Section 8.
Low mass stars and white dwarfs

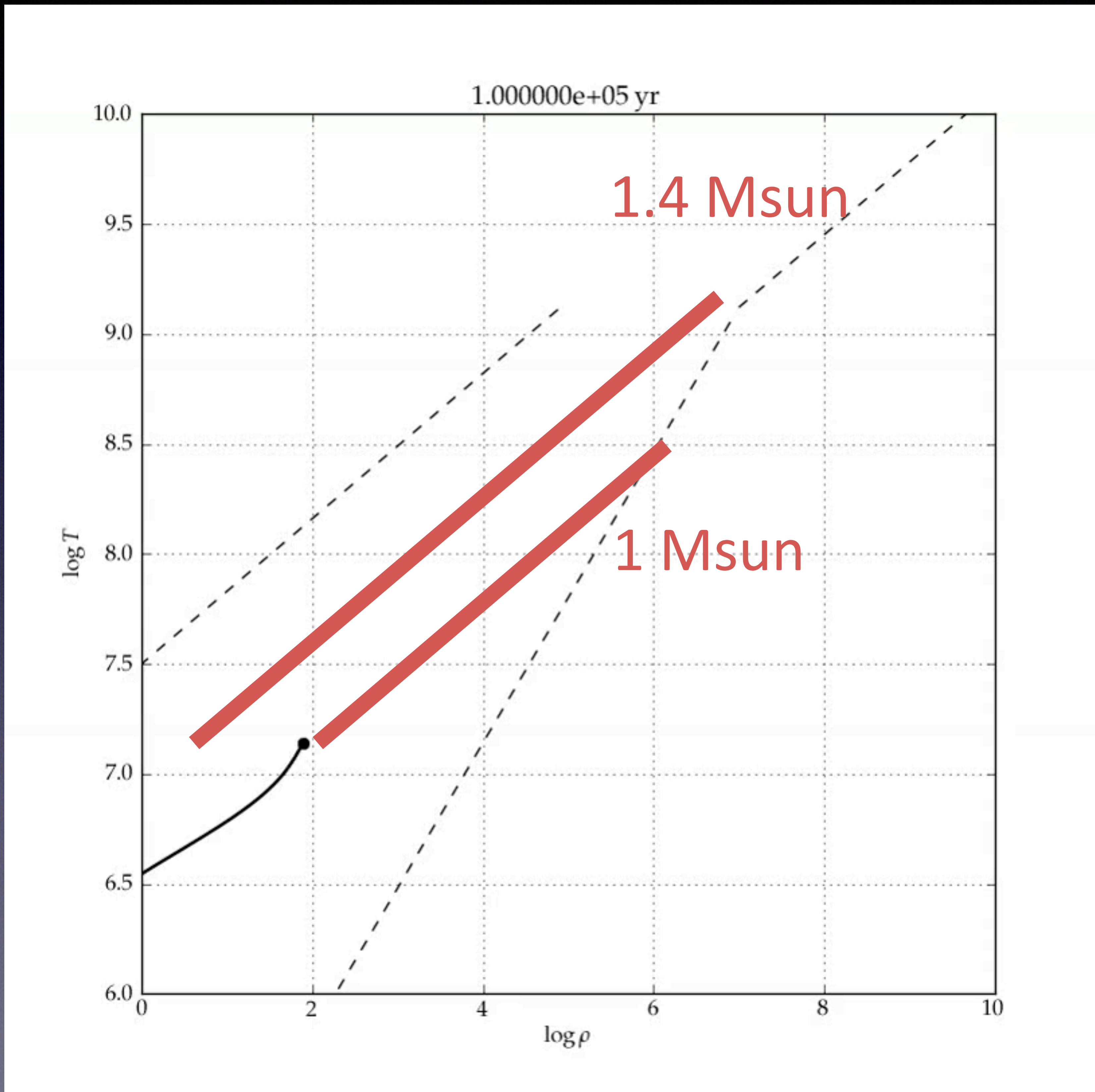
8.1 Evolution of low mass stars

8.2 White dwarfs

Let’s understand these questions with the words of physics

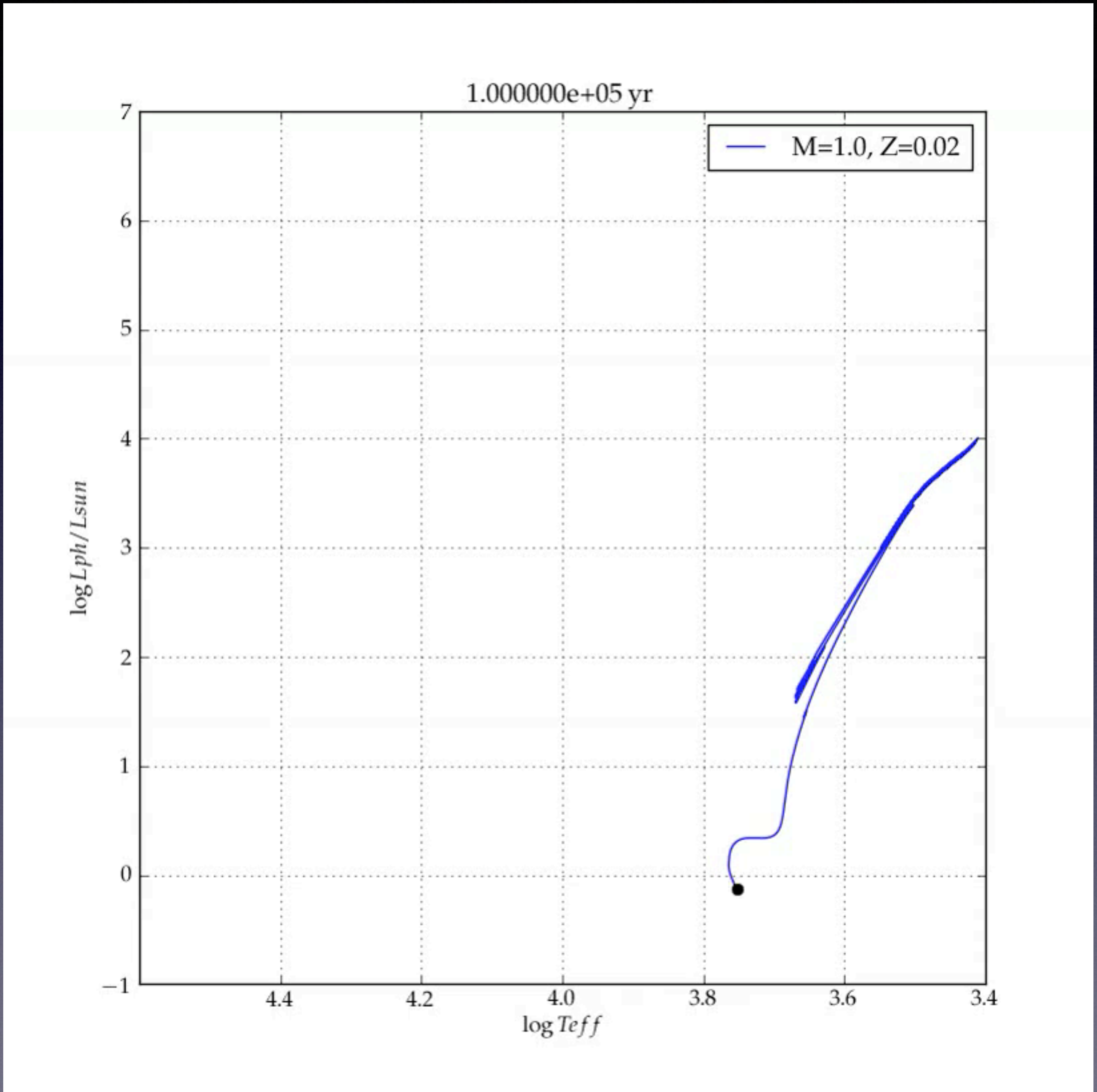
- Why are stars so luminous?
- Why do stars show L ~ M^4?
- Why do stars evolve?
- Why does the destiny of stars depend on the mass?
- Why do some stars explode?
- Why don’t normal star explode?
- Why does stellar core collapses?
- Why is the energy of supernova so huge?
- …

