Lecture 19 – 7th April 2009

HOMEWORK 7:
due this evening, 11:59pm
TEST 03: This Thursday

- **SCIENCE TOPICS**:
  Classifying the Stars (cont.)
  Stellar Evolution
- **READING**
  Ch 10, sec 10.2 – 10.5
  Ch 12, sec 12.1 – 12.4
  Beware of excessive detail
- **PRACTICE: Ch 12**
  Review: 1-3, 7-9, 11
  Self-test: 2, 3, 6, 9, 10, 12, 13
  Problems: none

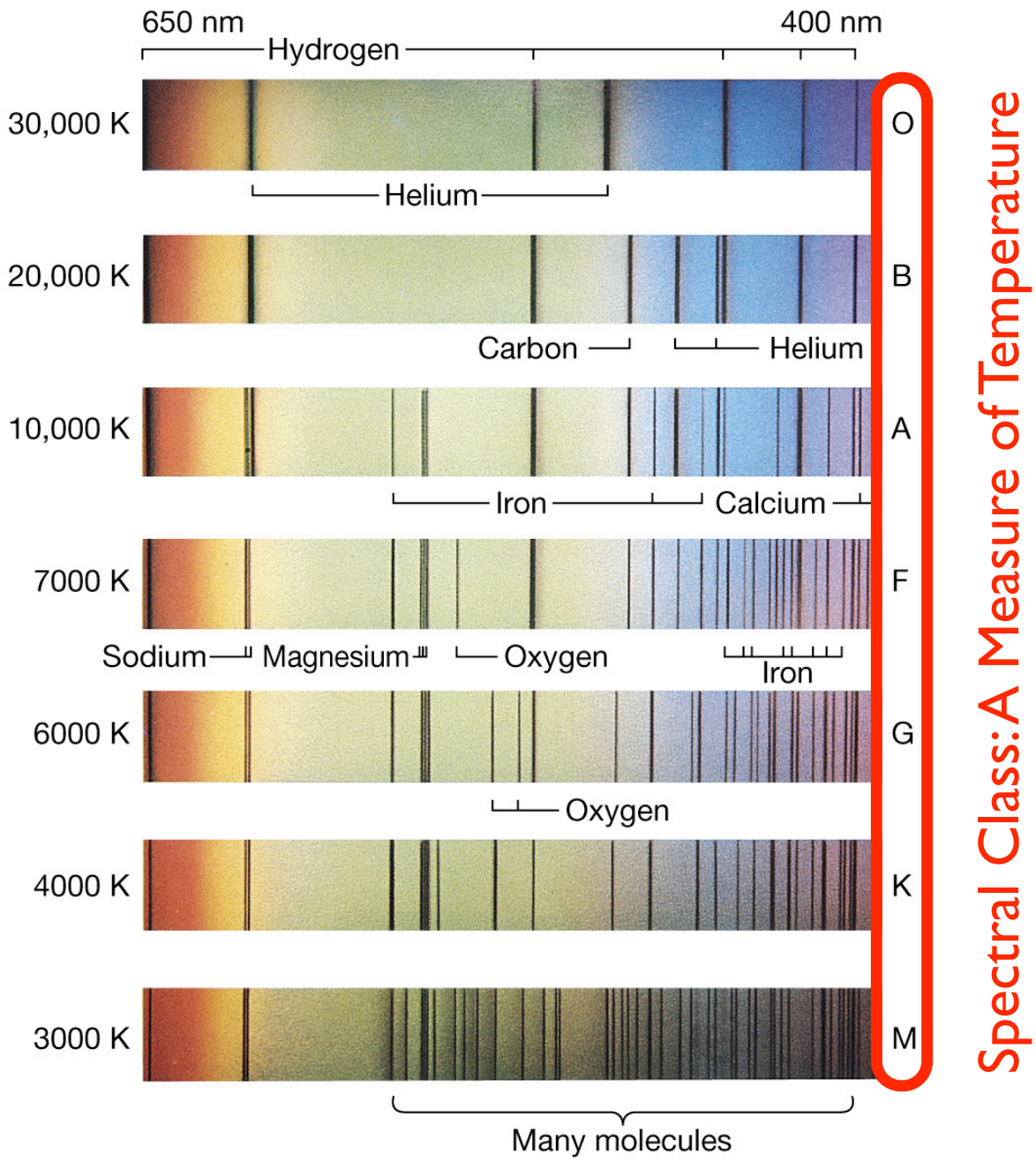
Annoucements

- Test 03
  - This ***Thursday***, 9th April 2009.
  - Lecture 12 (2nd half) to Lecture 19 (1st half)
  - Topics:
    - Inner and Outer Planets Close Up (Moons and tides)
    - Formation of the Solar System
    - Exoplanets
    - The Sun and how it shines, $E=mc^2$
    - Stars: Properties, Classification and H-R diagram

Test Prep

- Powerpoint slides, Class notes and the notes on the course website.
- Homeworks (05, 06 and 07) - know why you got questions wrong.
- Does reading over the notes, really mean you know something? Does reading over the notes really mean you ***understand*** something? "Explain the formation of the Solar System to your roommate..."
- RTQ
- 26 / 40 = 65 % = *guaranteed* 'C' grade.

Measuring the Stars II: The *Hertzsprung-Russell* diagram


650 nm
400 nm
Hydrogen
30,000 K
O
Helium
20,000 K
B
Carbon
Helium
10,000 K
A
Iron
Calcium
7000 K
F
Sodium
Magnesium
Oxygen
Iron
6000 K
G
Oxygen
4000 K
K
3000 K
M
Many molecules
Spectral Class: A Measure of Temperature

