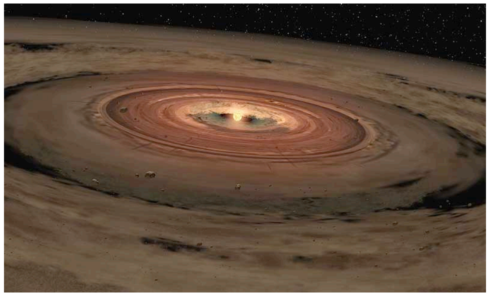
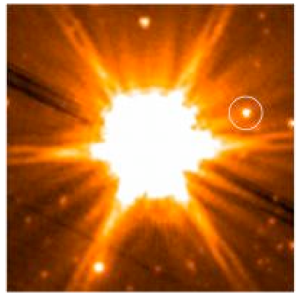
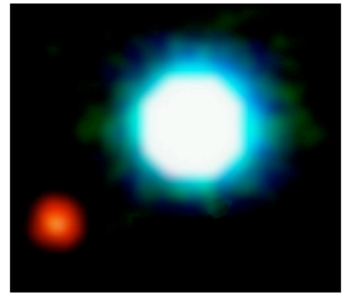
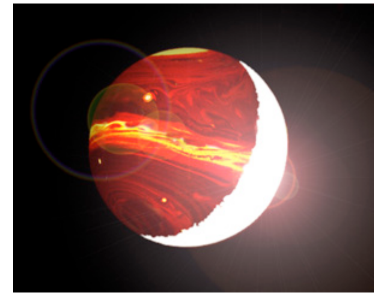
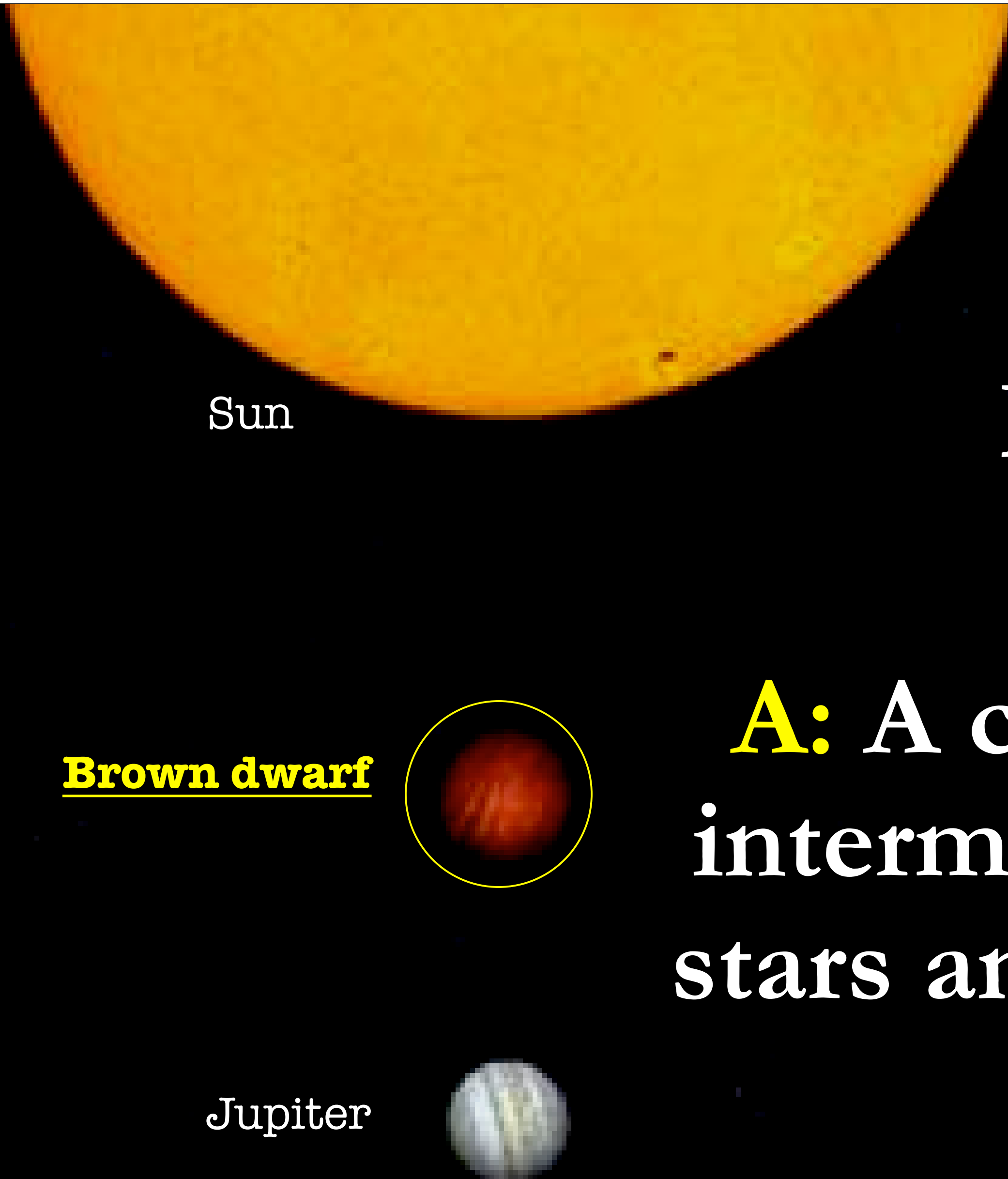
   

