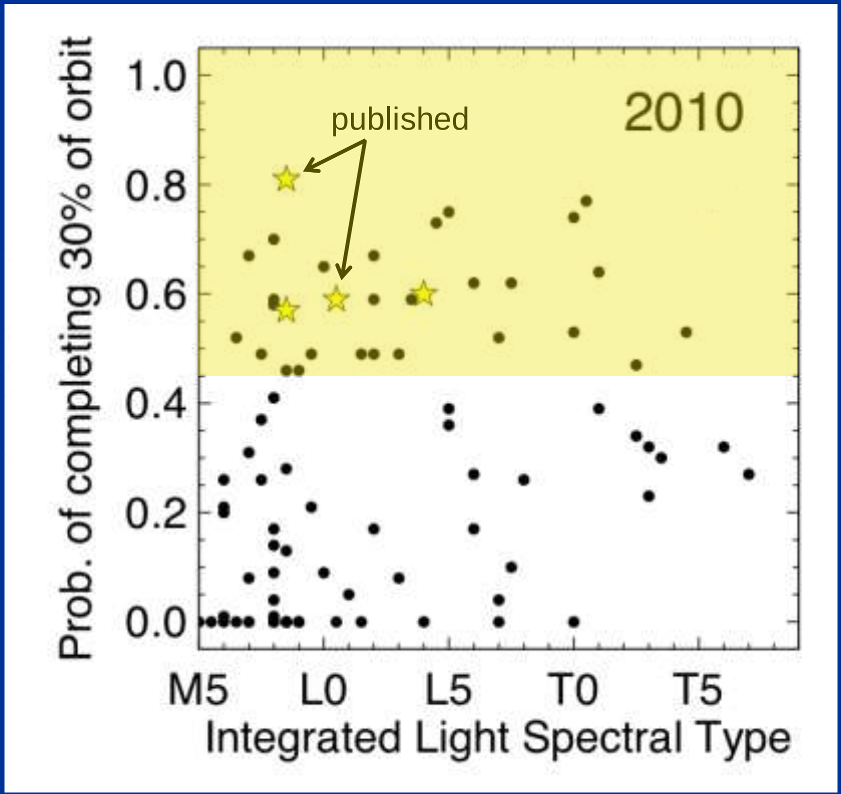
Young cluster ages

Brown Dwarf T_{eff} scale



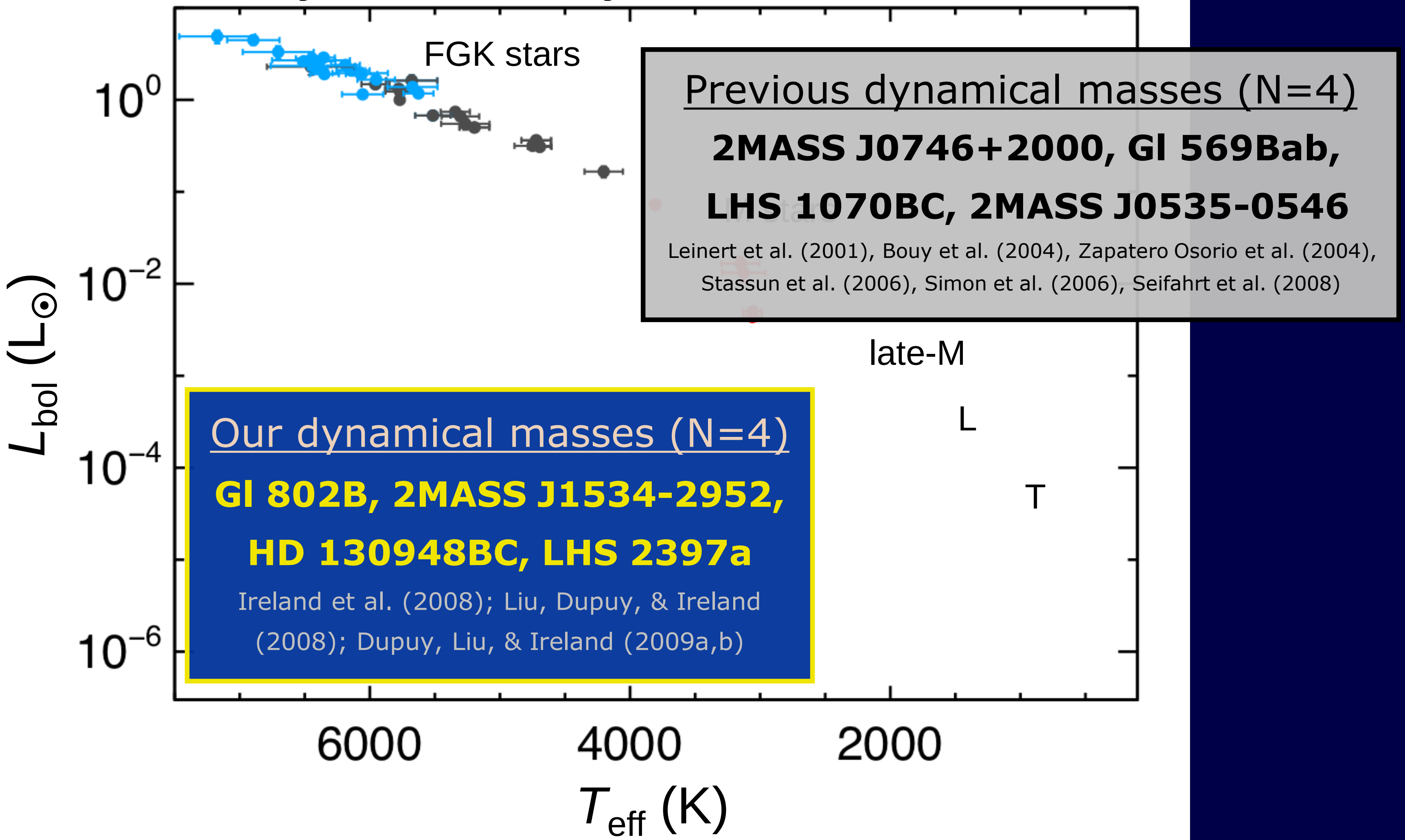
Keck LGS AO program targets ~30 binaries over ~3 years.