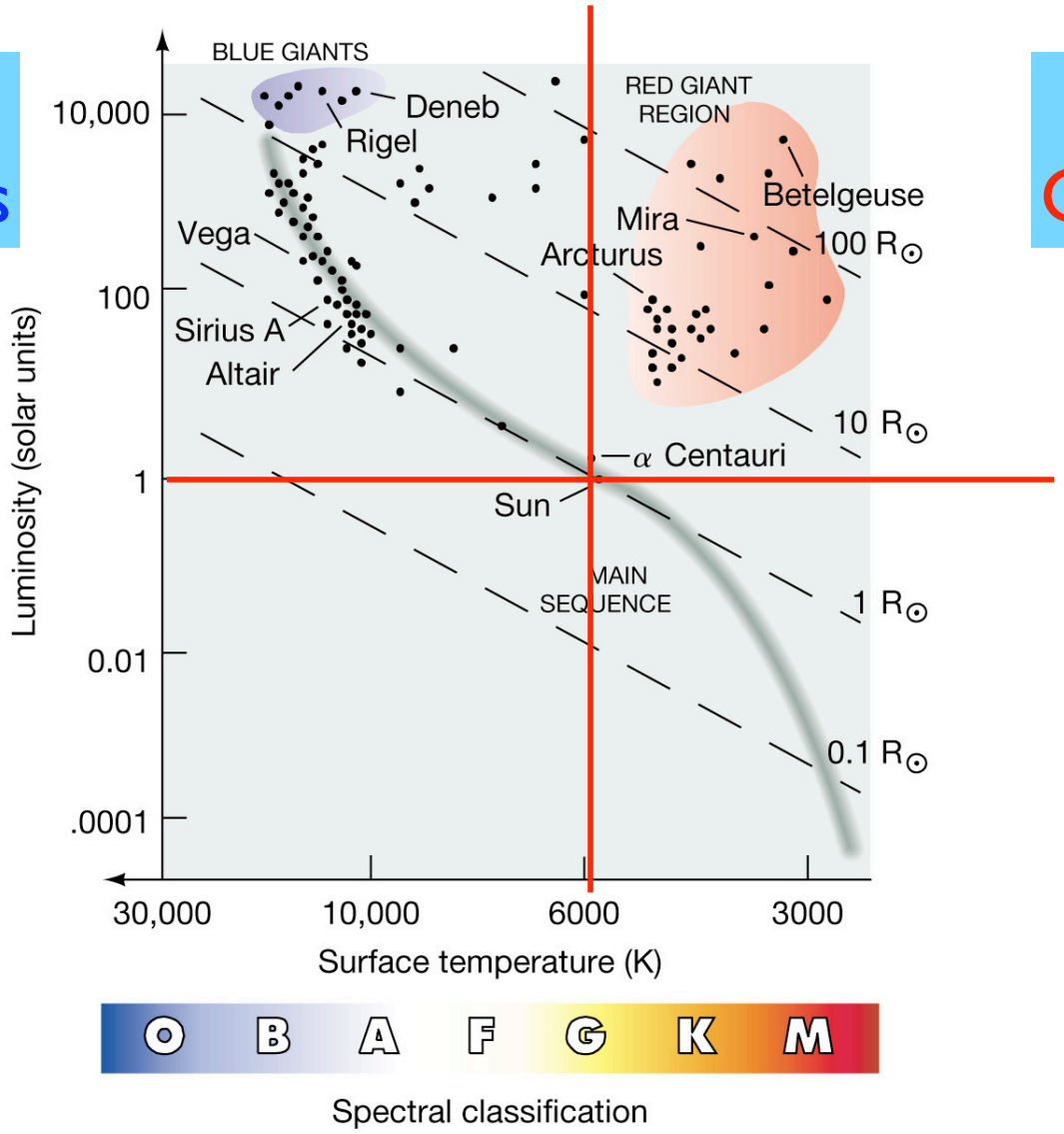
$L = 4 \pi R^2 \sigma T^4$

- L, Luminosity (Power; measured in Watts)
- $4\pi = 12.566$
- R, Radius (for stars, usually in km)
- $\sigma = 5.67 \times 10^{-8}$ W / m^2 / K^4
- T, Temperature

