Table of contents

- Introduction; History
- Origin
  - what is a brown dwarf?
  - classification
  - how do they form?
- Observations
  - distinguishing heavy brown dwarfs from light stars
  - distinguishing light brown dwarfs from large planets
  - recent observations
History

- Early 1960’s; there exist gaseous objects with a mass below H-burning limit
- Mass below $\sim 0.08 M_\odot$
- 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 $\sim 0.08M_\odot$
- Surface temperature $\sim 1000$ K
- Mass above $13M_J$ fuse $^2$H and above $65M_J$ also Li
Evolution

Luminosity evolution

$log(L/L)_0$ vs $log(t/\text{yrs})$

$T_{\text{eff}}$ evolution

$T_{\text{eff}}$ vs $log(t/\text{yrs})$
Evolution
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 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 too 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)

\[ ^6\text{Li} + ^1\text{H} \rightarrow ^3\text{He} + ^4\text{He} \]
\[ ^7\text{Li} + ^1\text{H} \rightarrow 2^4\text{He} \]
Distinguishing light brown dwarfs from large planets

- All dwarfs have about the same radius
- Density
  - mass higher than 10 M\(_J\) can’t be planet
- IR spectra
  - dwarfs can “glow” in IR
  - giant planets emit more heat than 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
Recent observations

- DEN 0255-477
- Nearest known L dwarf
- 100 million times fainter than 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?