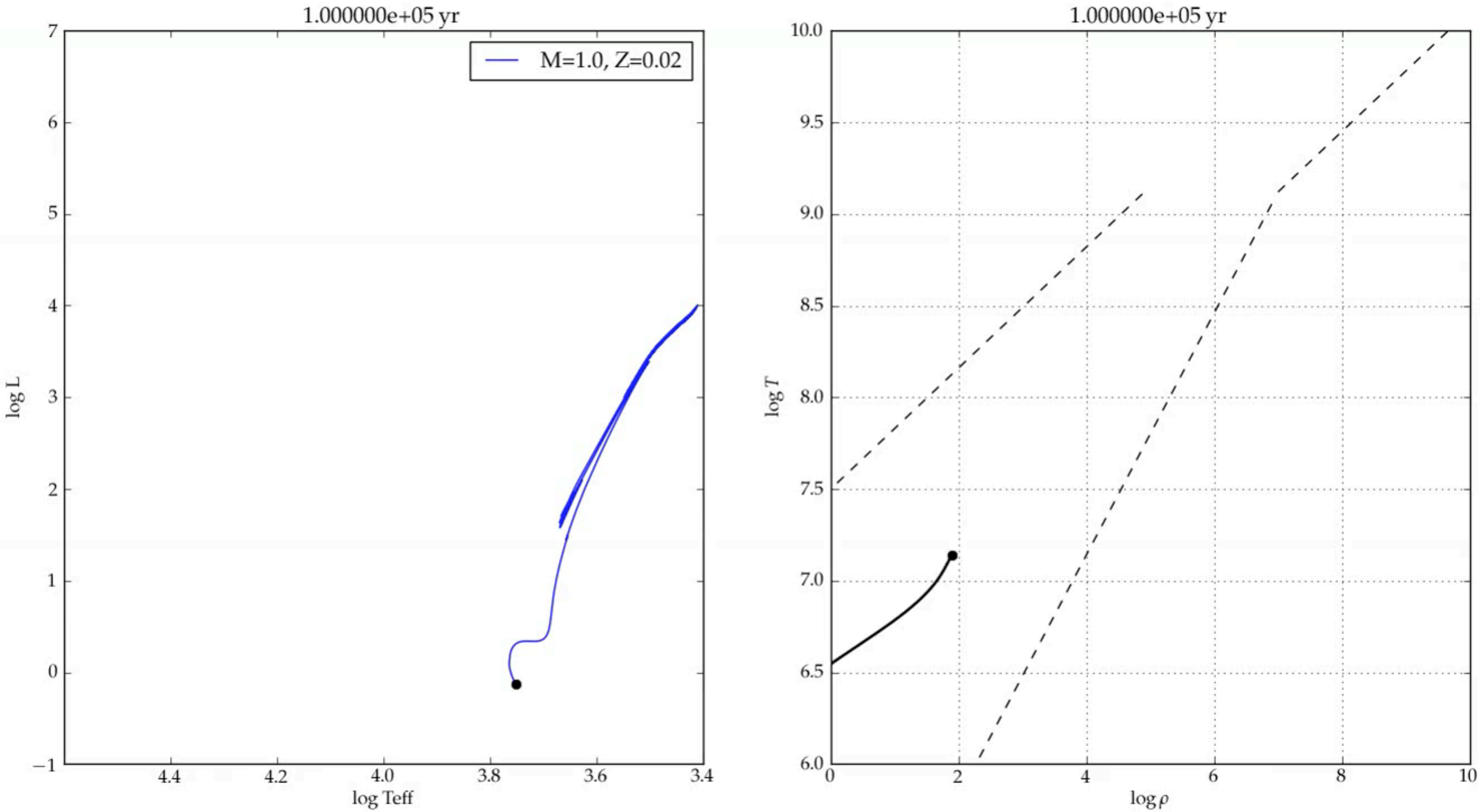
1 Msun (ρ-T)