The H-R diagram

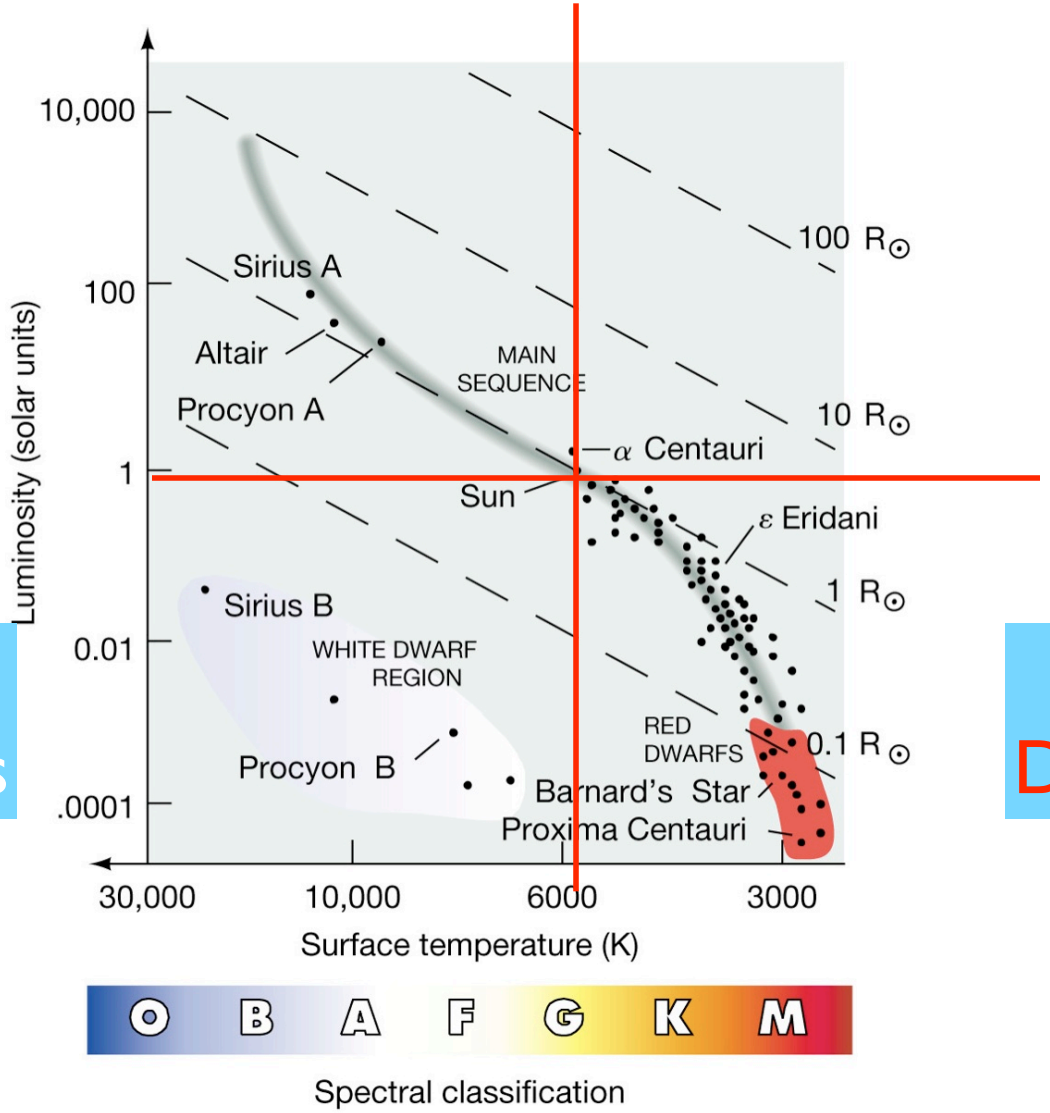
Blue Giants

Red Giants



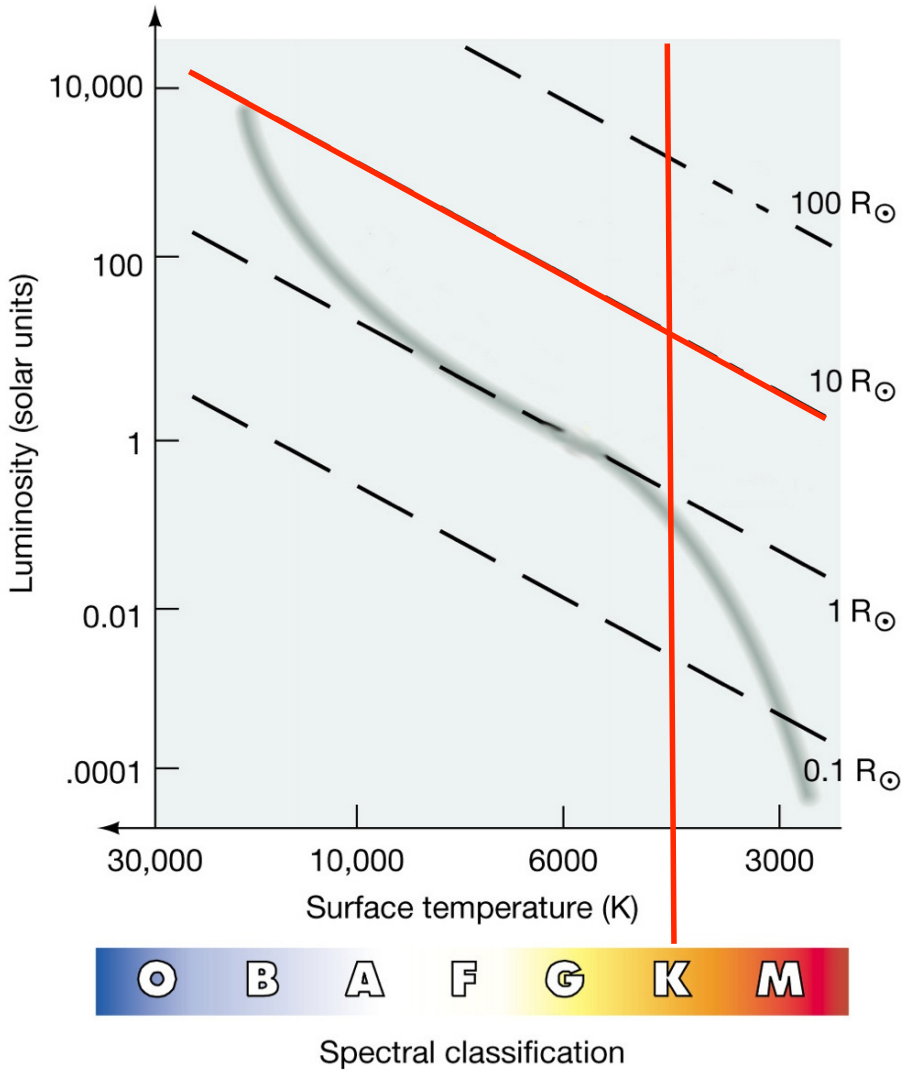
The H-R diagram

White Dwarfs

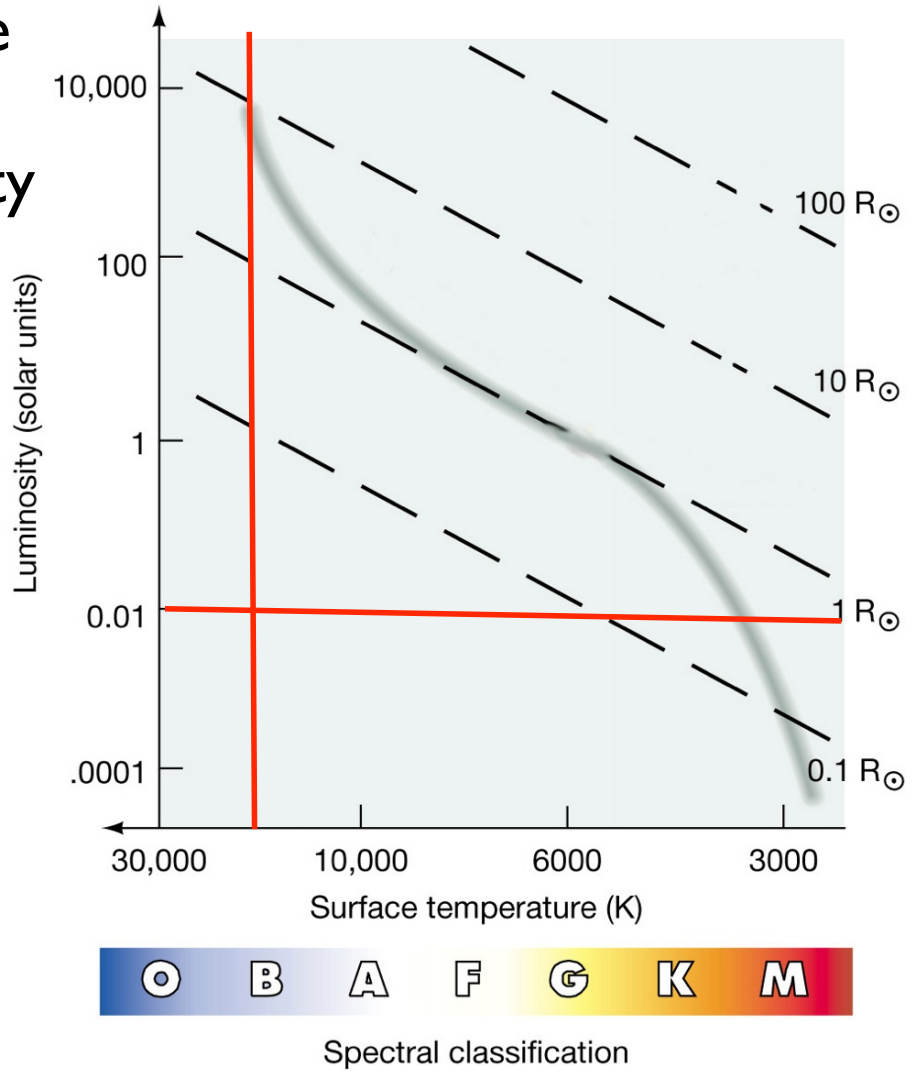


Red Dwarfs

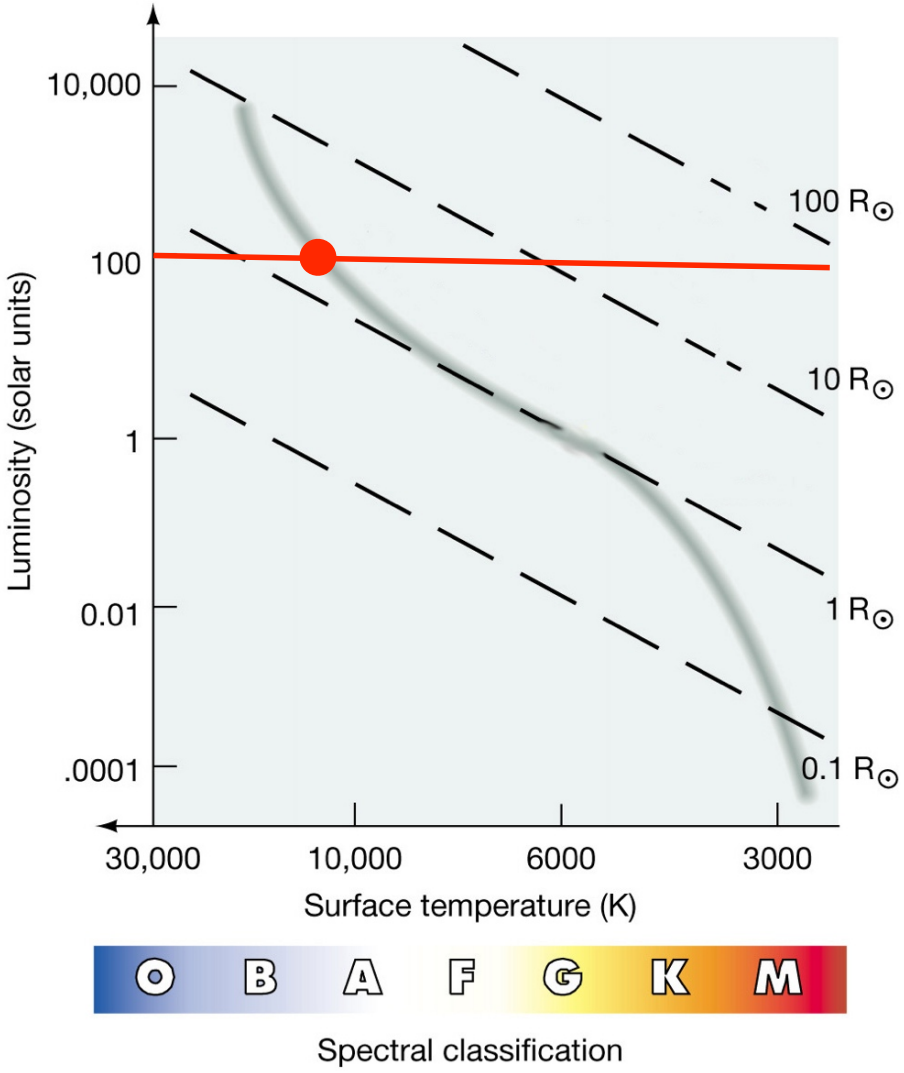
- where do we place a K giant with a radius of 10 $R_\odot$?