8.972
Exoplanets and Brown Dwarfs

Prof. Adam Burgasser

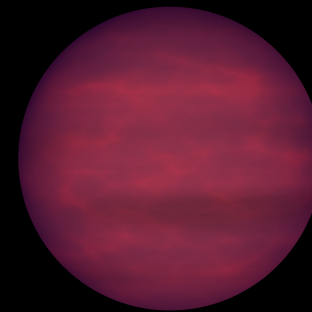
Prof. Josh Winn



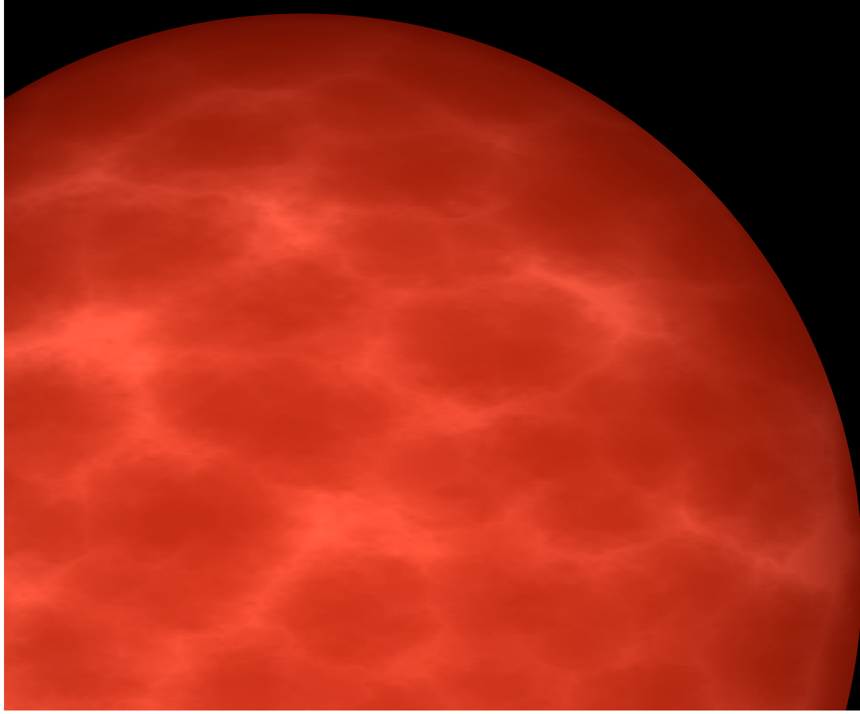
Q: **What is a Brown Dwarf?**

A: **A class of objects intermediate between stars and giant planets**

“Failed stars”

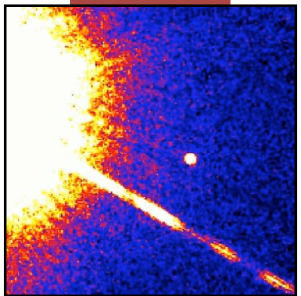


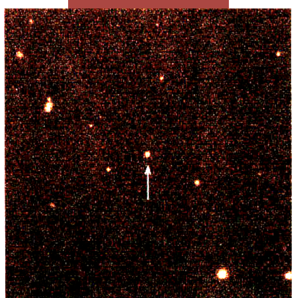
- Formed like stars but incapable of fusing Hydrogen
- Self luminous and found in isolation
- Other stellar characteristics (e.g., B fields, circumstellar disks, binary companions)

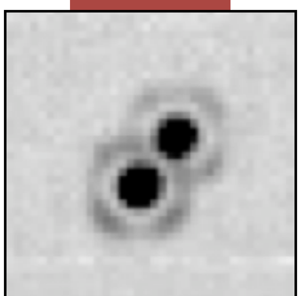


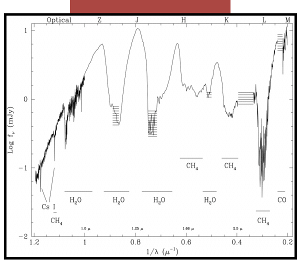
“Super Jupiters”

- Low temperature atmospheres
- Clouds and “weather”
- Planetary-like masses (~10 M_{Jup})
- Planetary sizes ($R \sim 1\ R_{Jup}$)





