Brown Dwarfs

Theories and observations

Nadieh Bremer

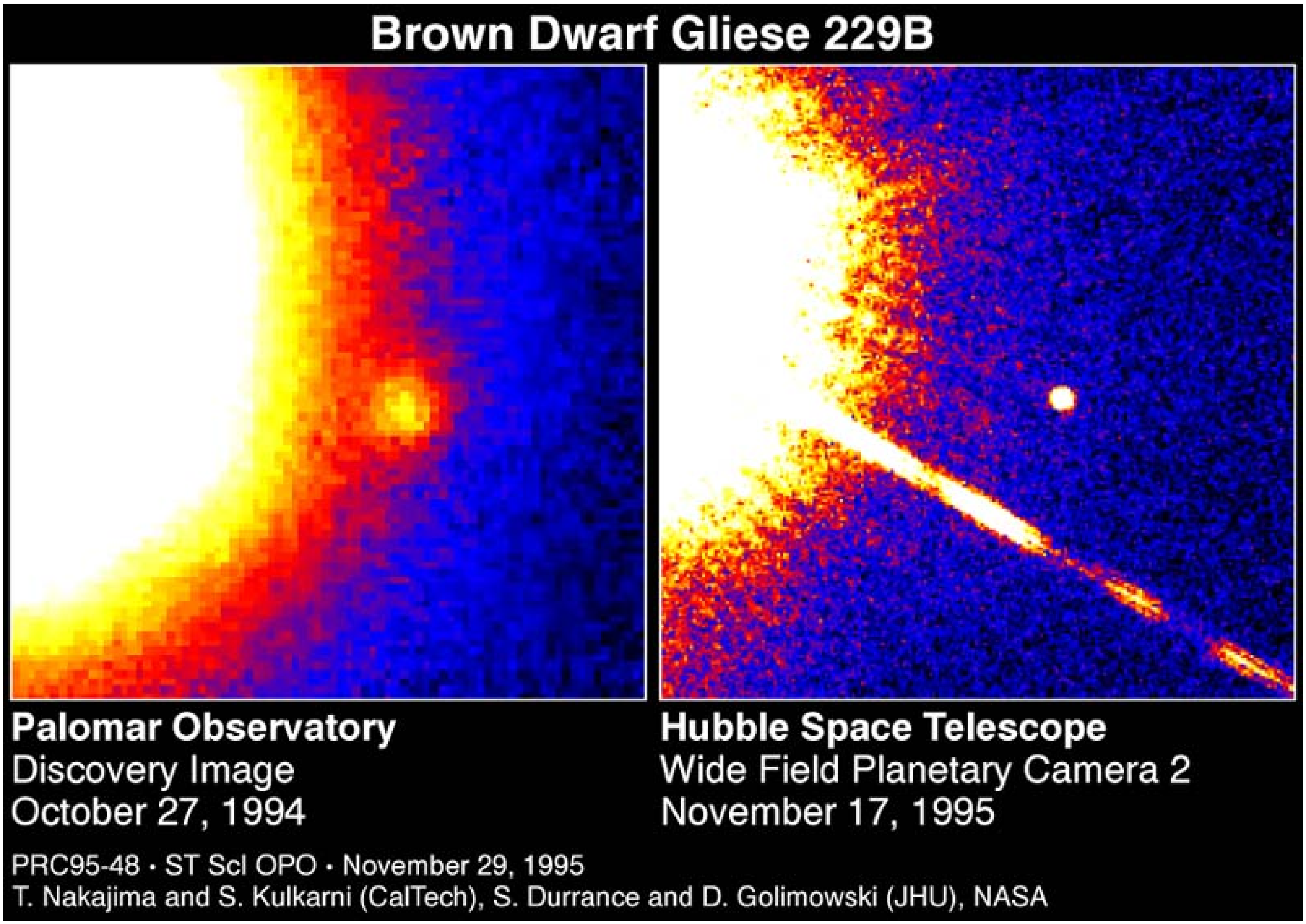
03-11-2006

Table of contents

History

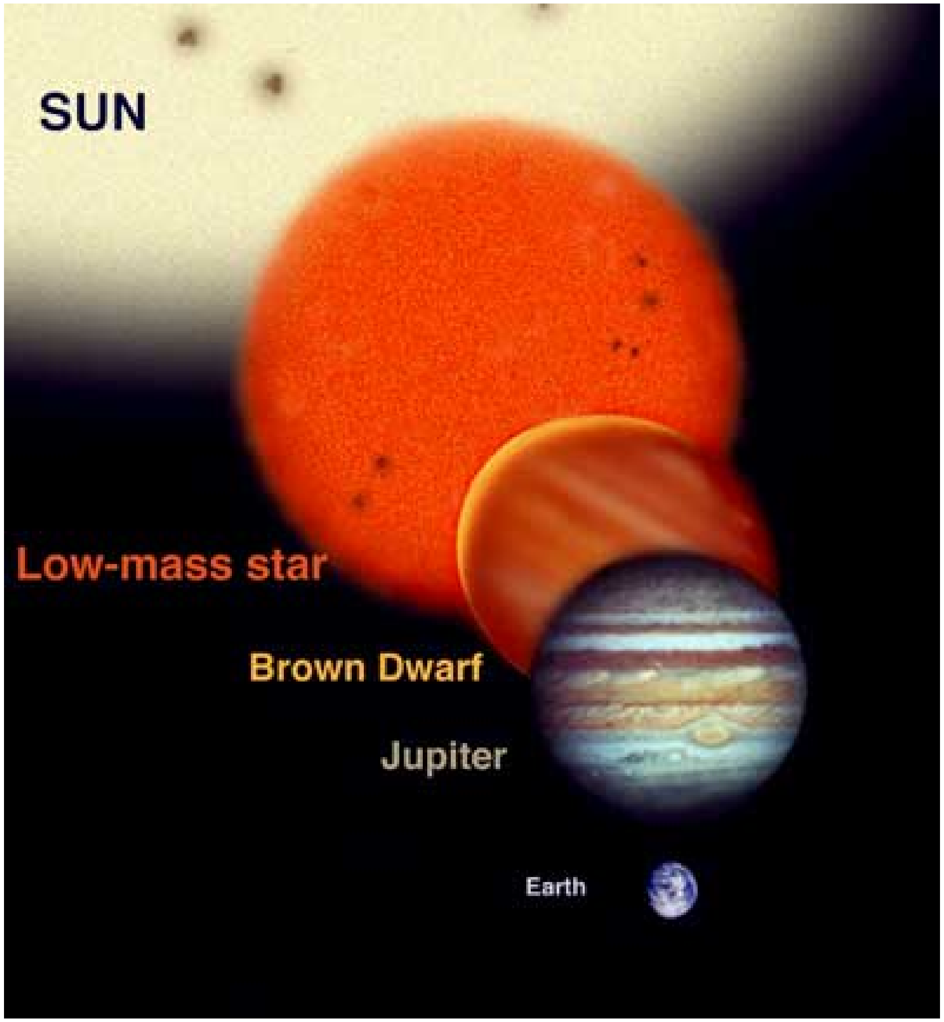
- Early 1960's; there exist gaseous objects with a mass below H-burning limit
- Mass below $\sim 0.08M_{\odot}$
- Discovering brown dwarfs was fruitless for several decades, but;
  - 1988: discovery of GD 165B
  - 1995: discovery of Gliese 229B
- Since 1995, hundreds have been identified