- where do we place a white dwarf with a temperature of 20,000K and a luminosity of 0.01 $L_\odot$?



- where do we place a main sequence star with a luminosity of 100 $L_\odot$?



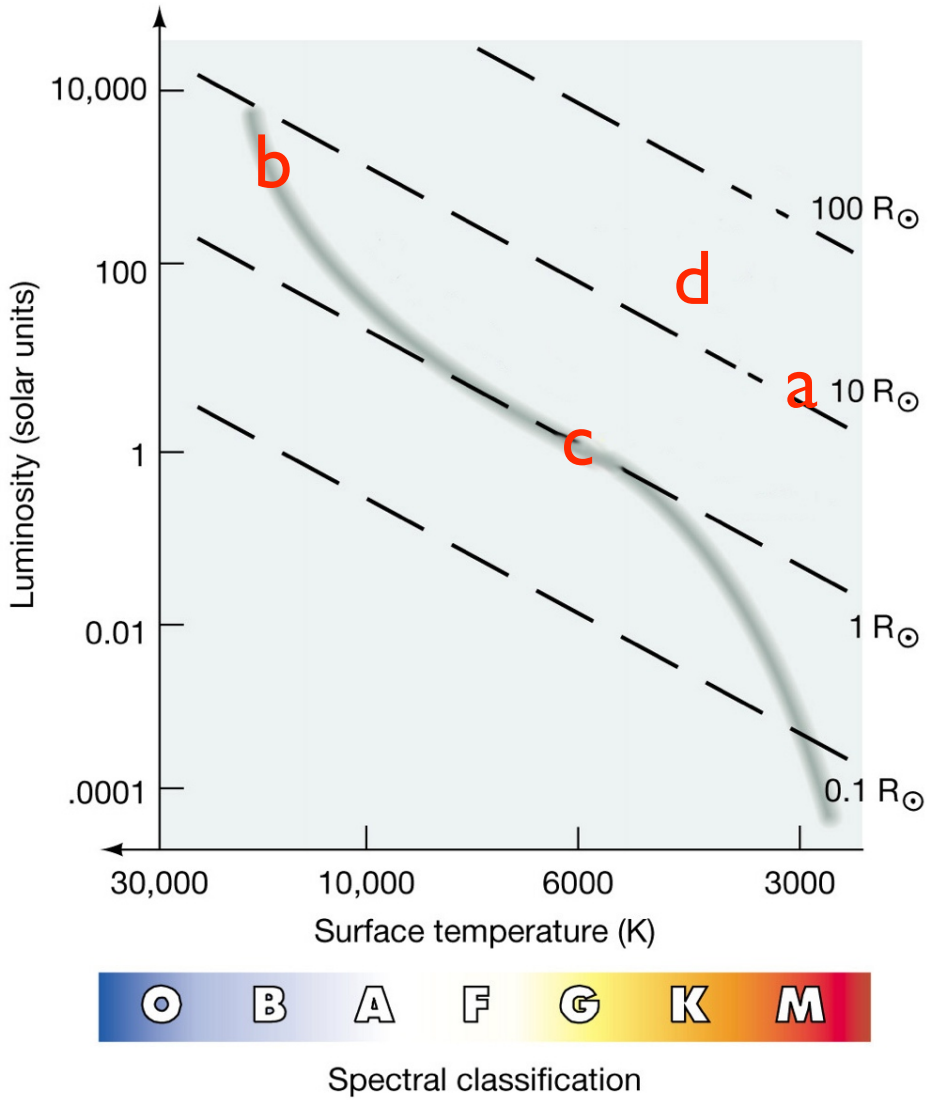
Which of the following stars is the most luminous?

a. An M giant with a radius of 10 $R_\odot$

b. A 20,000 K main sequence star

c. The Sun

d. A 100 $L_\odot$ K giant



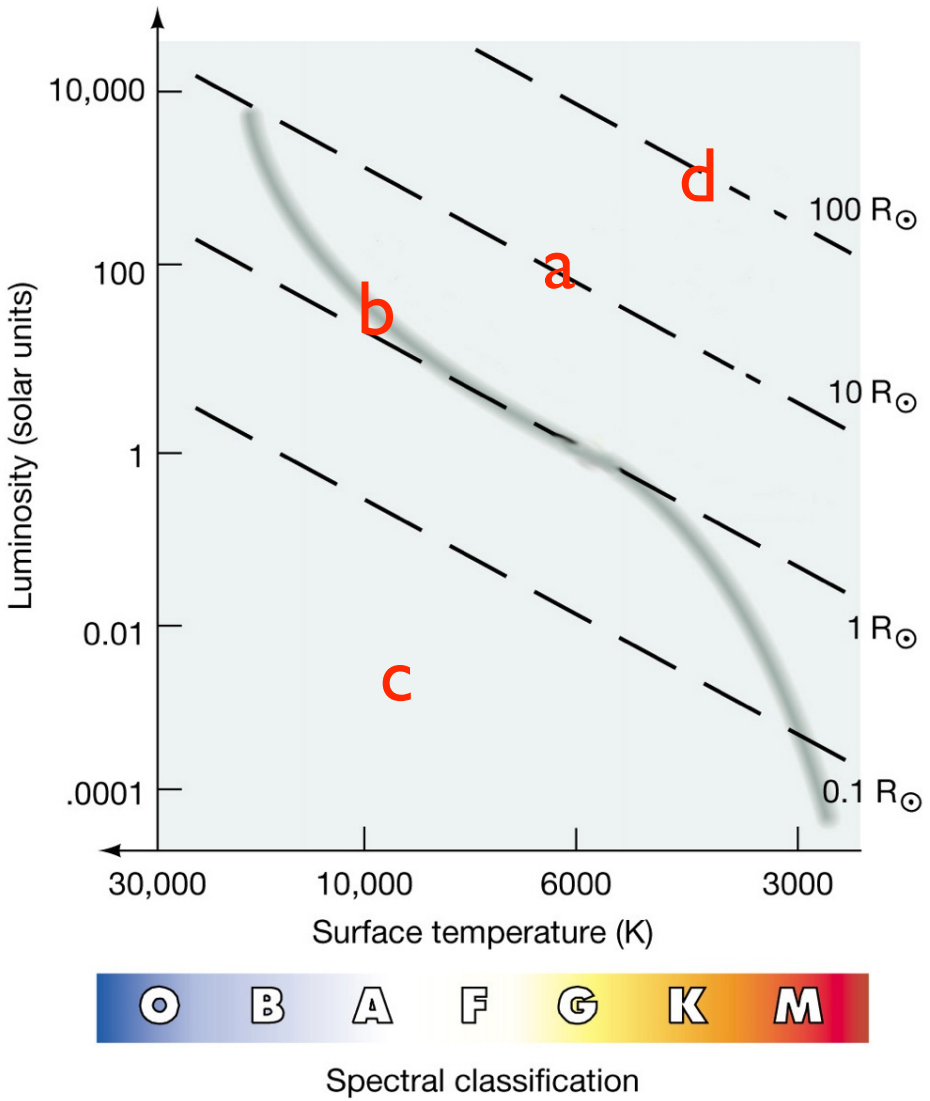
Which of the following stars is the largest?

a. A G giant with a radius of 10 $R_\odot$

b. A main sequence A star

c. A white dwarf

d. A 1,000 $L_\odot$ K giant



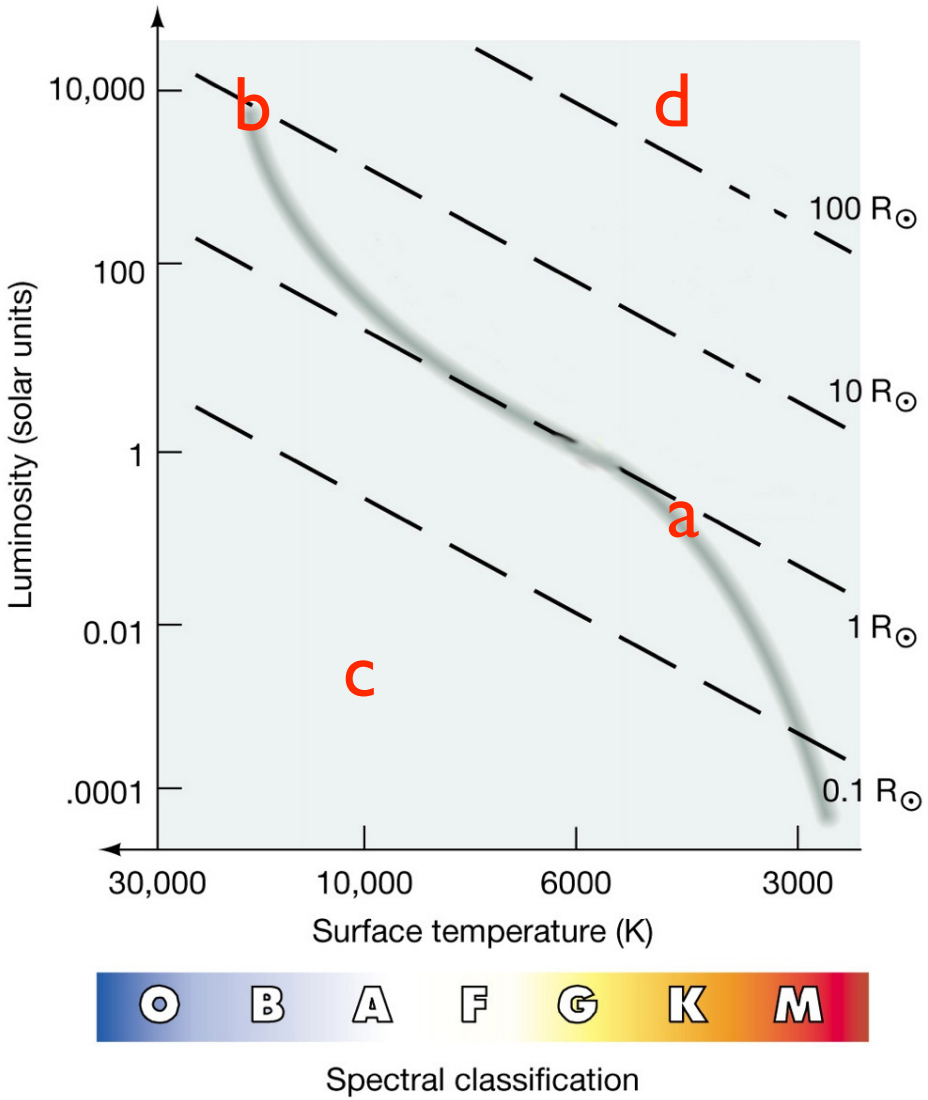
Which of the following stars is the hottest?

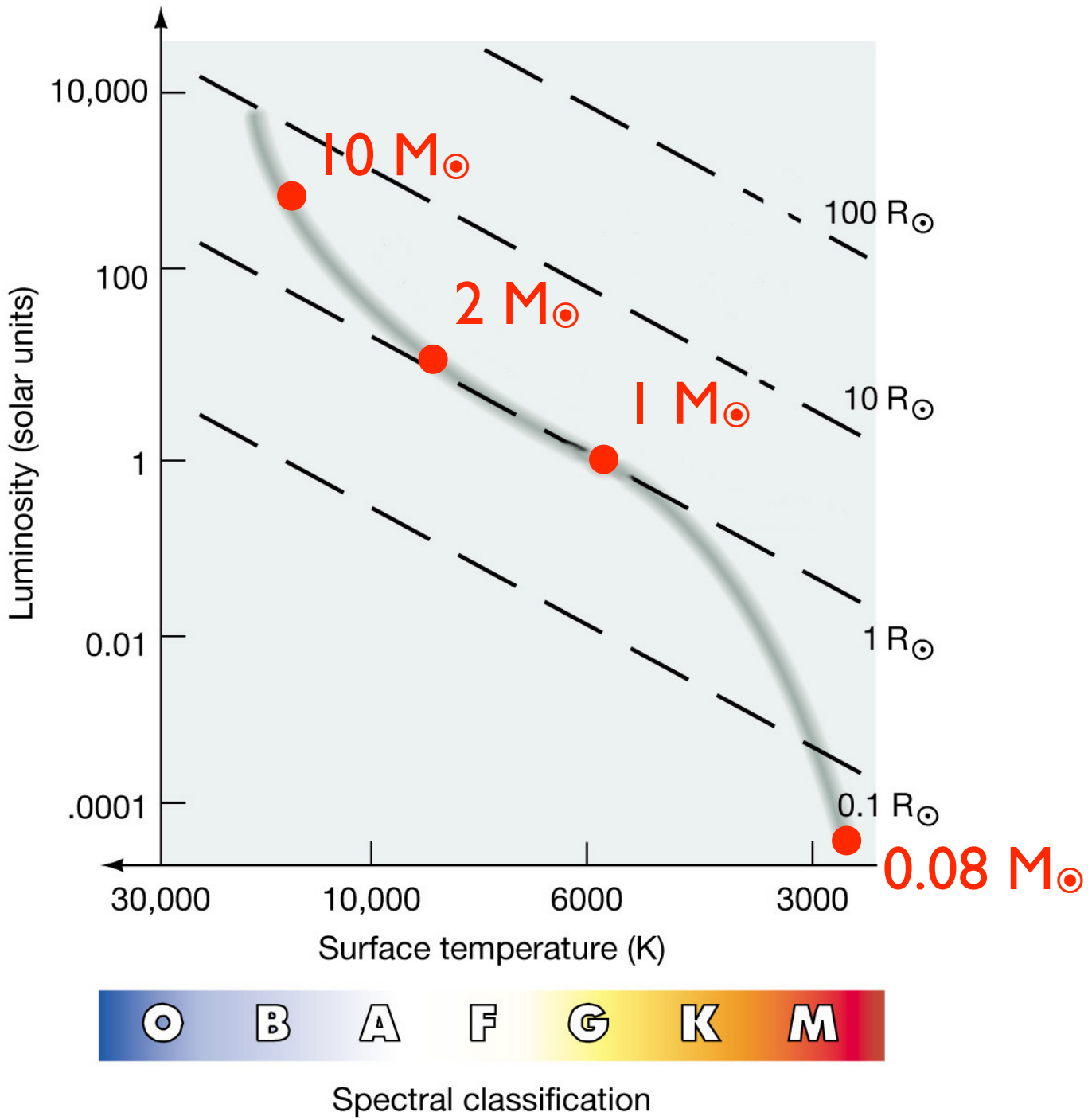
a. A main sequence K star

b. A main sequence star with a radius of 10 $R_\odot$

c. A 10,000 K white dwarf

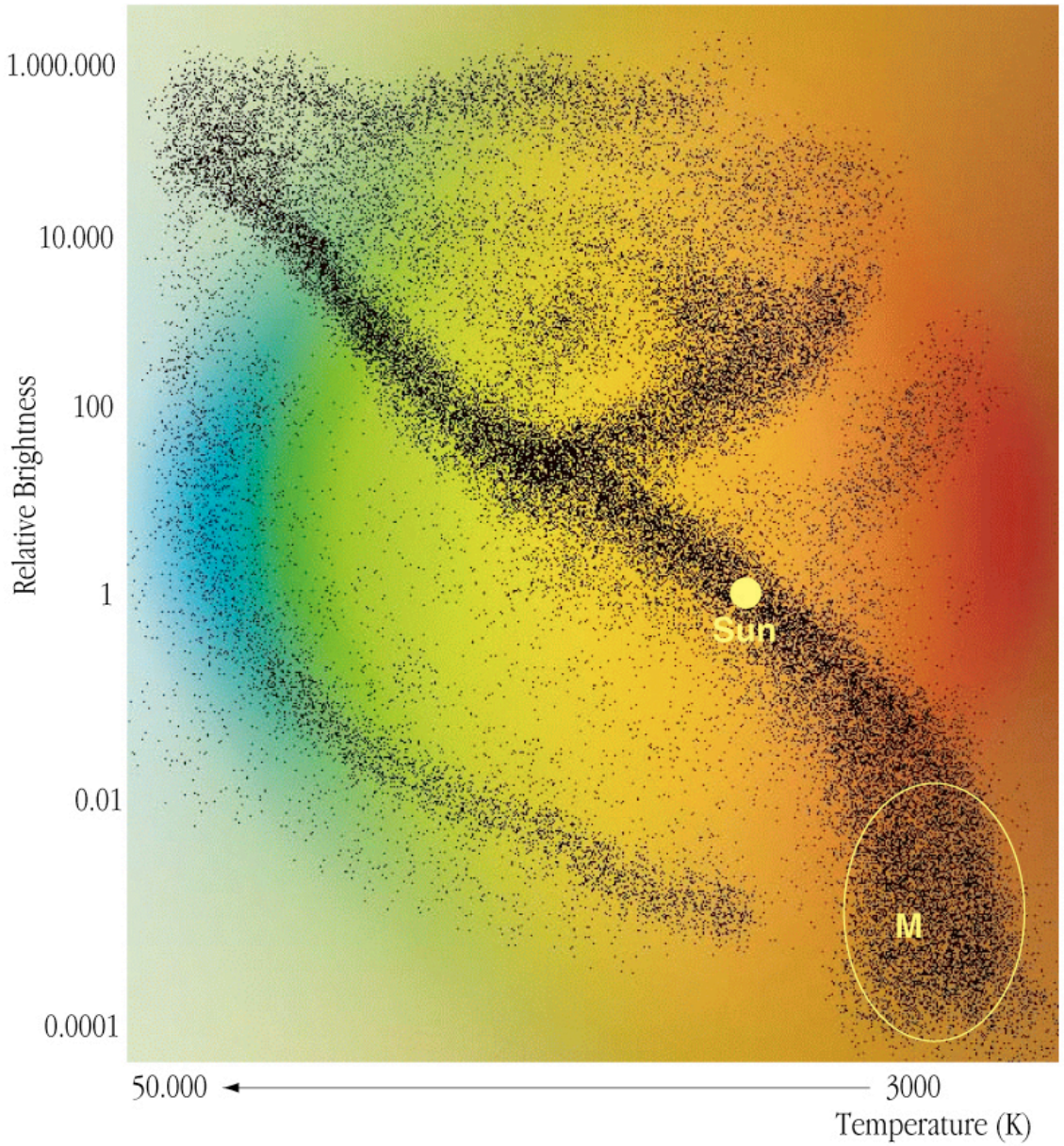
d. A 10,000 $L_\odot$ K giant




10,000
100
1
0.01
.0001
Luminosity (solar units)
10 M⊙
2 M⊙
1 M⊙
0.08 M⊙
100 R⊙
10 R⊙
1 R⊙
0.1 R⊙
30,000
10,000
6000
3000
Surface temperature (K)
O
B
A
F
G
K
M
Spectral classification

END OF MATERIAL FOR TEST 03

Stellar Evolution I: Evolution of a Solar-Type Star

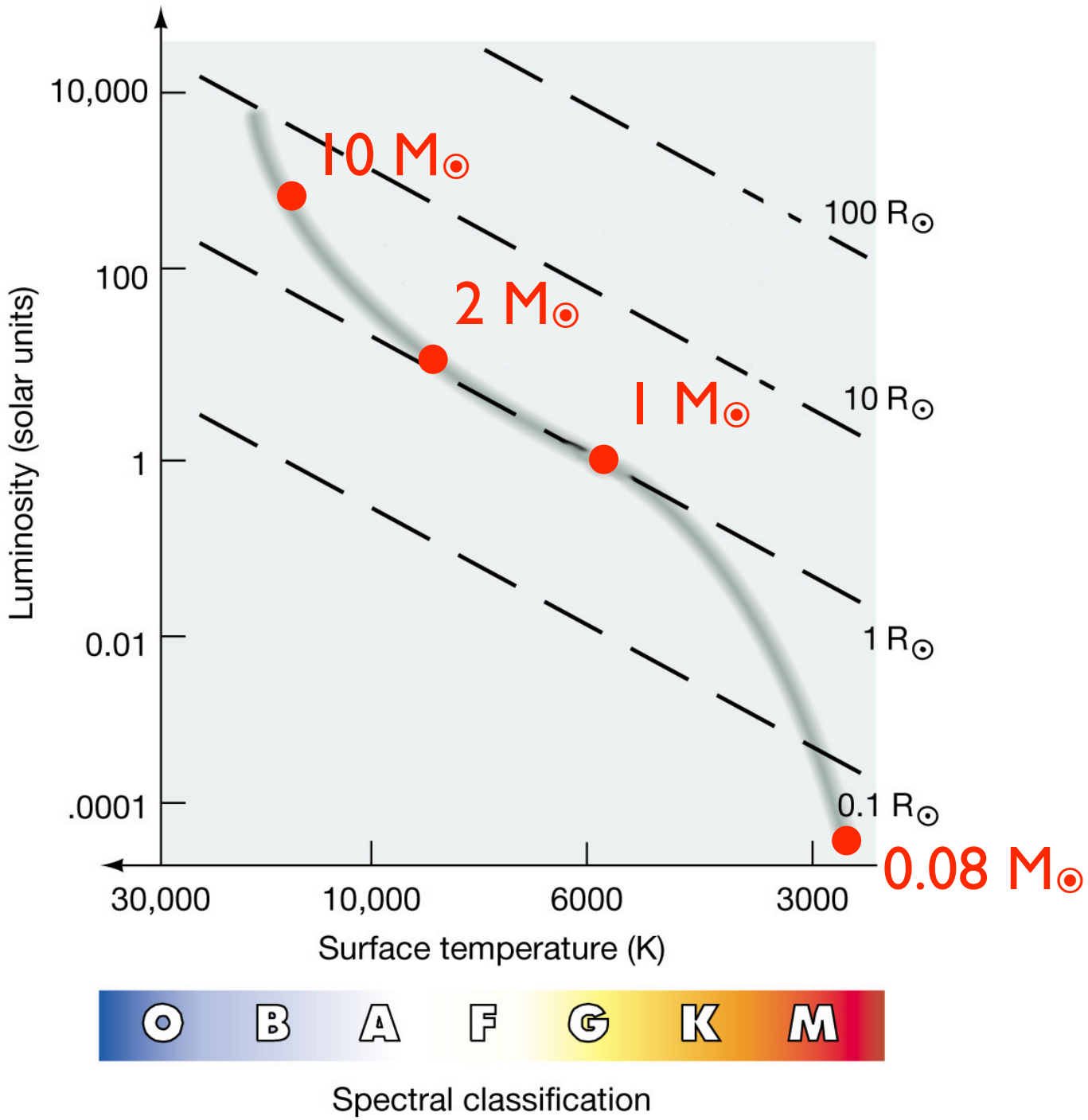


The "Hertzsprung-Russell" Diagram of Stars

ESO PR Photo 27b/02 (29 November 2002)

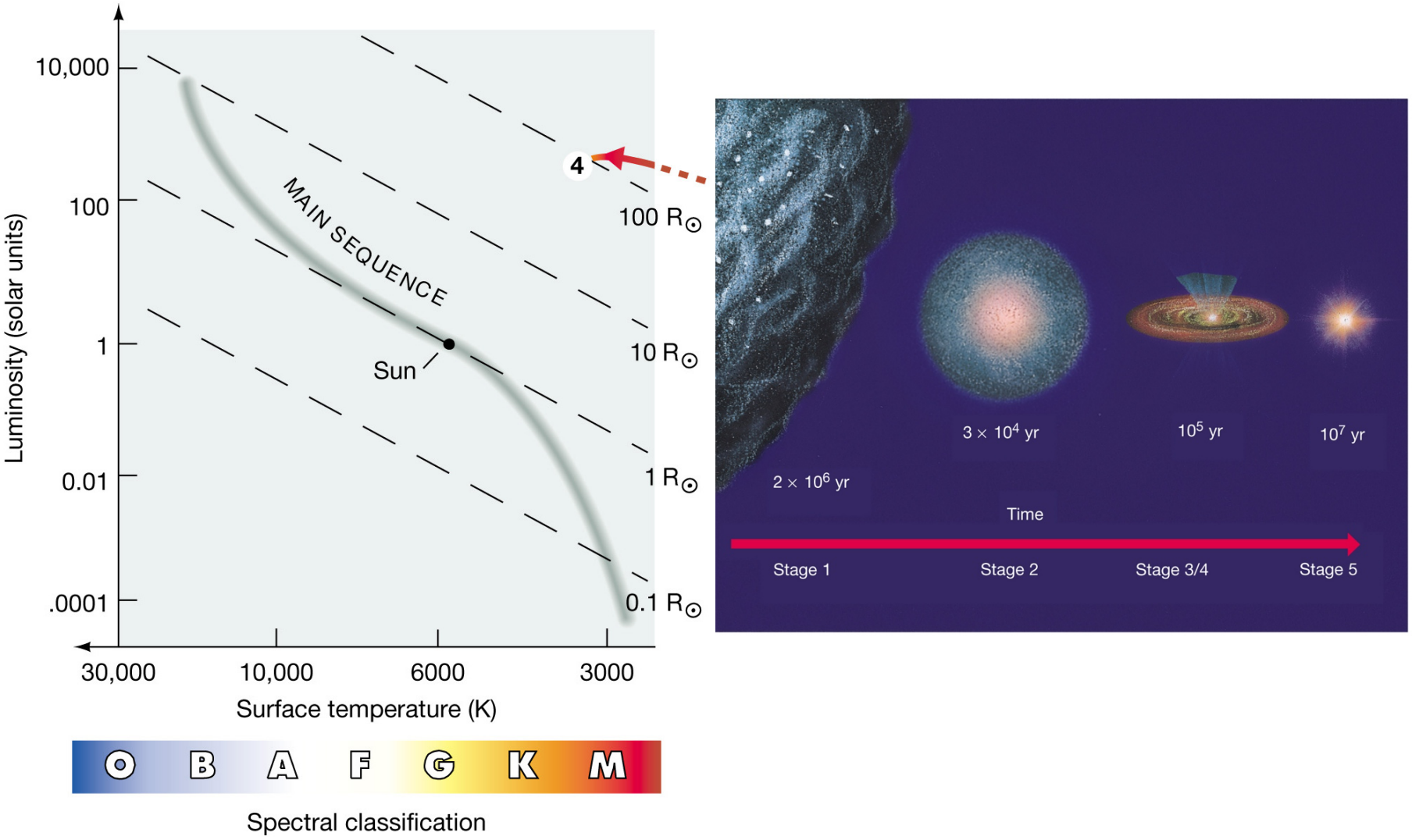
What Fundamental Properties of a Star Determine its Position in the H-R Diagram?