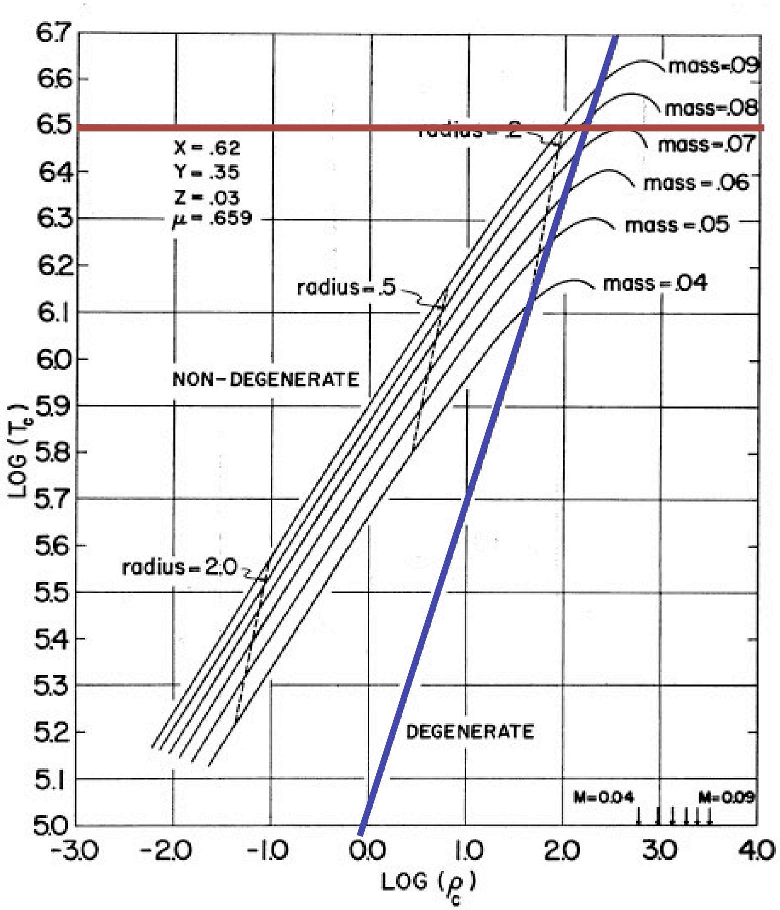




Why are Brown Dwarfs Important?

- As numerous as stars? Possibly, an important local population
- Low temperature atmospheres - chemistry, cloud formation, “extreme” climatology
- Directly detectable planetary analogues
- Unique probes of Galactic processes - star formation, metal enrichment, dynamics