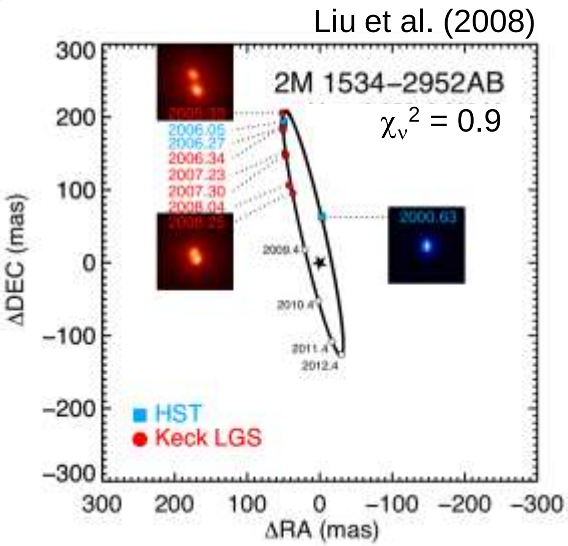




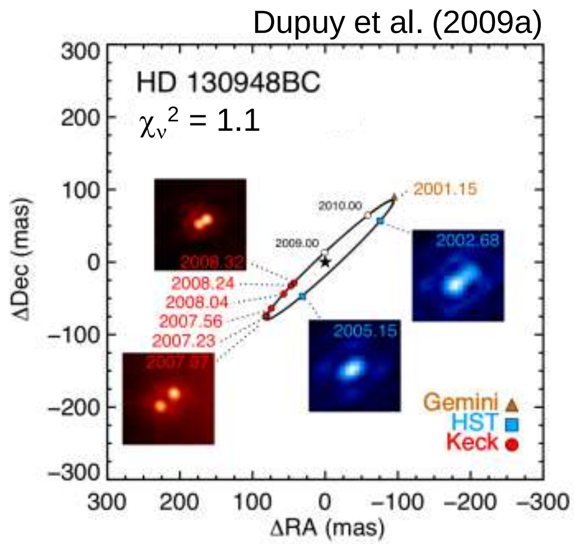
Carefully selected binaries likely to complete enough of their orbit by 2010.

