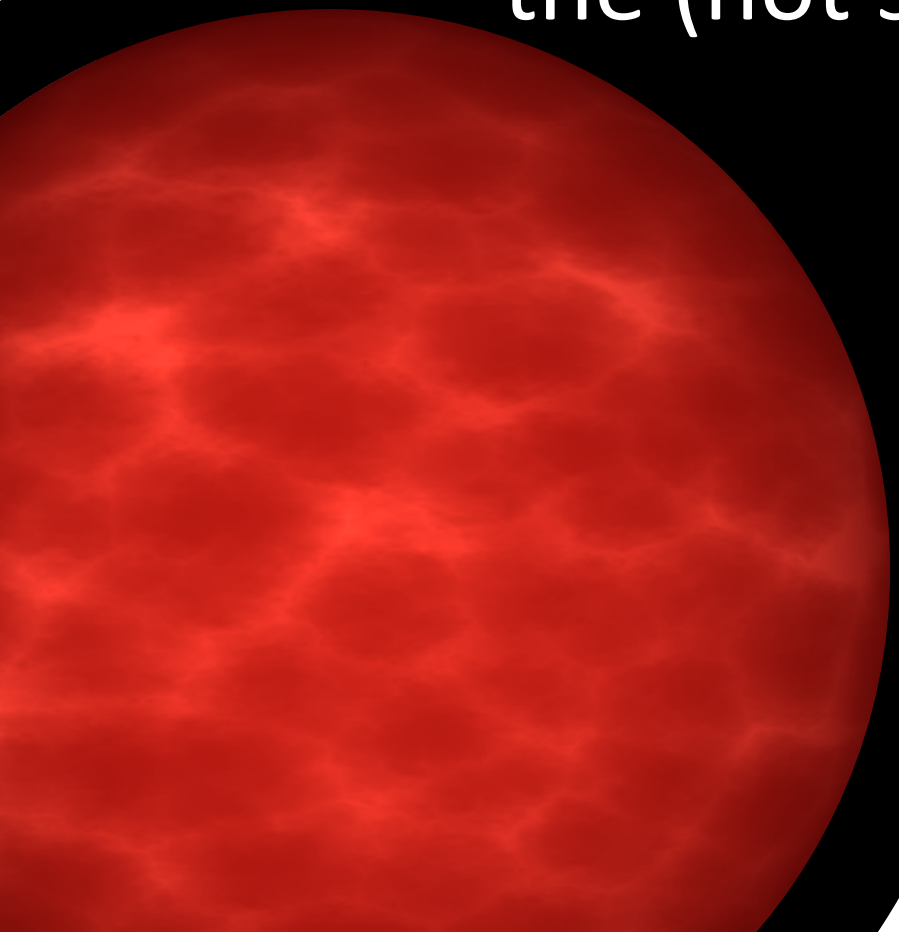
Brown Dwarfs

the (not so) dark realm between stars and planets



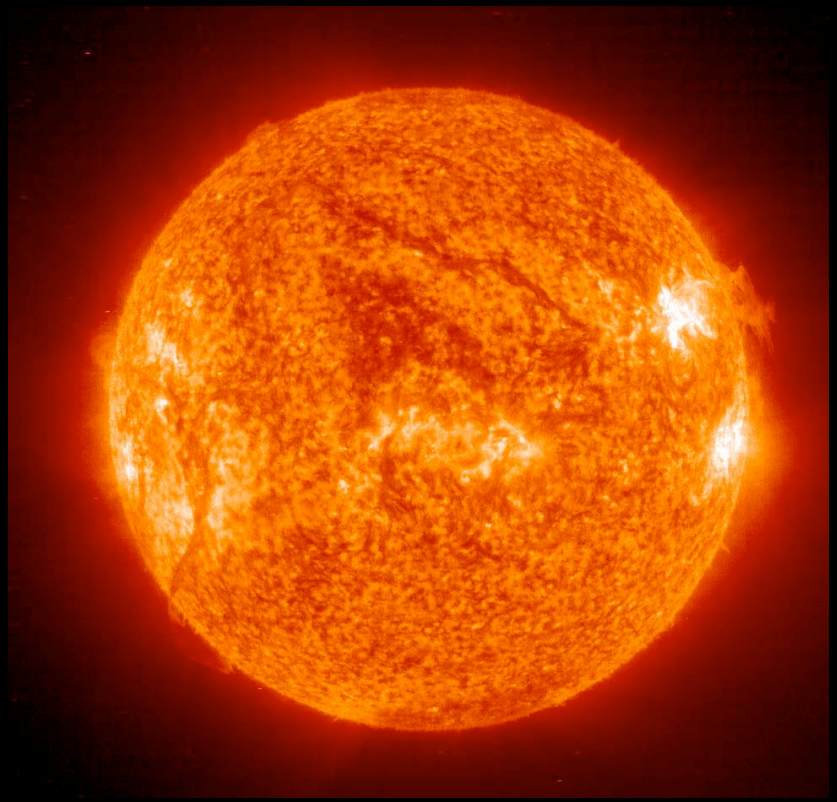
Prof. Adam Burgasser

UC San Diego

There are cultural distinctions between stars and planets

from Sacred Geometry
Robert Lawlor, 1982

There are physical distinctions between stars and planets

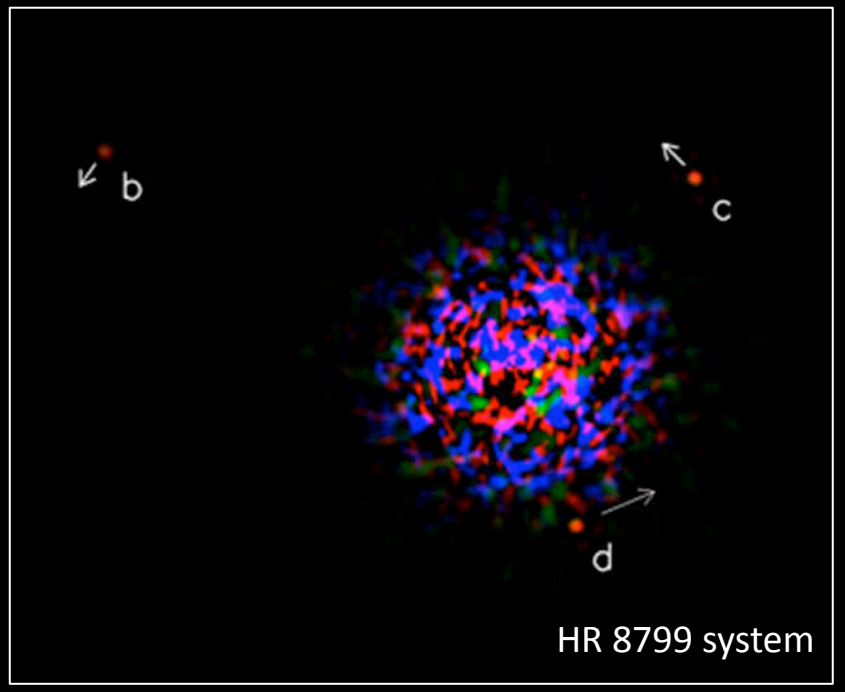


Sun emits light across whole surface

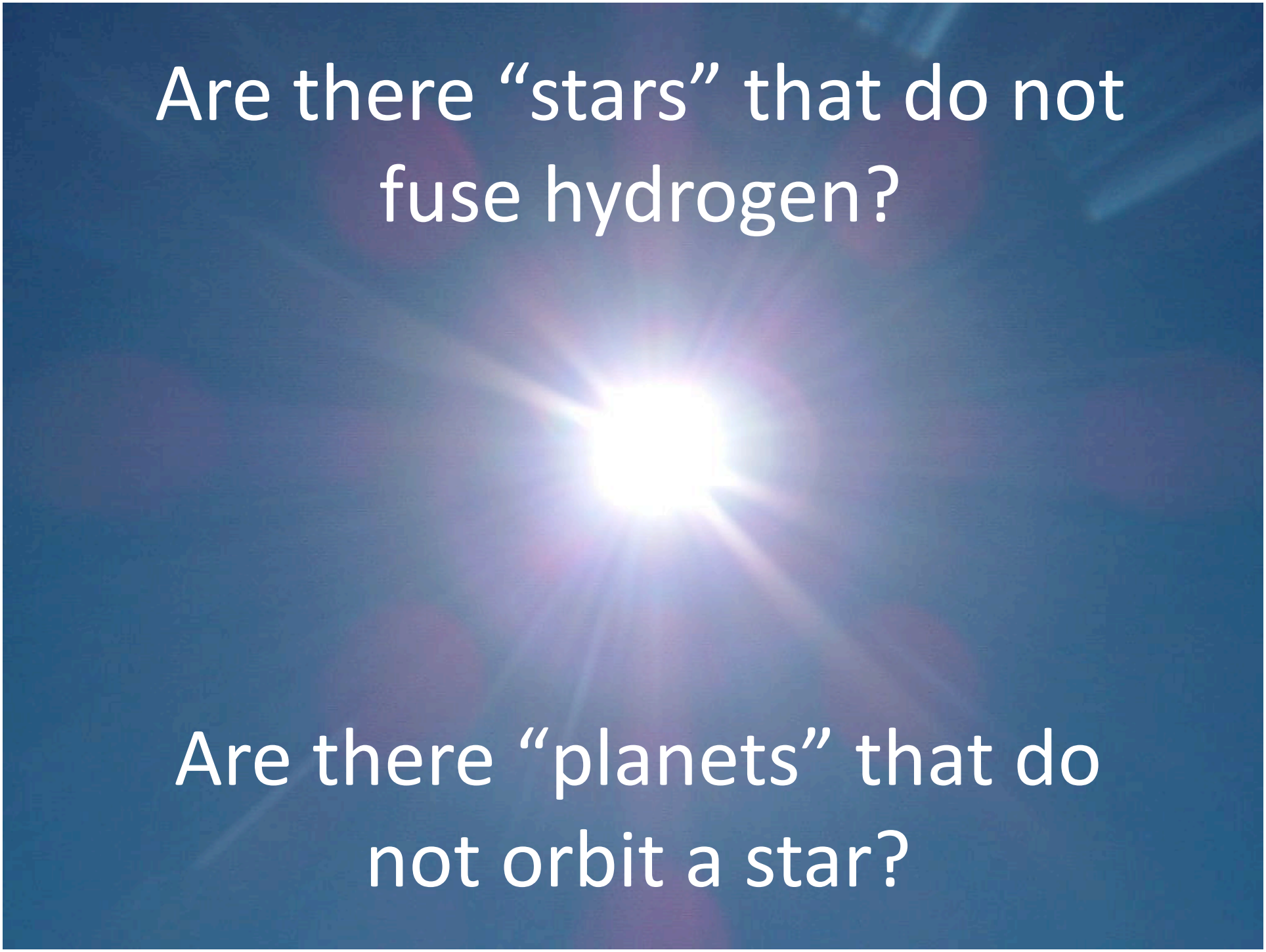
Jupiter reflects light from surface facing Sun

There are physical distinctions between stars and planets

Stars are found as isolated sources



Planets seem to be always in orbit around stars

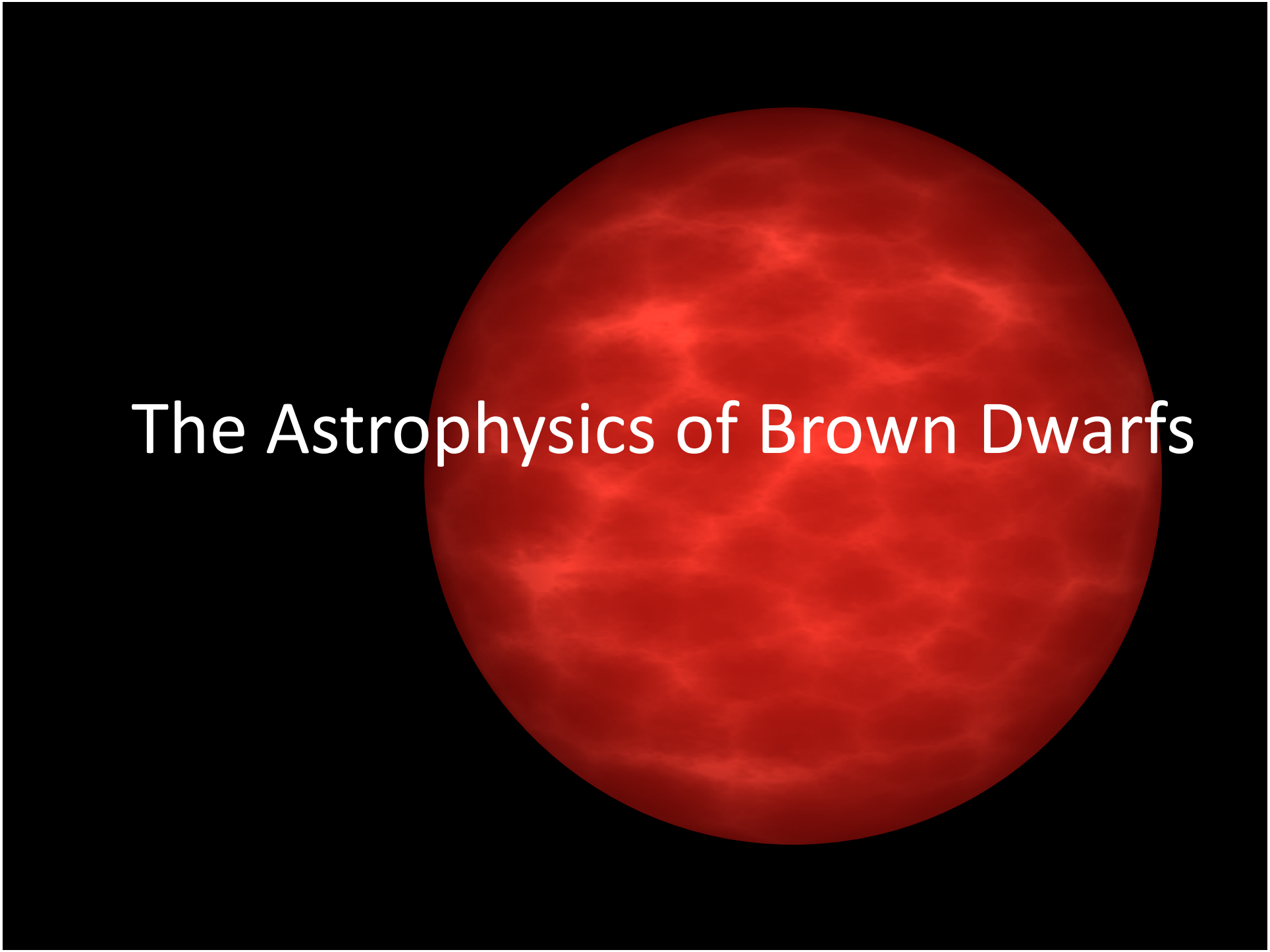

Are there “stars” that do not fuse hydrogen?
Are there “planets” that do not orbit a star?

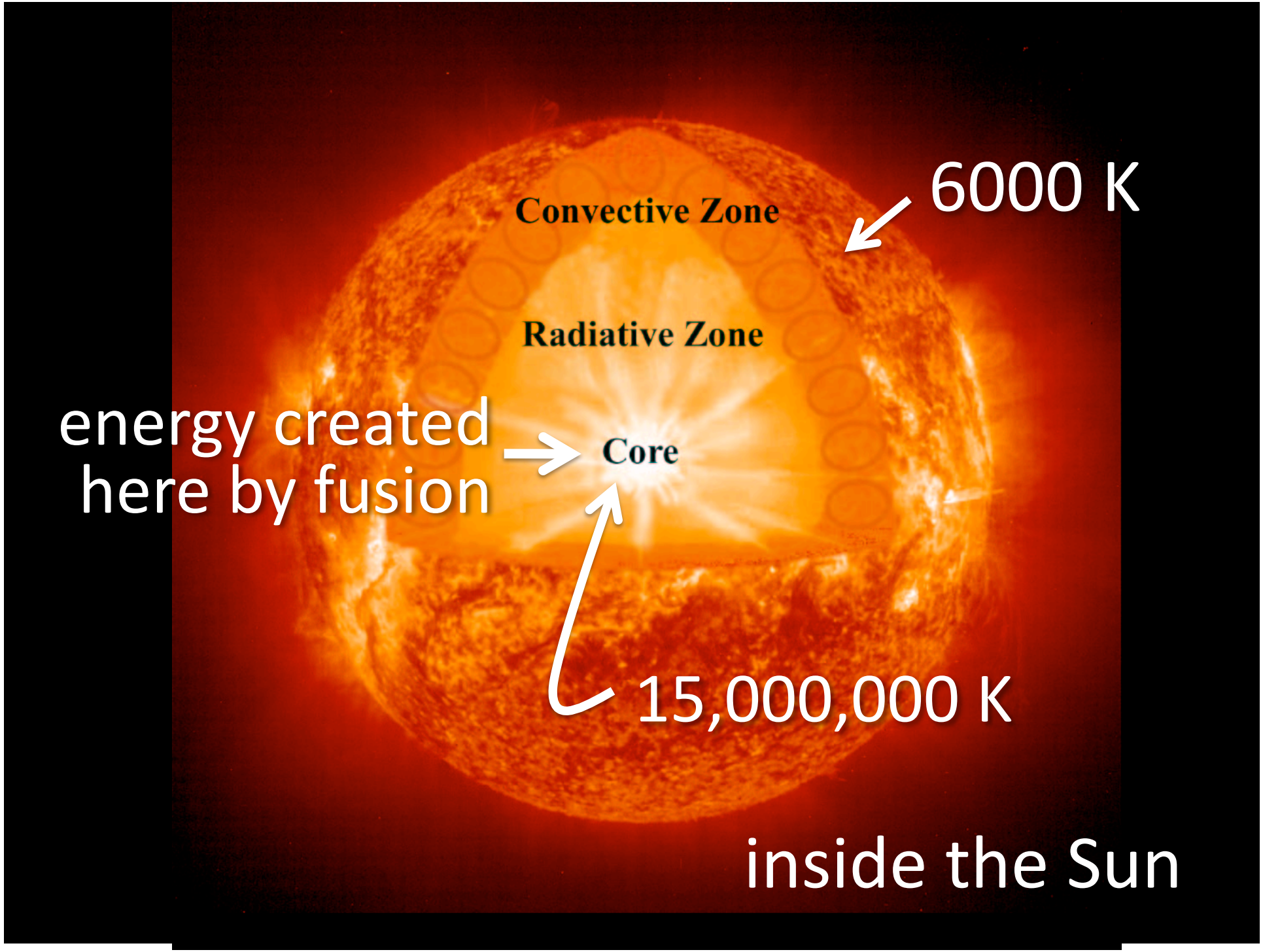
Are there “stars” that do not fuse hydrogen?