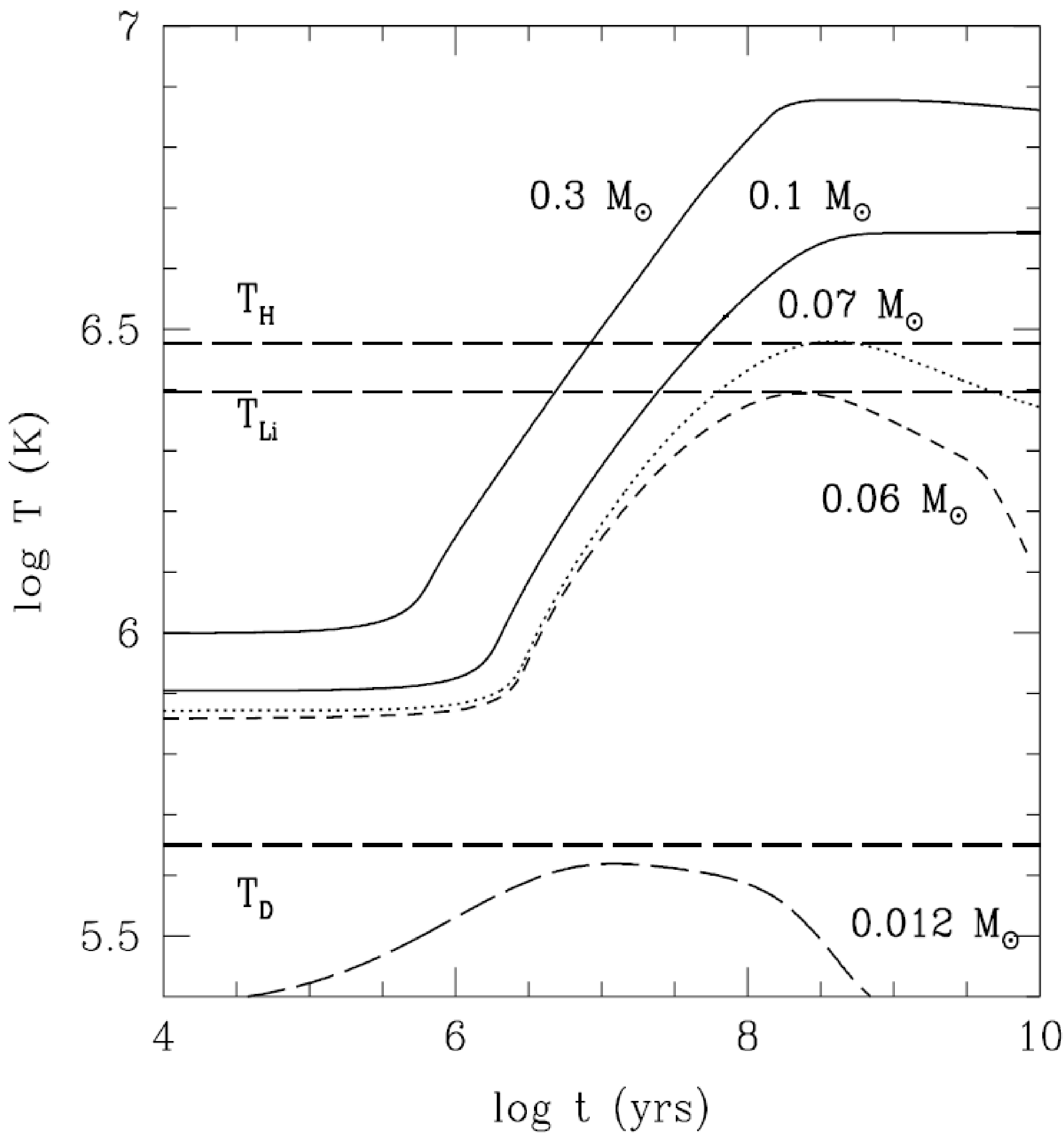
Gliese 229B


Brown Dwarf Gliese 229B
Palomar Observatory
Discovery Image
October 27, 1994
Hubble Space Telescope
Wide Field Planetary Camera 2
November 17, 1995
PRC95-48 · ST ScI OPO · November 29, 1995
T. Nakajima and S. Kulkarni (CalTech), S. Durrance and D. Golimowski (JHU), NASA

What is a brown dwarf?

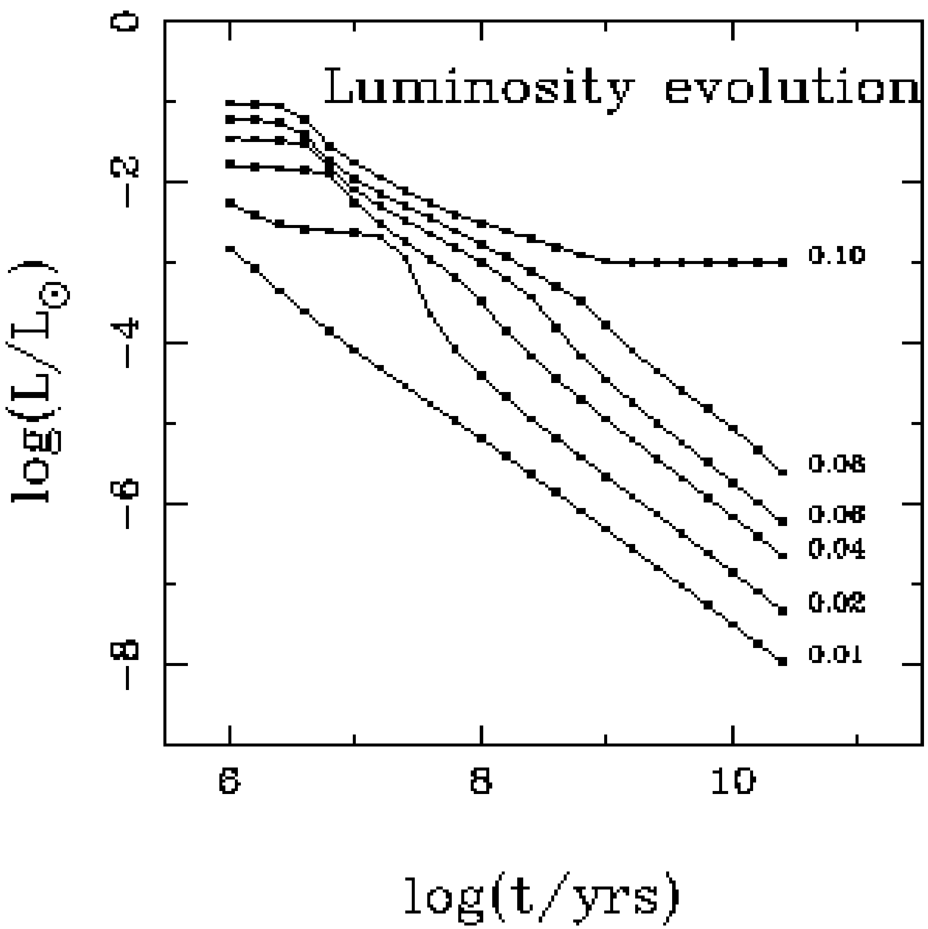
- About the size of Jupiter
- Gravitational versus degeneracy pressure
- Never hot enough for H-fusion
- Mass lower then ~ $0.08M_{\odot}$
- Surface temperature ~ 1000 K
- Mass above 13 M_J fuse ^{2}H and above 65 M_J also Li



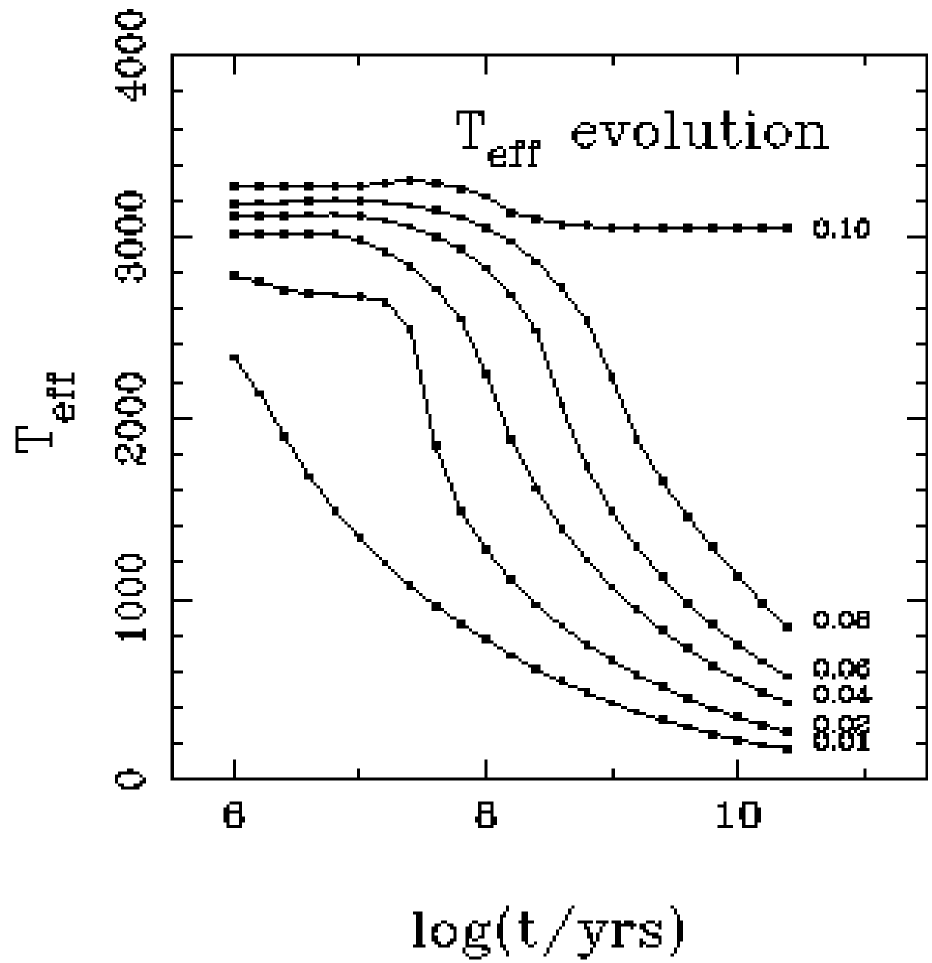


7
6.5
6
5.5
4
6
8
10
log T (K)
log t (yrs)
0.3 $M_\odot$
0.1 $M_\odot$
0.07 $M_\odot$
0.06 $M_\odot$
0.012 $M_\odot$
T_H
T_{Li}
T_D

Evolution

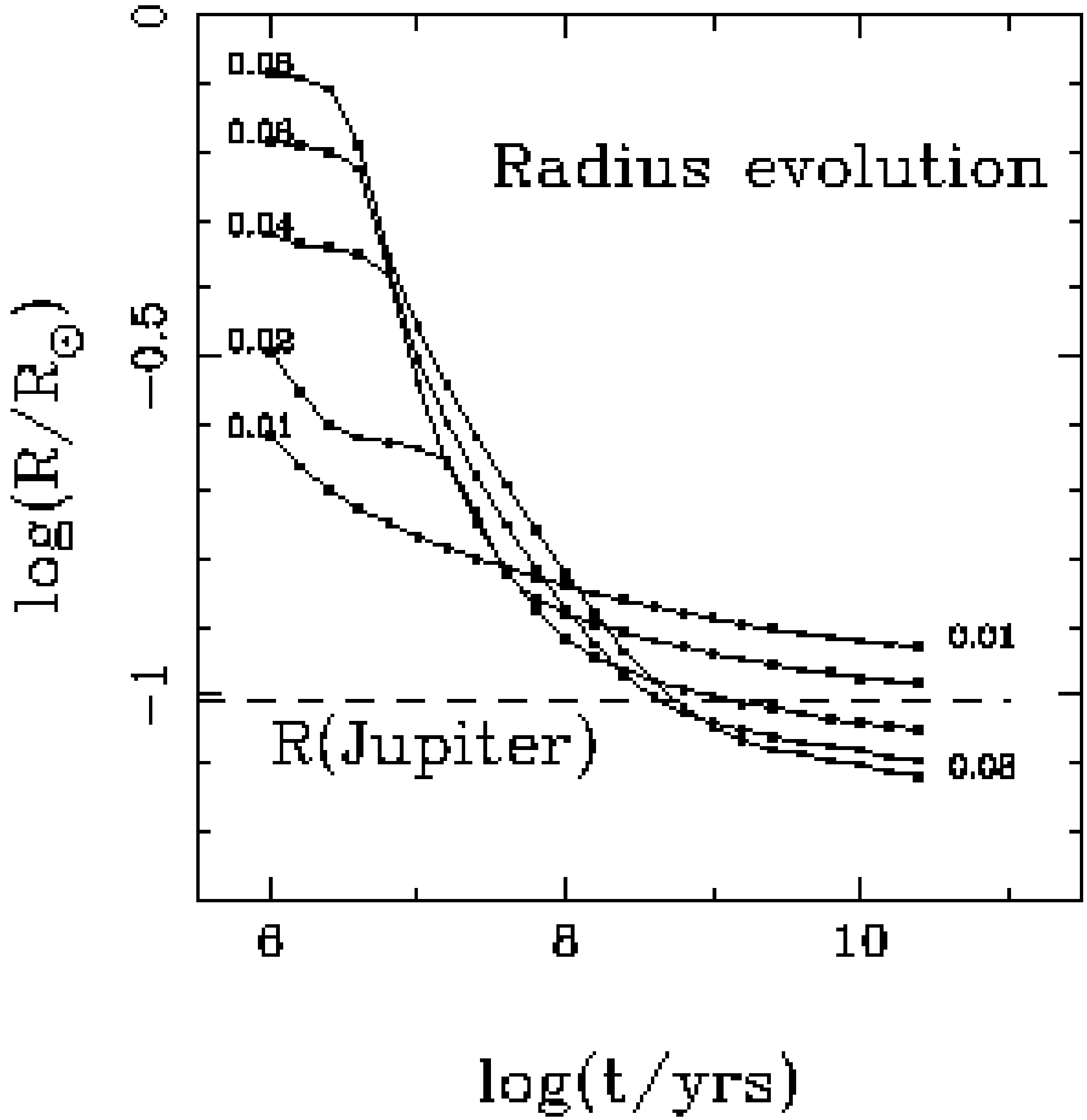


Luminosity evolution
log(L/L☉)
0
−2
−4
−6
−8
6
8
10
log(t/yrs)
0.10
0.08
0.06
0.04
0.02
0.01



T eff evolution
T eff
4000
3000
2000
1000
0
6
8
10
log(t/yrs)
0.10
0.08
0.06
0.04
0.02
0.01

Evolution



Radius evolution
R(Jupiter)
0.08
0.06
0.04
0.02
0.01
0.01
0.08
0
−0.5
−1
6
8
10
log(R/R$_\odot$)
log(t/yrs)

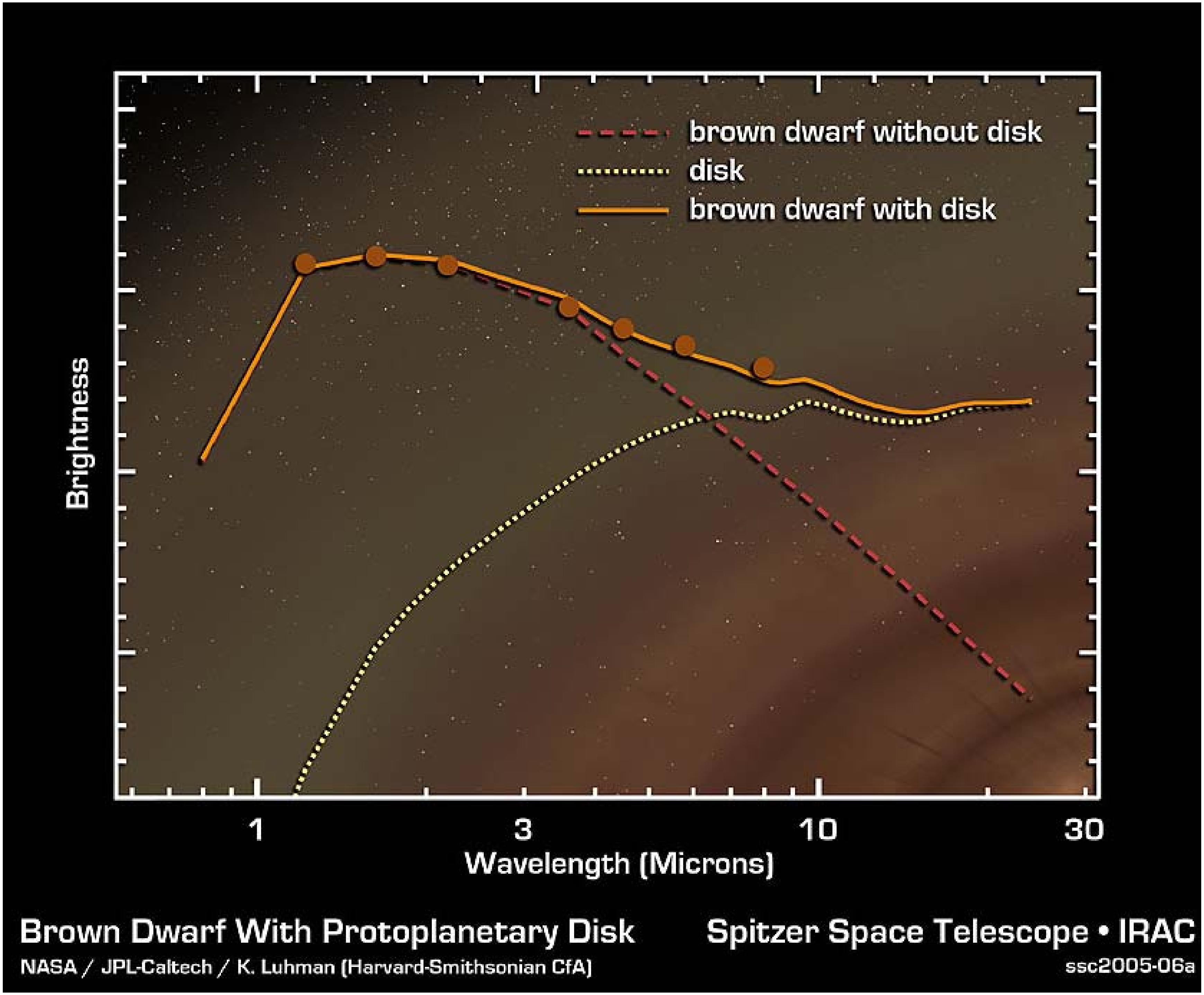
Classification

- L dwarf:
  - almost no TiO and VO bands
  - strong metal hydride bands (FeH, CrH, MgH, CaH) and alkali lines (Na I, K I, Cs I, Rb I)
- “Cooler” T dwarf:
  - also methane (CH_4) bands

What origin?

- Very low mass brown dwarfs discovered
- More like planets or like stars?
  - circumstellar disk found around low-mass brown dwarfs
  - extremely dim objects found in molecular clouds

- Conclusion: brown dwarfs most likely have a stellar origin



brown dwarf without disk
disk
brown dwarf with disk
Brightness
1
3
10
30
Wavelength (Microns)
Brown Dwarf With Protoplanetary Disk
Spitzer Space Telescope • IRAC
NASA / JPL-Caltech / K. Luhman (Harvard-Smithsonian CfA)
ssc2005-06a

How do they form?

- Small, dense molecular cloud
  - Jeans mass: $M_j = \frac{c_s^3}{G^{3/2}\rho^{1/2}}$
- Ejected from unstable multiple system
  - circumstellar disk
    - fragments due rapid accretion
    - pulled away by stellar encounter
  - molecular cloud

How do they form?

- Contradictions to ejection theory
  - difficult to keep their disks
  - existence of wide binary dwarfs
  - found in places with no dense gas

- There might be other ways to create brown dwarfs

Distinguishing heavy brown dwarfs from light stars

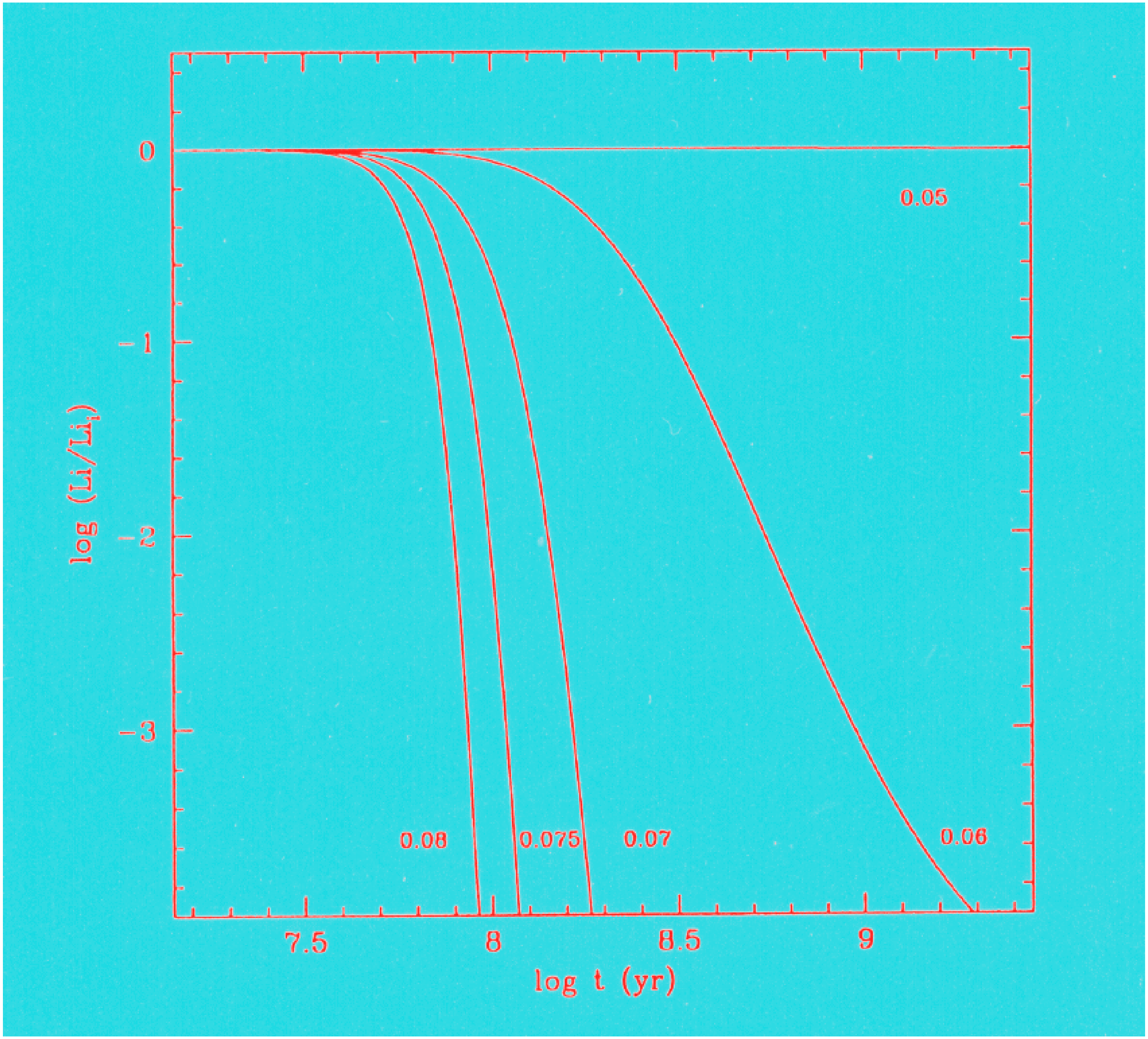
- Mass doesn’t give enough information
- Methane
  - older cooler dwarfs gather methane
  - stars get much to hot
  - Gliese 229B

Distinguishing heavy brown dwarfs from light stars

- Lithium test
  - brown dwarfs below 65 M_J do not deplete their lithium
  - low luminosity
  - low-mass stars are fully convective
  - not for young objects (open cluster)

$$^{6}Li + ^{1}H \rightarrow ^{3}He + ^{4}He$$

$$^{7}Li + ^{1}H \rightarrow 2\,^{4}He$$



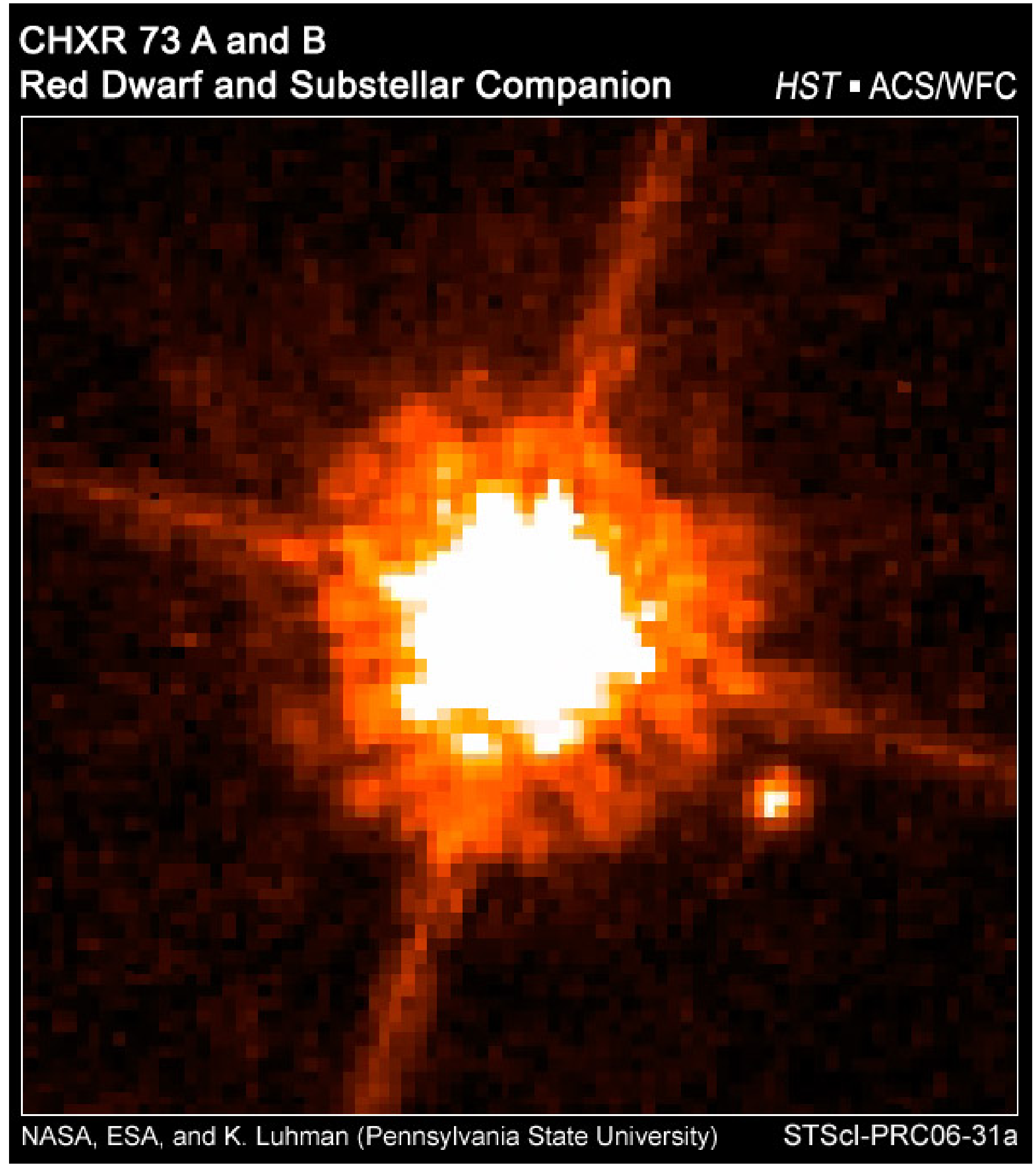
0
−1
−2
−3
log (Li/Li$_i$)
0.05
0.08
0.075
0.07
0.06
7.5
8
8.5
9
log t (yr)

Distinguishing light brown dwarfs from large planets

- All dwarfs have about the same radius
- Density
  - mass higher then 10 M_J can’t be planet
- IR spectra
  - dwarfs can “glow” in IR
  - giant planets emit more heat then they receive
- Inside
  - planets: solid metal core
  - brown dwarfs: starlike convective interior

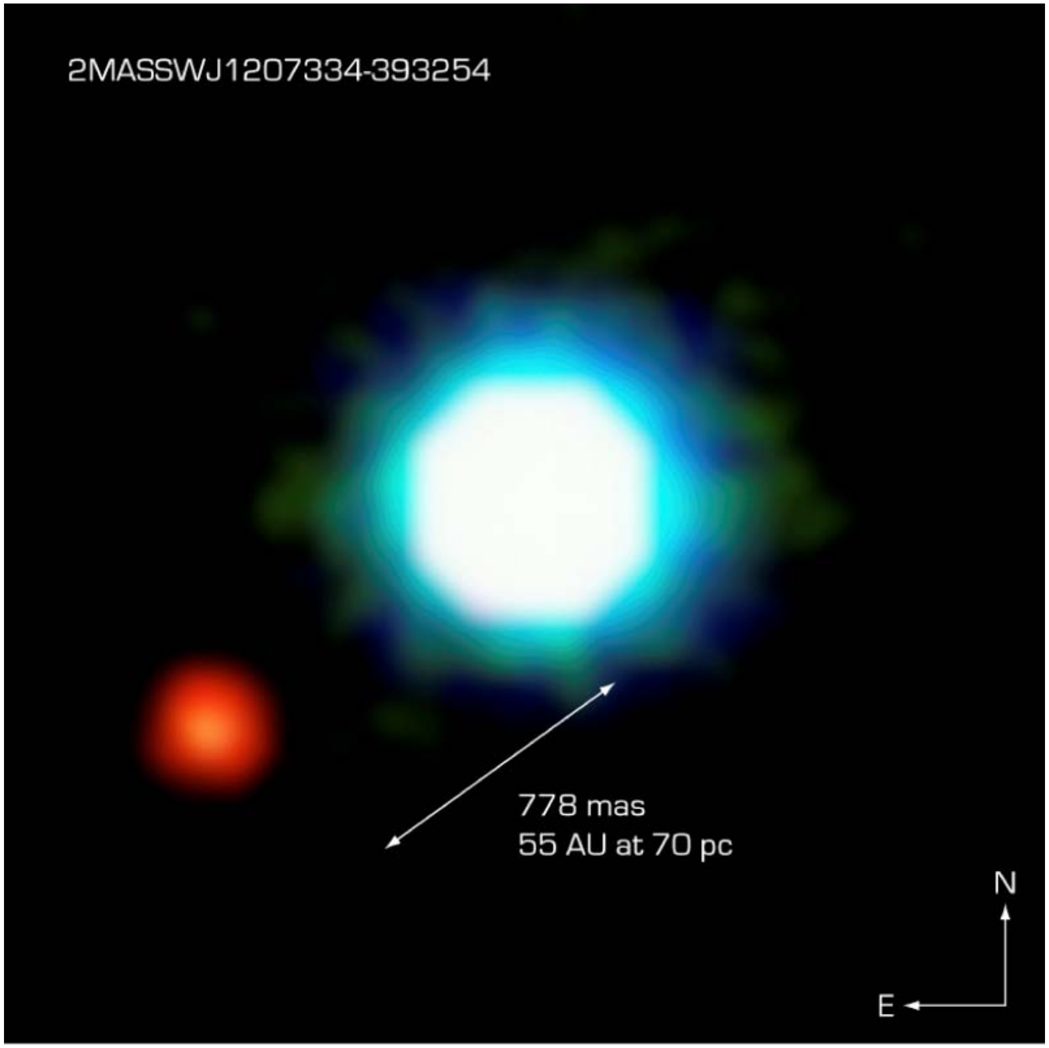
Recent observations

- CHXR 73 B
- 12 Jupiter masses
- 19.5 billion miles from its star
- 135 pc away from Earth



Recent observations

- 2M1207
- First planet directly detected (around brown dwarf) in 2004
- 21 Jupiter masses
- 53 pc from Earth

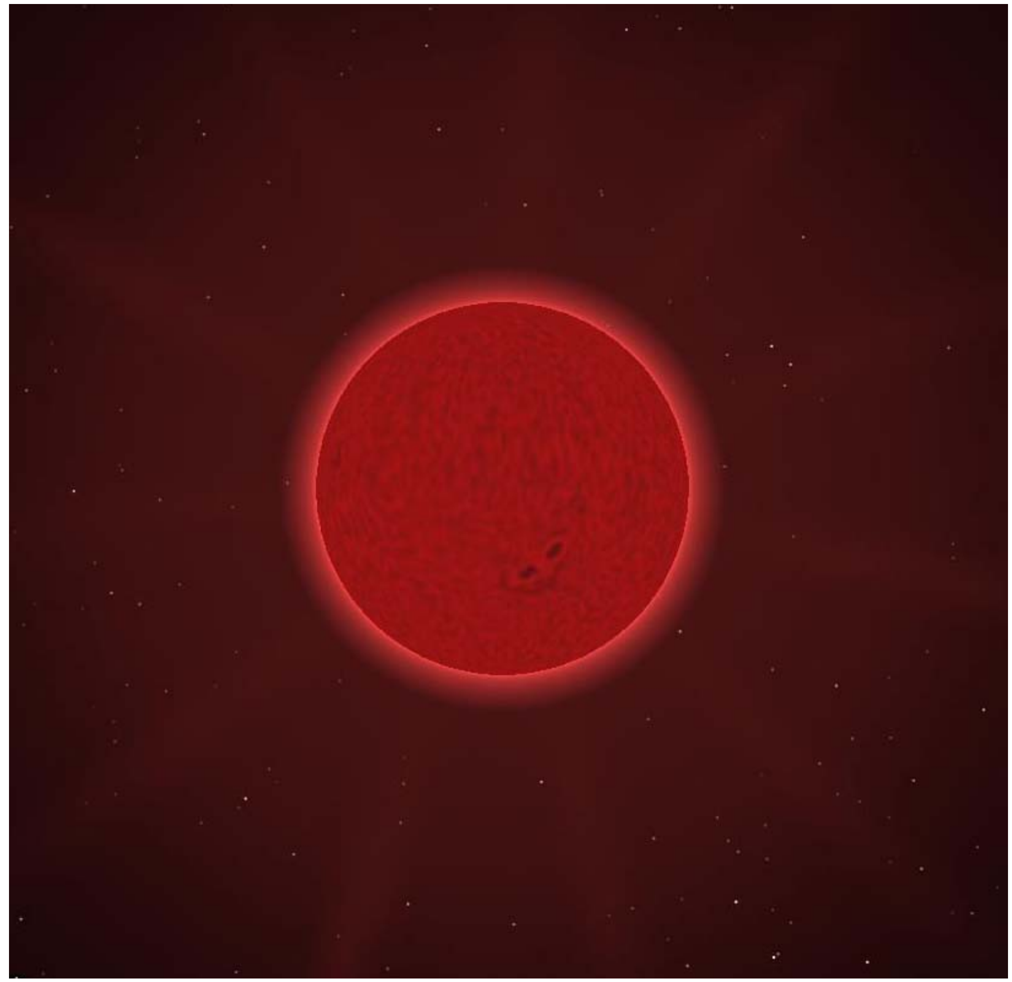


The Brown Dwarf 2M1207 and its Planetary Companion (VLT/NACO)

ESO PR Photo 14a/05 (30 April 2005)

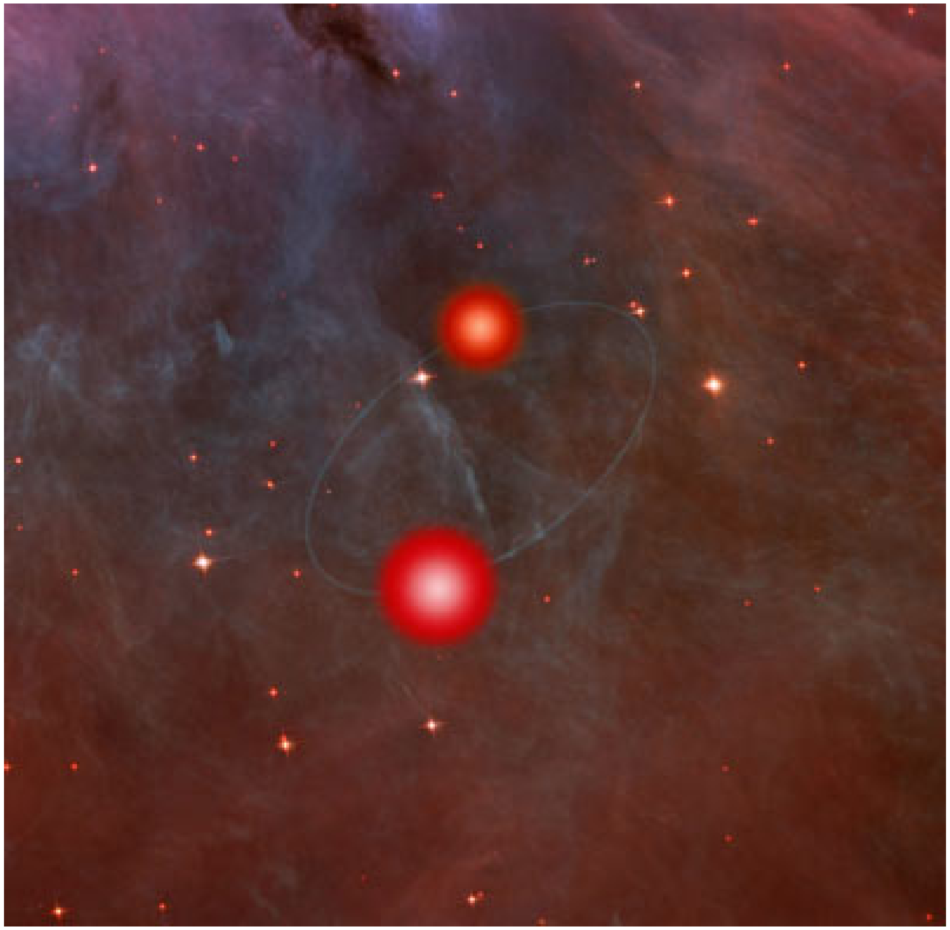
Recent observations

- DEN 0255-477
- Nearest known L dwarf
- 100 million times fainter that the sun
- 5 pc from Earth



Recent observations

- Binary brown dwarf system
- Weigh and measure brown dwarfs
- 0.055 and 0.035 $M_{\odot}$
- Smaller one is hotter



Summary

- Stellar origin
- All have about the same size
- Mass can differ greatly
- Will eventually emit no more light
- Difficult to distinguish between planet, brown dwarf and low-mass star
- Not known how they form

Any Questions?