Lecture 17 – 31st March 2009

- **SCIENCE TOPICS**:
  How the Sun shines (cont.)
  Measuring the Stars
- **READING**
  Ch 9, sec 9.1, 9.2, 9.5
  Ch 10, sec 10.2 – 10.5
  Beware of excessive detail

HOMEWORK 06: due tonight, 11:59pm

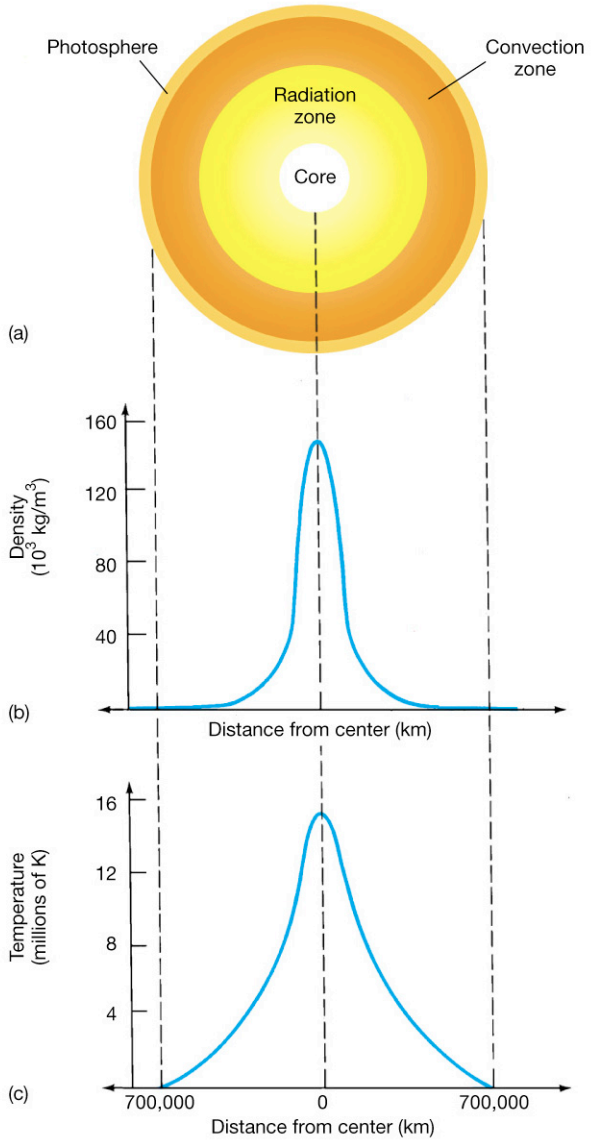
HOMEWORK 07: Out now, due next Tuesday, 7th April, 11:59pm

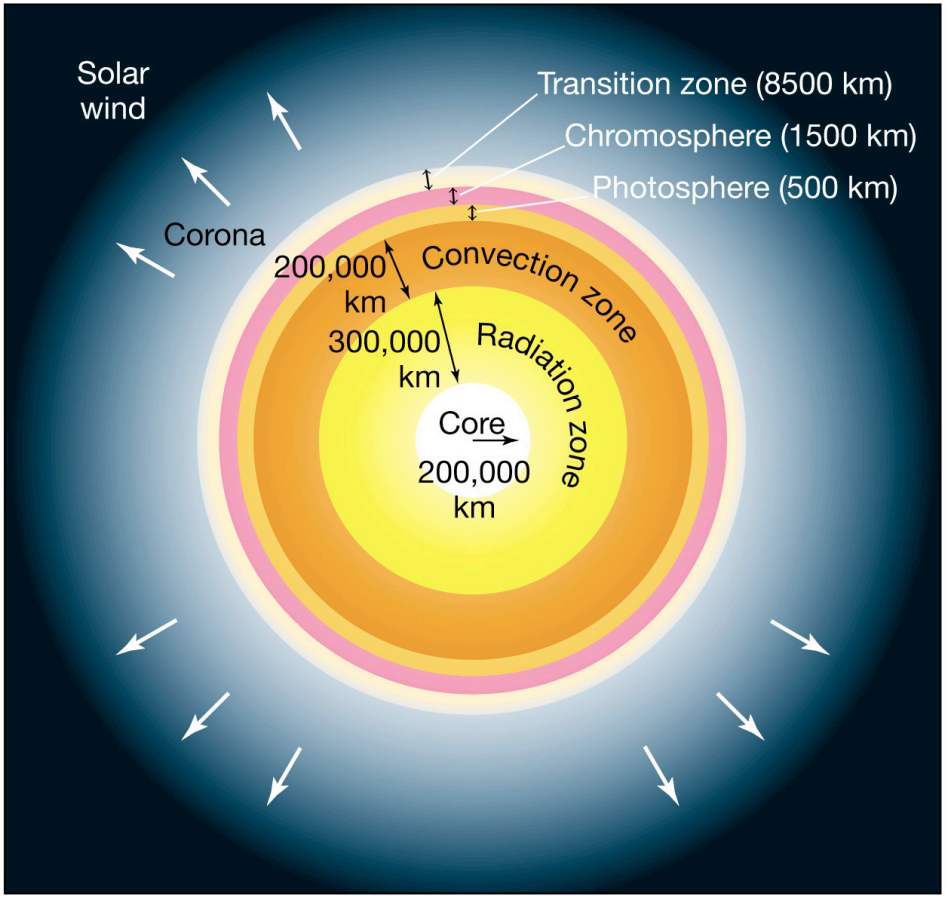
PRACTICE:

Chp. 9: Review: 1-3, 5,8,11, 13, 15
Chp. 9. Self-test: 1, 3, 6, 13, 14, 15;
Chp. 9. Problems: 8, 9
Chp. 10 Review: 4, 6, 8, 9, 13, 14
Chp. 10 Self-test: 1, 3, 4, 10, 11, 14
Chp. 10 Problems: 3, 4, 10