$T \sim M^{2/3} \rho^{1/3}$

1 Msun (HR diagram)

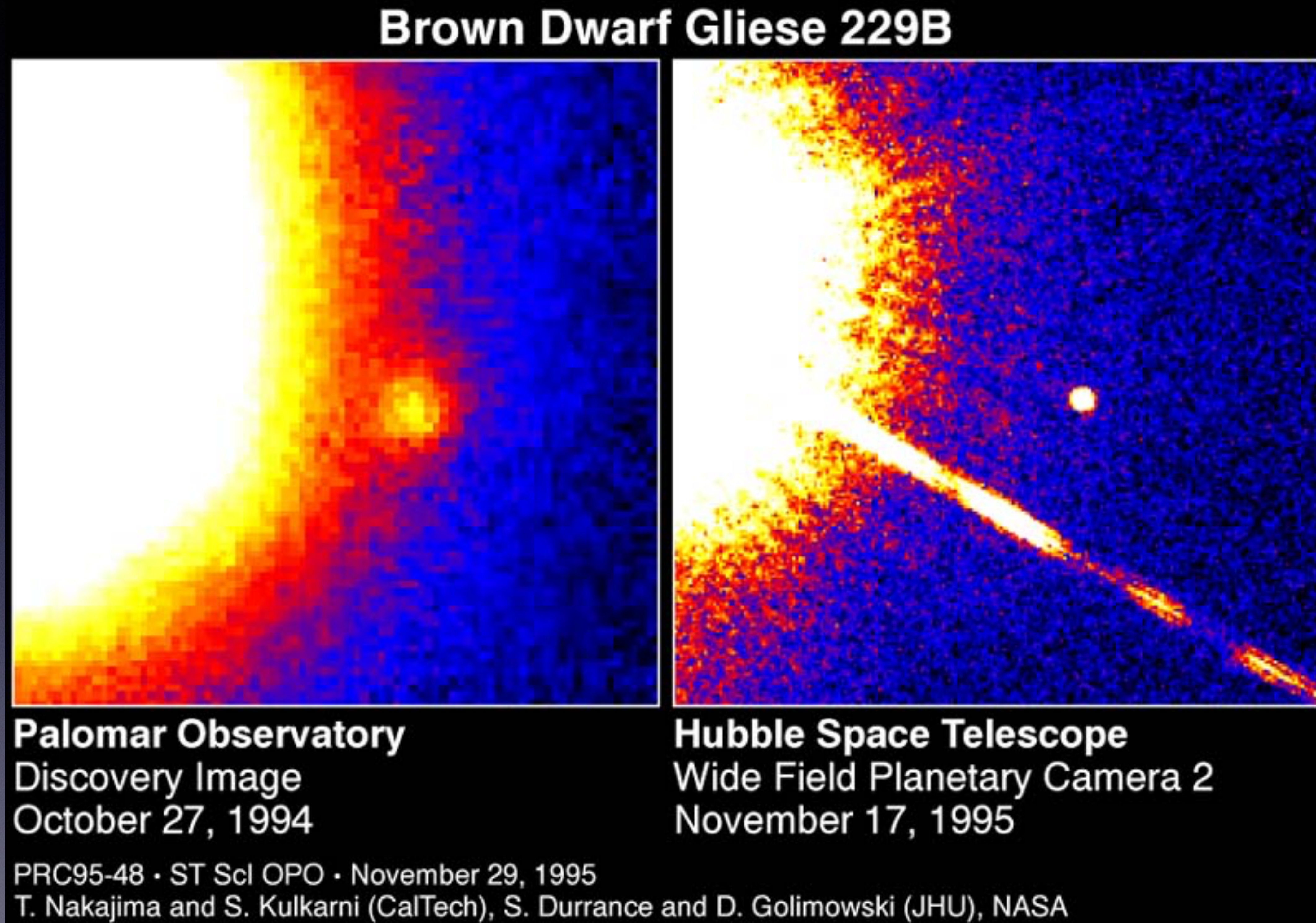


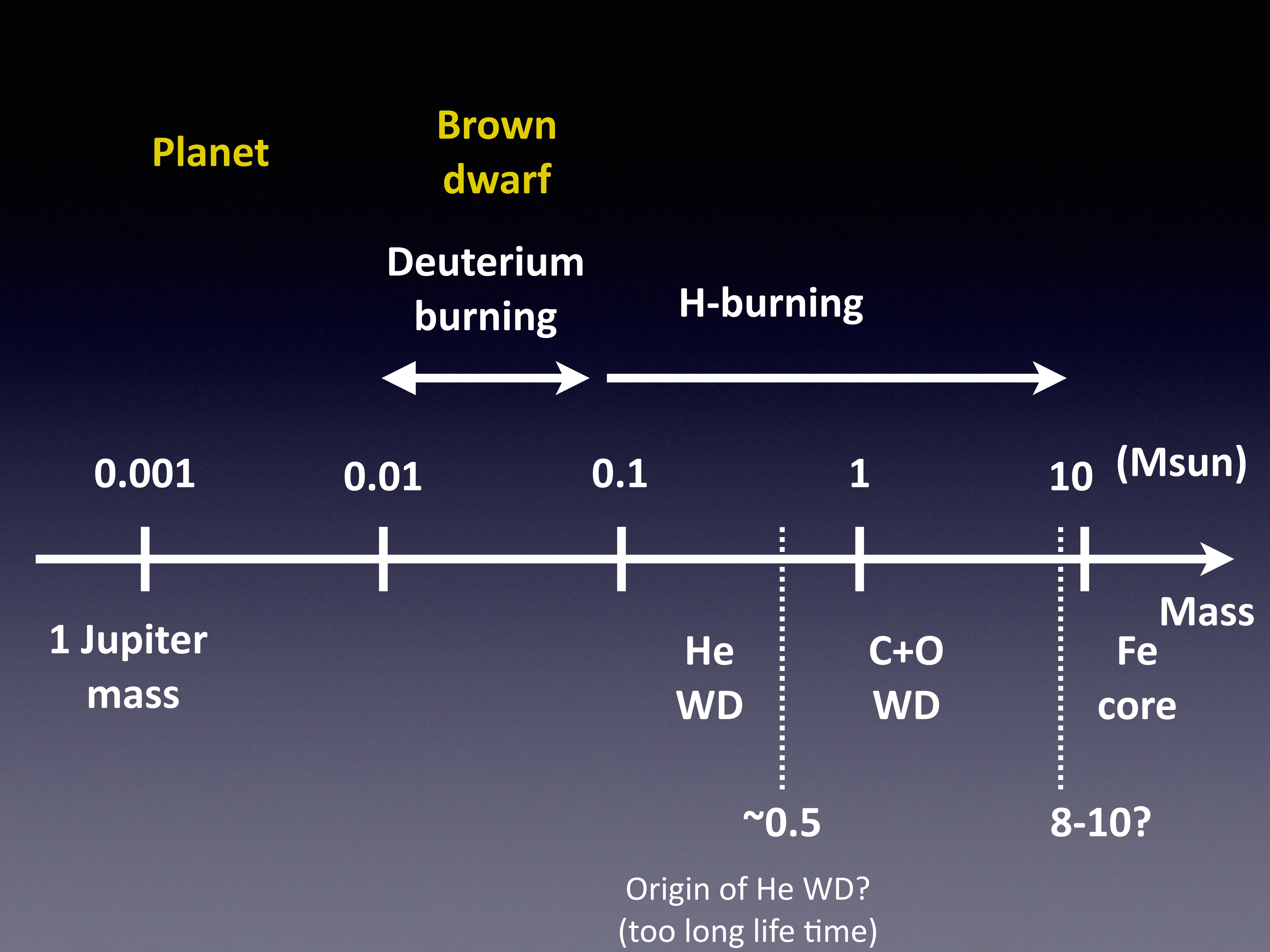

1.000000e+05 yr
M=1.0, Z=0.02
log L
7
6
5
4
3
2
1
0
−1
4.4
4.2
4.0
3.8
3.6
3.4
log Teff
1.000000e+05 yr
log T
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
0
2
4
6
8
10
log ρ

What about lower mass stars?

What is the minimum mass of the stars?

What is the fate of low mass stars?


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



Planet
Brown dwarf
Deuterium burning
H-burning
0.001
0.01
0.1
1
10
(Msun)
Mass
1 Jupiter mass
He WD
C+O WD
Fe core
~0.5
8-10?
Origin of He WD?
(too long life time)

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https://kids.yahoo.co.jp/zukan/astro/winter/0001.html

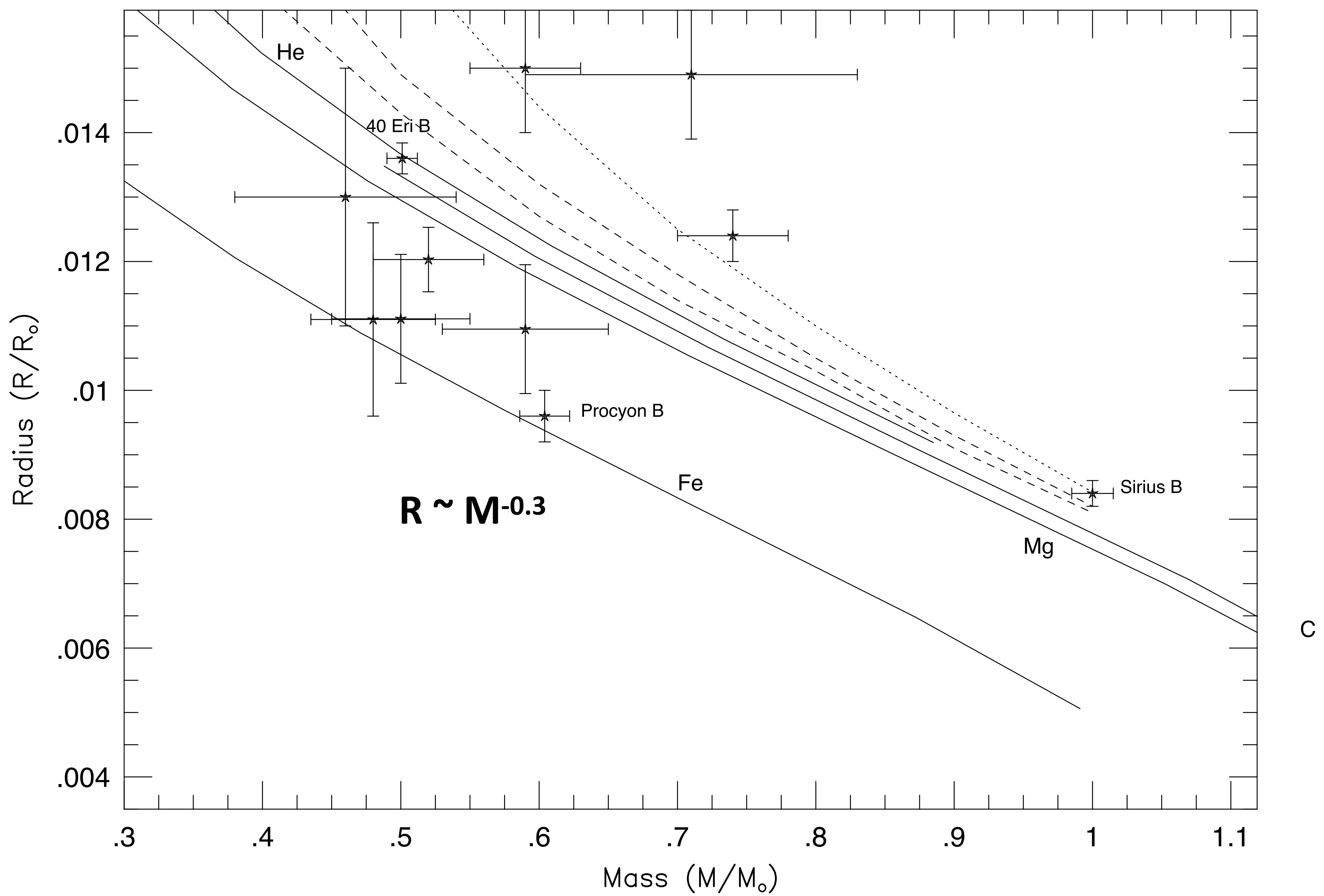
Cat’s eye nebula

(J.P. Harrington and K.J. Borkowski, and NASA)

Helix nebula

(NASA, ESA, and C.R. O'Dell)

Mass-radius relation for white dwarfs



Provencal et al. 1998

More massive white dwarfs are smaller
Opposite to the main sequence stars

Why??

Assignment 3 / レポート課題 3

Typical mass scale in the Universe can be expressed by fundamental constants.
Under a simple one-zone approximation,
show the following two relations and calculate the masses.

(3a) the lowest mass for main sequence mass

$M \sim O(1) \times (m_p/m_e)^{3/4} (\alpha/\alpha_G)^{3/2} m_p$

(3b) Chandrasekhar mass

$M \sim O(1) \times \alpha_G^{-3/2} m_p$

宇宙に存在する天体の質量スケールは物理定数で表すことができる。
One-zone近似のもとで、以下の関係を示し、質量を計算せよ。

(3a) 核融合が起こる星の最小質量

$M \sim O(1) \times (m_p/m_e)^{3/4} (\alpha/\alpha_G)^{3/2} m_p$

(3b) チャンドラセカール質量

$M \sim O(1) \times \alpha_G^{-3/2} m_p$

Summary: Low mass stars and white dwarfs

- **Low mass stars**
  - Maximum temperature to reach
  - M < 0.08 Msun: cannot reach H burning => brown dwarfs
- **White dwarfs**
  - Supported by electron degeneracy pressure
    => Stellar equations become independent on temperature
  - More massive stars have smaller radius
    $R \sim M^{-1/3}$ (non-relativistic)
  - Limit of relativistic electrons
    M = constant (Chandrasekhar limit) ~ 1.4 Msun