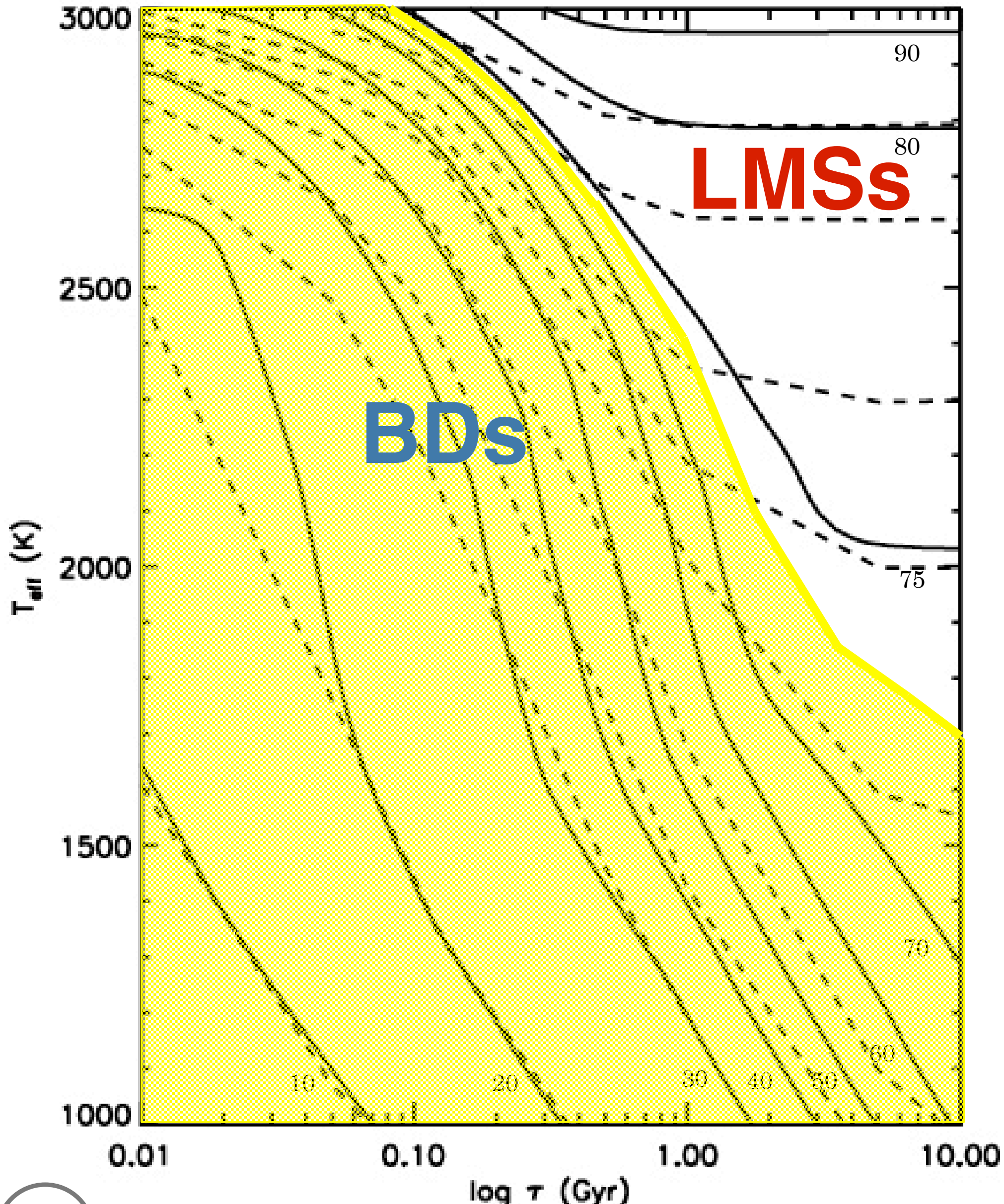
1963: A Theoretical Conjecture



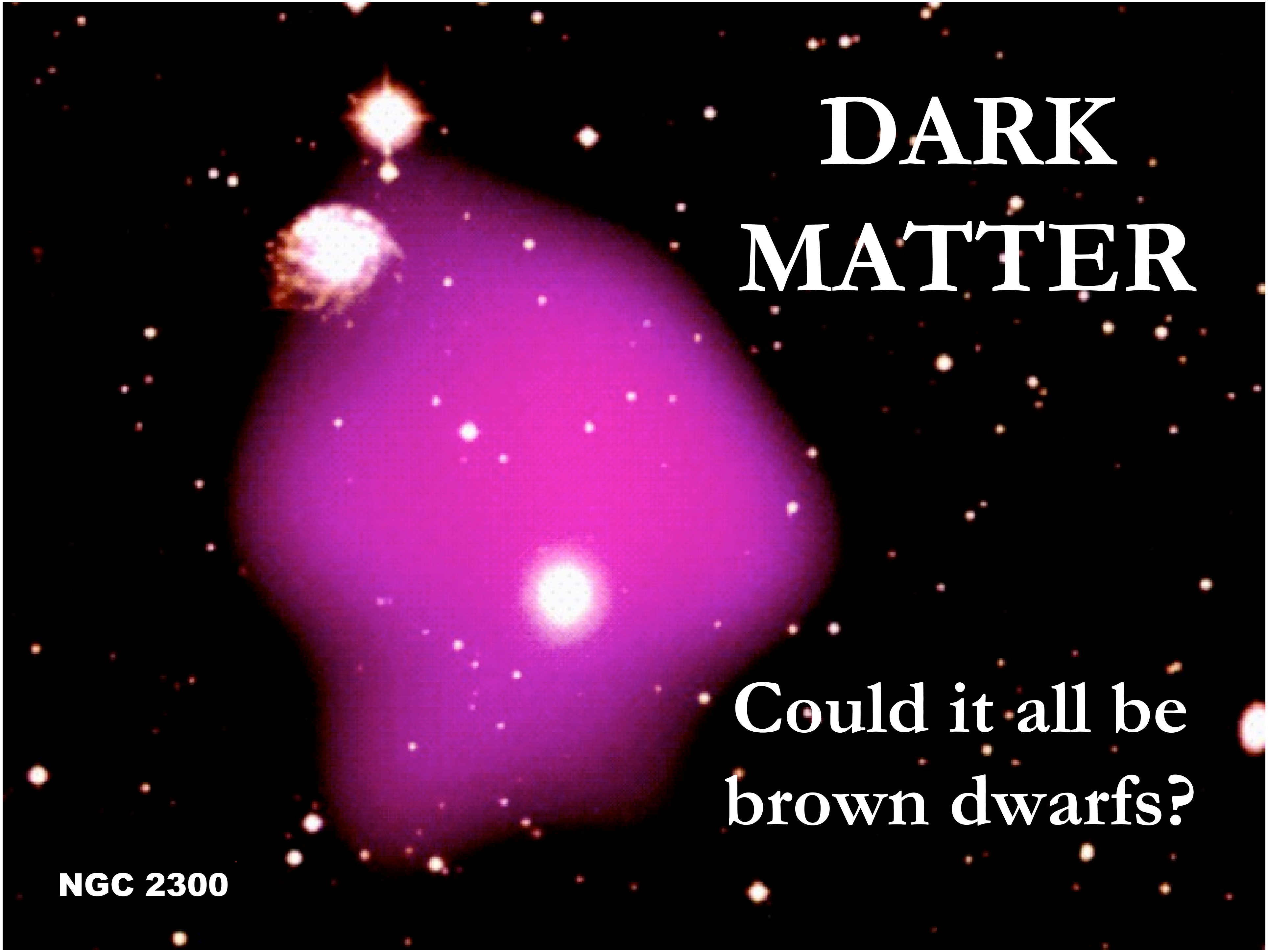
Kumar (1963)
also Hayaski & Nakano (1963)

Hydrogen fusion requires **high temperature (> 3x10^6 K) and high pressure** - possible in the cores of stars.

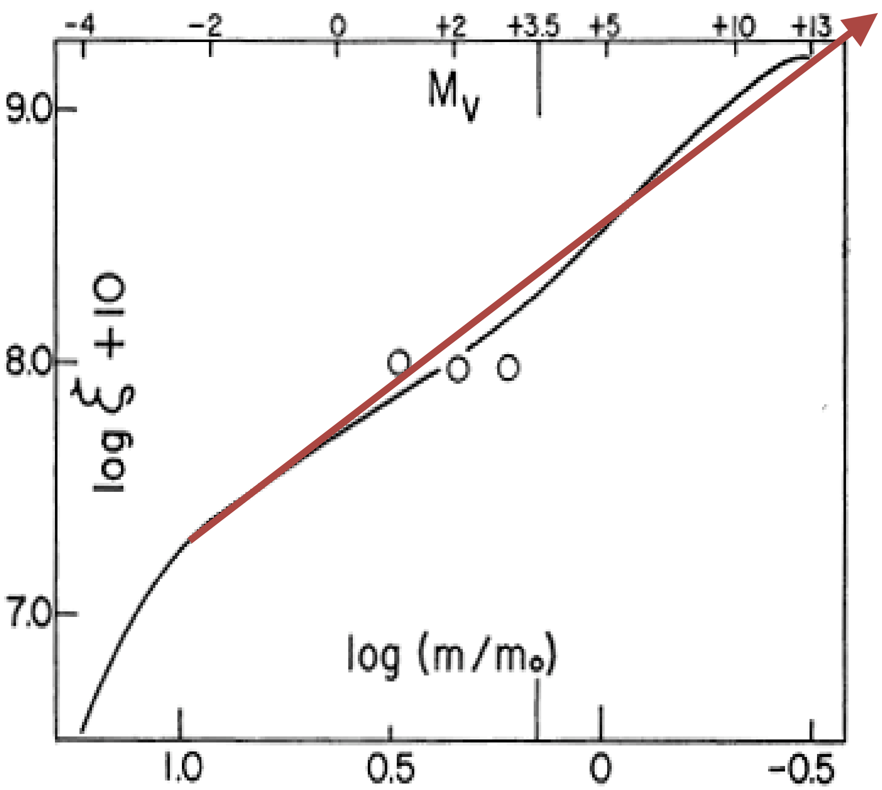
Very low mass stellar cores are supported by electron degeneracy ⇒ **brown dwarf cores are unable to initiate H fusion**