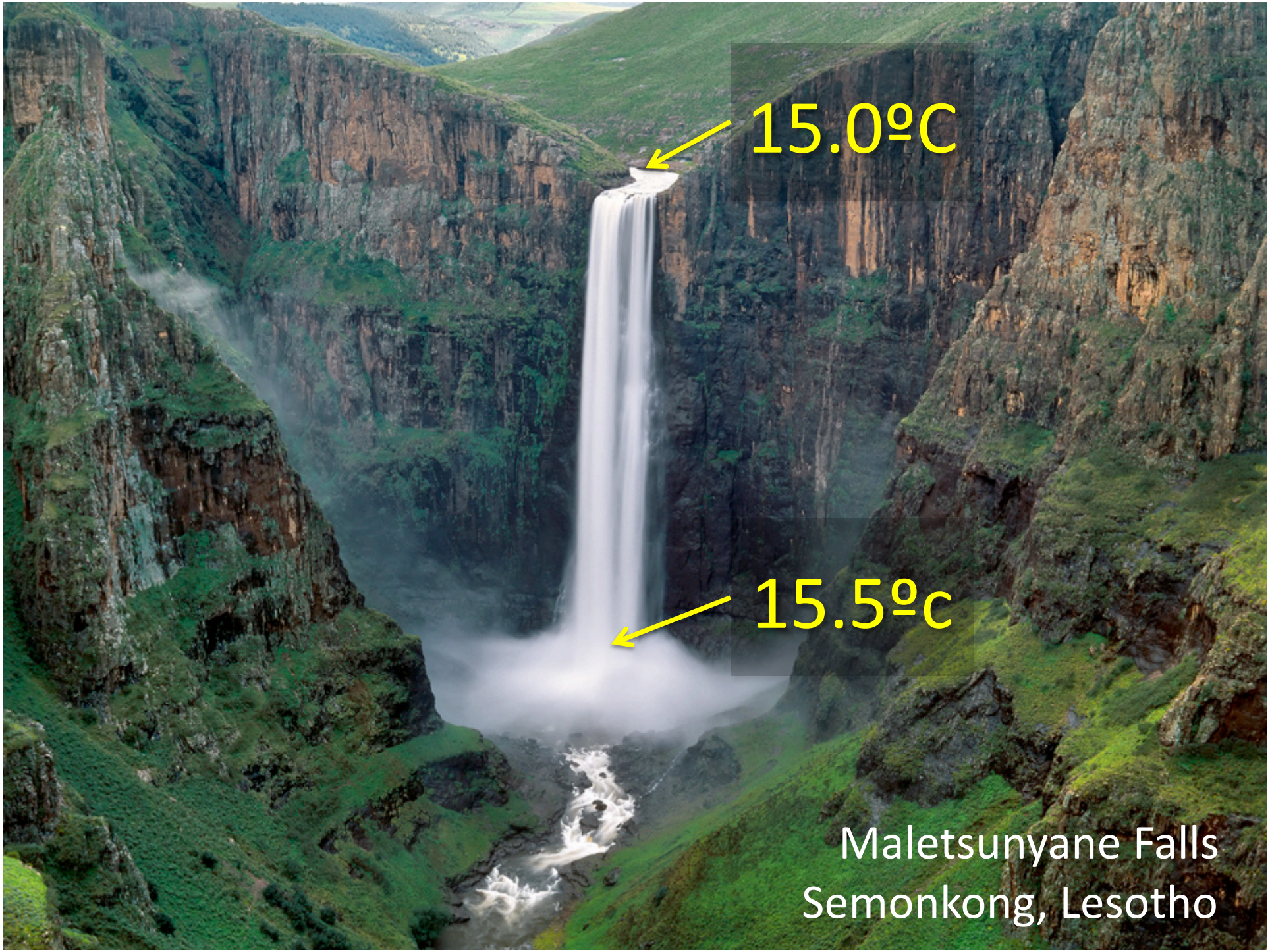
Brown dwarfs

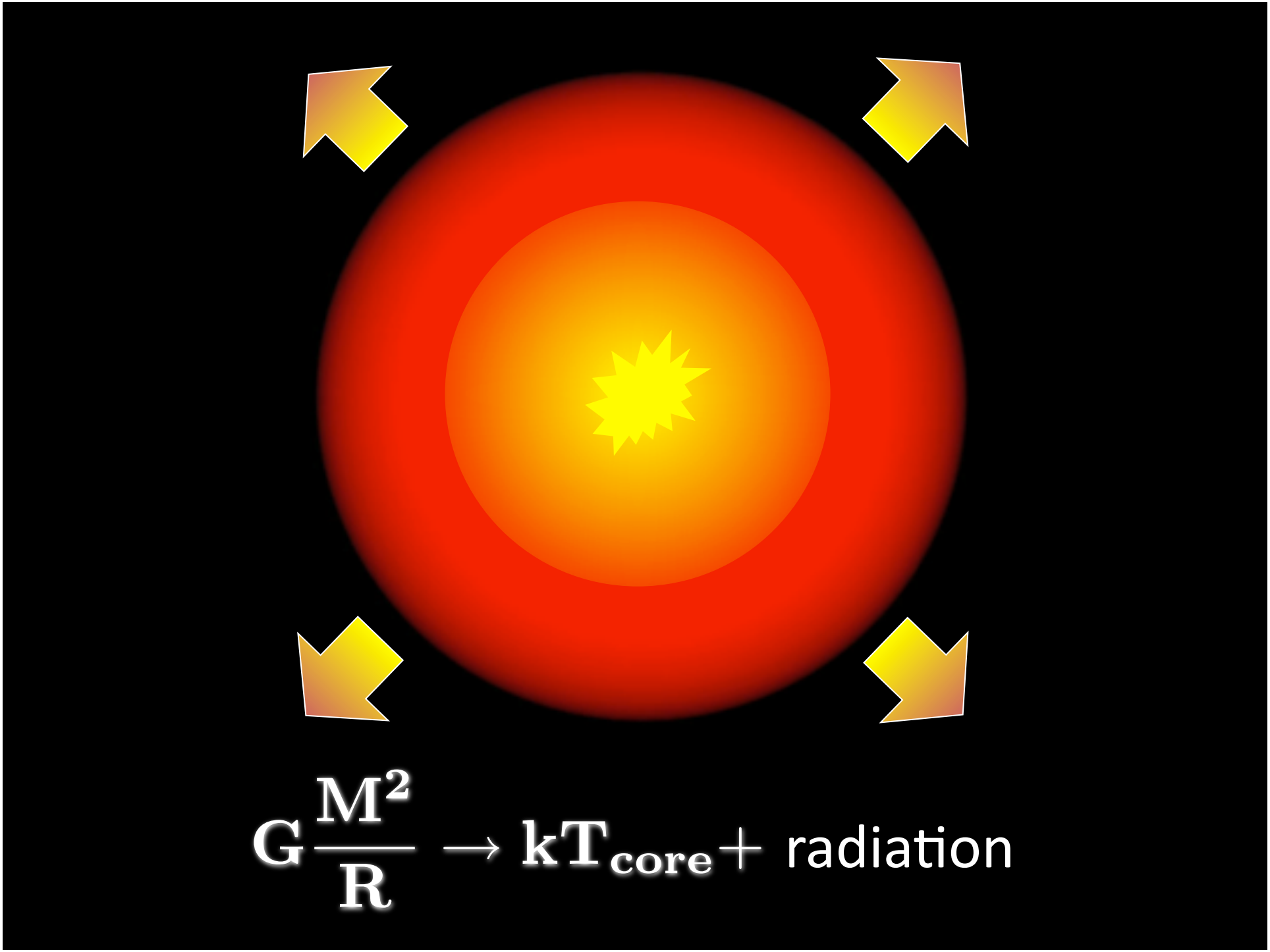
Are there “planets” that do not orbit a star?

The Astrophysics of Brown Dwarfs

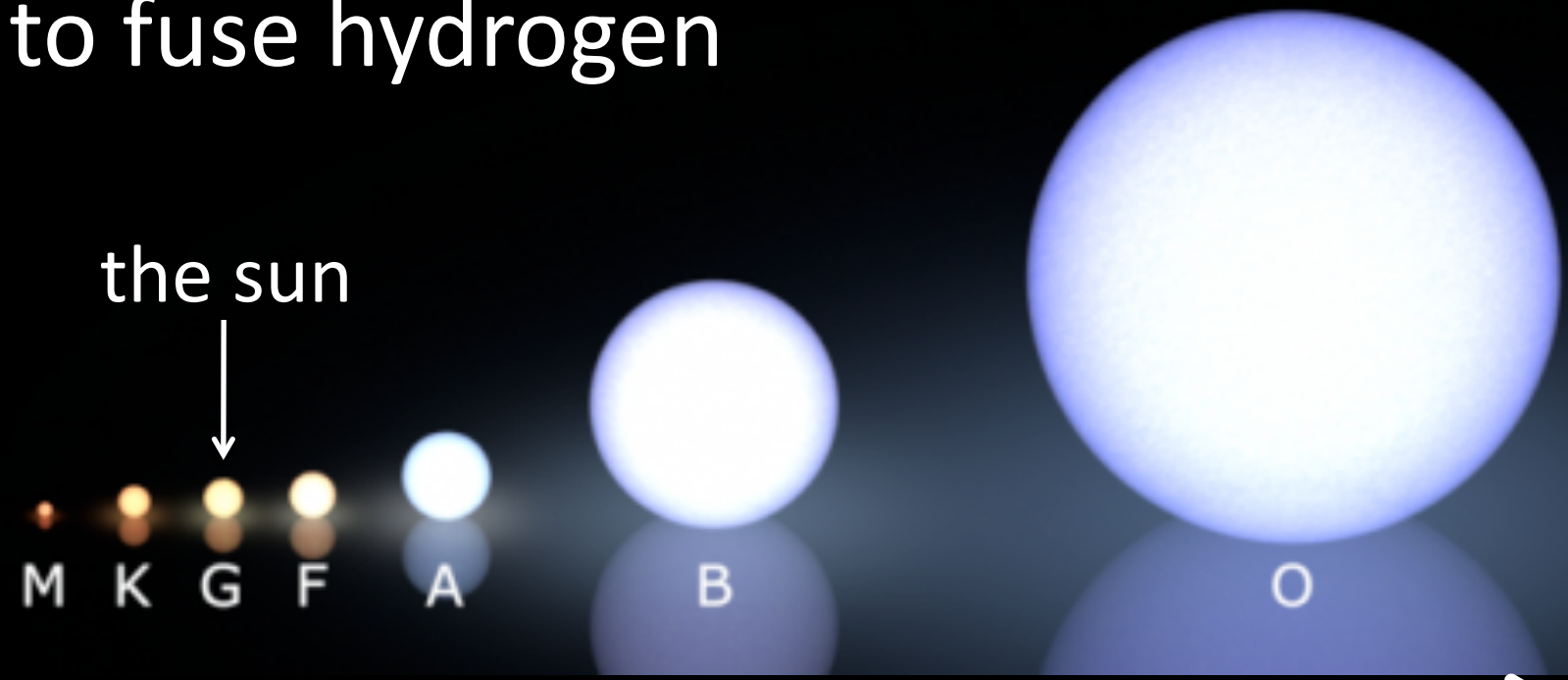



Convective Zone
6000 K
Radiative Zone
energy created
here by fusion
Core
15,000,000 K
inside the Sun


15.0ºC
15.5ºc
Maletsunyane Falls
Semonkong, Lesotho


$G\frac{M^2}{R} \rightarrow kT_{core}$ + radiation

the less mass you have, the smaller you have to be to fuse hydrogen



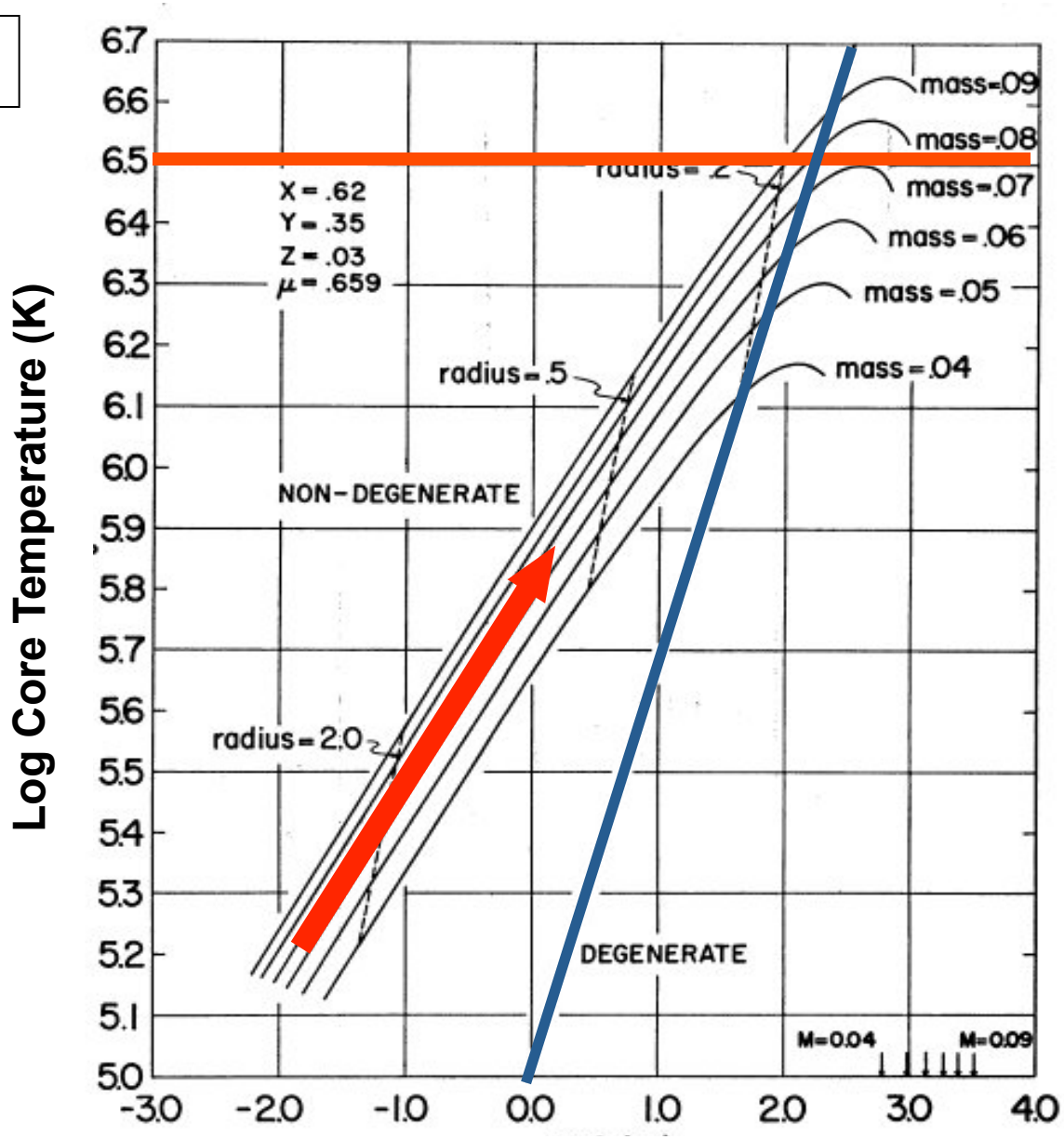
low mass, small size

HIGH MASS, BIG SIZE

How Tightly Can you Pack a Star?

There is a quantum mechanical limit
based on the Pauli exclusion principle:
two electrons cannot occupy the same state

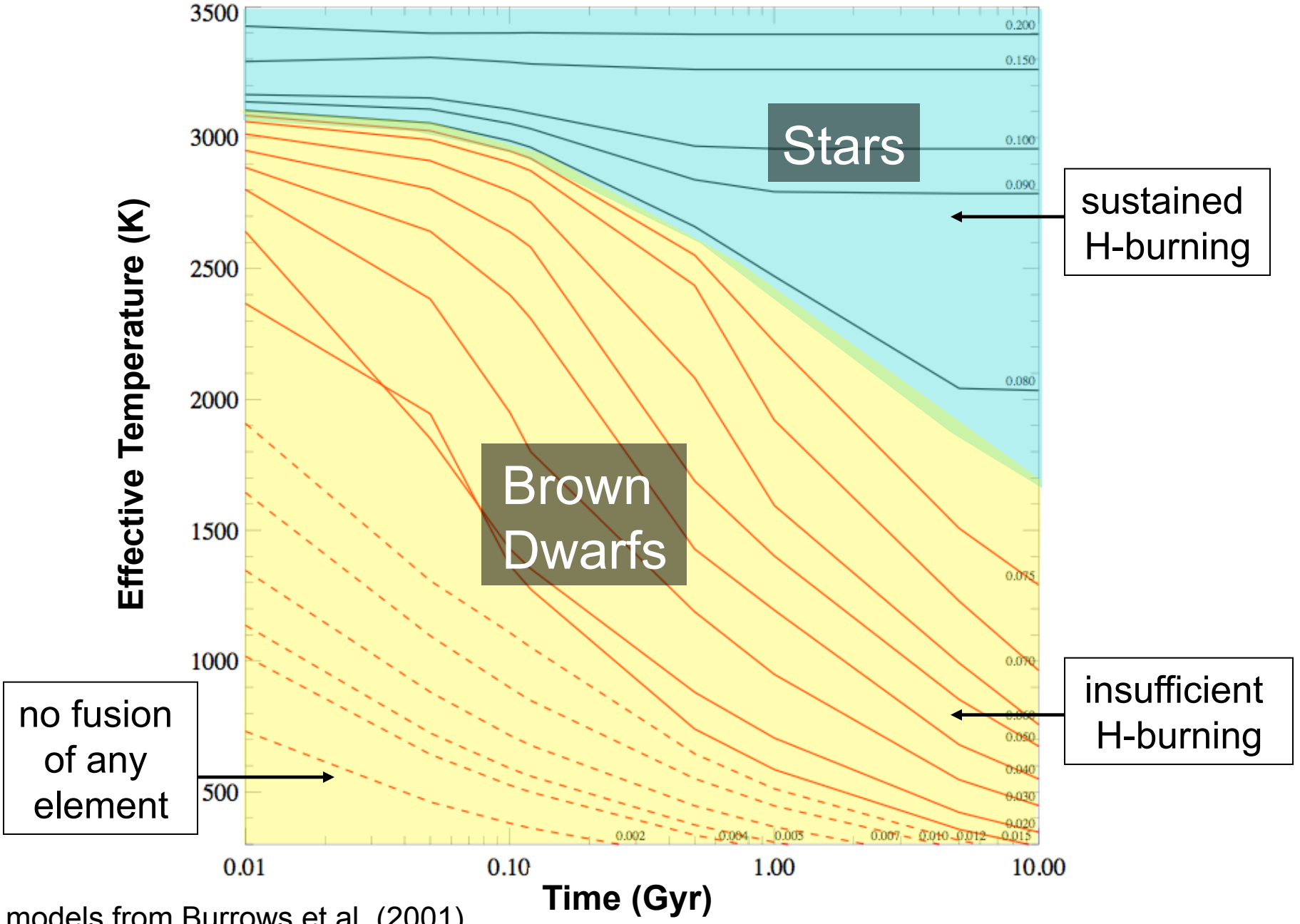
ca. 1963



H-burning threshold ≈ 3×10^6 K

Threshold Mass ≈ 0.07 M_{sun}

Kumar (1962, 1963)
see also Hayashi & Nakano (1963)



models from Burrows et al. (2001)

Atmosphere:

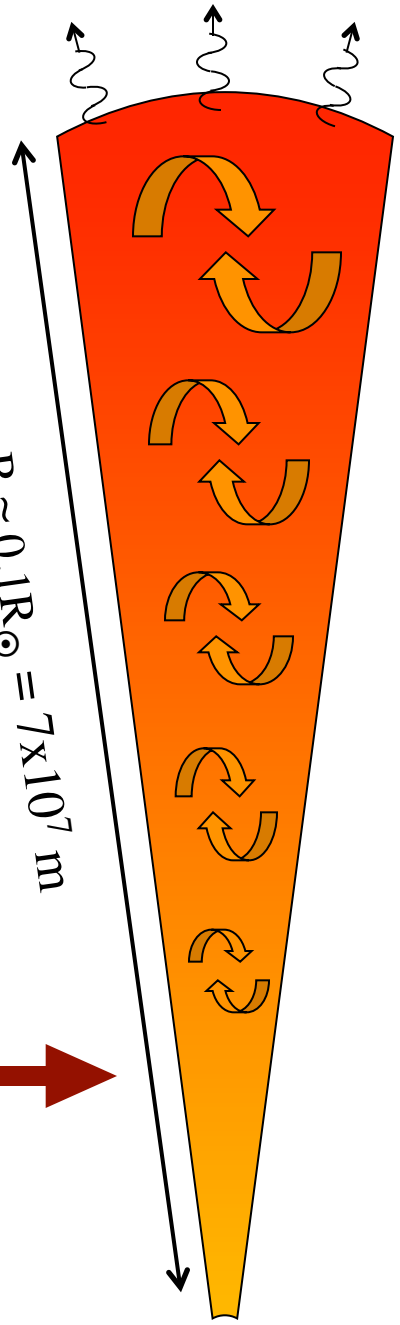
$\rho \approx 10^{-4}$-10^{-6} g/cm^3 T < 2500 K
P ≈ 0.1-10 bar log g ≈ 3-5.5 cm/s^2
H_{scale} ≈ 1 km

Interior:

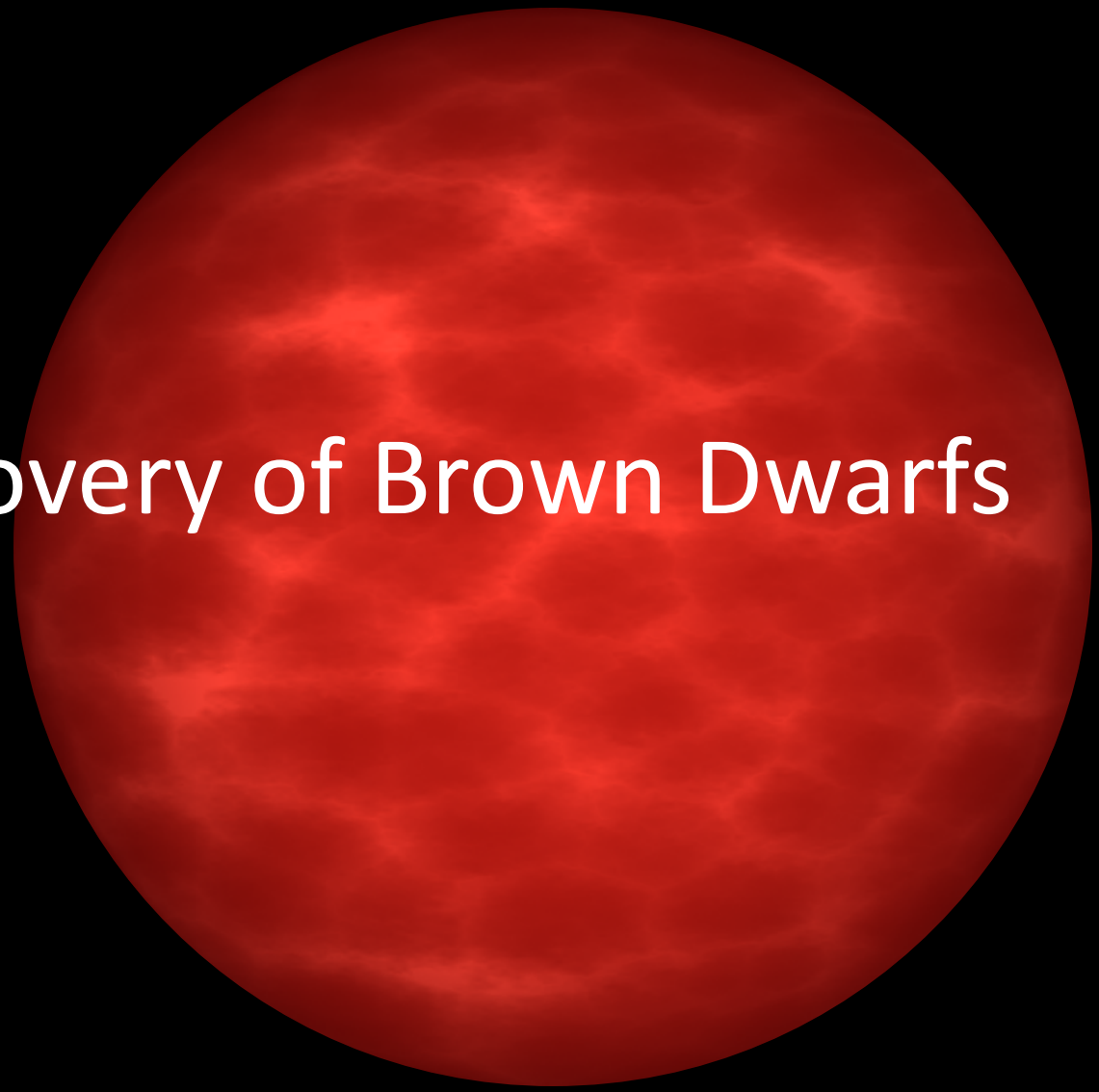
- Strongly coupled, partially degenerate plasma - metallized H^+/e^- fluid
- Bulk composition (by mass): 73% H, 25% He, < 2% "metals"
- Energy transport: primarily convection (n=1.5 polytrope)

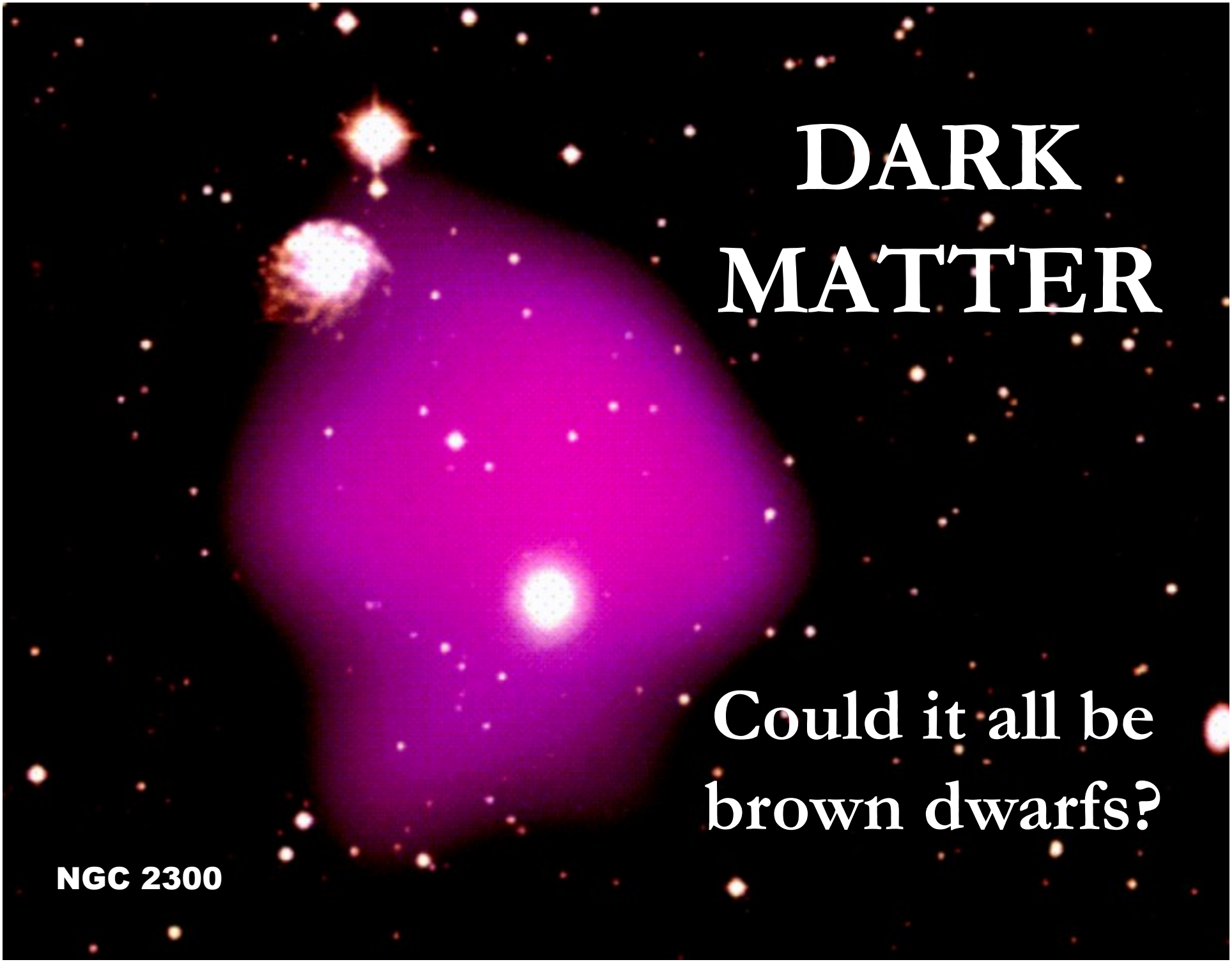
Core:

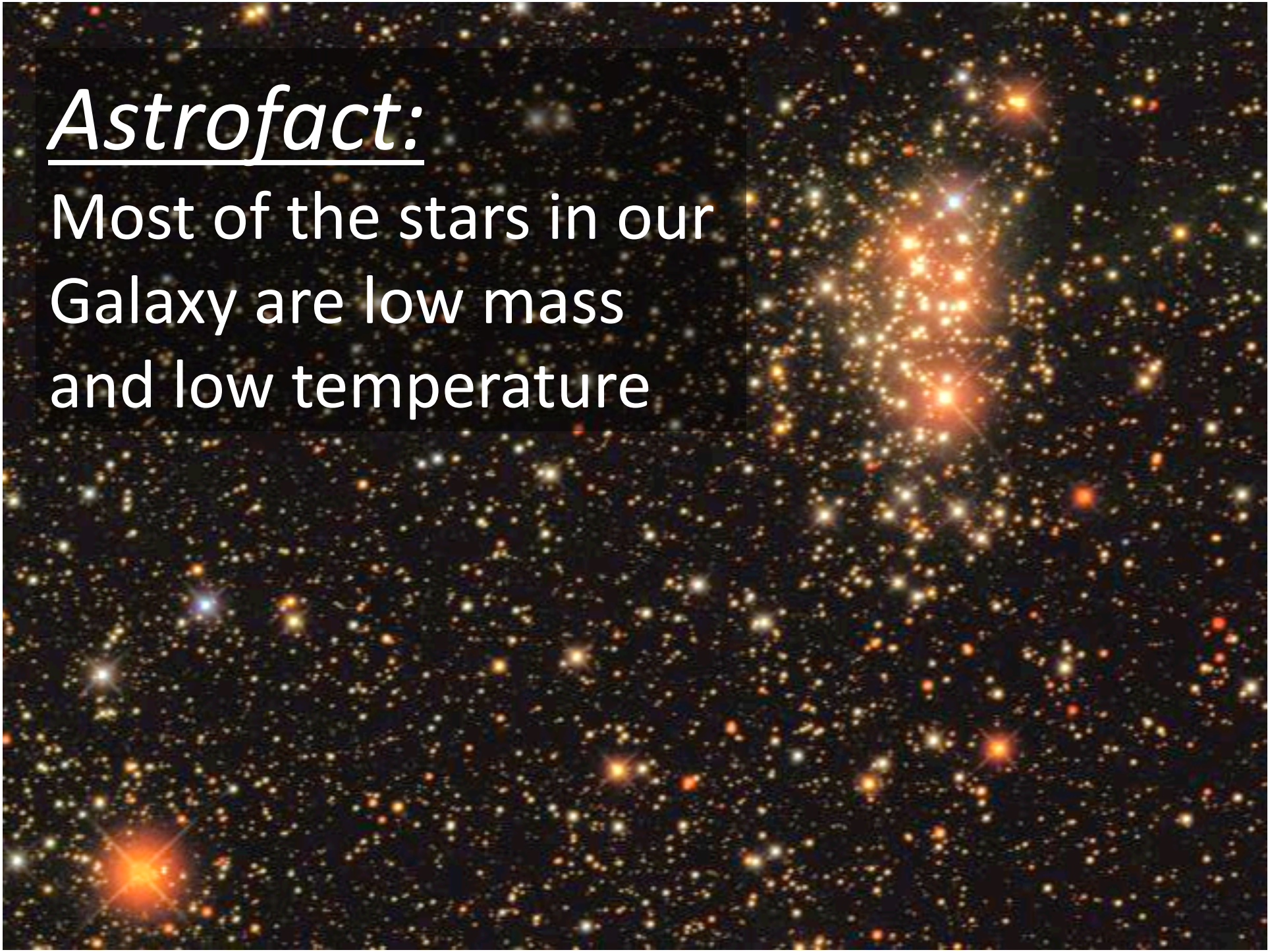
$\rho \approx 10$-10^3 g/cm^3
P ≈ 10^{11} bar
T < 3×10^6 K



The Discovery of Brown Dwarfs




DARK
MATTER
Could it all be
brown dwarfs?
NGC 2300


Astrofact:
Most of the stars in our Galaxy are low mass and low temperature

What's in a Name…

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

Dr. Jill Tarter

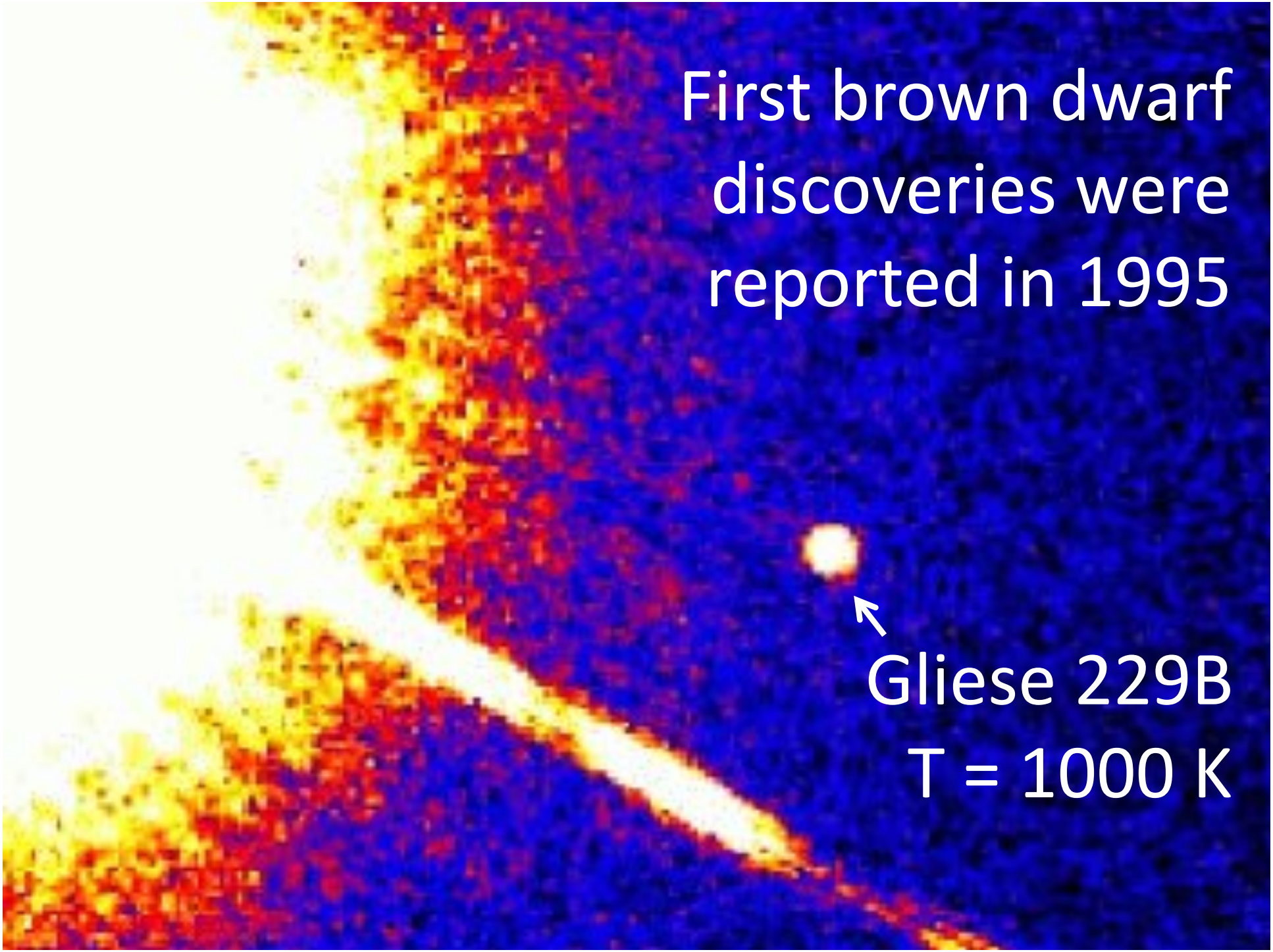
SETI Institute

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

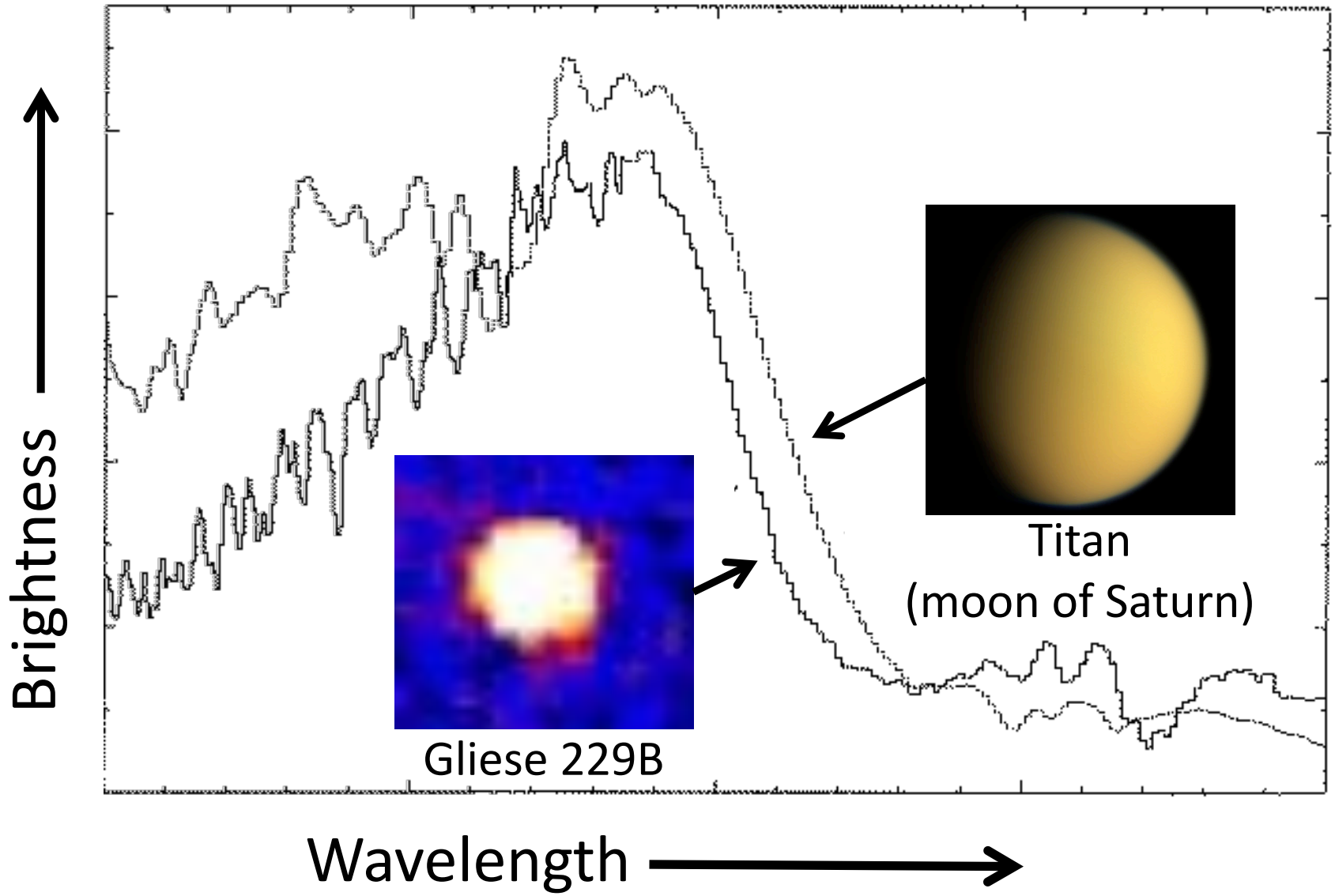
Number of Brown Dwarf Discoveries from 1963 to 1994:

Number of Brown Dwarf Discoveries from 1963 to 1994:

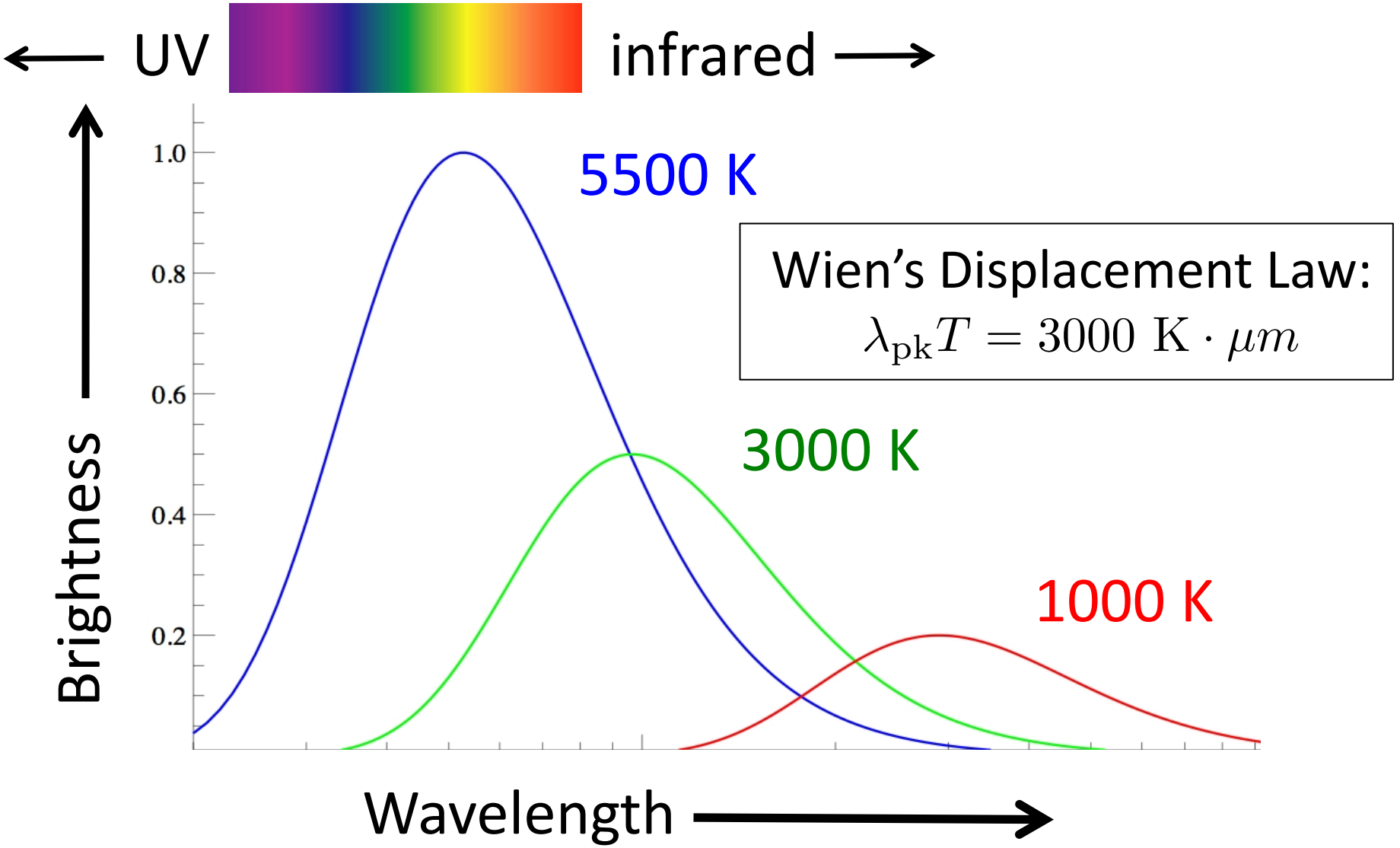
0


First brown dwarf discoveries were reported in 1995
Gliese 229B
T = 1000 K

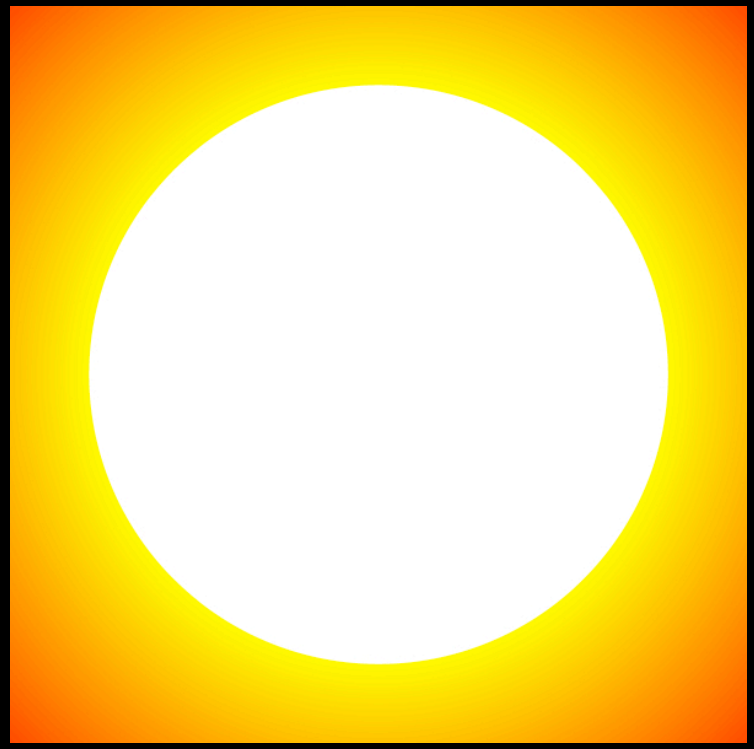
The spectrum of Gliese 229B



Very Cool Stars are (infra)red



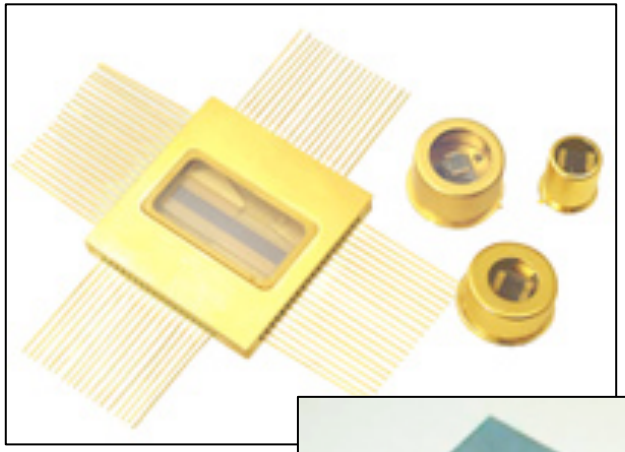
The Sun vs. A Campfire



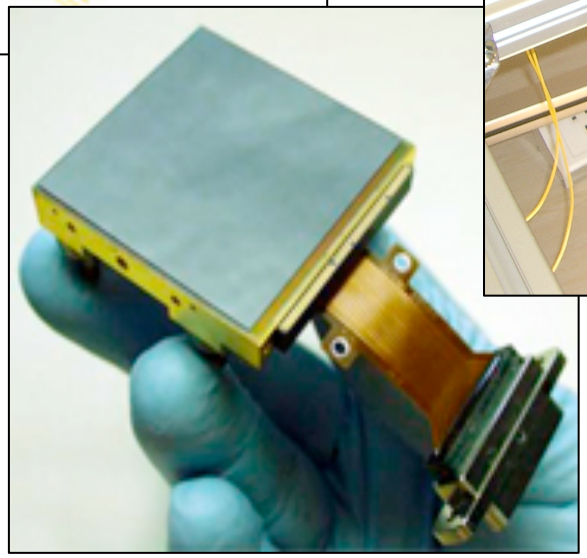
T = 6000 K
more bright than hot
less infrared radiation

T = 750 K
more hot than bright
more infrared radiation

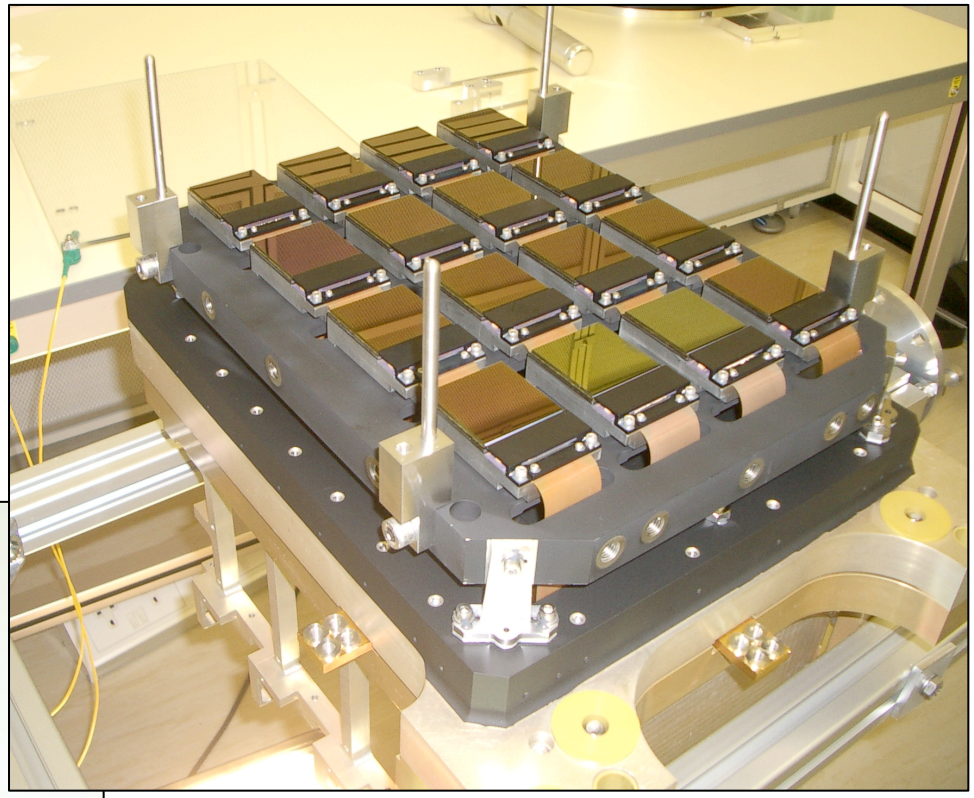
Infrared array technology



Lead Sulfide
strip array



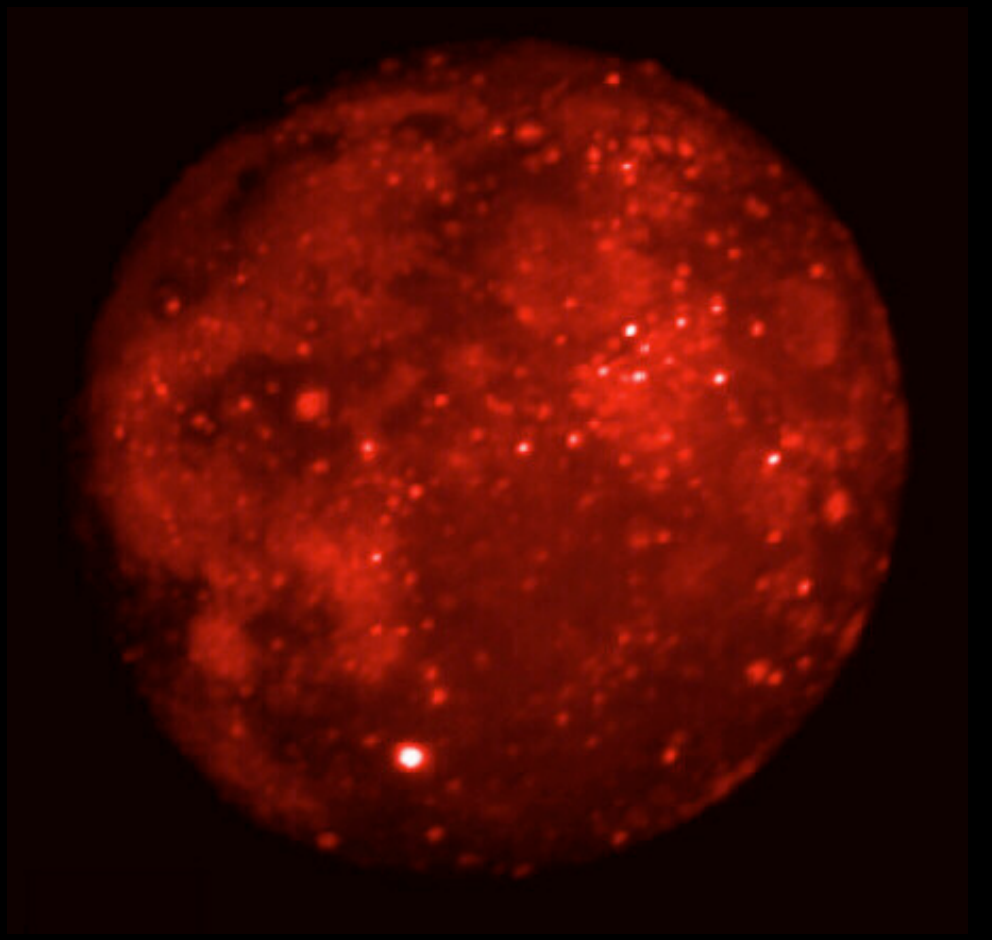
HgCdTe
array detector



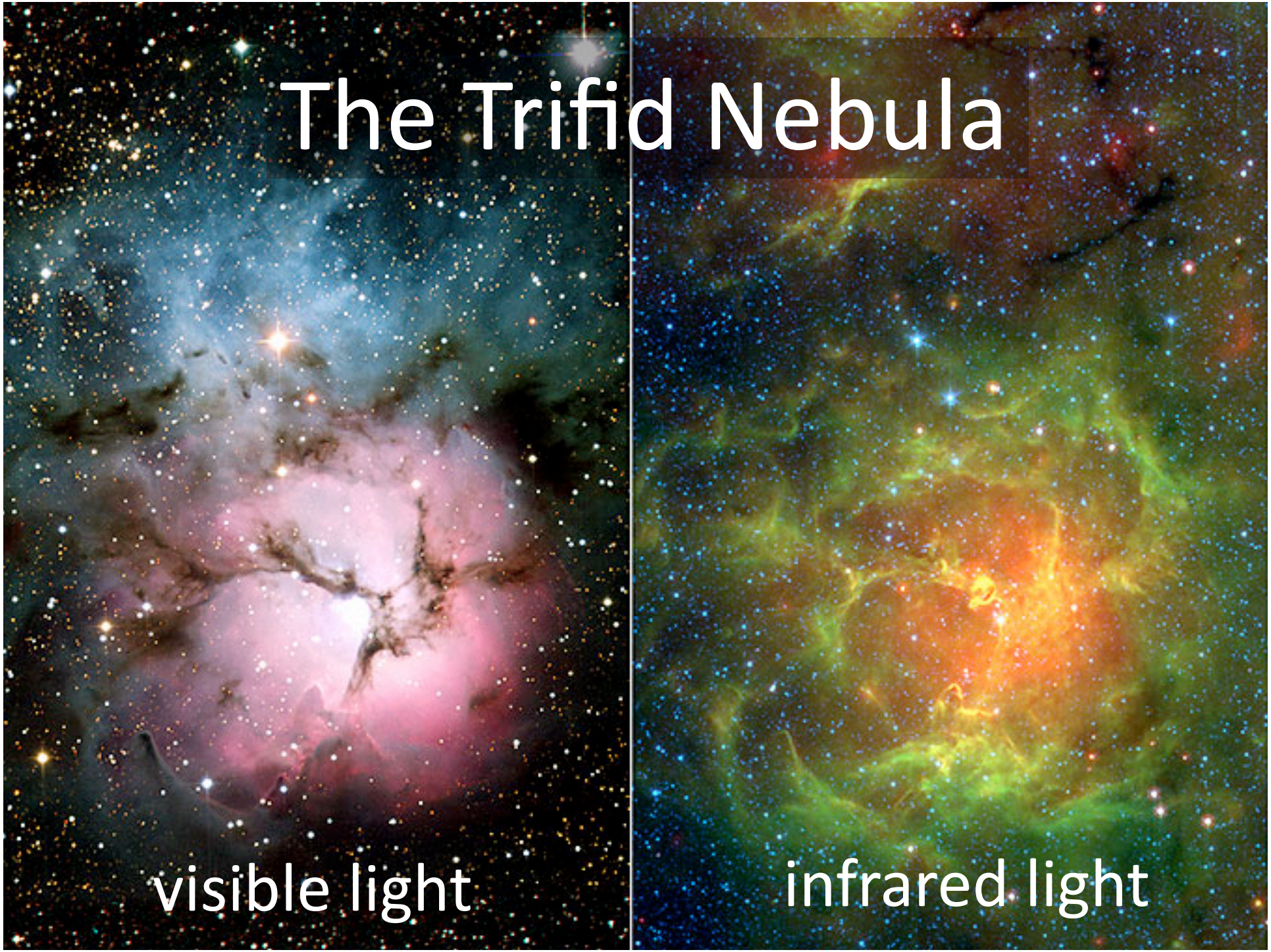
Vista Survey focal plane array
67 million pixel IR camera

The Moon

visible light



infrared light

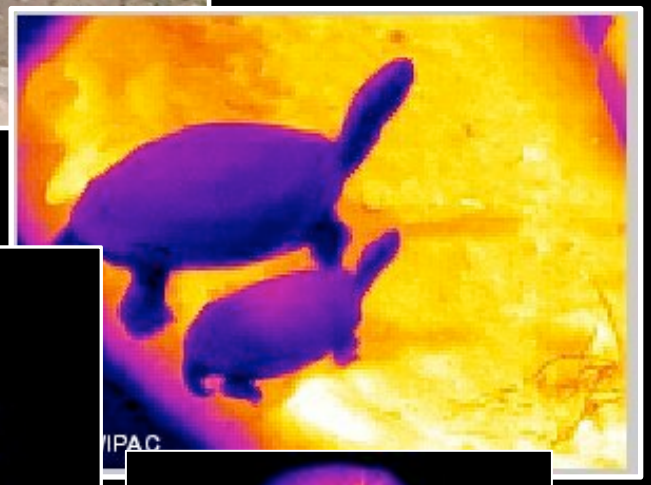

The Trifid Nebula
visible light
infrared light

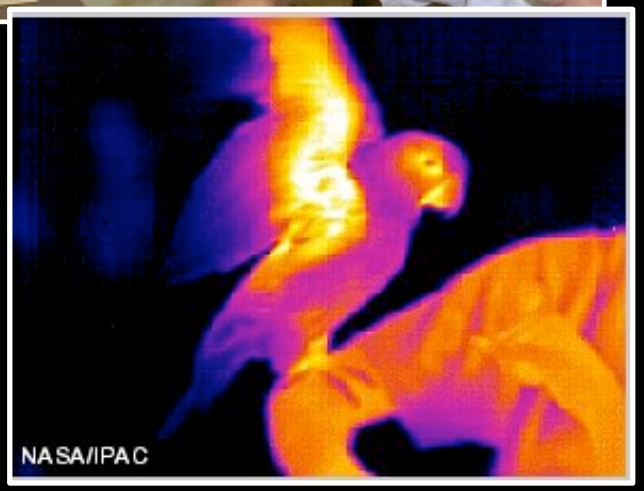
Messier 81:
A spiral galaxy

visible light

infrared light

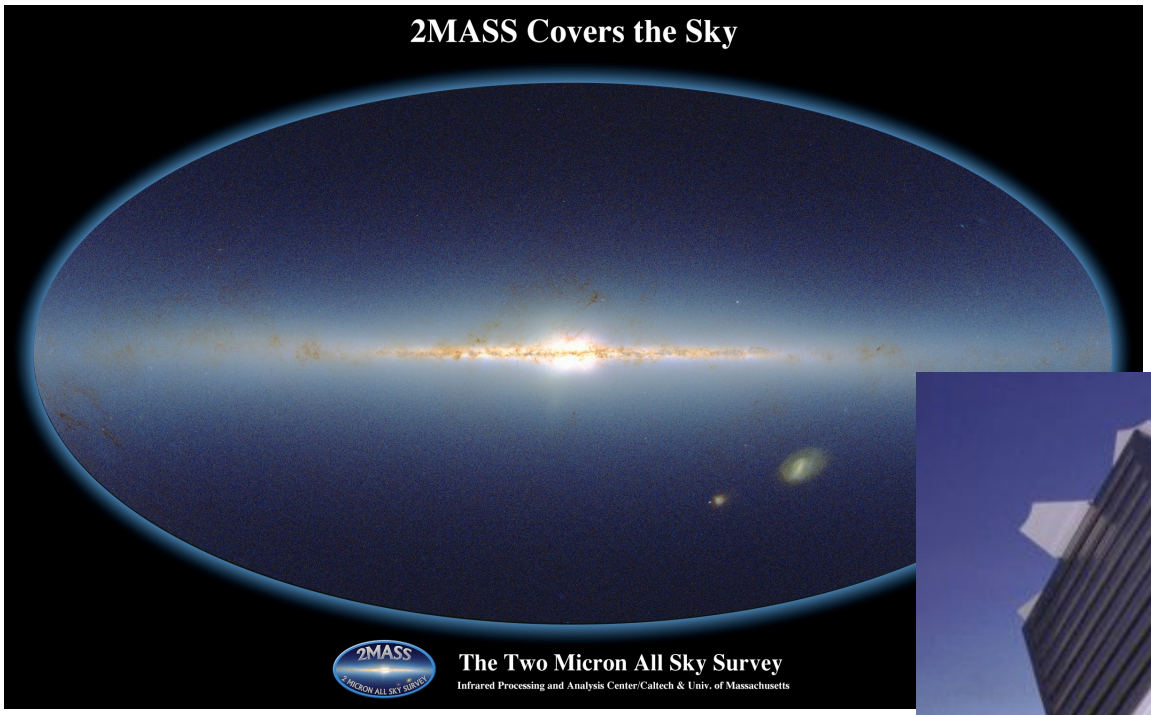
Infrared Animals





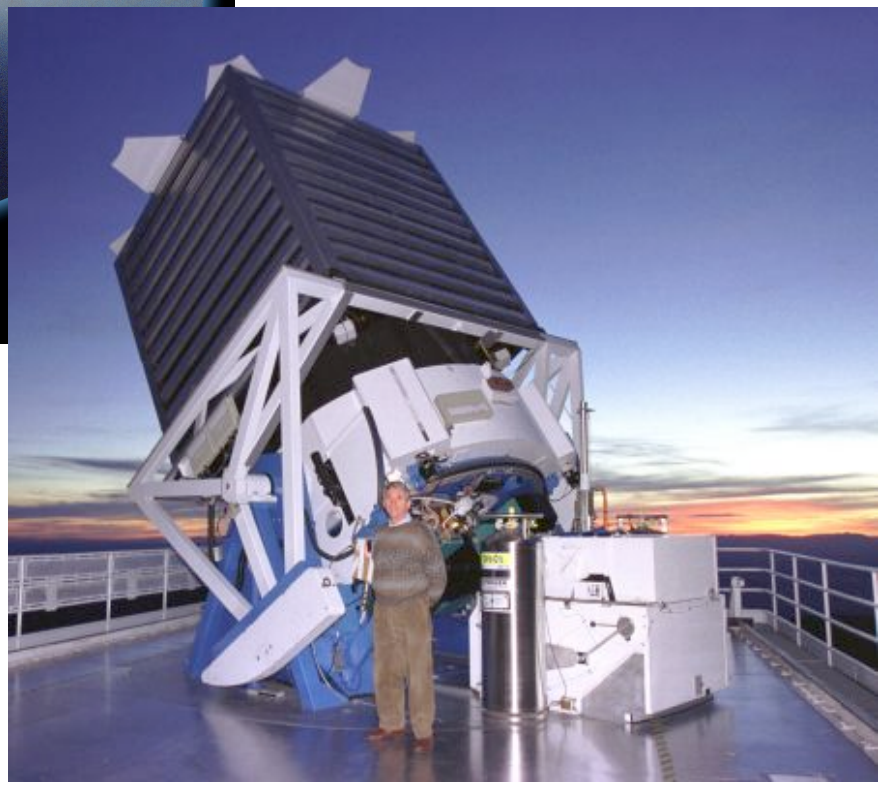
Images from Cool Cosmos: http://coolcosmos.ipac.caltech.edu

Red/Near-infrared Sky Surveys

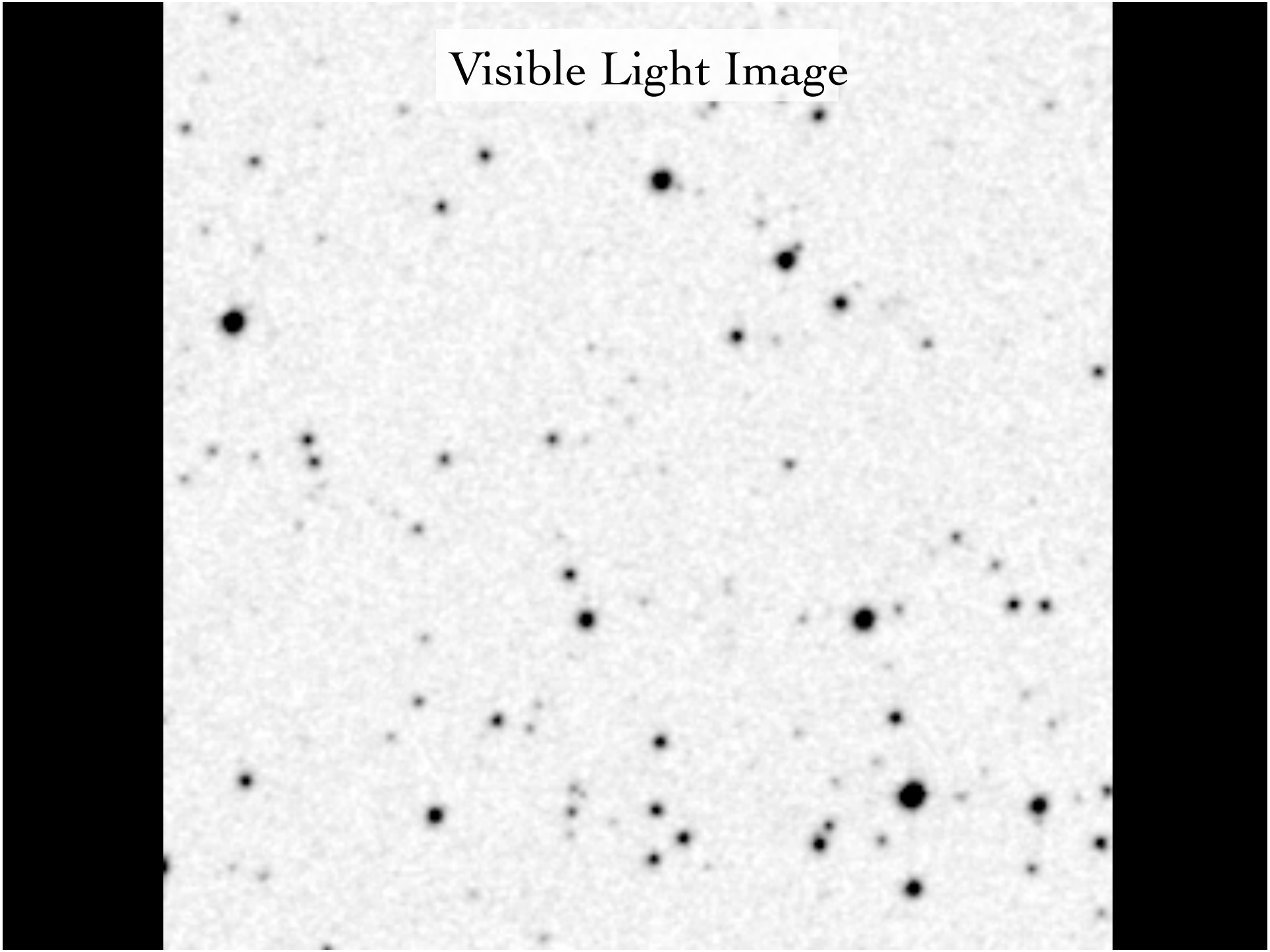


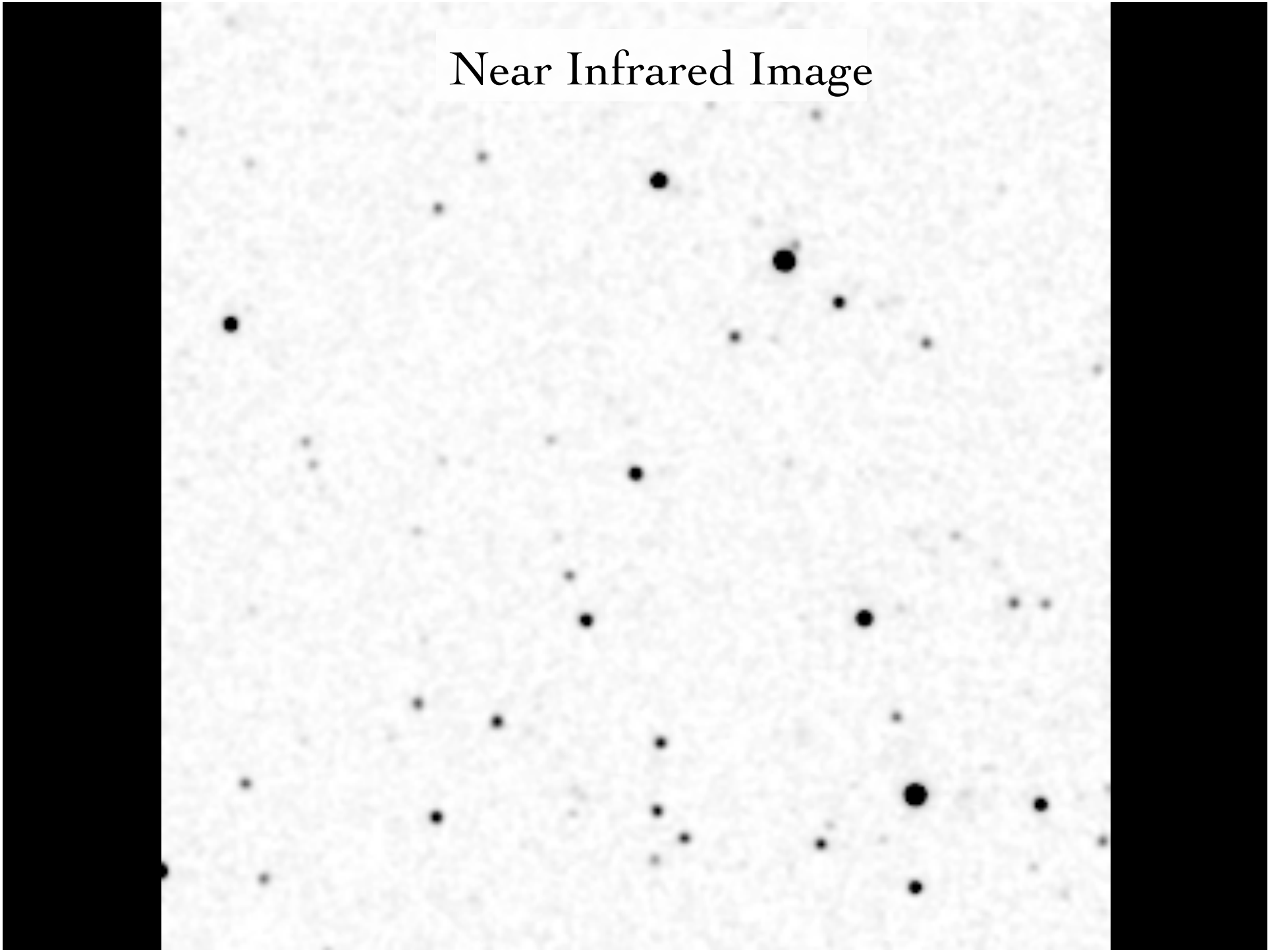
2 Micron All Sky Survey

Sloan Digital Sky Survey



Large-area surveys measuring near-infrared light are responsible for most brown dwarf discoveries


Visible Light Image


Near Infrared Image


Near Infrared Image
a dark star!

The New York Times
Wednesday, February 11, 2009

U.S.

WORLD | U.S. | N.Y. / REGION | BUSINESS | TECHNOLOGY | SCIENCE | HEALTH

Cosmic Players That Could've Been Stars

By JOHN NOBLE WILFORD
Published: June 8, 2001

FOXNEWS.COM HOME > SCITECH

'Missing Link' Between Stars, Planets Found

Sunday, April 13, 2008

USA TODAY

Home | News

Science & Space | Inside Technology

Wild weather: Iron rain on failed stars

Updated 7/5/2006 9:16 AM ET

Brown dwarfs are dull, but they shed light on planets

By Chris Oliver
Advertiser Staff Writer

Brown Dwarfs, Poorly Understood, Poorly Named

By Robert Roy Britt
Senior Science Writer
posted: 12:22 pm ET
07 June 2001

DwarfArchives.org

Photometry, spectroscopy, and astrometry of M, L, and T dwarfs

The Archives | News & Updates | Citing Us | Publications | For Educators | Interesting Links | FAQs | Help Desk

L Dwarfs and T Dwarfs

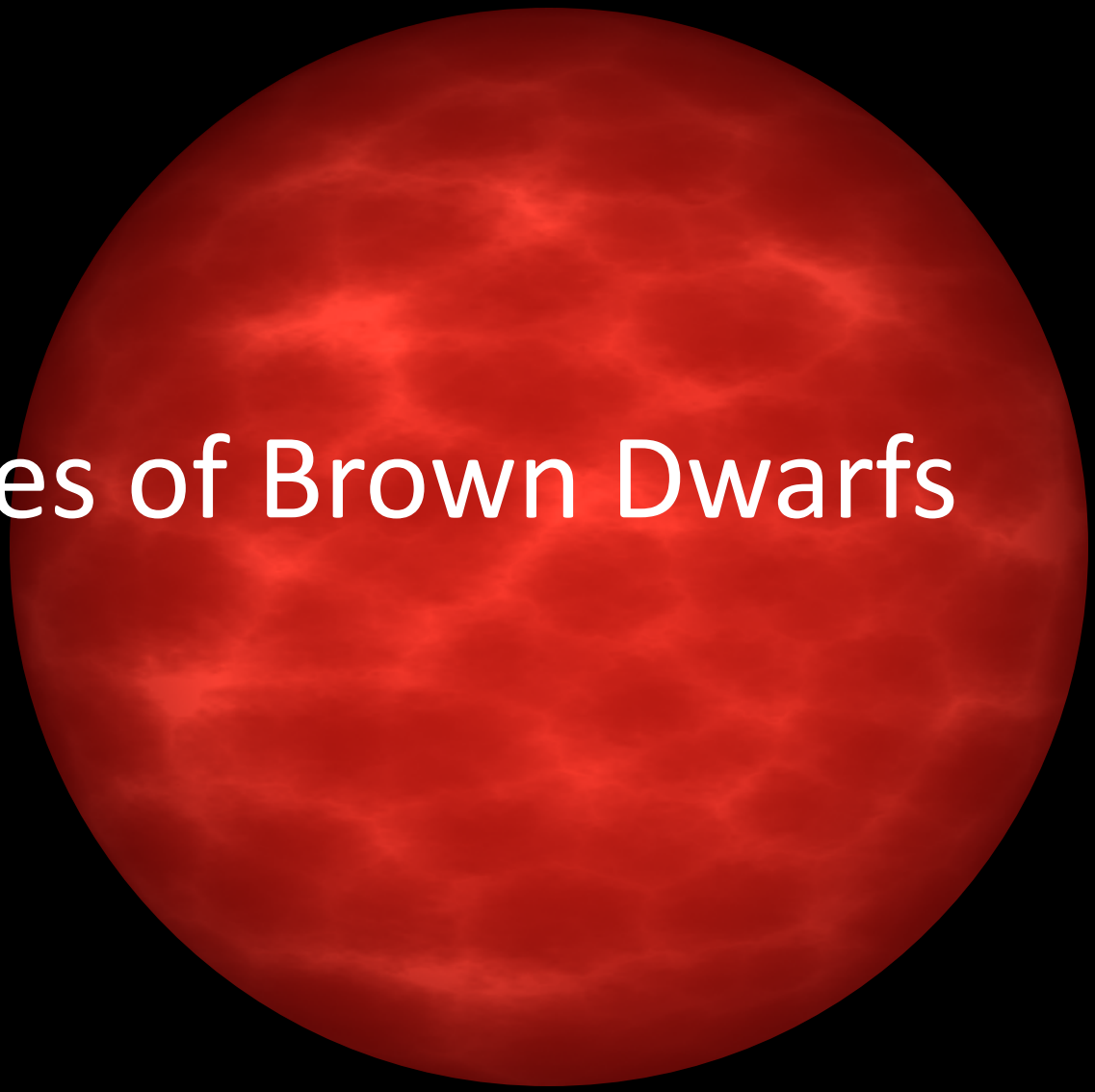
Last update 16 November 2009

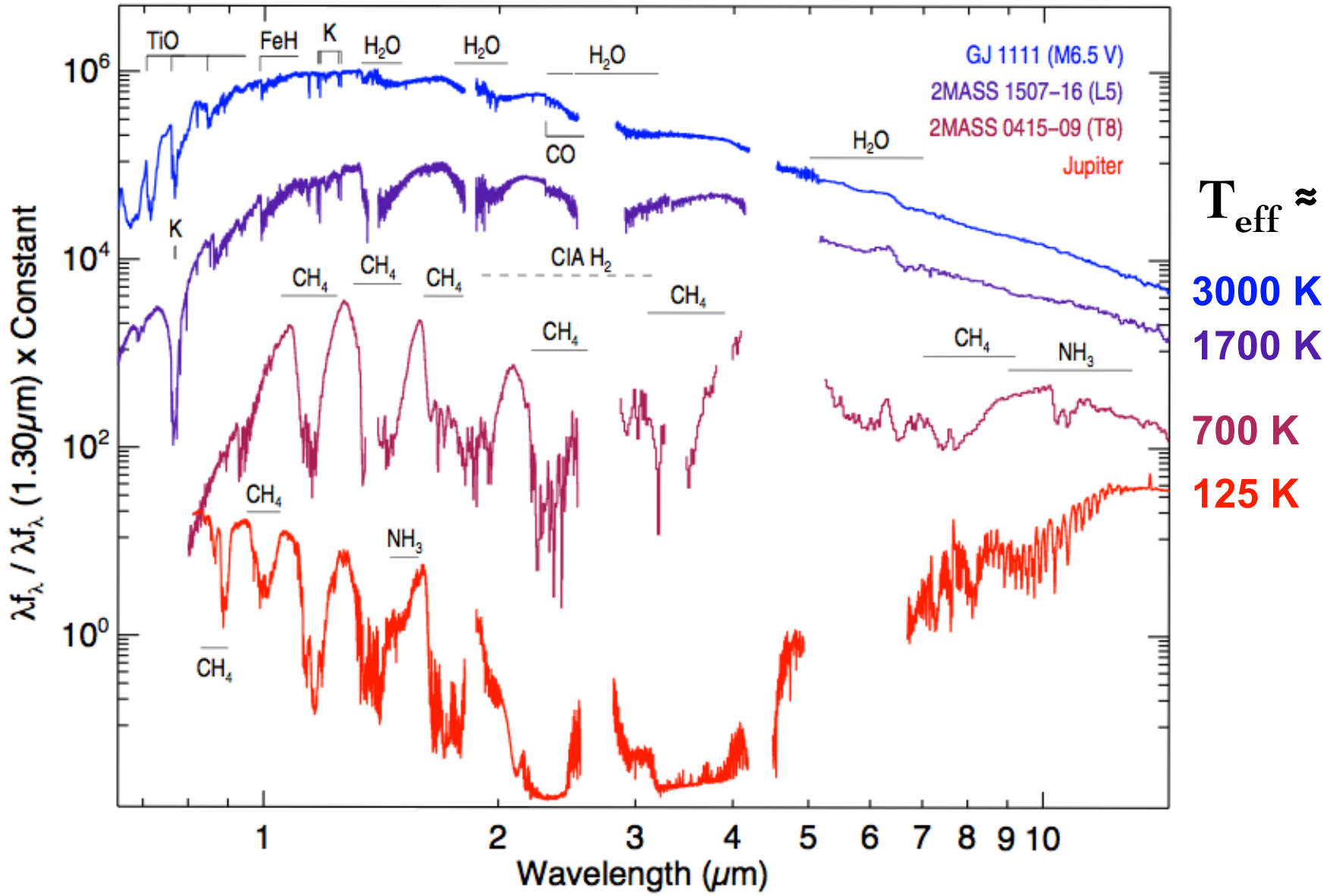
A compendium of all 752 known L and T dwarfs:

- Archive Search
- List of L and T dwarfs: HTML, ASCII
  - L dwarfs only: HTML, ASCII
  - T dwarfs only: HTML, ASCII
- Parallaxes: HTML, ASCII

dwarfarchives.org maintained by Chris Gelino, Davy Kirkpatrick & Adam Burgasser

Properties of Brown Dwarfs





$T_{eff} \approx$

3000 K

1700 K

700 K

125 K

Marley & Leggett (2008)

data from Cushing et al. (2005,2007)

M dwarfs (3500-2100 K)
magnetically active, youngest brown dwarfs

L dwarfs (2100-1300 K)
molecule-rich atmospheres contain clouds of "hot dirt"

T dwarfs (1300-600? K)
coldest known brown dwarfs, H_2O, CH_4 and NH_3 gases

known

Y dwarfs (<600? K)
As yet undiscovered, possibly hosting H_2O clouds

O

B

A

F

G

K

M

L

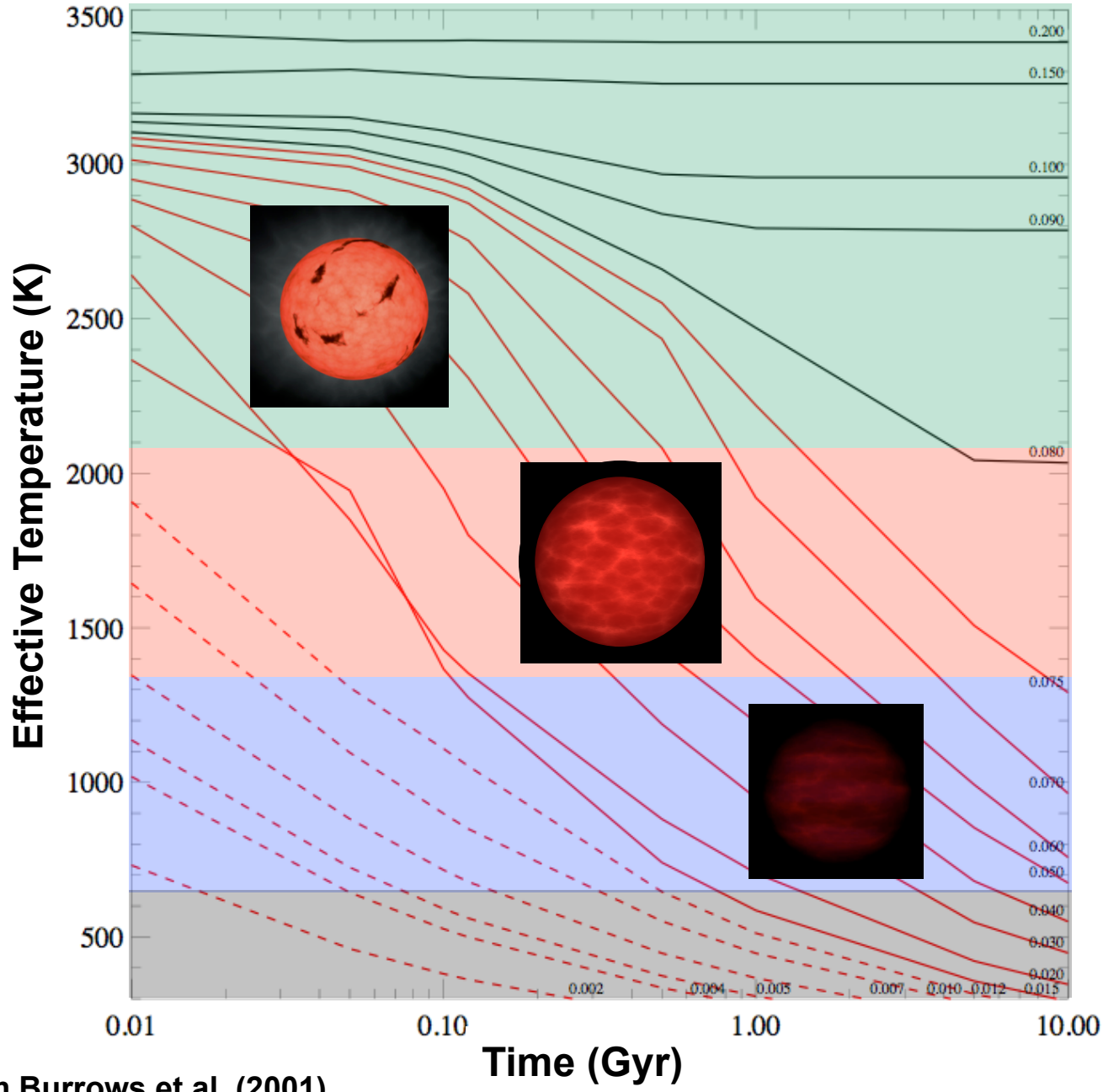
T

Y

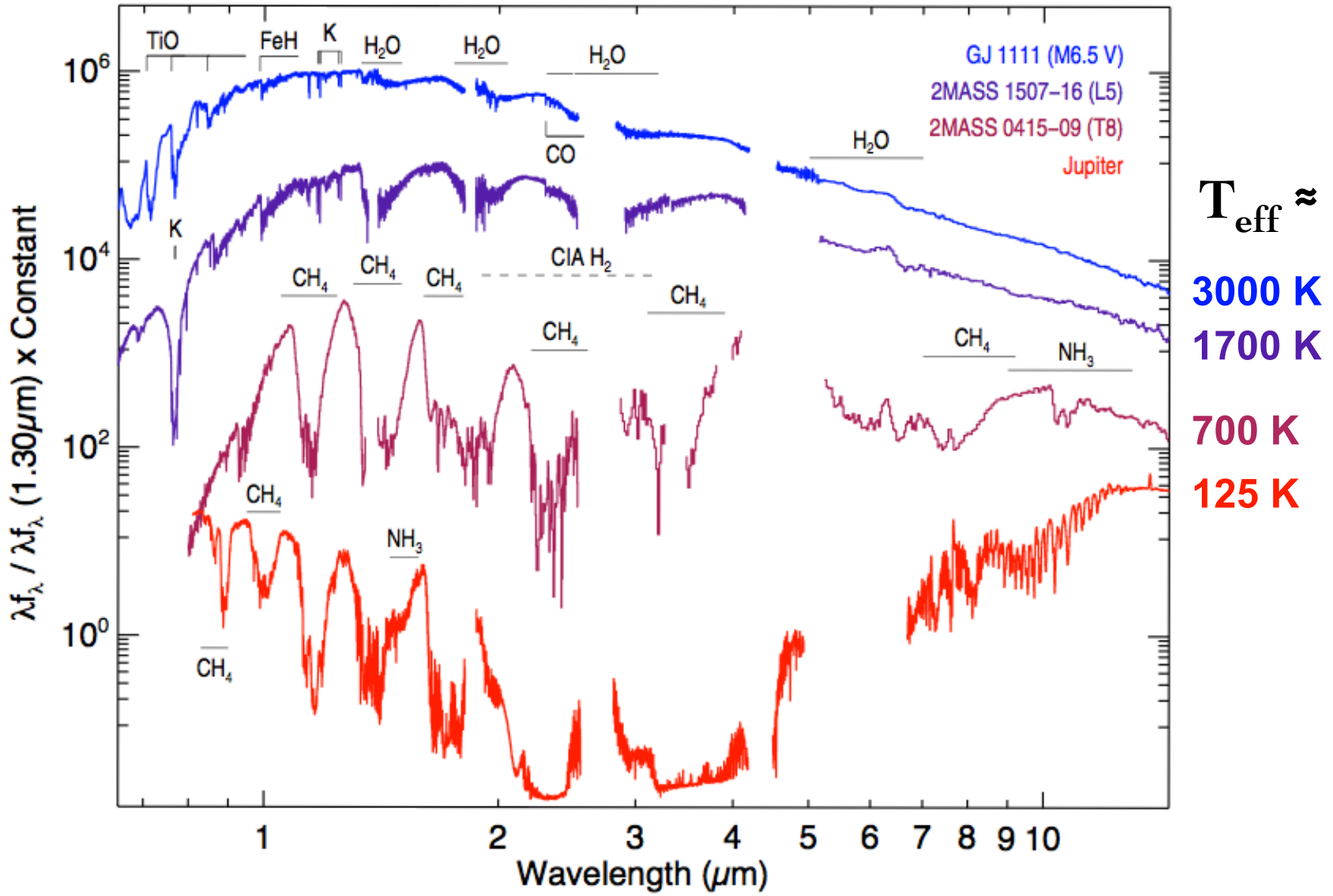
Oh
Be
A
Fine
Girl/Guy
Kiss
My
Lips
Tonite
Yahoo!

Obama's
Bailout
A
Federal
Government
Killer
Much
Luck
To
You

Owners
Beware!
A
Free
Ginsu
Knife
Might
Last
Two
Years



models from Burrows et al. (2001)



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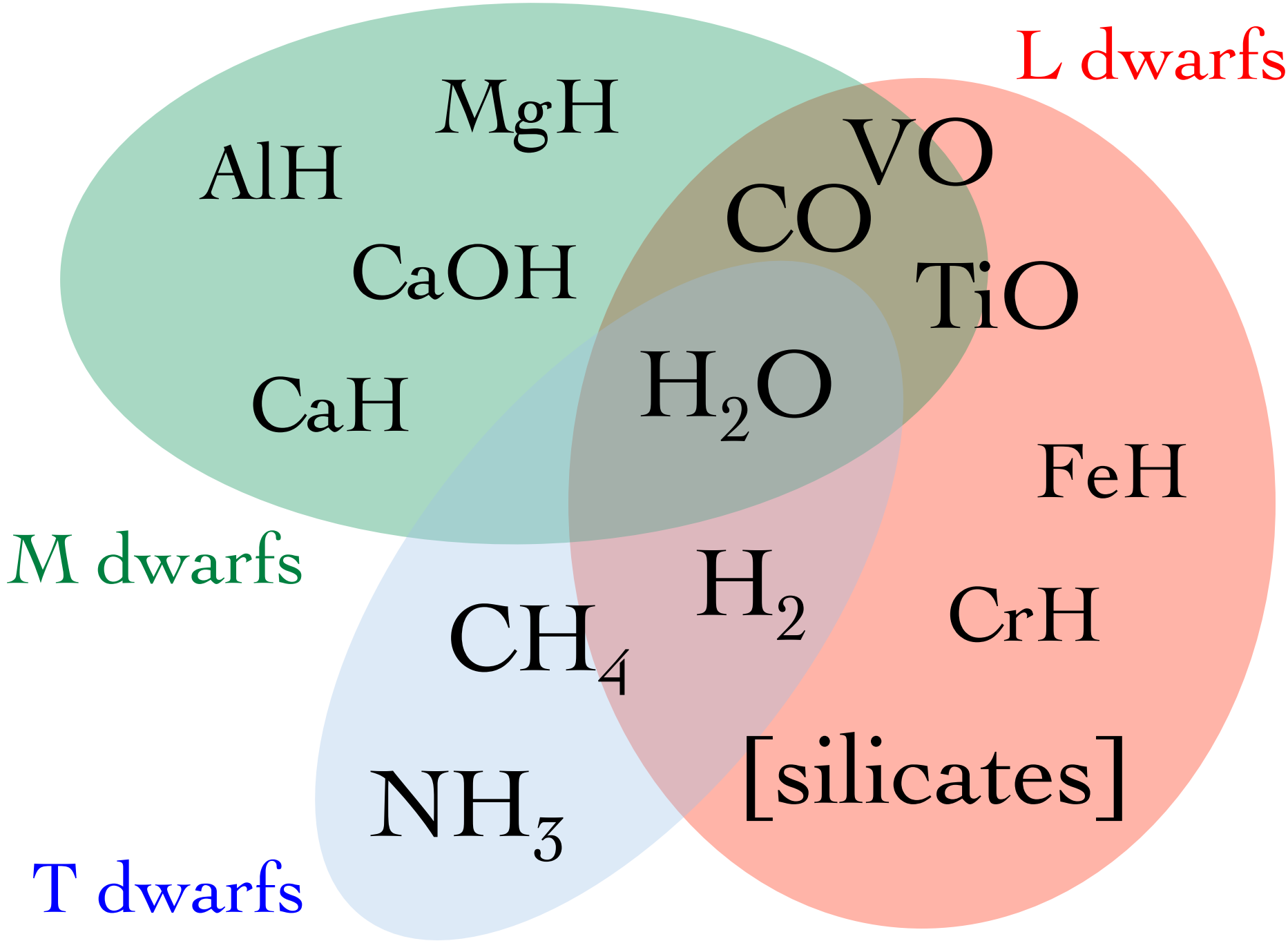
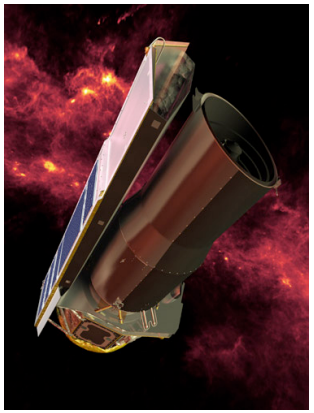

L dwarfs
MgH
AlH
VO
CO
CaOH
TiO
CaH
H_2O
FeH
M dwarfs
H_2
CH_4
CrH
[silicates]
NH_3
T dwarfs



Spitzer IRS spectra
from Cushing et al. (2006)

Condensate species in brown dwarf atmospheres

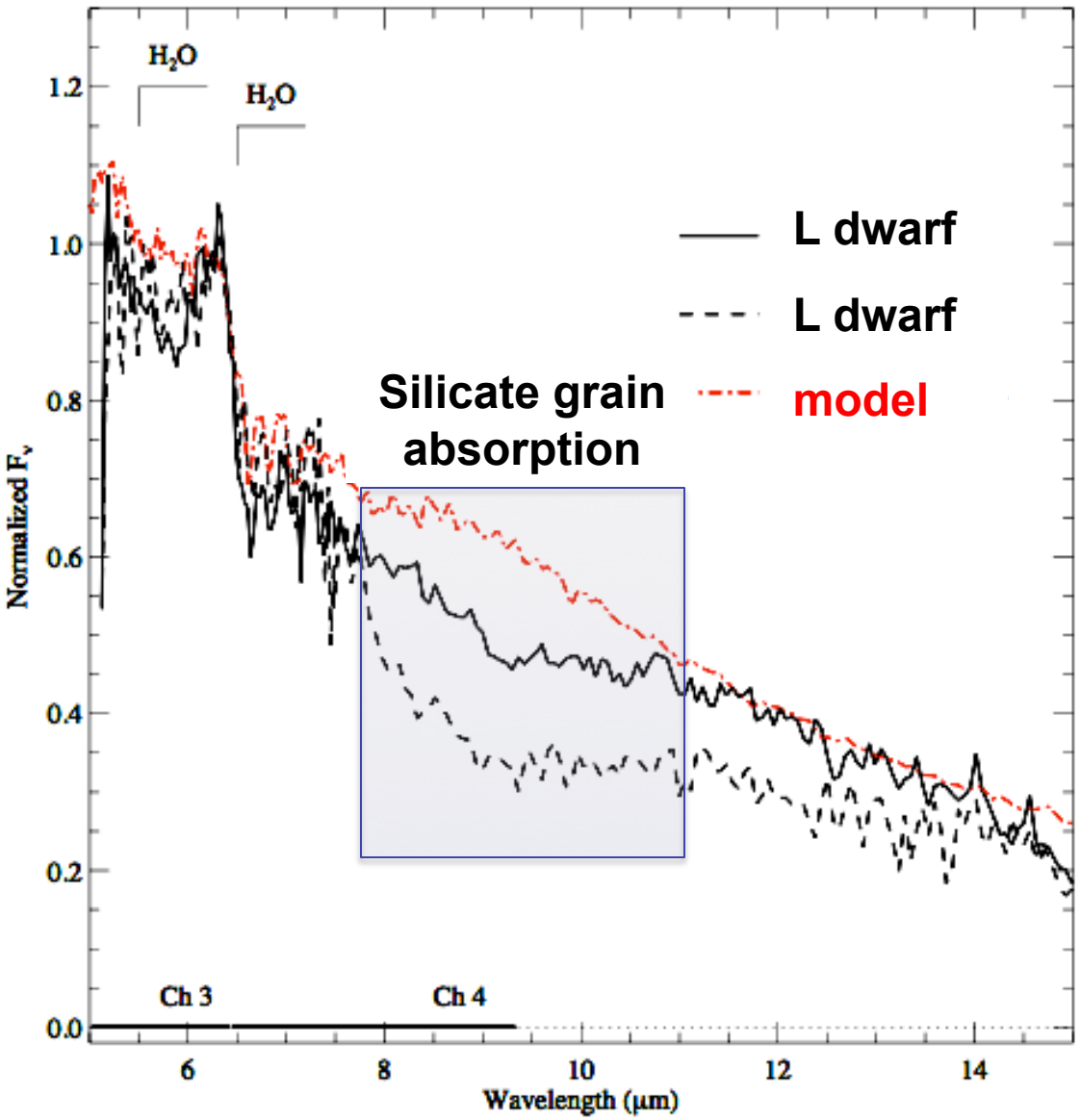
aluminum oxide
(Al_2O_3)

enstatite
($MgSiO_3$)

perovskite
($CaTiO_3$)

forsterite
(Mg_2SiO_4)

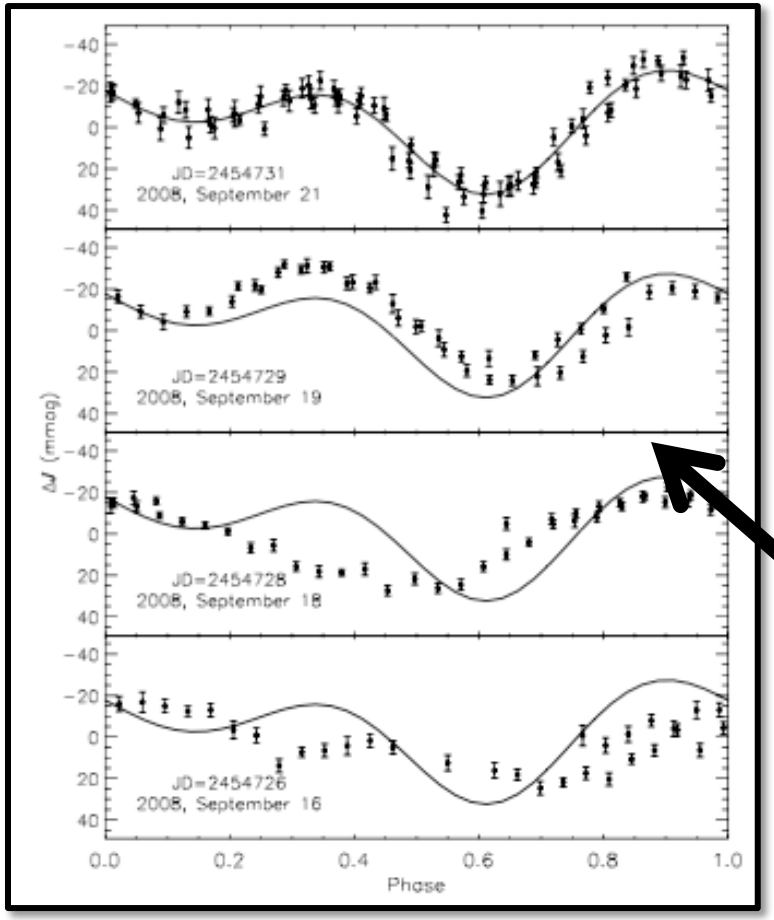
molten iron



Burgasser et al. (2008)

See also Cushing et al. (2006); Looper et al. (2008)

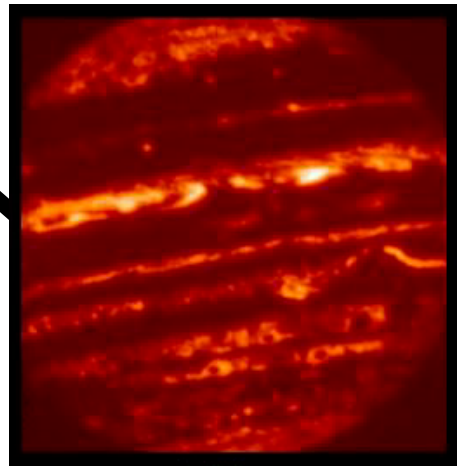
Watching clouds roll by



Artigau et al. (2009)

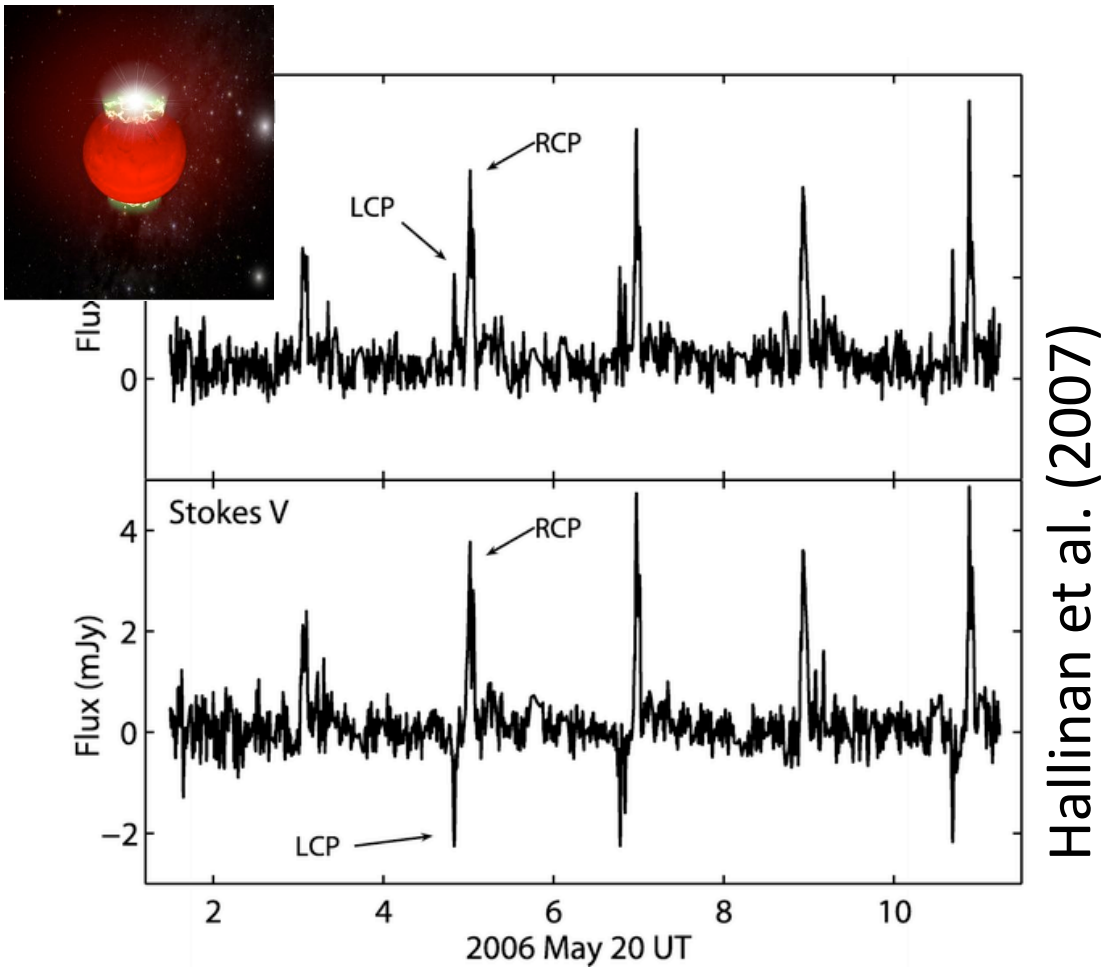
As a brown dwarf rotates, we see distinct changes in their brightness.

Variability itself changes with time – weather?



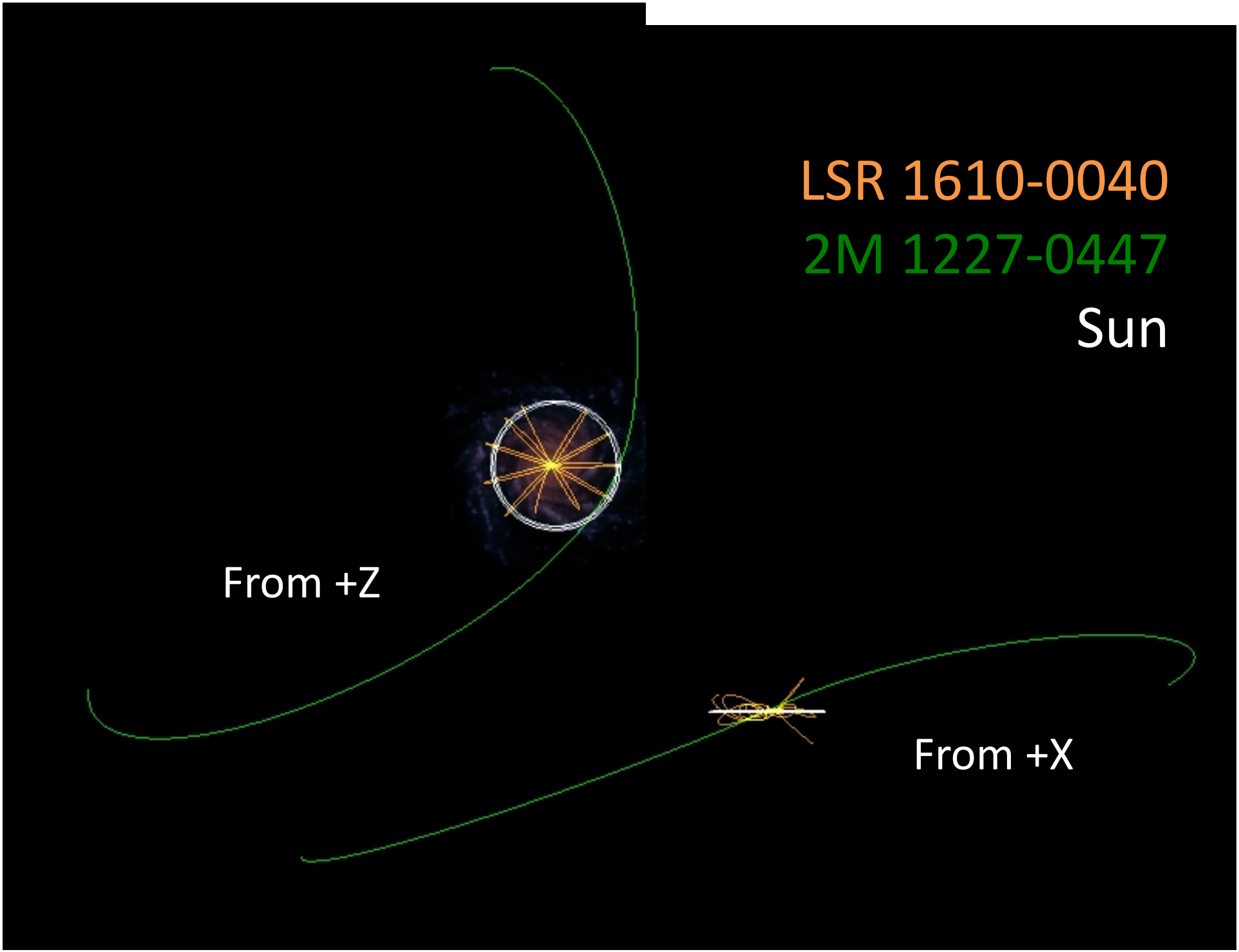
Jupiter at 4.7μm

Brown Dwarfs are Magnetically Active

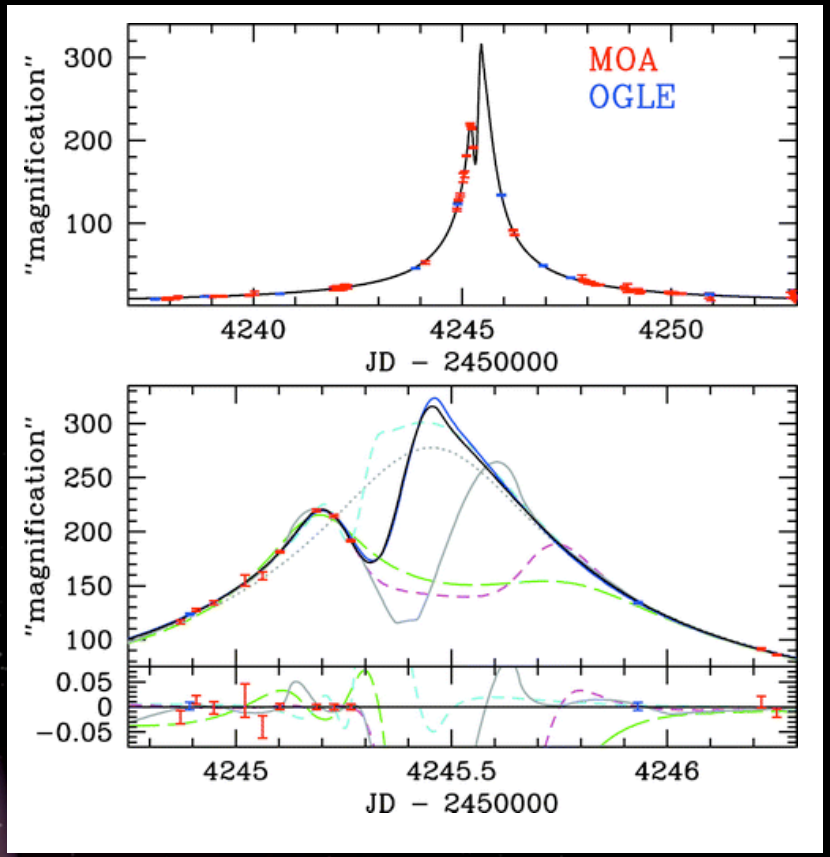


Hallinan et al. (2007)

Optical, X-ray and radio emission observed, including pulsar-like radio bursts

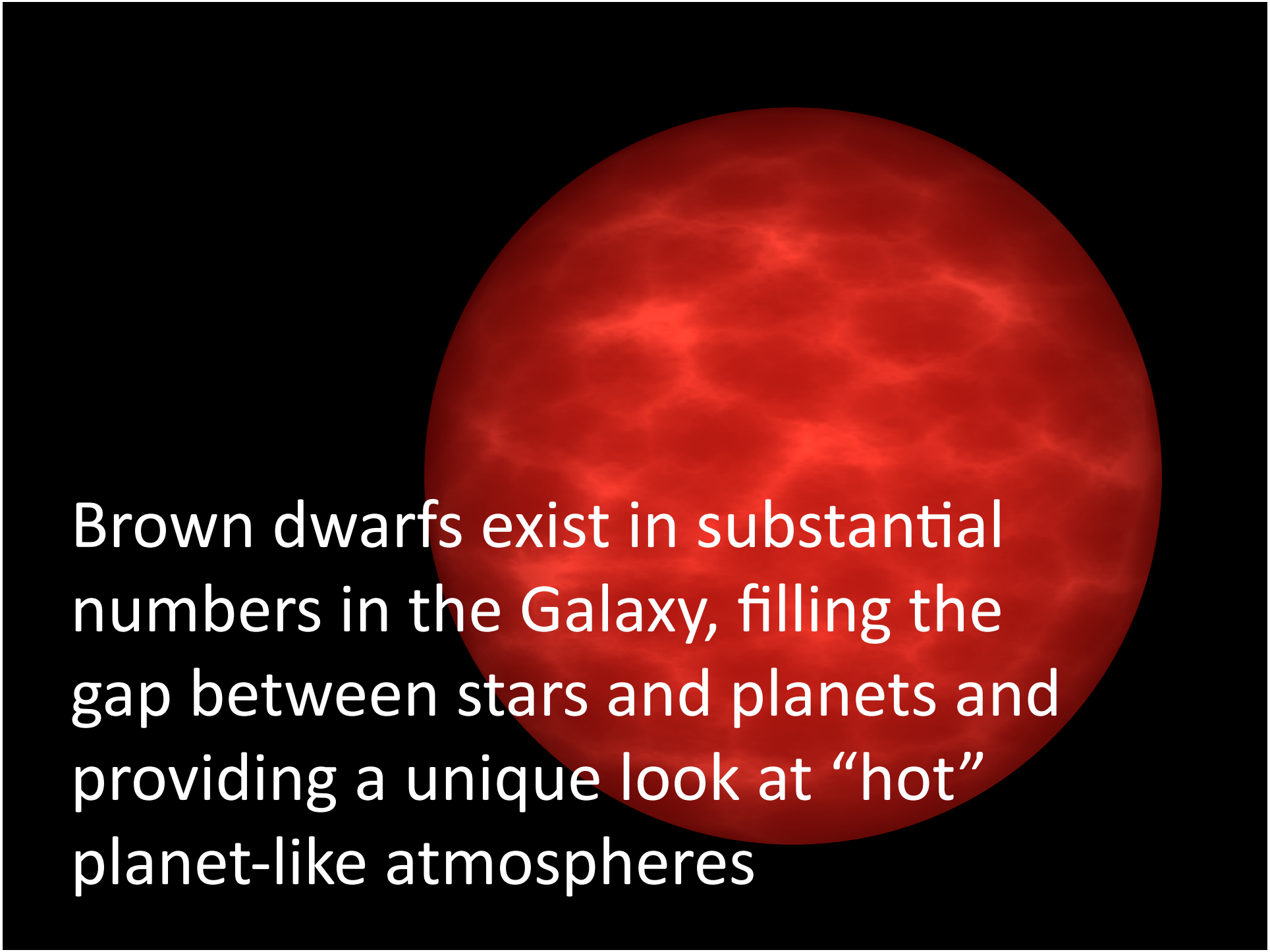

LSR 1610-0040
2M 1227-0447
Sun
From +Z
From +X

Brown dwarf – planet systems



M = 0.06 Solar mass

M = 3.3 Earth mass


Brown dwarfs exist in substantial numbers in the Galaxy, filling the gap between stars and planets and providing a unique look at “hot” planet-like atmospheres