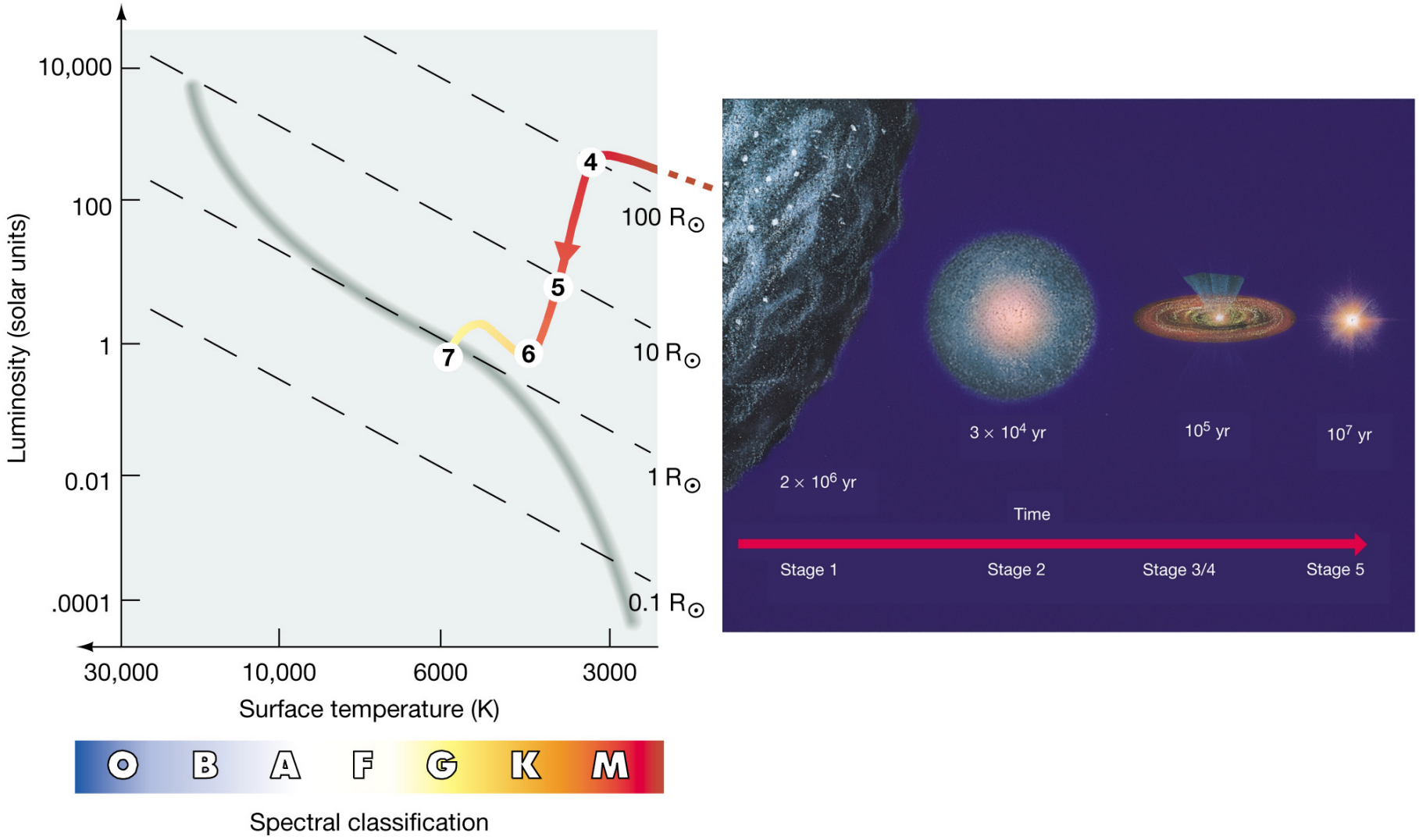
- Its age
- Its mass

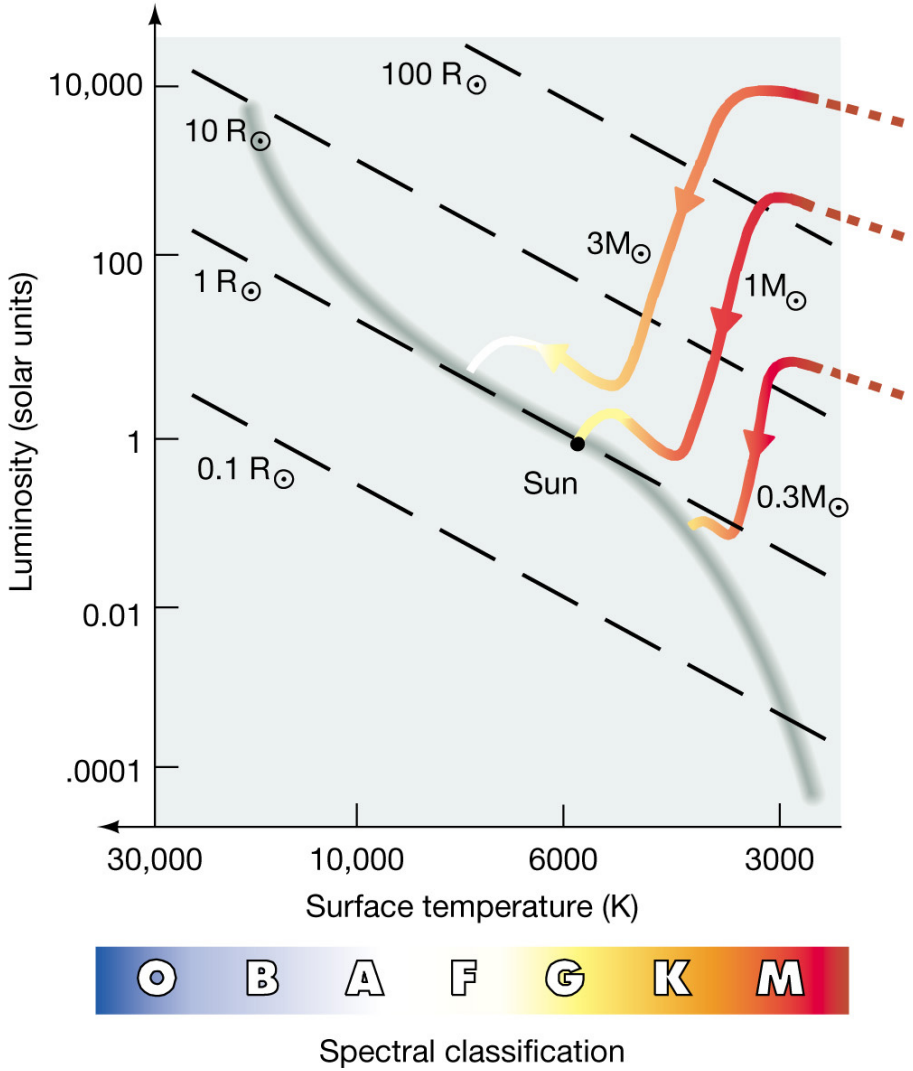

10,000
100
1
0.01
.0001
Luminosity (solar units)
10 M⊙
2 M⊙
1 M⊙
0.08 M⊙
100 R⊙
10 R⊙
1 R⊙
0.1 R⊙
30,000
10,000
6000
3000
Surface temperature (K)
O
B
A
F
G
K
M
Spectral classification

Meaning of the M-S:

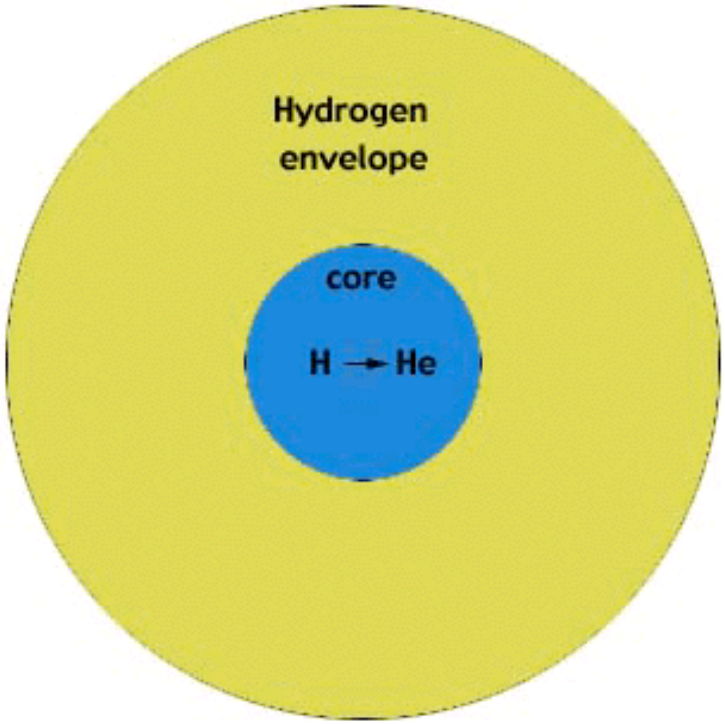
- Stable equilibrium
- Where a star spends ~90% of its life
- power by nuclear fusion, "hydrogen burning".


10,000
100
1
0.01
.0001
Luminosity (solar units)
MAIN SEQUENCE
Sun
4
100 R⊙
10 R⊙
1 R⊙
0.1 R⊙
30,000
10,000
6000
3000
Surface temperature (K)
O
B
A
F
G
K
M
Spectral classification
2 × 10^6 yr
3 × 10^4 yr
10^5 yr
10^7 yr
Time
Stage 1
Stage 2
Stage 3/4
Stage 5


10,000
100
1
0.01
.0001
Luminosity (solar units)
100 R⊙
10 R⊙
1 R⊙
0.1 R⊙
4
5
6
7
30,000
10,000
6000
3000
Surface temperature (K)
O
B
A
F
G
K
M
Spectral classification
2 × 10^6 yr
3 × 10^4 yr
10^5 yr
10^7 yr
Time
Stage 1
Stage 2
Stage 3/4
Stage 5


10,000
100
1
0.01
.0001
Luminosity (solar units)
100 R⊙
10 R⊙
1 R⊙
0.1 R⊙
3M⊙
1M⊙
0.3M⊙
Sun
30,000
10,000
6000
3000
Surface temperature (K)
O
B
A
F
G
K
M
Spectral classification

Main Sequence phase (equilibrium)



Dependence of luminosity and main-sequence life time on the **mass** of a star

$$L \propto M^3 \quad \text{or} \quad \frac{L}{L_\odot} = \left(\frac{M}{M_\odot}\right)^3$$

$$t \propto \frac{1}{M^2} \quad \text{or} \quad \frac{t}{t_\odot} = \left(\frac{M_\odot}{M}\right)^2$$