Without a fusion energy source, brown dwarfs simply get **colder and fainter** as they age.


DARK
MATTER
Could it all be
brown dwarfs?
NGC 2300

A Major Extrapolation



Salpeter (1955)

The # of solar-type stars per unit mass follows a power law: **$dN_*/dM \propto M^{-2.35}$**

Extend to $0.01 < M < 0.075$ $M_\odot$ **⇒ 8× more mass in brown dwarfs than stars!**

An early motivator for brown dwarf searches

What's in a Name…

- Black dwarfs
- Dark stars
- Failed stars
- Substars
- Infrared dwarfs
- Lilliputian dwarfs
- Planetars
- Super Jupiters

Dr. Jill Tarter

SETI Institute

"We don't know what color they are, so let's just call them BROWN DWARFS."

Three Decades of Frustration

Probst & O'Connell (1982)	NIR imaging around white dwarfs
Probst (1983ab)	NIR imaging around white dwarfs
Jameson, Sherrington, & Giles (1983)	NIR imaging around white dwarfs
McCarthy, Probst, & Low (1985)	NIR speckle interferometry around white dwarfs
Krishna & Kumar (1985,1987)	NIR imaging around nearby stars
Boeshaar, Tyson, & Seitzer (1986)	Deep CCD Survey
Shipman (1986)	IRAS search around white dwarfs
Beichman (1987)	IRAS sky survey
Becklin & Zuckerman (1988)	NIR imaging around white dwarfs
Campbell, Walker, & Yang (1988)	Radial velocity survey
Leggett & Hawkins (1988,1989)	NIR imaging of Hyades candidates
Forrest et al. (1989)	Imaging survey of Taurus
Jameson & Skillen (1989)	CCD imaging survey of Pleiades
Skrutskie, Forrest, & Shure (1989)	NIR imaging around nearby stars
Skrutskie (1990)	NIR imaging around nearby stars, Hyades, & Taurus
Henry & McCarthy (1990,1992)	NIR speckle interferometry around M dwarfs
Rieke & Rieke (1990)	NIR imaging of ρ Oph
Bryja et al. (1992,1994)	Proper motion survey of Hyades
Simons & Becklin (1992)	I,K survey of Pleiades
Hambly, Hawkins, & Jameson (1993)	Proper motion survey of Pleiades
Leinert et al. (1994)	NIR speckle interferometry around M dwarfs
Stauffer, Hamilton, & Probst (1994)	CCD survey of Pleiades

1985: VB 8B

INFRARED DETECTION OF A CLOSE COOL COMPANION TO VAN BIESBROECK 8

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Received 1984 October 23; accepted 1984 November 29