Objects with dynamical masses

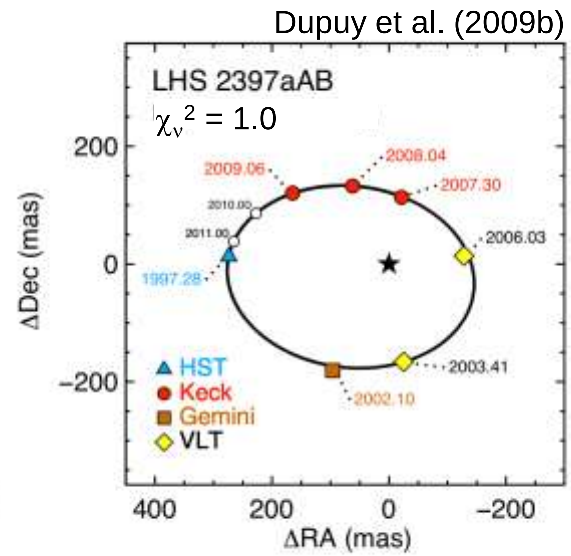




$M_{tot} = 59 \pm 3\ M_{Jup}$

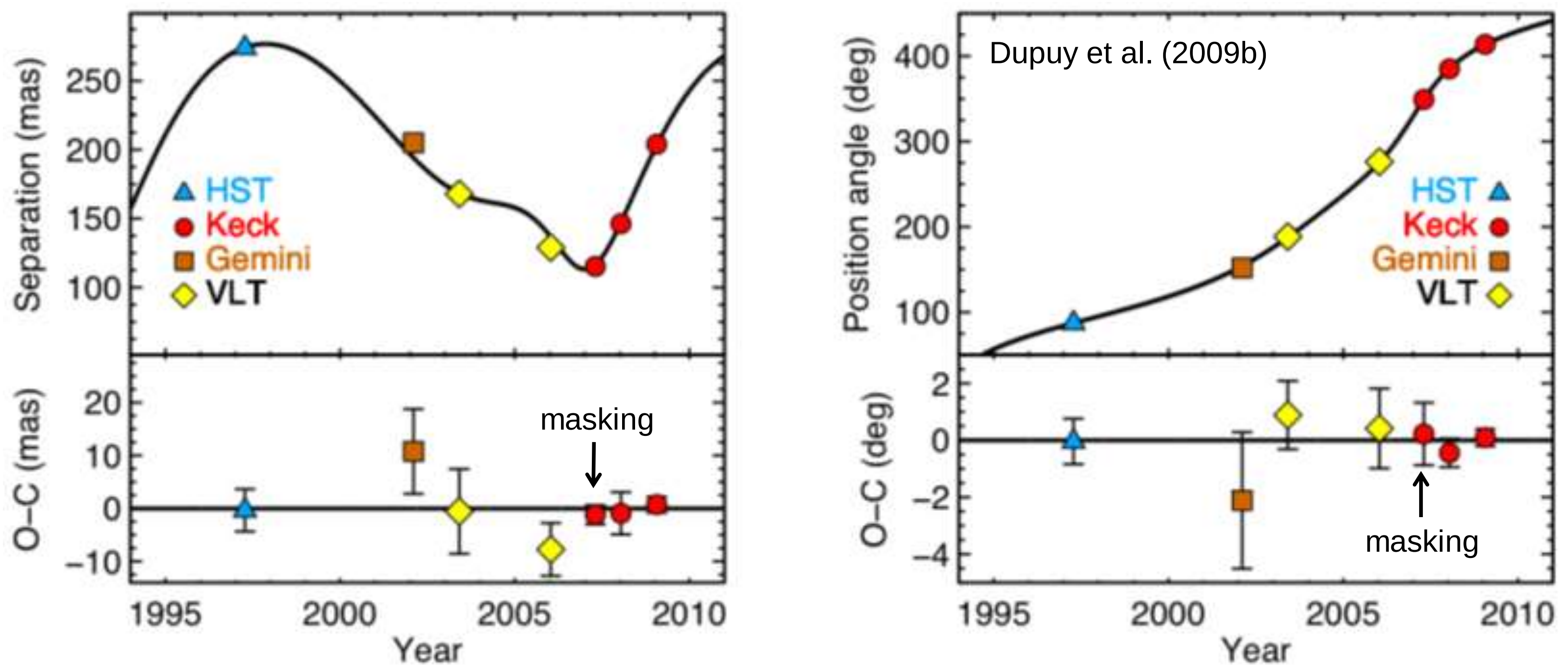


$M_{tot} = 114 \pm 3\ M_{Jup}$



$M_{tot} = 153 \pm 15\ M_{Jup}$

- Orbit fit using Markov Chain Monte Carlo
- Astrometric errors derived from Monte Carlo simulations of artificial binaries
- Covariances tracked in analysis (e.g., M_{tot} and L_{bol} correlated via distance)