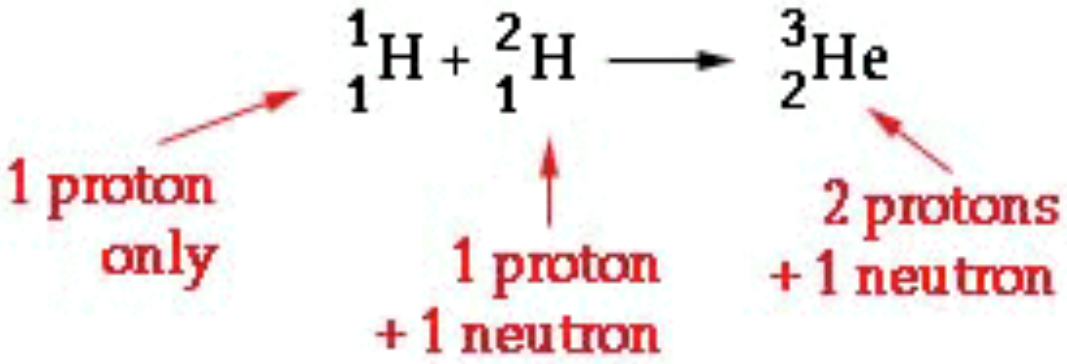
The Sun and How it Shines

Quick Anatomy of the Sun

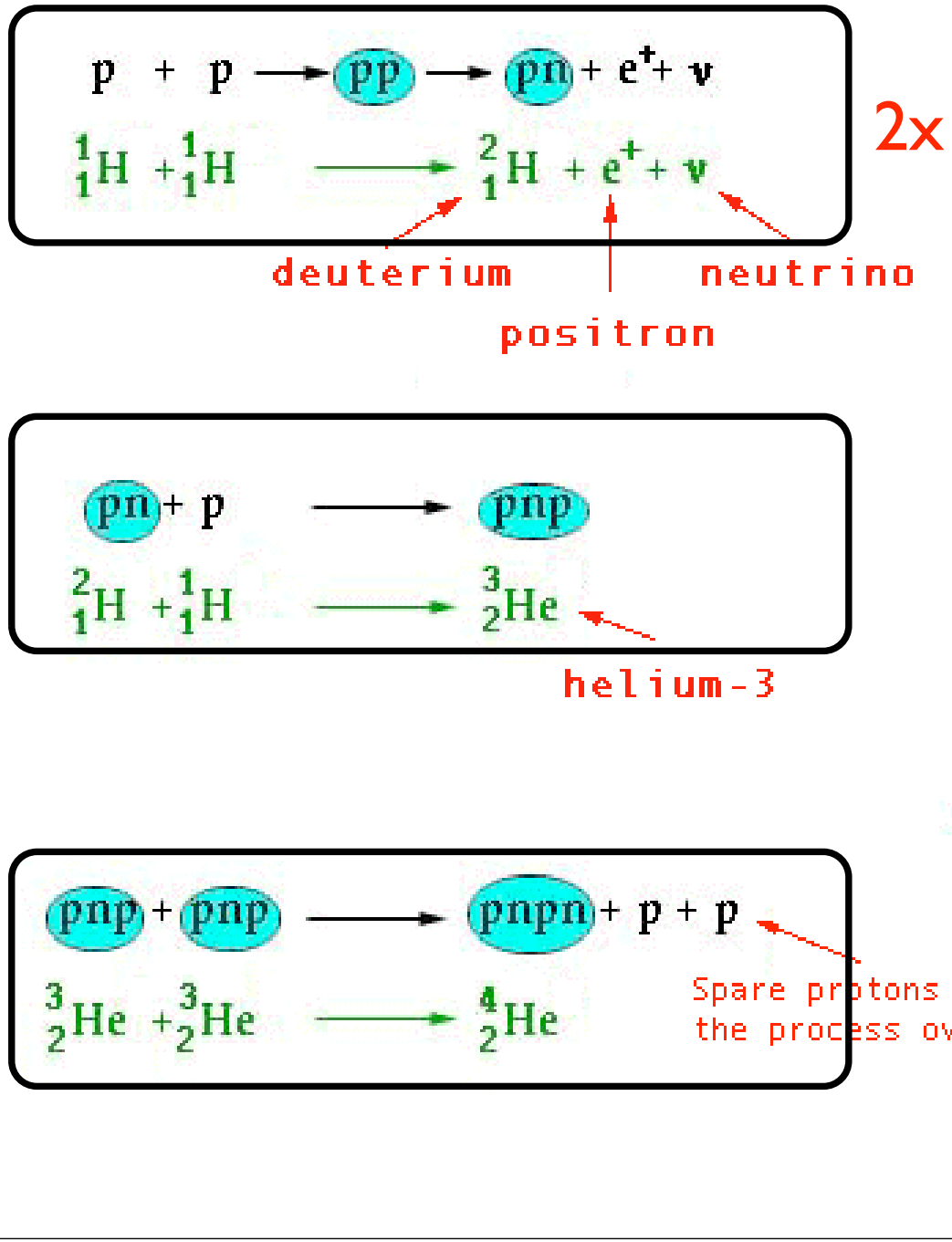




Example of a Nuclear Reaction



We add the mass numbers and the atomic numbers of the ingredients to get the product.


p + p → pp → pn + e+ + ν
1 1H + 1 1H → 2 1H + e+ + ν
2x
deuterium
positron
neutrino
pn + p → pnp
2 1H + 1 1H → 3 2He
helium-3
pnp + pnp → pnpn + p + p
3 2He + 3 2He → 4 2He
Spare protons start
the process over again
4 H
+
2 H
He + 2 H

Nuclear Physics

- 1 proton has a mass of 1.6726×10^{-27} kg
  - therefore, 4 protons have a mass of 6.6904×10^{-27} kg

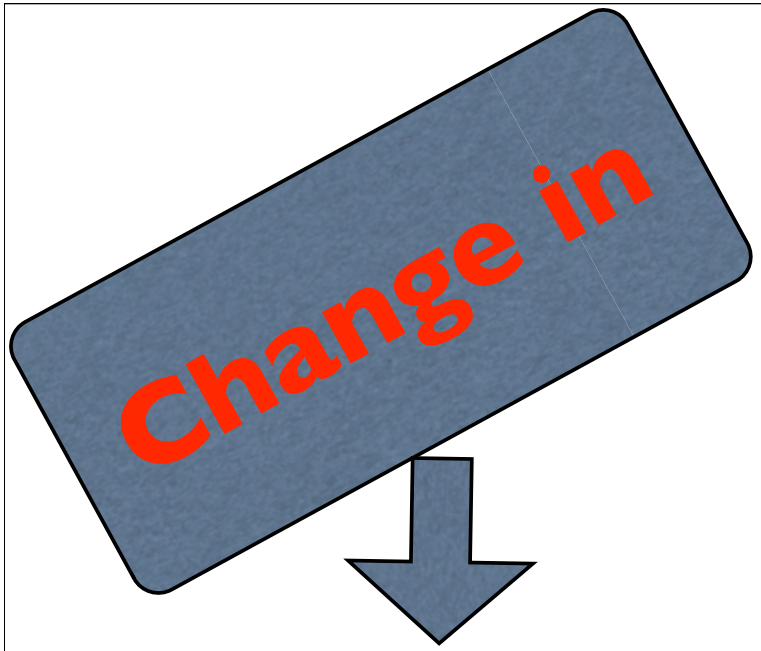
- 1 Helium nuclei (2 protons + 2 neutrons) has a mass of 6.6465×10^{-27} kg

- Therefore there is a MASS DIFFERENCE (or MASS DEFICIT) of **0.0439×10^{-27} kg.**
- Enter Uncle Albert....