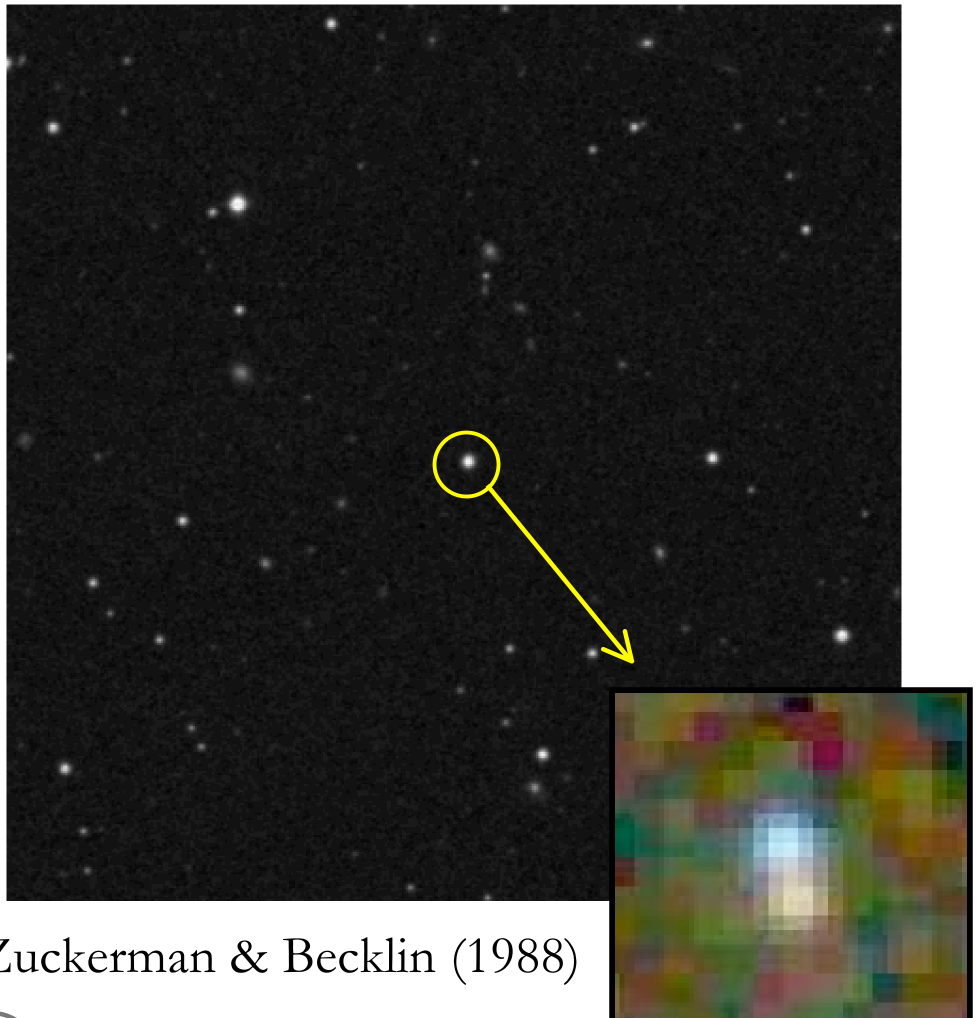
ABSTRACT

We have detected, via infrared speckle interferometry, a cool object 1″ from the very low-luminosity star VB 8, 3 mag fainter than VB 8 at 2.2 μm. Measurements at 1.6 and 2.2 μm give $T_e = 1360$ K and (assuming a physical association) $R = 0.09\ R_\odot$, $L = 3 \times 10^{-5}\ L_\odot$, consistent with a substellar brown dwarf. These observations may constitute the first direct detection of an extrasolar planet.

Subject headings: infrared: sources — planets: general — stars: late-type

"Companion" detected through speckle interferometry - but never confirmed!

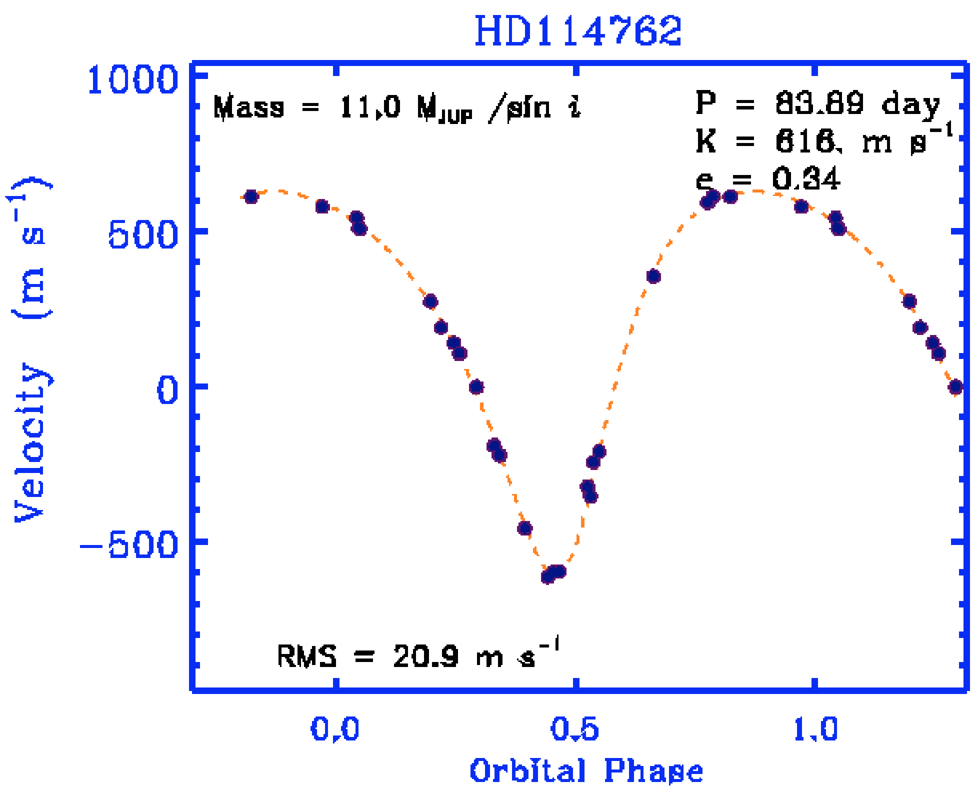
1988: GD 165B



Zuckerman & Becklin (1988)

A faint, cool companion to a white dwarf with a bizarre spectrum - brown dwarf or polluted star?