- Orbit fit using Markov Chain Monte Carlo
- Astrometric errors derived from Monte Carlo simulations of artificial binaries
- Covariances tracked in analysis (e.g., M_{tot} and L_{bol} correlated via distance)

Substellar model tests

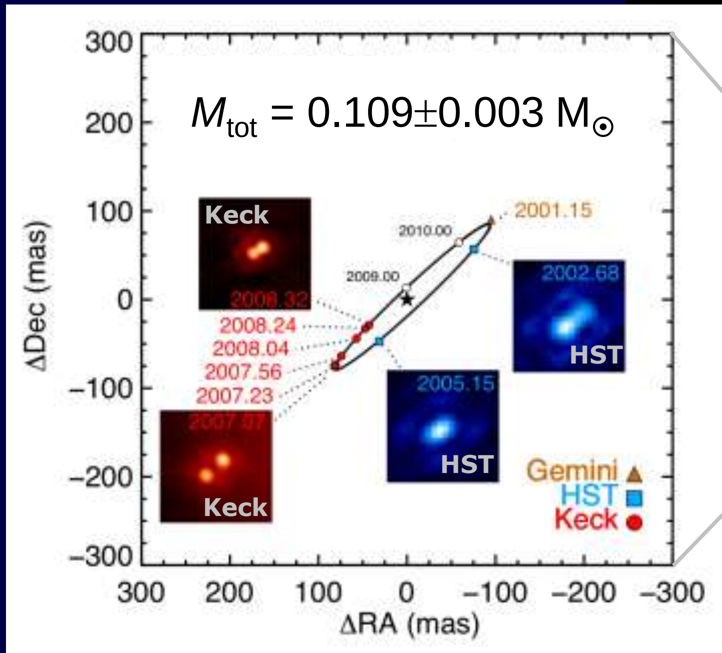
1. Do models predict the luminosity evolution of substellar objects accurately?

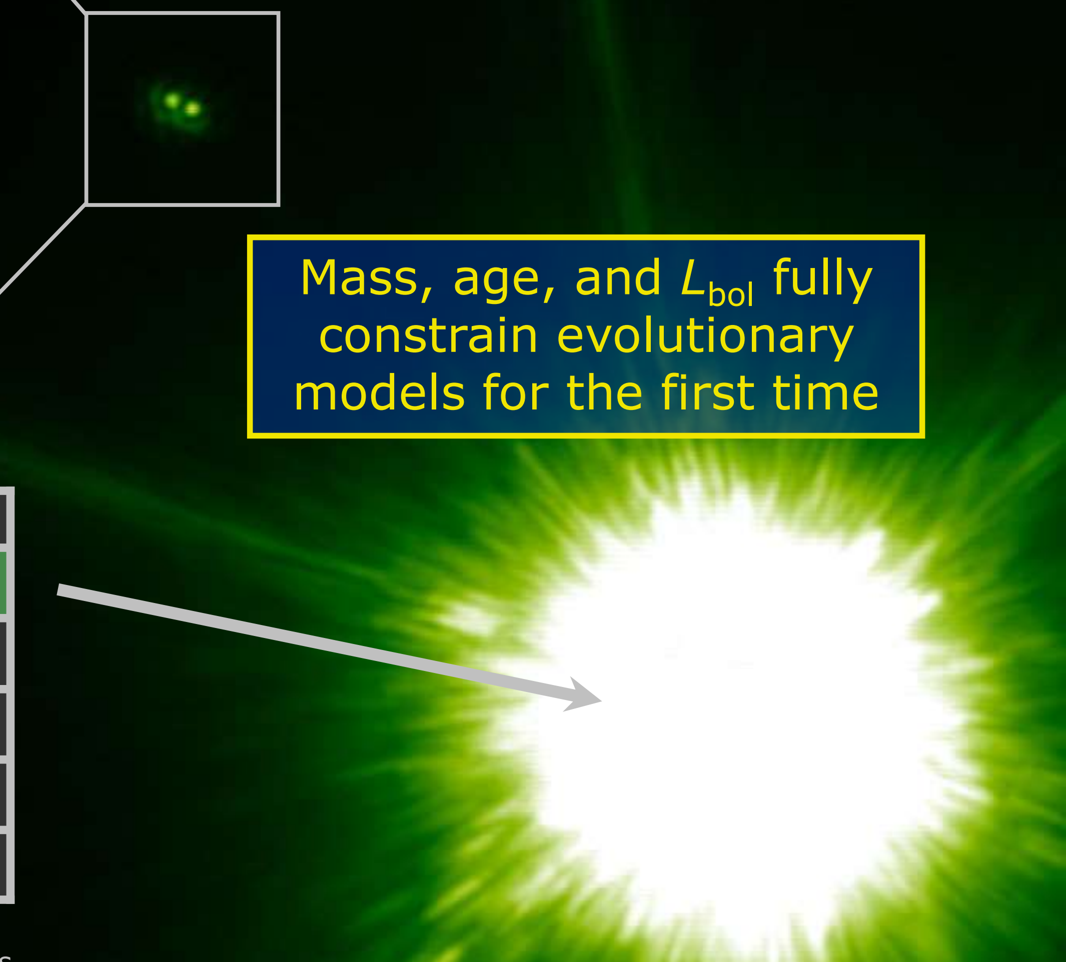
2. Do evolutionary and atmospheric models give consistent temperature estimates?

3. Do evolutionary models accurately predict near-infrared colors of ultracool dwarfs?

HD 130948BC

Dupuy et al. (2009)





Mass, age, and L_{bol} fully constrain evolutionary models for the first time

Age Indicator	Age (Gyr)	Precision
Gyrochronology	0.8±0.2	25%
Chrom. activity	0.5±0.3	60%
Isochrones	0.3–2.5	~2×
X-ray activity	~Hyades	…
Lithium	~Hyades	…

References — Mamajek & Hillenbrand (2008); Barnes (2007); Takeda et al. (2007); Stern et al. (1995); Gaidos (1998); Gaidos (2000); Hünsch et al. (1999); Stelzer & Neuhäuser (2001); Soderblom et al. (1993a,b,c)

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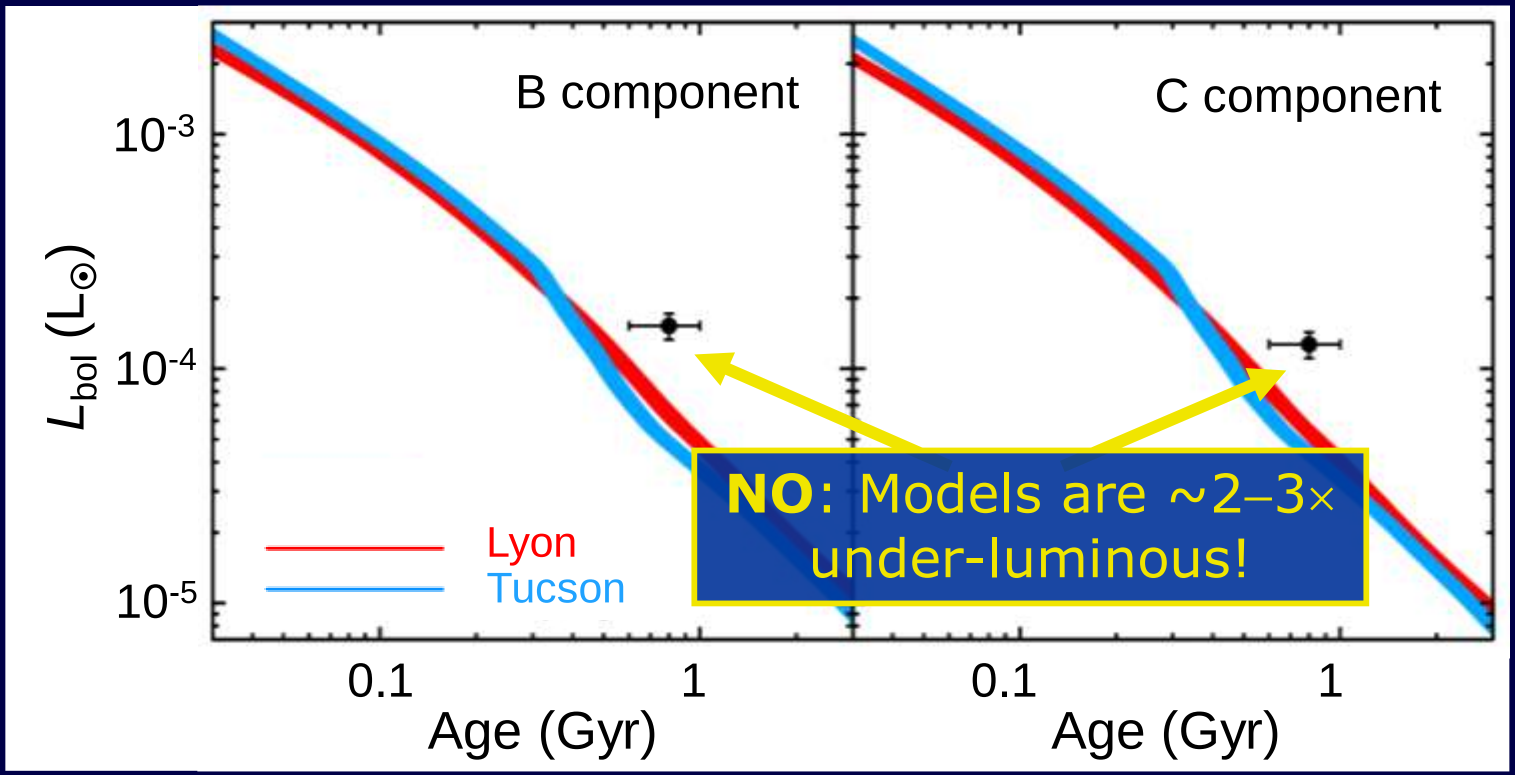
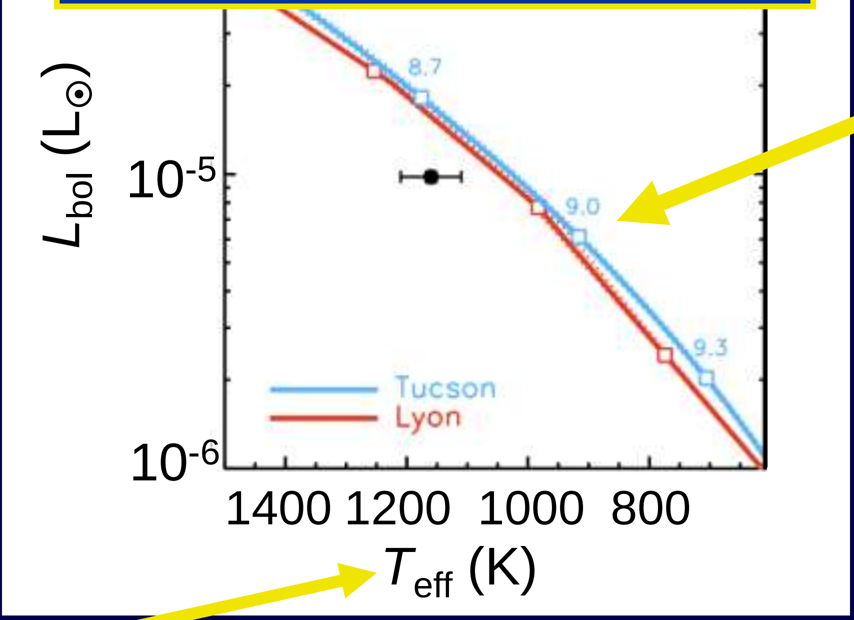


2. Do evolutionary and atmospheric models give consistent temperature estimates?

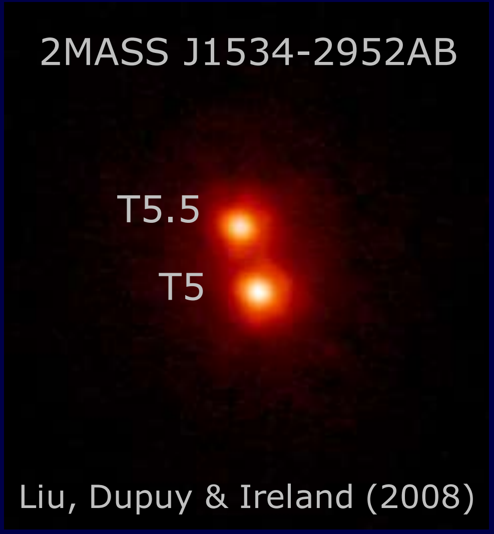
Measure L_{bol} directly

NO: atm. models ~100 K warmer than evol. models

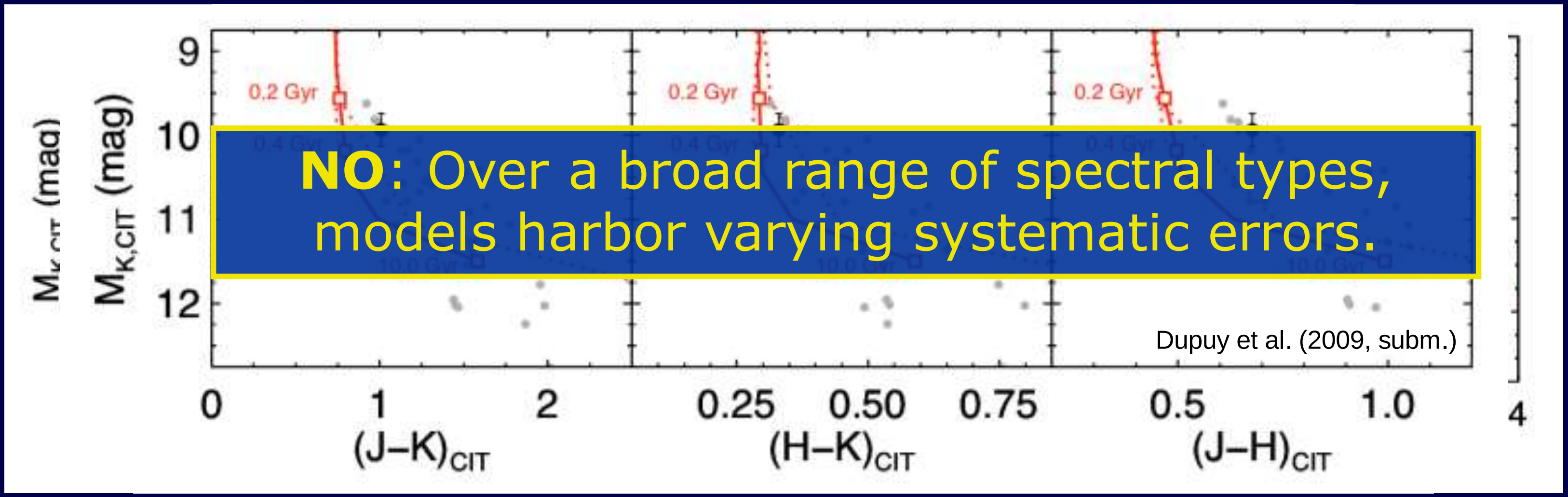
Evol. model tracks for the measured mass



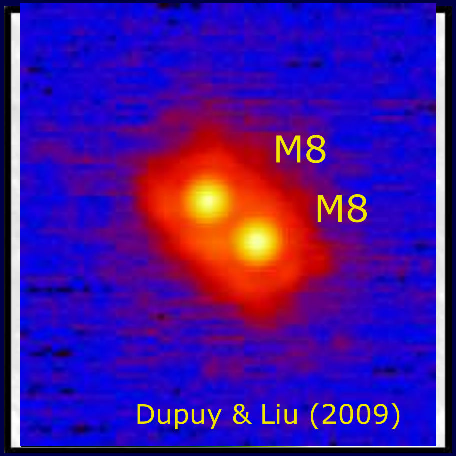
T_{eff} from fitting model atms to T dwarf SEDs



3. Do evolutionary models accurately predict near-infrared colors of ultracool dwarfs?



NO: Over a broad range of spectral types, models harbor varying systematic errors.



Substellar model tests

1. Do models predict the luminosity evolution of substellar objects accurately?
   - **No: ~2–3× *under*-luminous**
2. Do evolutionary and atmospheric models give consistent temperature estimates?
   - **No: typically off by > 100 K**
3. Do evolutionary models accurately predict near-infrared colors of ultracool dwarfs?
   - **No: for *JHK* colors at *all* spectral types**

Future model tests:

4. Do models predict the lithium depletion of substellar objects accurately?
    - young cluster ages (e.g., Pleiades)

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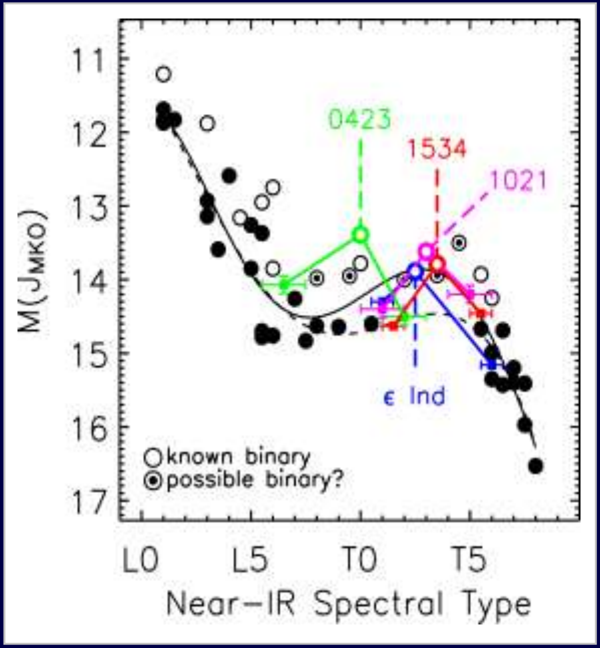
    - young cluster ages (e.g., Pleiades)
5. Does the L/T transition (dust removal) depend on surface gravity?
    - dust physics in stars/BDs/planets



Future model tests:

4. Do models predict the **lithium depletion** of substellar objects accurately?
    - young cluster ages (e.g., Pleiades)
5. Does the **L/T transition** (dust removal) depend on surface gravity?
    - dust physics in stars/BDs/planets
6. Do orbital parameters (e.g., eccentricity) match **brown dwarf formation** models?