Albert Einstein

- 1879-1955, German
- Theories
  - Photoelectric Effect (wave/particle duality, 1905)
  - Brownian motion (atomic theory, 1905)
  - Special Relativity (1905)
  - Mass-Energy equivalence
  - General Relativity (1916)
- *Time* magazine "Person of the Century"

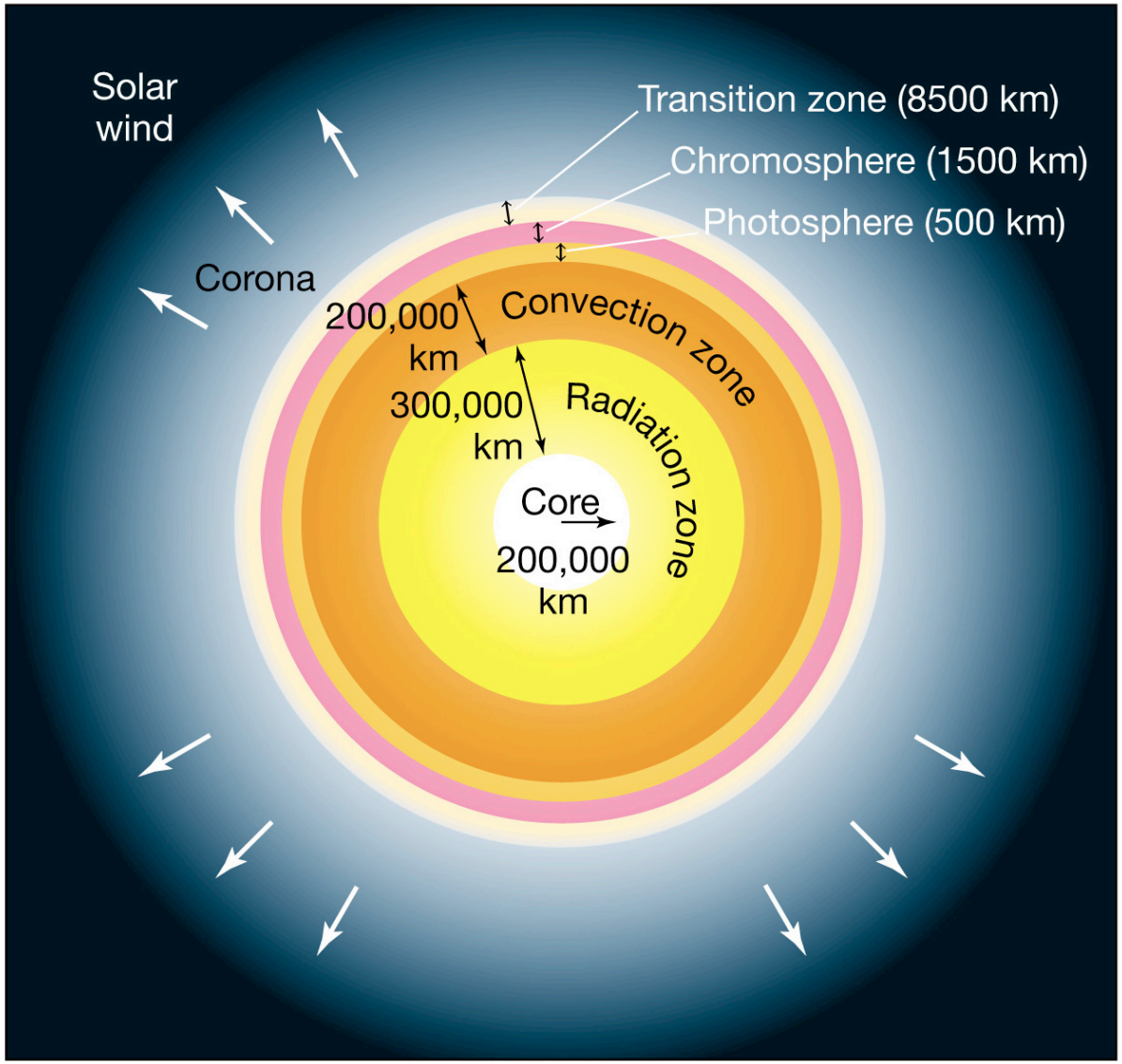
$$E = m c^2$$



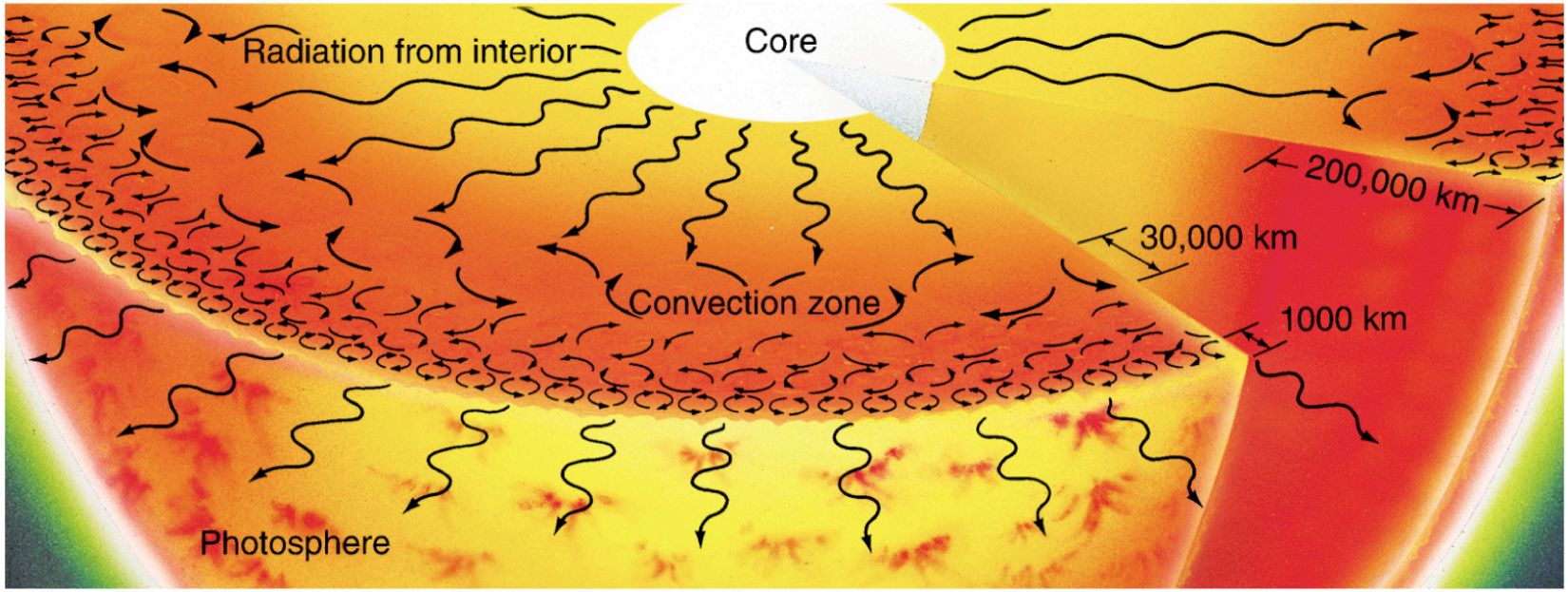
$$\dot{m}\, c^2 = E$$

How does the energy get out after it is produced?

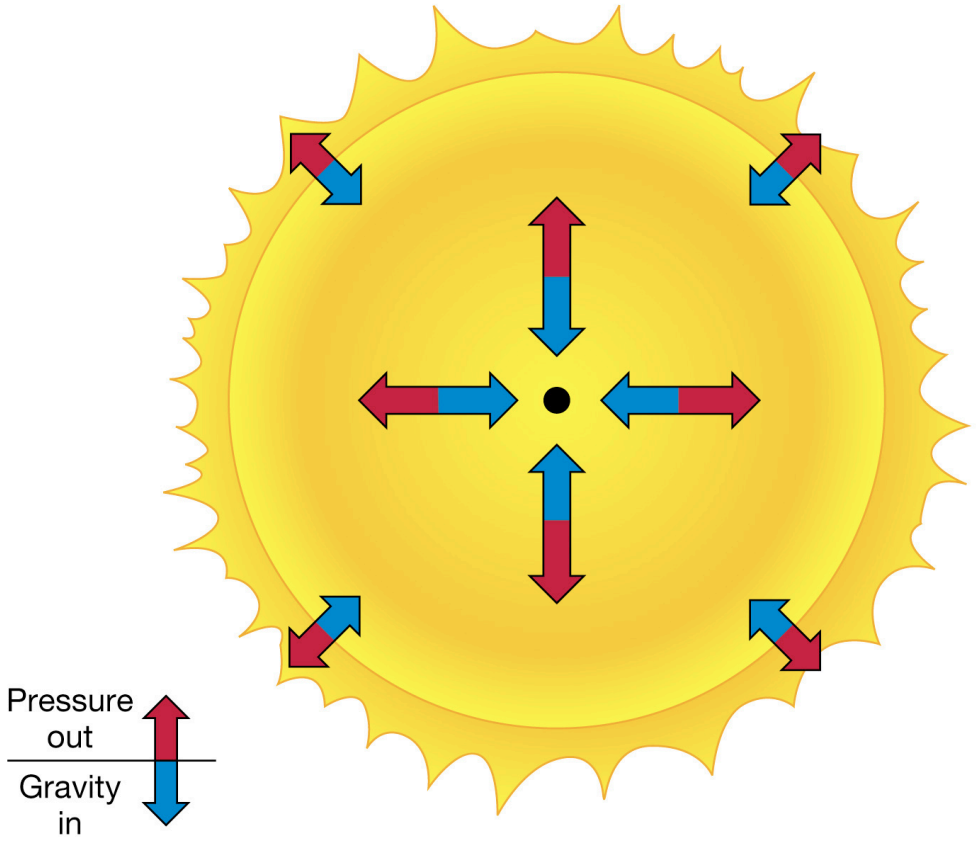
Solar anatomy revisited



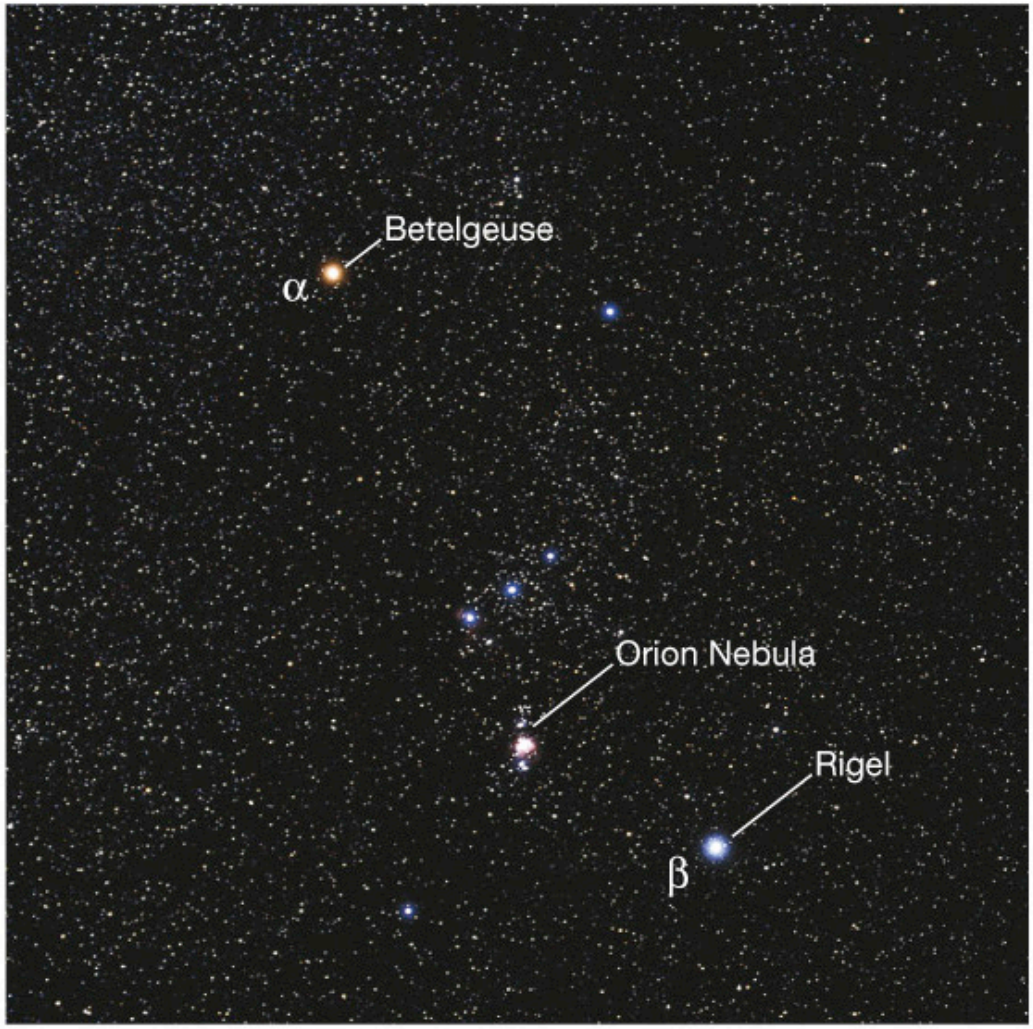
Energy transport inside the Sun

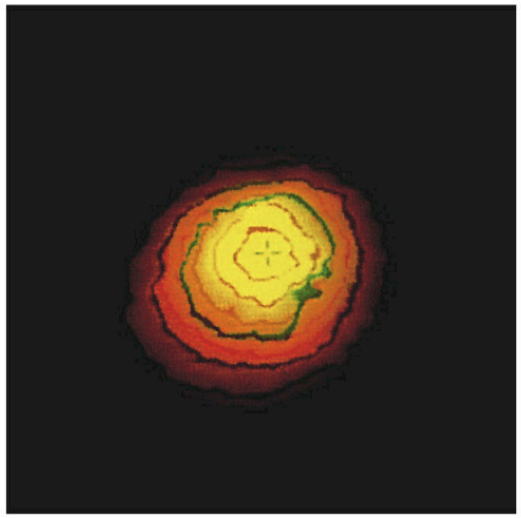


What does the Sun need a power source anyway?

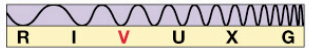


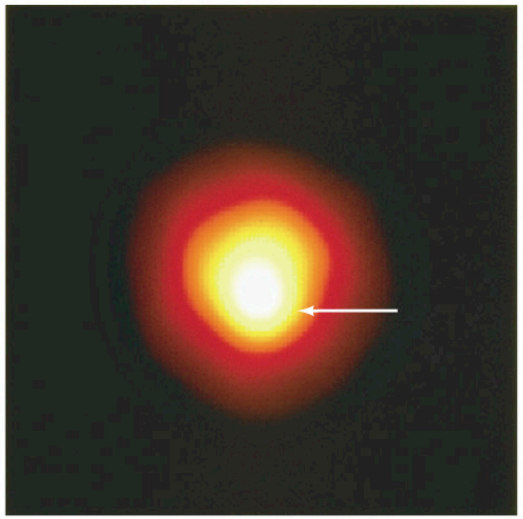
Measuring the Stars





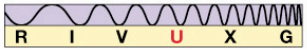
(a)



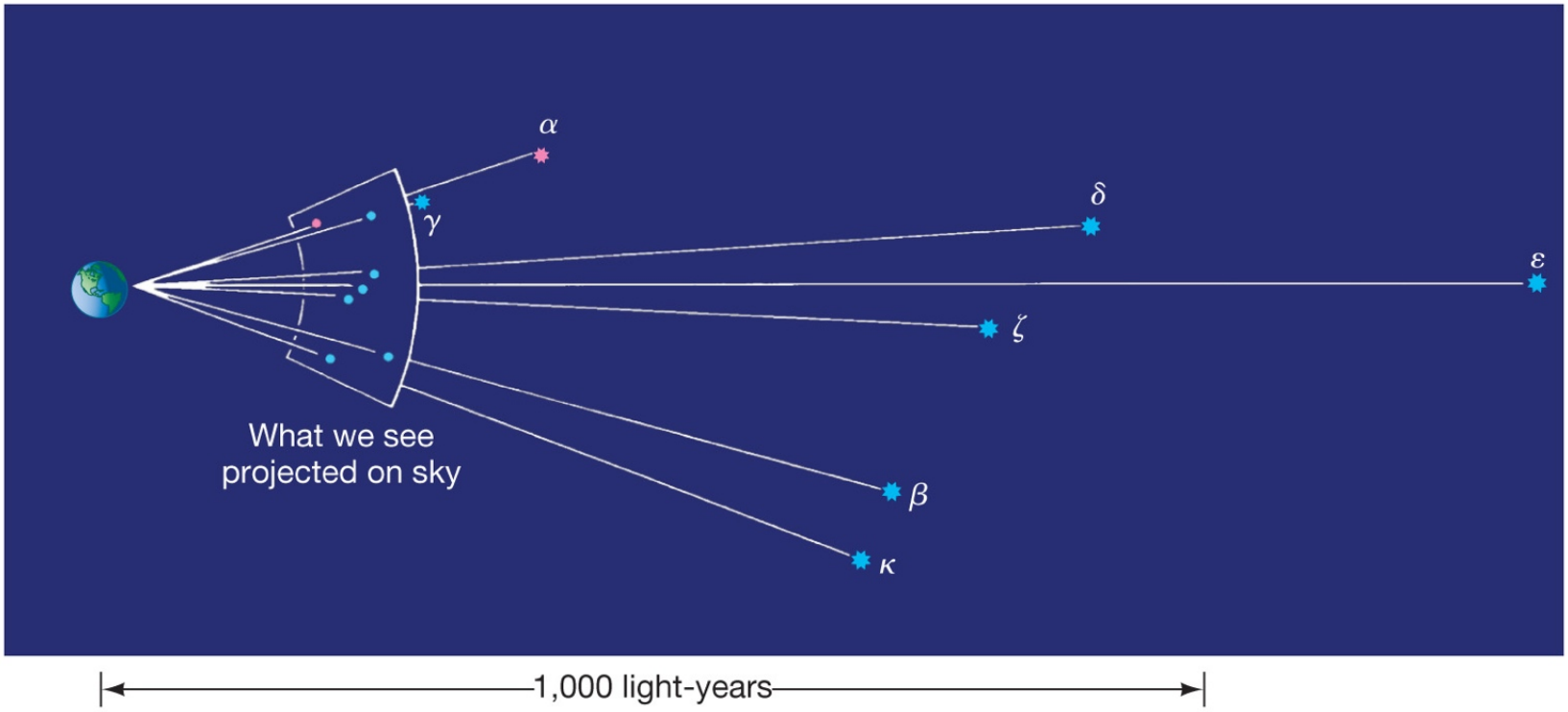


(b)

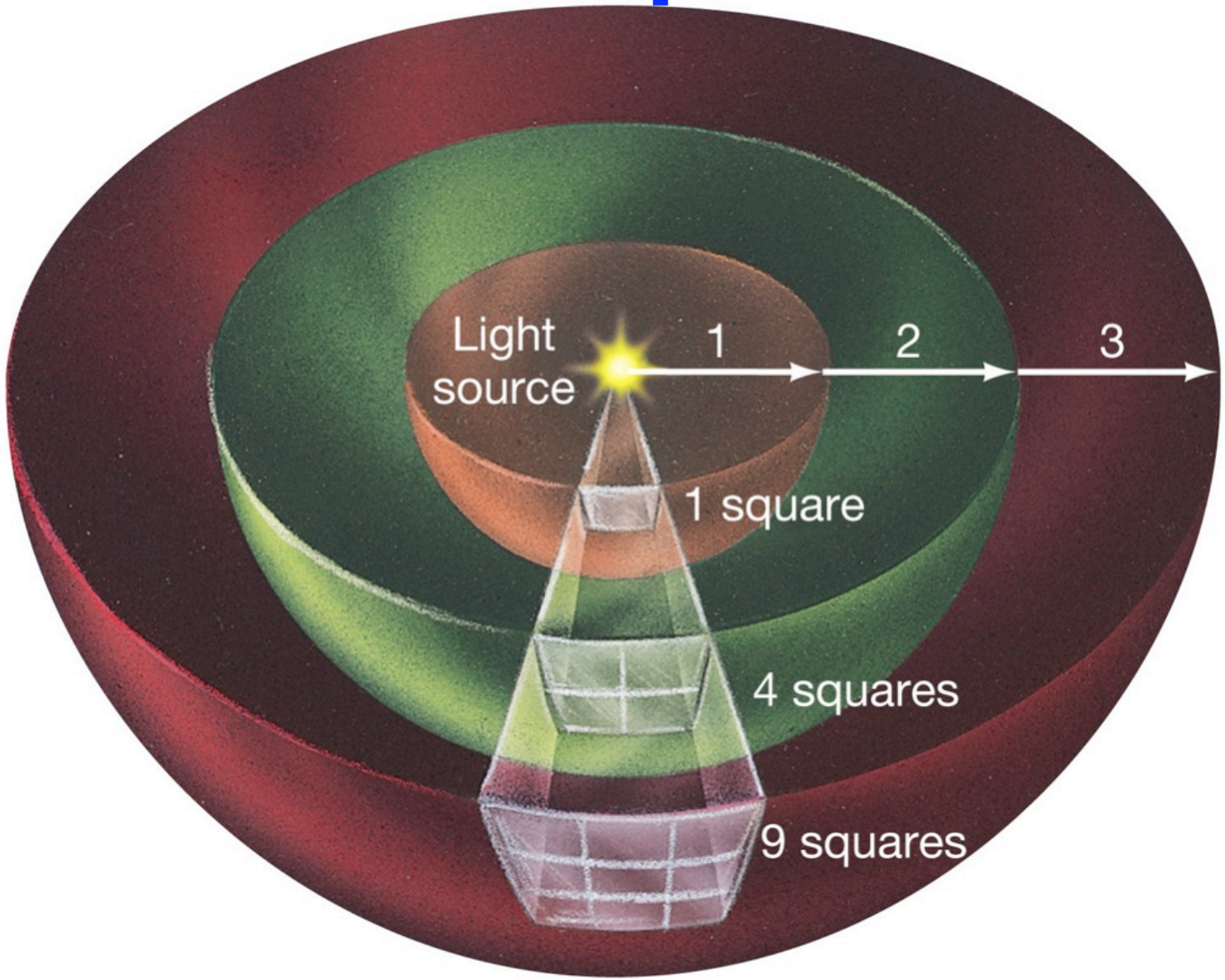
Size of Earth's orbit



Orion in 3-D



Inverse square law



100 W

25 W

same distance:
100 W bulb is
4 times brighter

100 W

25 W

same distance:
100 W bulb is
4 times brighter

100 W bulb is
twice as far away:

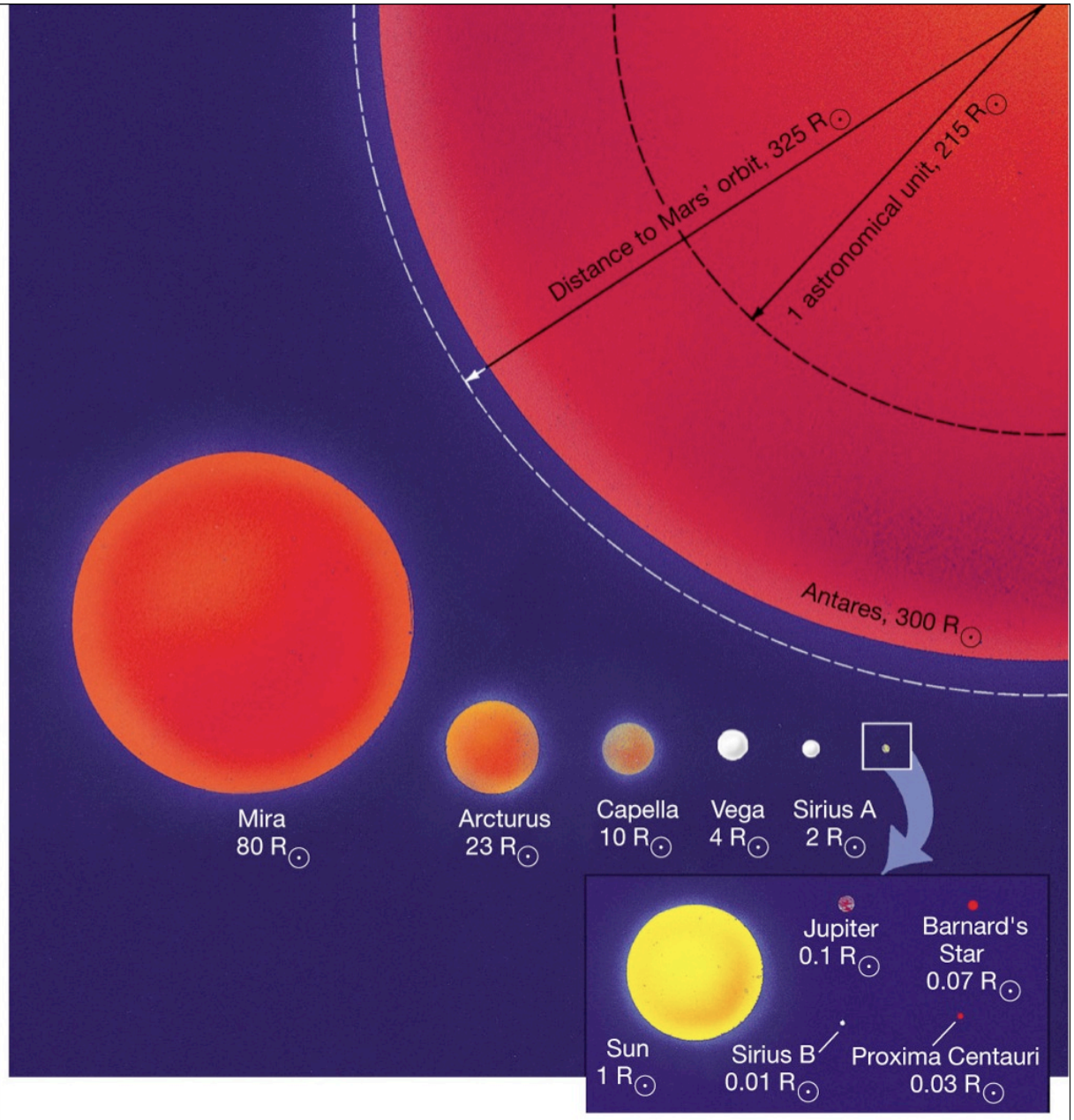
$$B \propto \frac{1}{d^2} = \frac{1}{4}$$

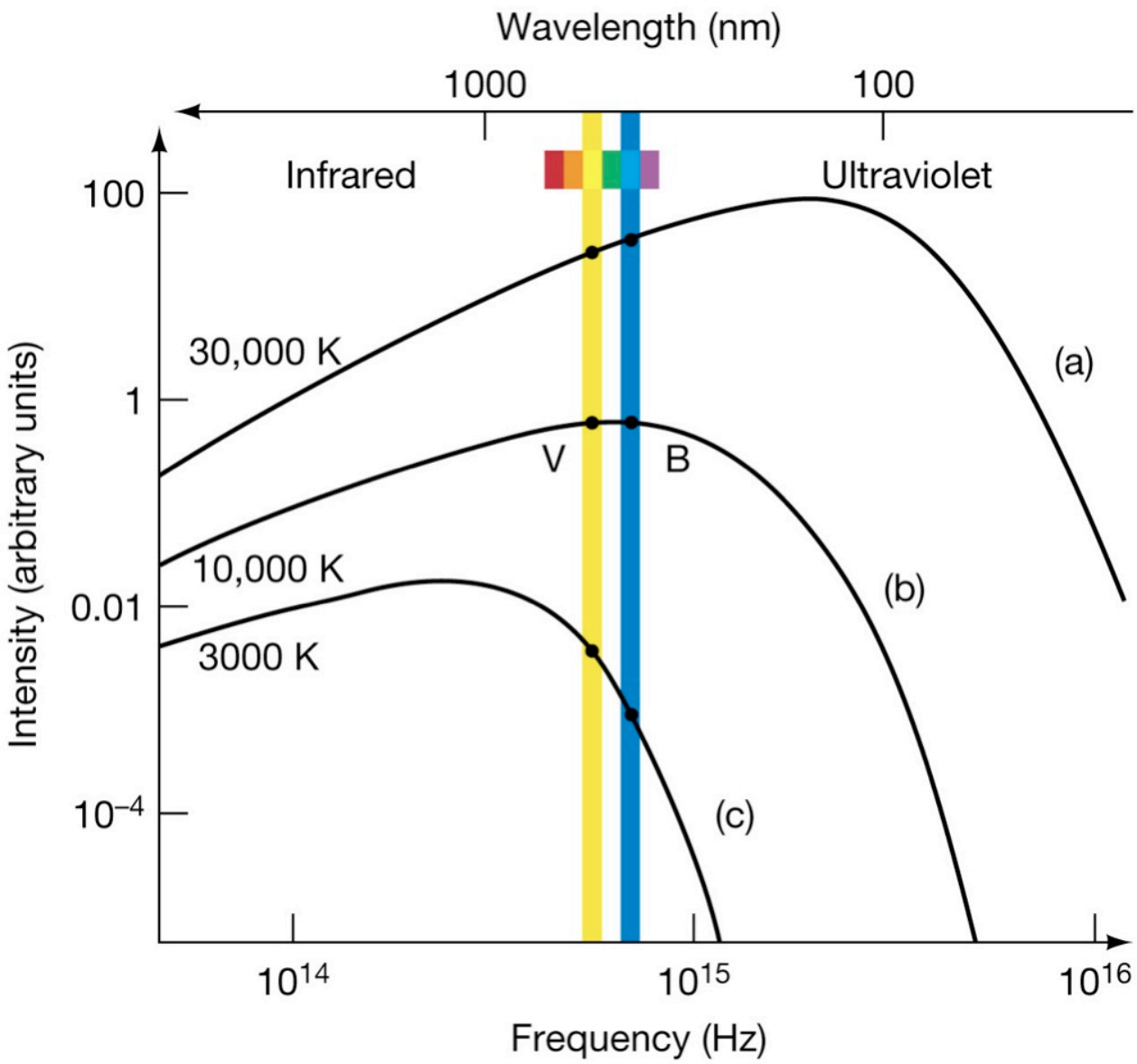
appears the same
brightness as the
25 W bulb

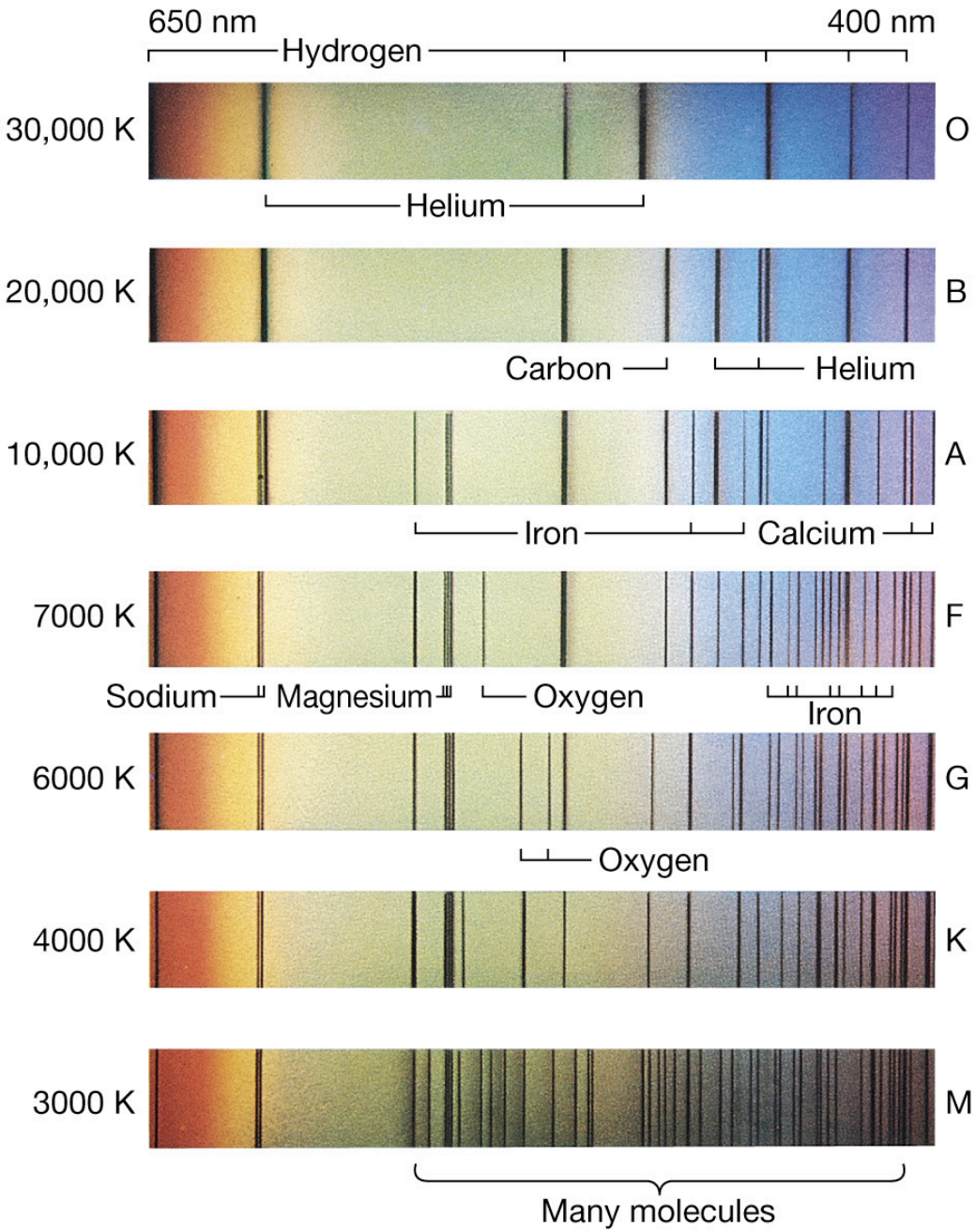
100 W bulb is
4 times as far away:

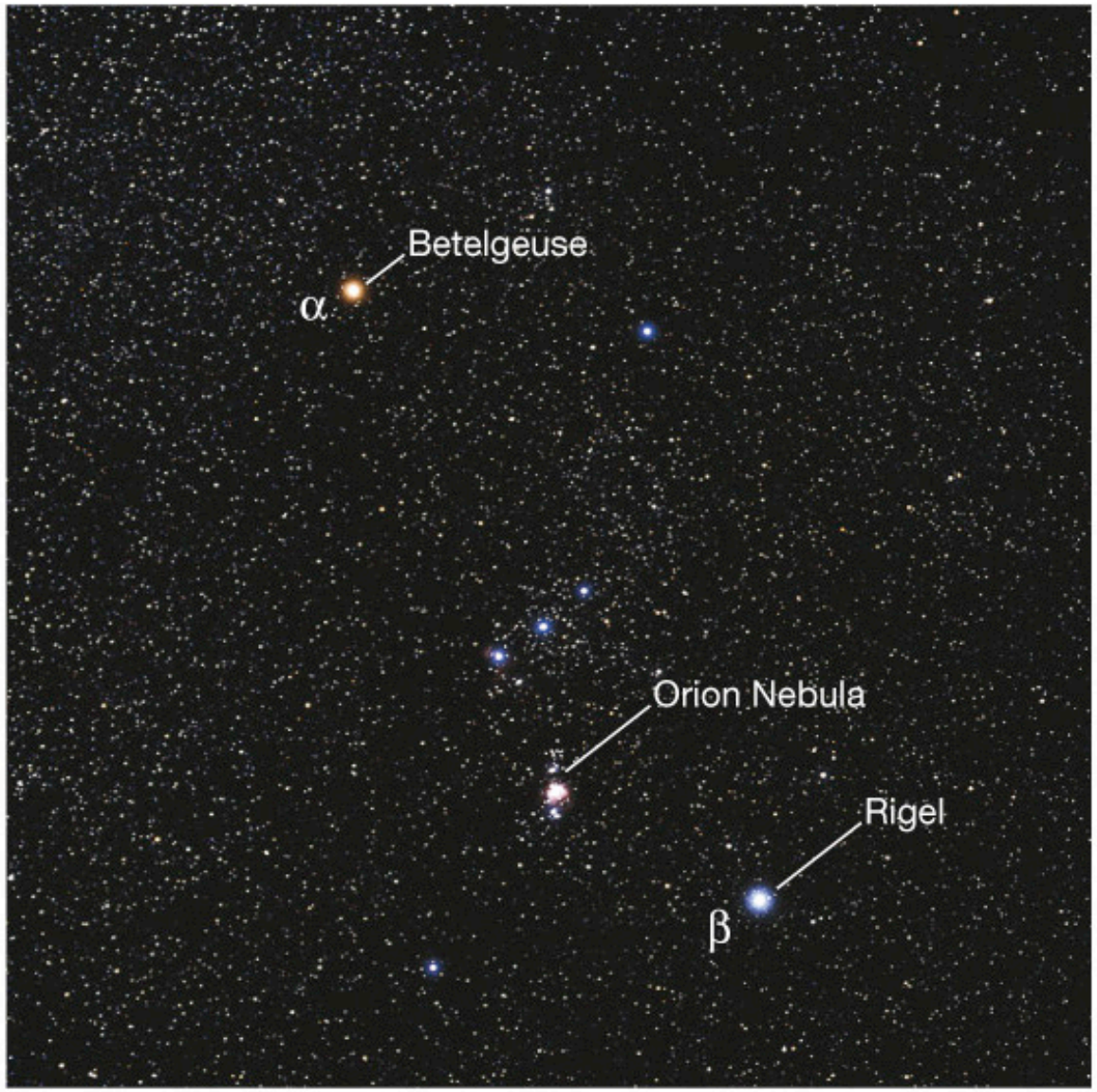
$$B \propto \frac{1}{d^2} = \frac{1}{16}$$

appears 4 times
fainter than the
25 W bulb


Distance to Mars' orbit, 325 R⊙
1 astronomical unit, 215 R⊙
Antares, 300 R⊙
Mira
80 R⊙
Arcturus
23 R⊙
Capella
10 R⊙
Vega
4 R⊙
Sirius A
2 R⊙
Jupiter
0.1 R⊙
Barnard's
Star
0.07 R⊙
Sun
1 R⊙
Sirius B
0.01 R⊙
Proxima Centauri
0.03 R⊙


Wavelength (nm)
1000
100
Infrared
Ultraviolet
100
1
0.01
10^{-4}
Intensity (arbitrary units)
30,000 K
10,000 K
3000 K
V
B
(a)
(b)
(c)
10^{14}
10^{15}
10^{16}
Frequency (Hz)


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


Betelgeuse
α
Orion Nebula
Rigel
β