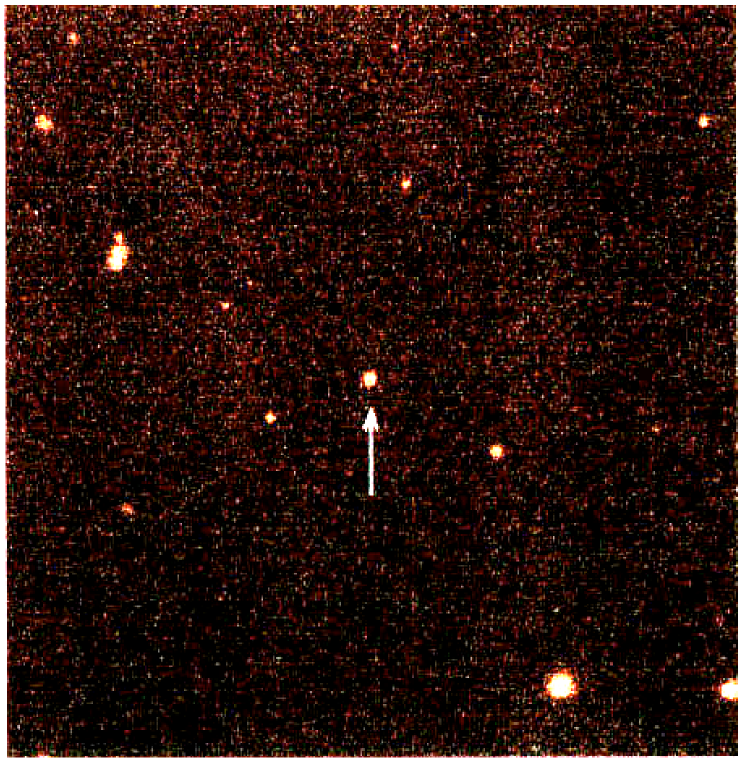
1989: HD114762



Latham et al. (1989)

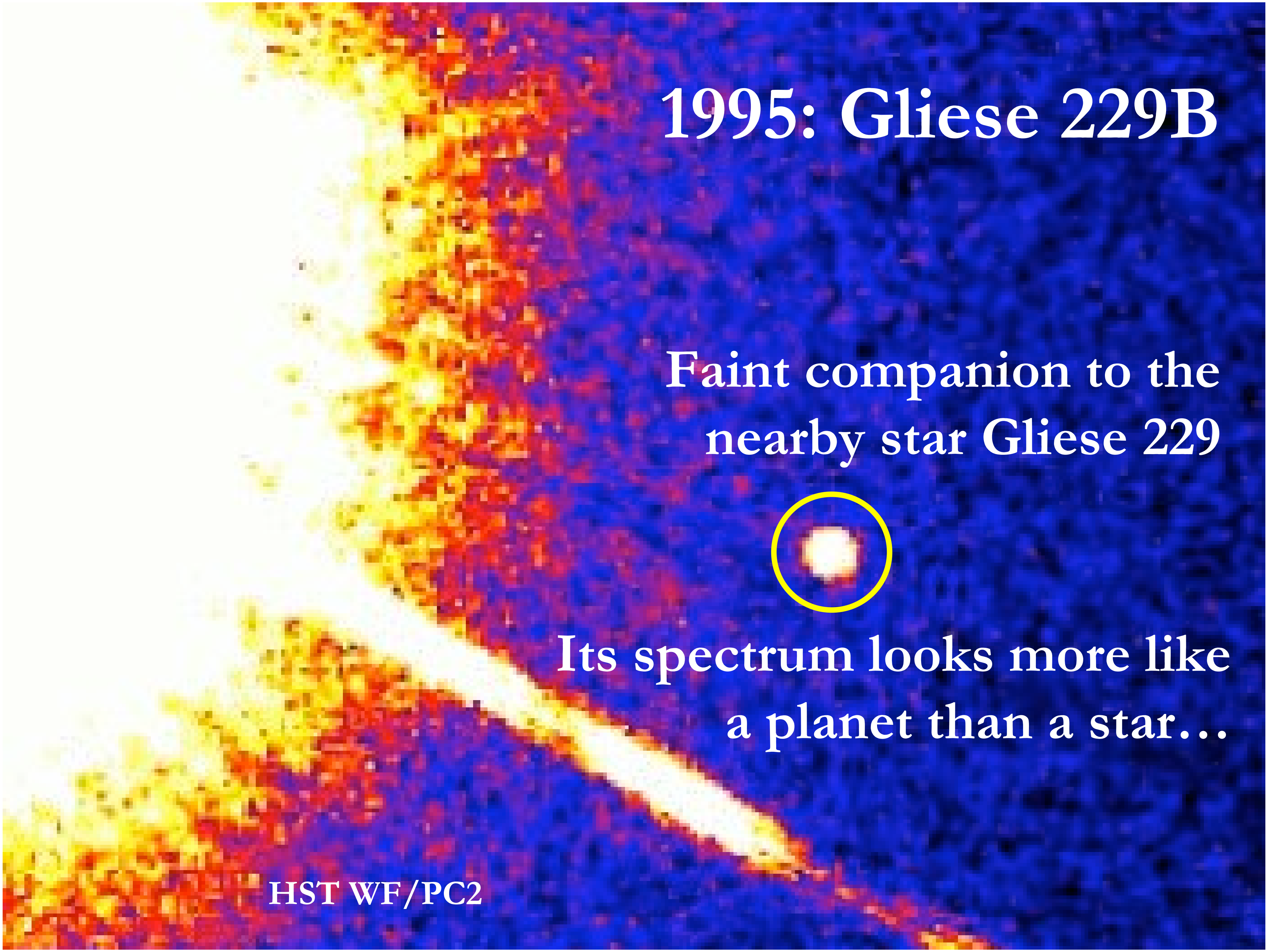
A companion to a nearby star with a minimum mass of **11 $M_{Jupiter}$,** found by radial velocity variations - planet, brown dwarf or star?

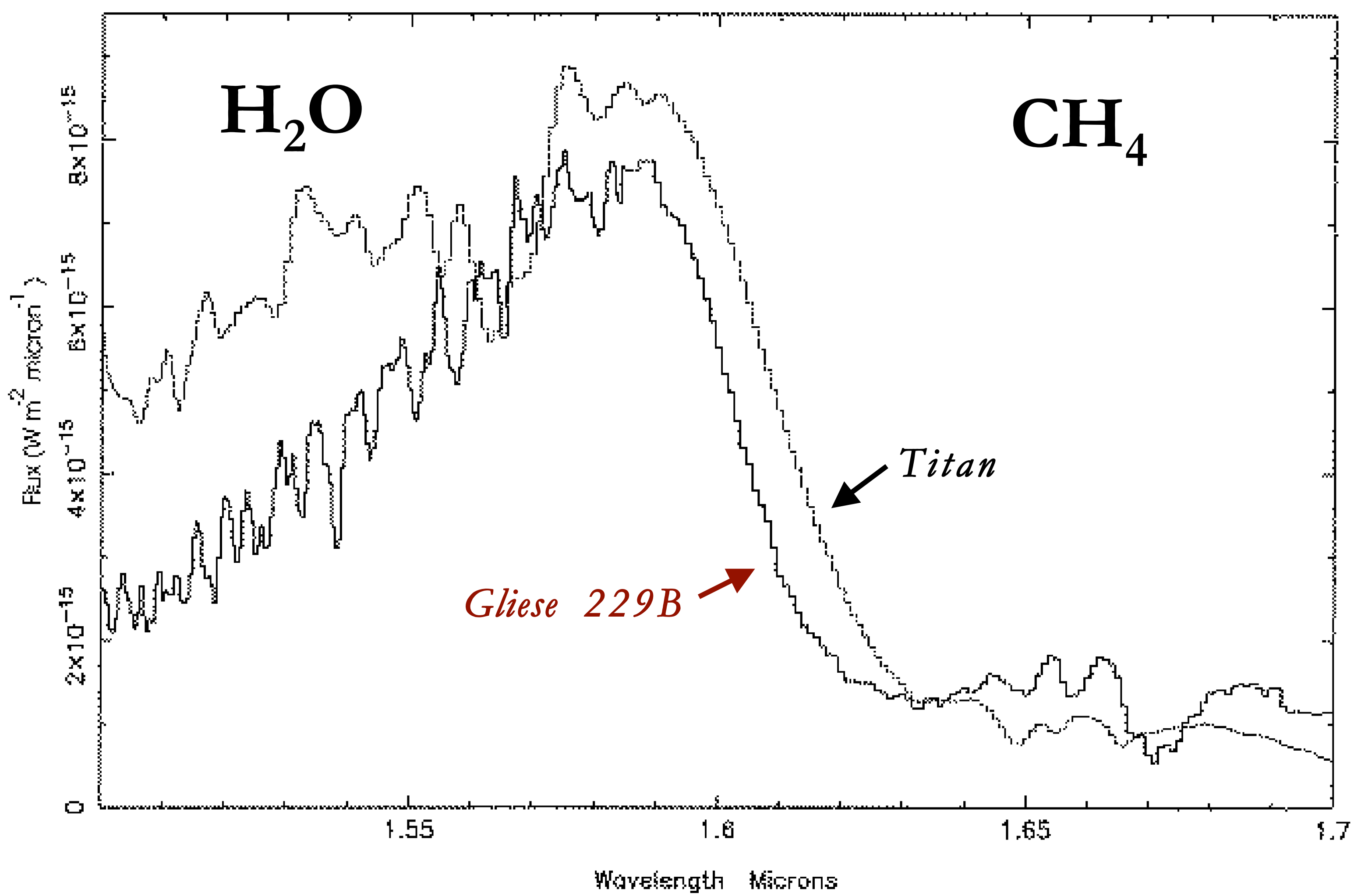
1995: Teide 1



Teide 1 (Rebolo et al. 1995)

A young, warm brown dwarf which exhibits Li I absorption - but several astronomers were skeptical about their age.


1995: Gliese 229B
Faint companion to the nearby star Gliese 229
Its spectrum looks more like a planet than a star…
HST WF/PC2



Geballe et al. (1996)

Brown Dwarf Astrophysics Begins!

Wide field near-infrared surveys uncover 100s of brown dwarfs - discoveries continue to this day.

By the Numbers

< 0.07	Mass of a brown dwarf in Solar masses
< 75	Mass of a brown dwarf in Jupiter masses
0.1	Radius of an evolved brown dwarf in Solar radii
1	Radius of an evolved brown dwarf in Jupiter radii
10^{-6}	Lowest measured brown dwarf luminosity (solar units)
700	Lowest surface temperature of a brown dwarf in ºK
10^{11}	Pressure at the center of a brown dwarf in bar
3	Number of "spectral classes" of brown dwarfs
≈ 500	Number of brown dwarfs known today
1:1	Ratio of brown dwarfs to stars in the Galaxy (est)
< 2	Percentage of Dark Matter

Brown Dwarfs

:o: Overview & History :o: