Extreme Astrophysics

UNIVERSITY of GLASGOW

ASTRONOMY ASTROPHYSICS

PPARC

Dr Martin Hendry
Dept of Physics and Astronomy

Extreme astrophysics: Jan 2007

Extreme Astrophysics

Provisional schedule

22/01	Introduction / Life and death of	M. Hendry
29/01	stars / supernovae	
05/02	The search for gravitational waves	M. Pitkin
12/02	The story of cosmic rays	A. Mackinnon
19/02	The threat of asteroid impact	B. Steves
26/02	Gamma ray bursts	F. Speirits
05/03	A recipe for galaxy formation	L. Teodoro /
12/03	Echoes of the Big Bang	M. Hendry
19/03	Welcome to quantum gravity!	N. Gray / M. Hendry

Also: 03/02 Transits and Eclipses Day School

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ASTRONOMY ★ ASTROPHYSICS

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Extreme astrophysics: Jan 2007

We can extend our 'map' of the Universe downwards to sub-atomic scales.

See e.g. wikipedia

http://en.wikipedia.org/wiki/Orders_of_magnitude_(length)

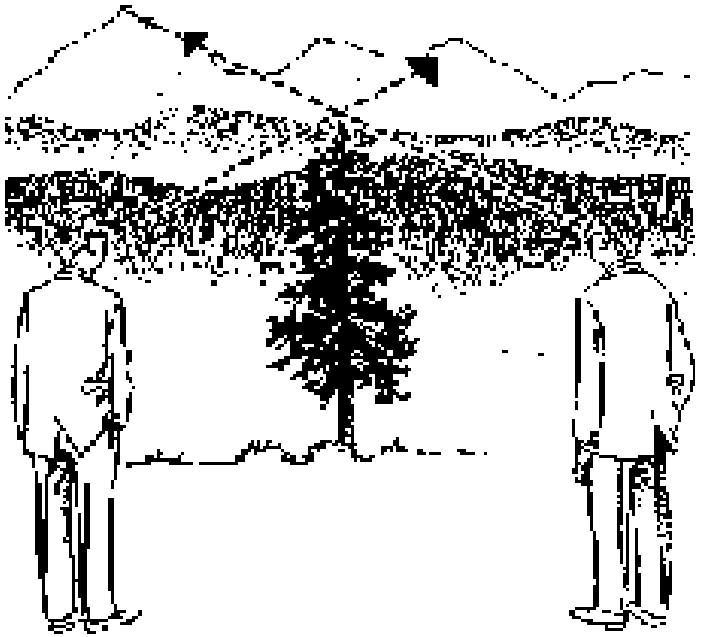
Other useful units:

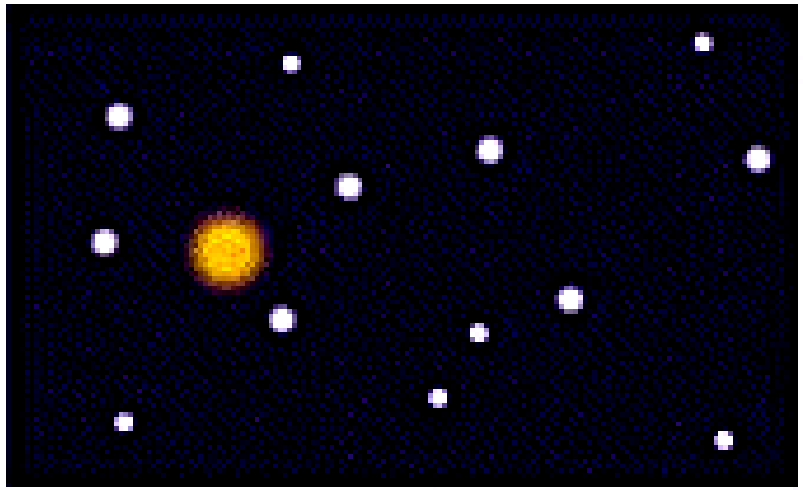
1 Astronomical Unit = 150 million km

1 parsec = 3.26 light years

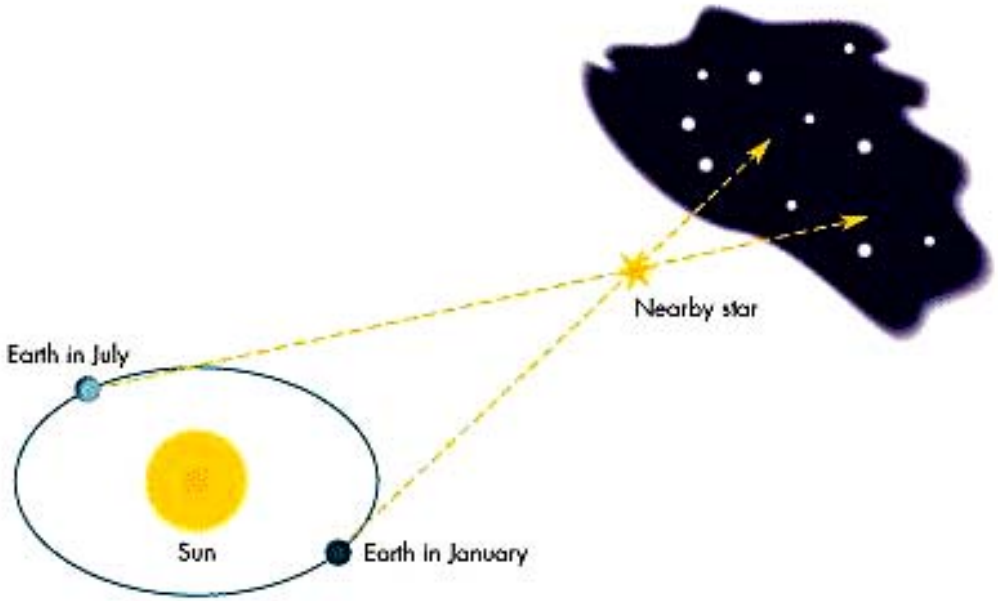
= 206265 AU

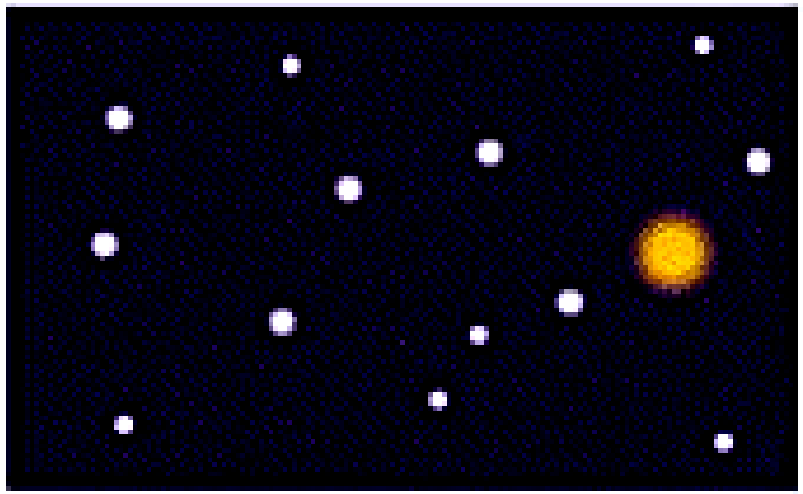
Measuring Astronomical Distances: Parallax





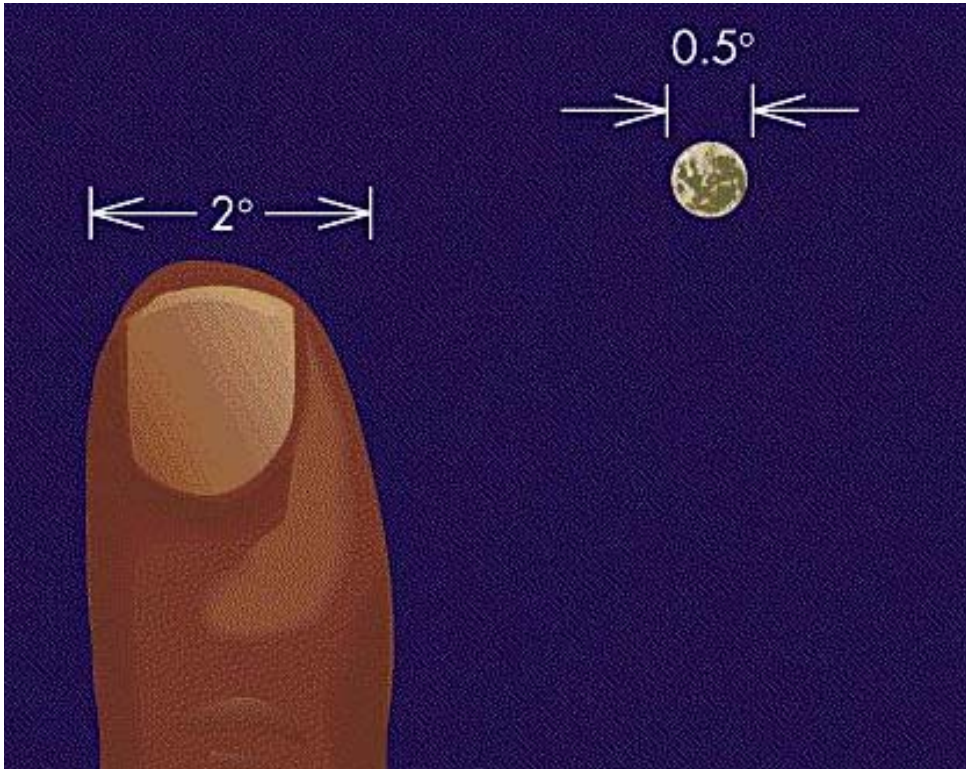
View from the Earth in January

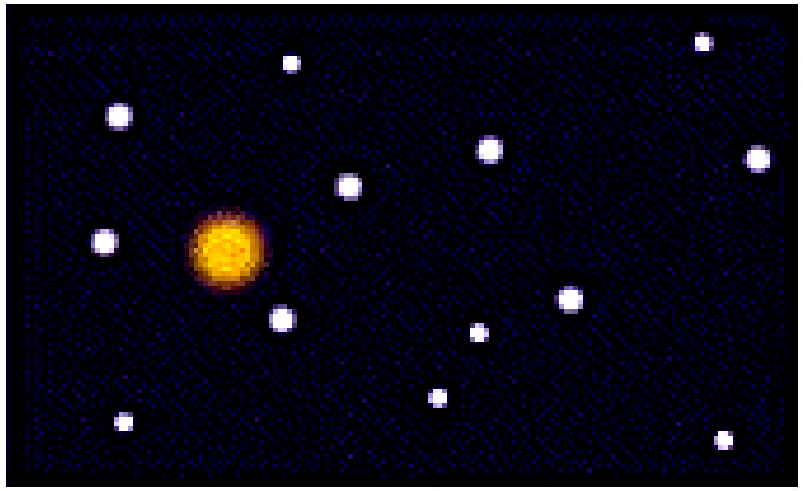




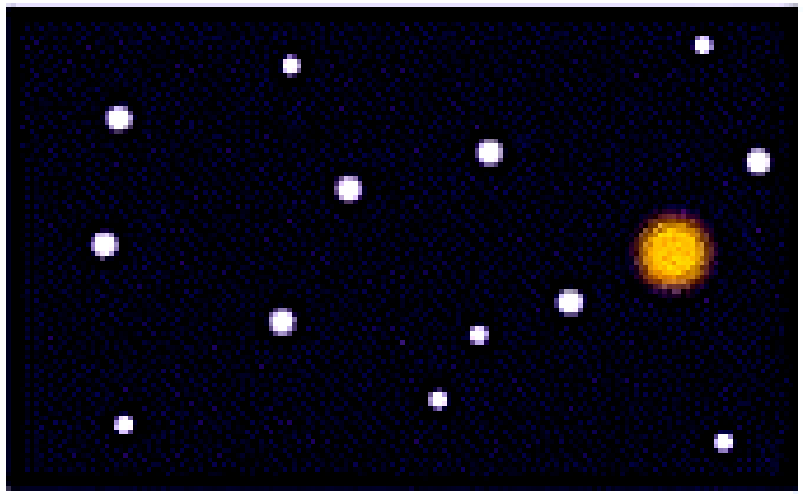
View from the Earth in July

Measuring Astronomical Distances: Parallax





View from the Earth in January



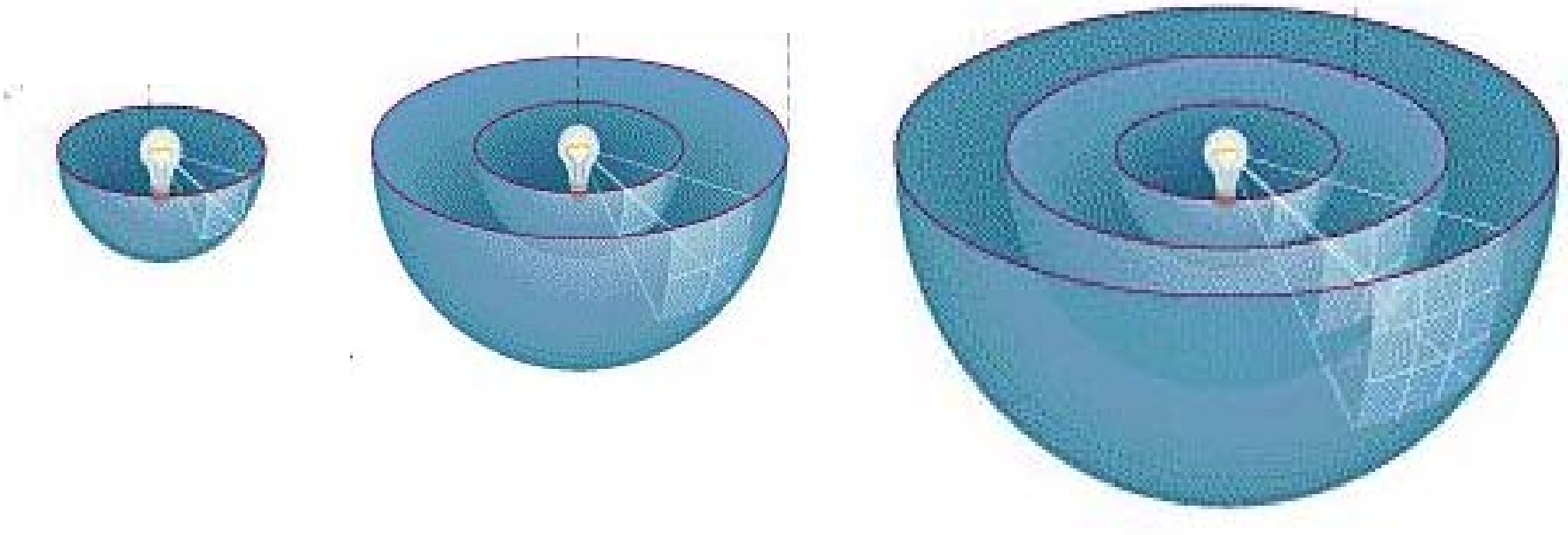
View from the Earth in July

Even the nearest star shows a parallax shift of only 1/2000th the width of the full Moon

The stars are VERY far away. The nearest star (after the Sun) is about 40 million million km from the Earth. It takes light more than 4 years to travel this distance.

If the distance from the Earth to the Sun were the width of this screen, the next nearest star would be in Rome.

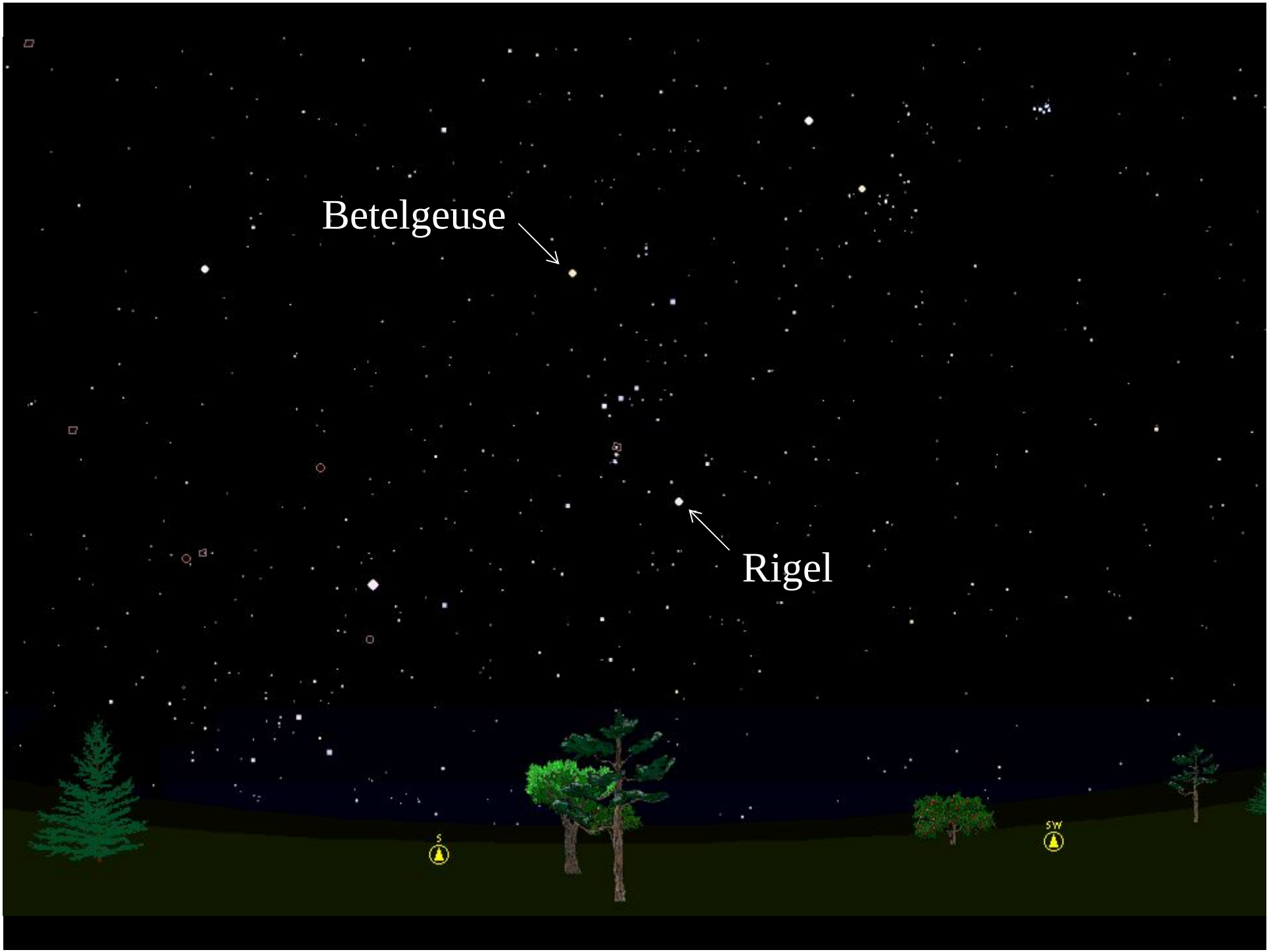
Stars radiate equally in all directions

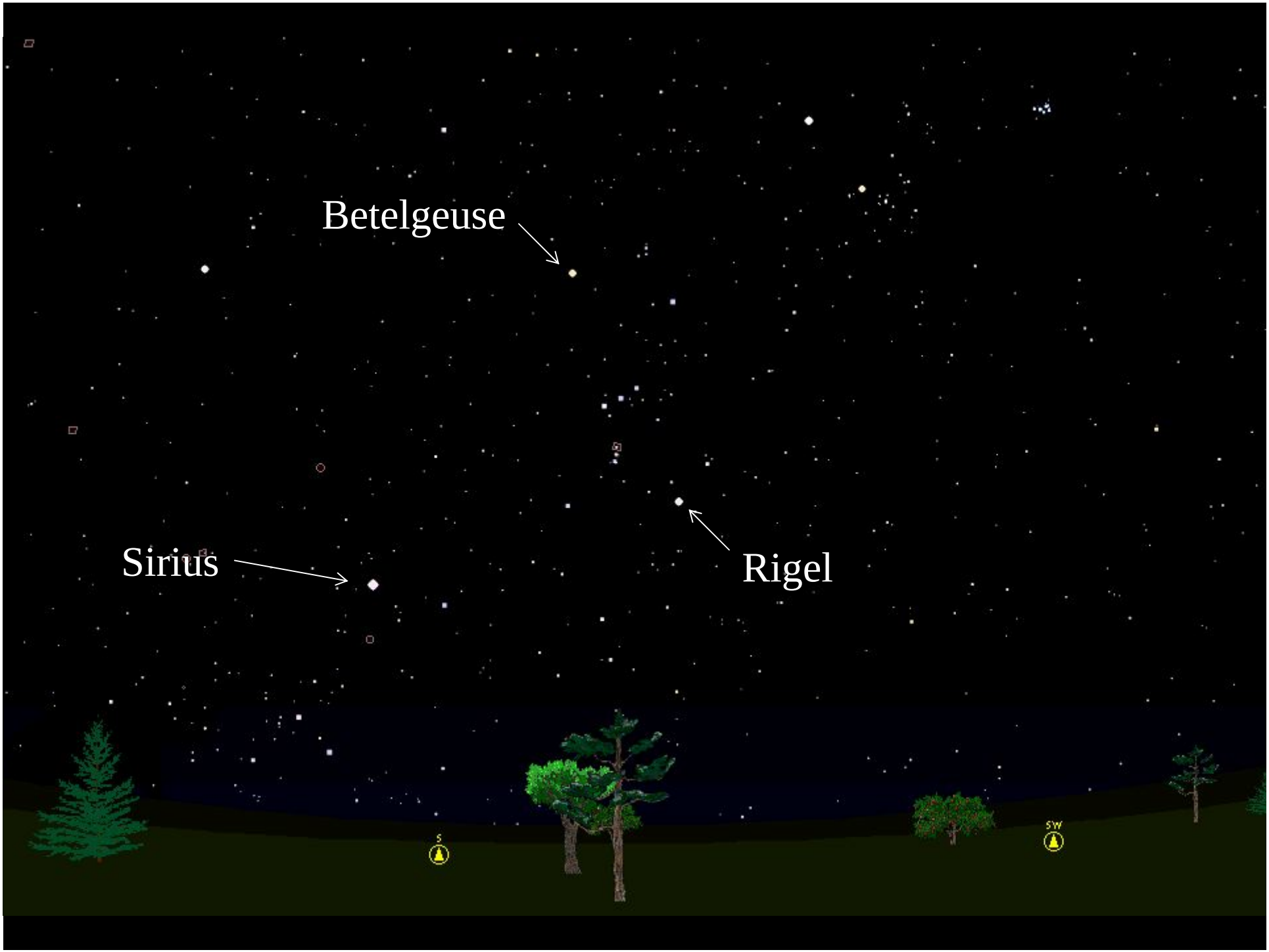


This gives rise to the ***Inverse-Square Law:***

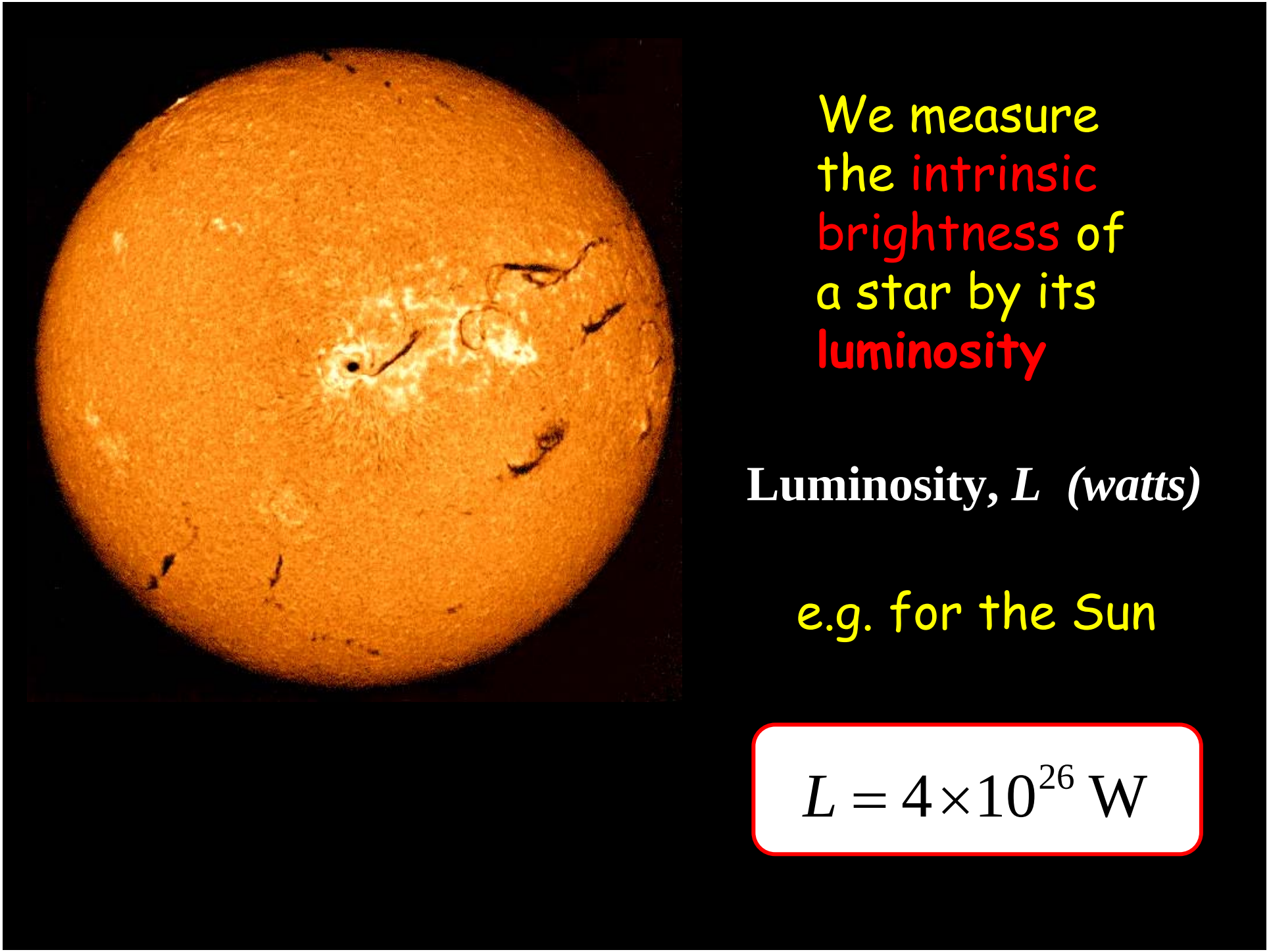
The apparent brightness of a star falls off with the square of its distance

1000w
1000w


Betelgeuse
Rigel
S
SW


Betelgeuse
Sirius
Rigel
S
SW

“These are small, while the ones out there are *far away*…”


We measure
the intrinsic
brightness of
a star by its
luminosity
Luminosity, L (watts)
e.g. for the Sun
$L = 4 \times 10^{26}$ W

1 Watt = 1 Joule of energy per second

= *power needed to lift 1 kg bag of sugar vertically about 10cm in one second*

Luminosity varies with colour (see later)

e.g. consider Rigel *and* Betelgeuse in Orion

Luminosity varies with colour (see later)

e.g. consider Rigel *and* Betelgeuse in Orion

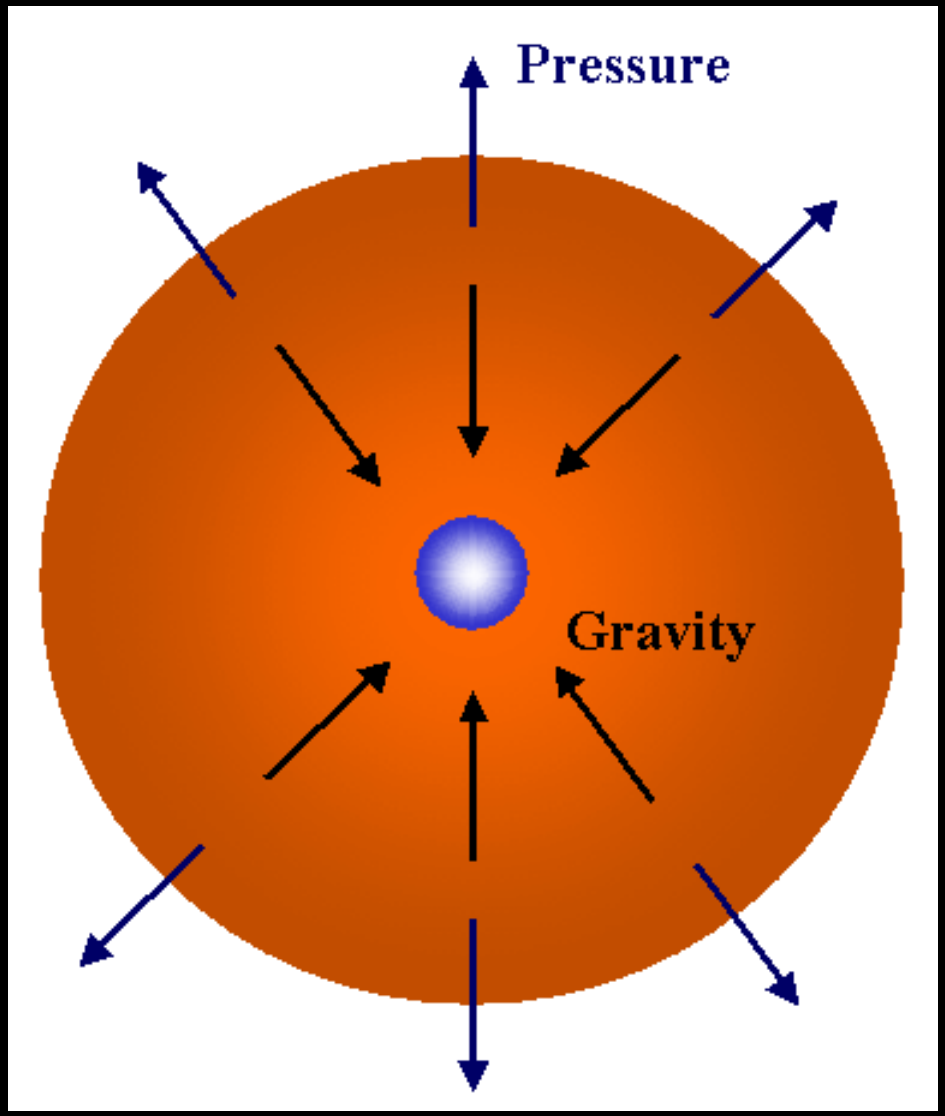
Adding up luminosity L at all colours

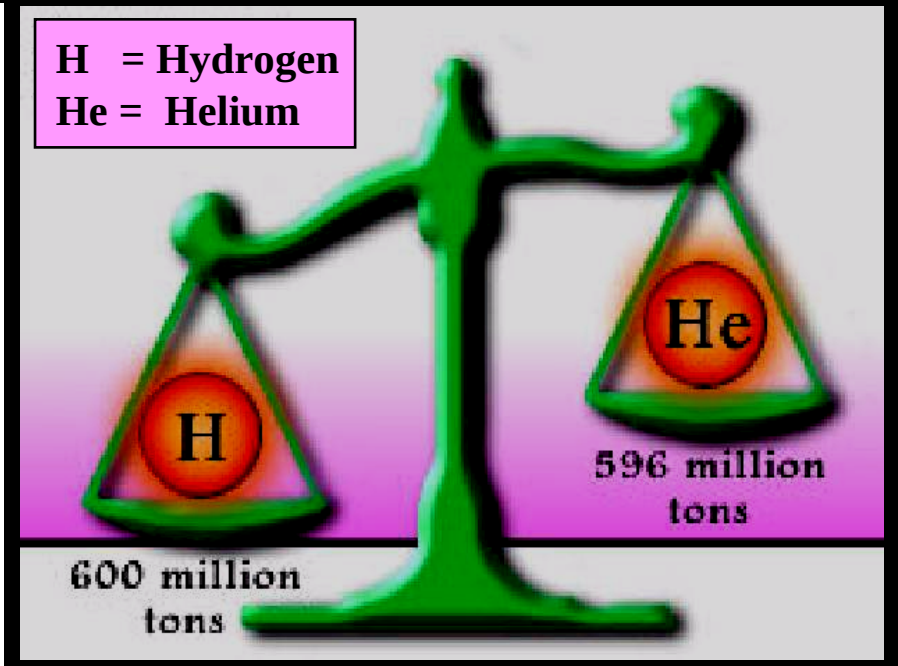
$\Rightarrow$ Bolometric luminosity

e.g. for the Sun

$$L_{\text{bol}} = 4 \times 10^{26}\ \text{W}$$

Hydrogen fusion – fuelling a star's nuclear furnace



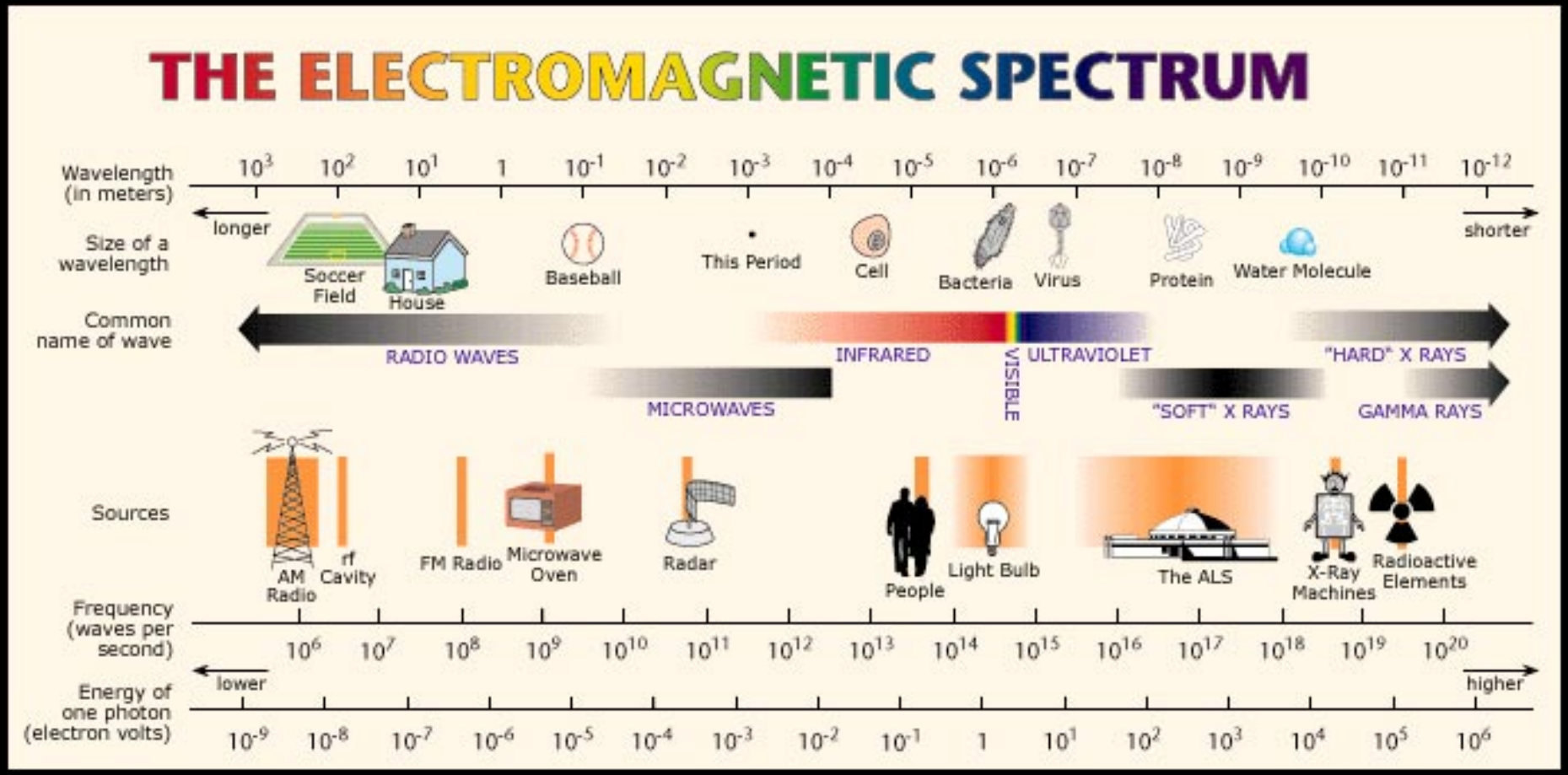


$$E = mc^2$$

Speed of light

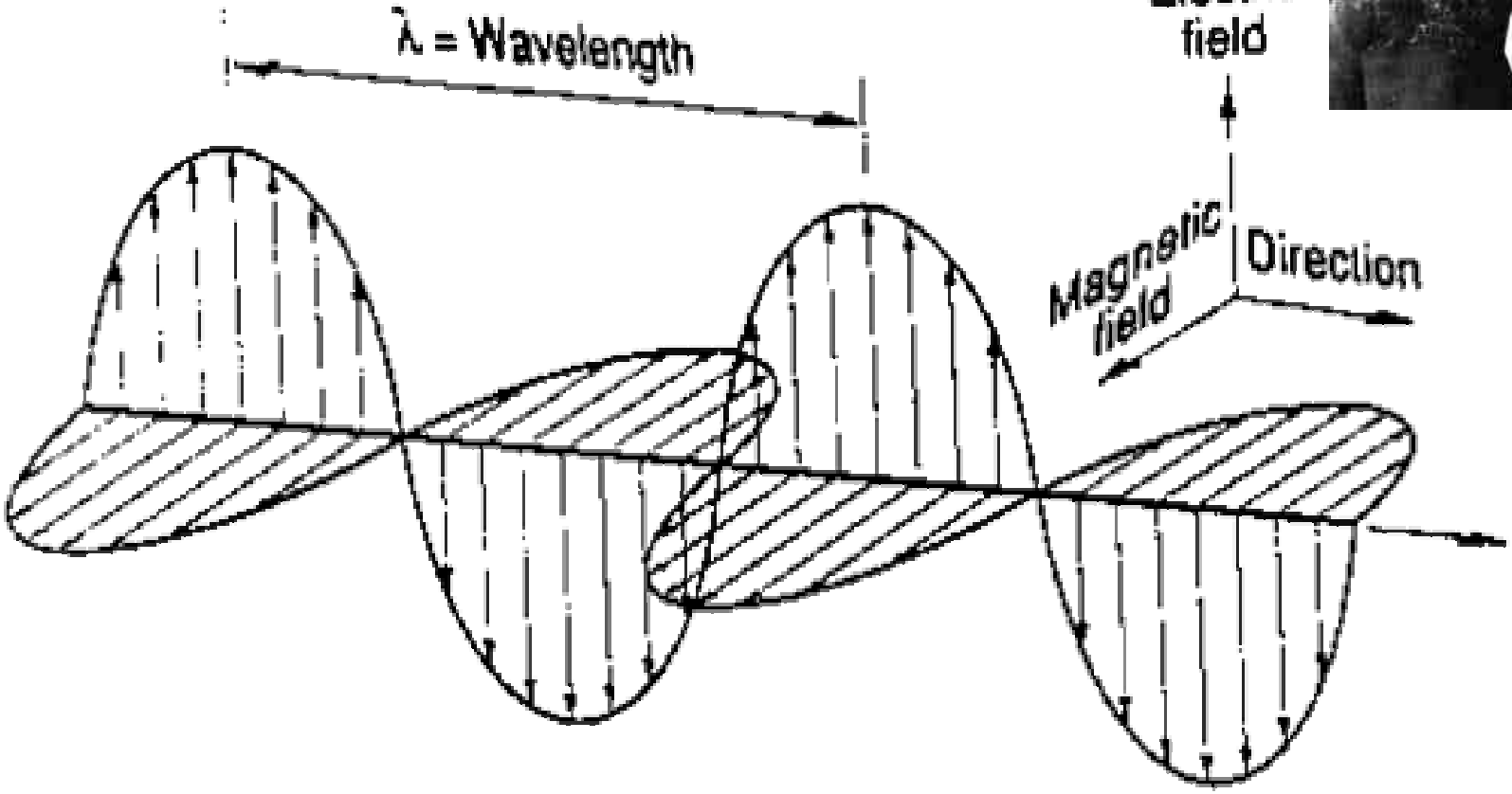
Einstein's Relativity

The speed of light is the **ultimate speed limit** in the Universe



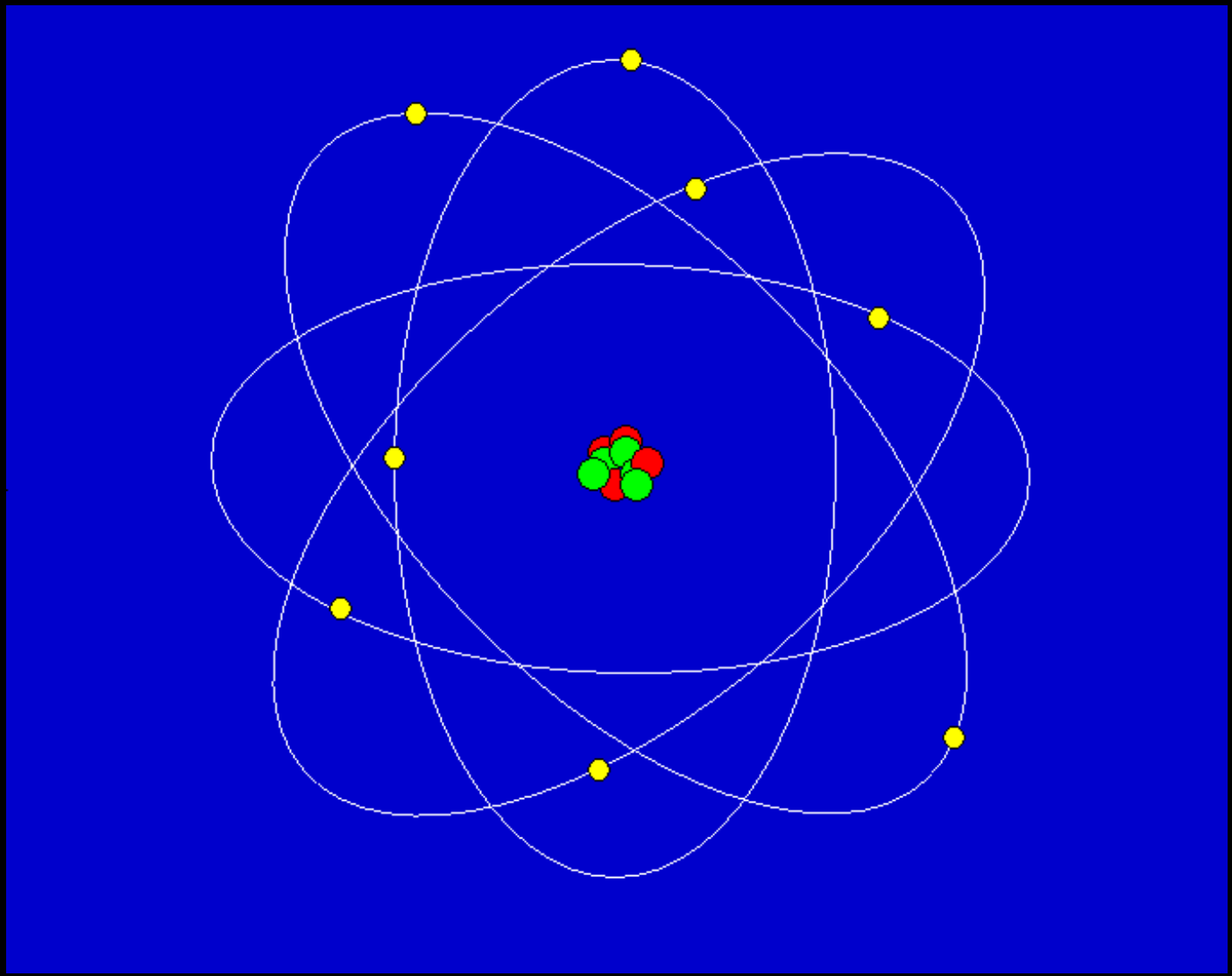
Speed = wavelength x frequency

Maxwell's theory of light

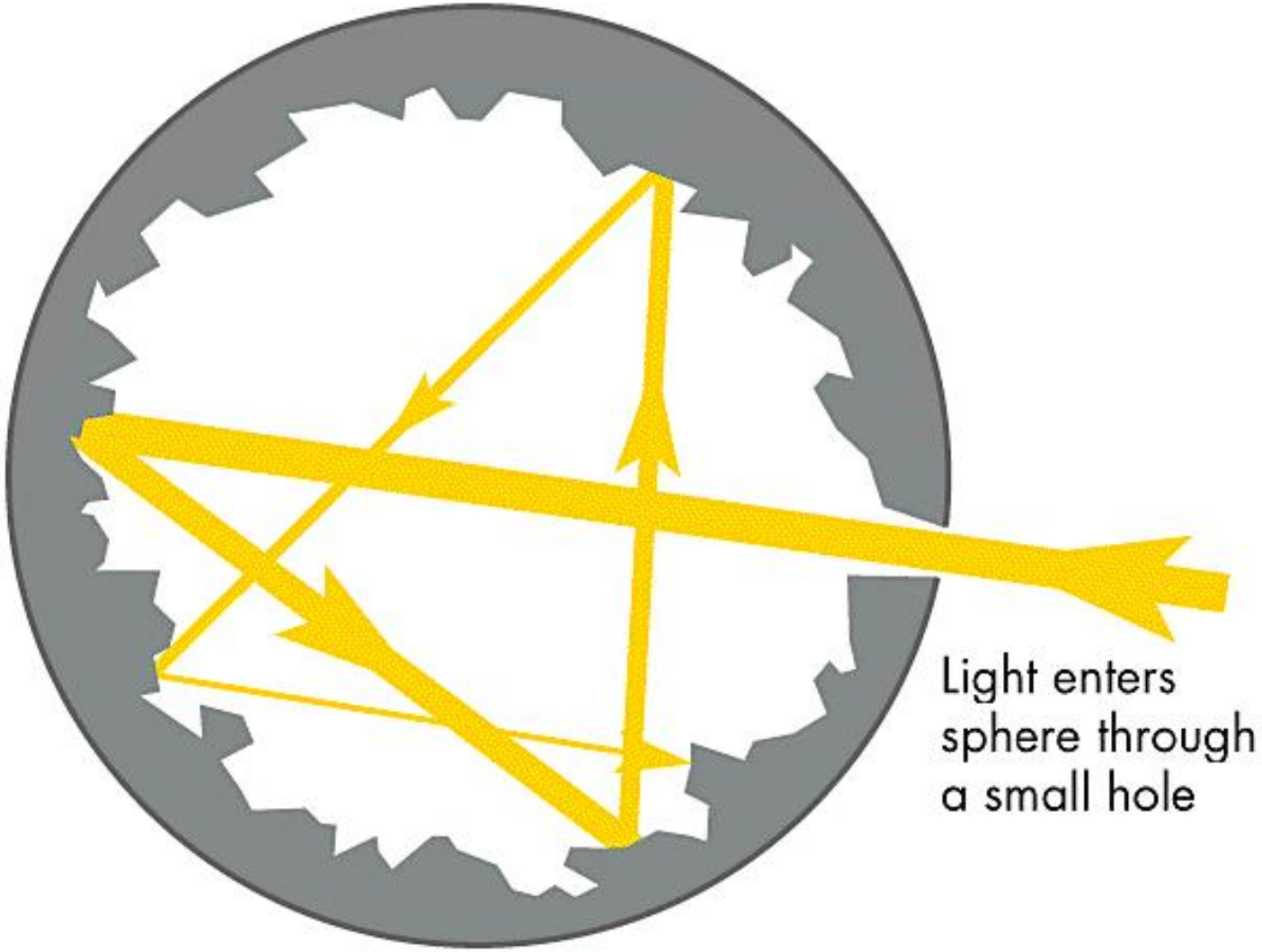


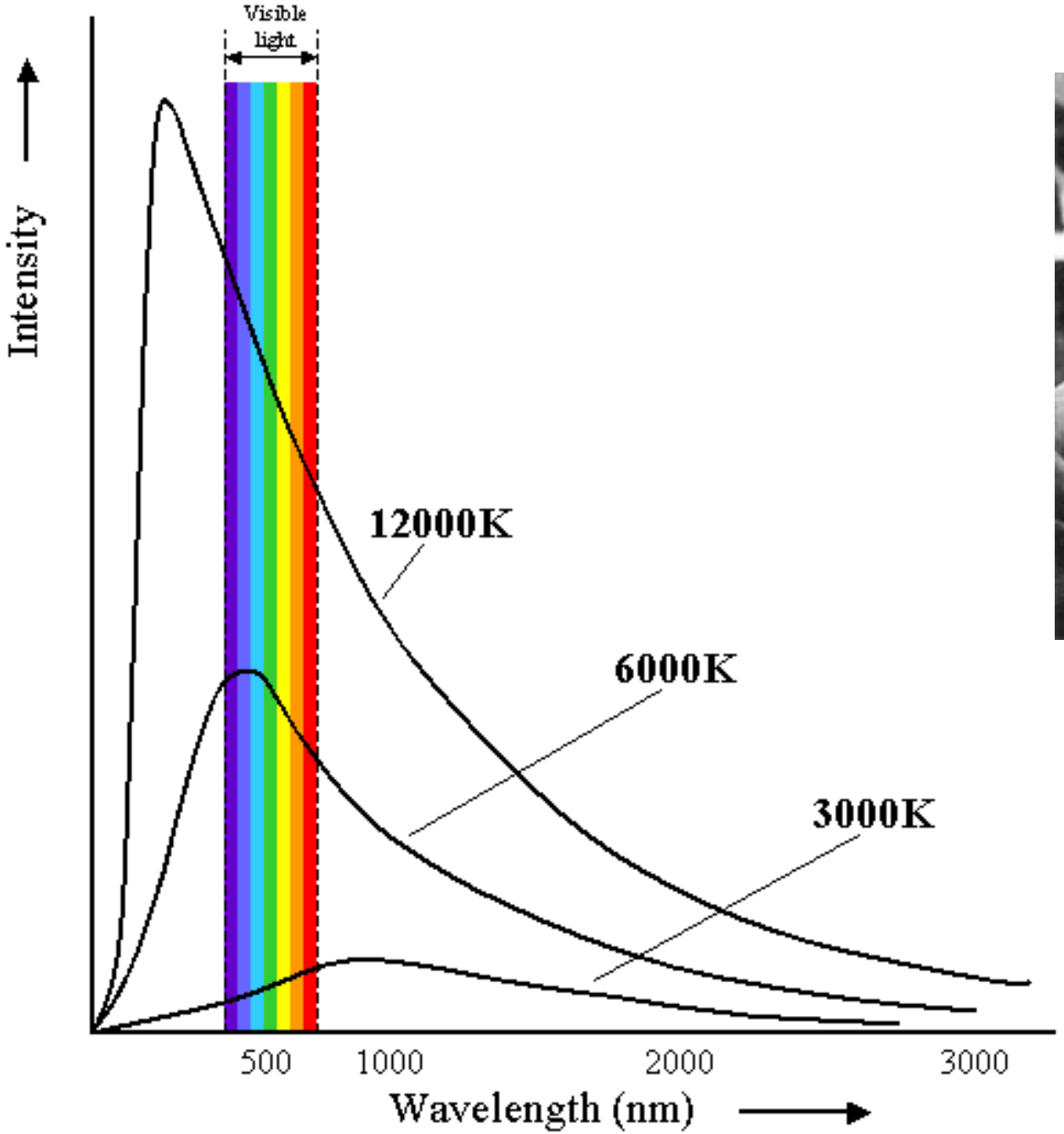
Early 1900s: accelerated electron radiates

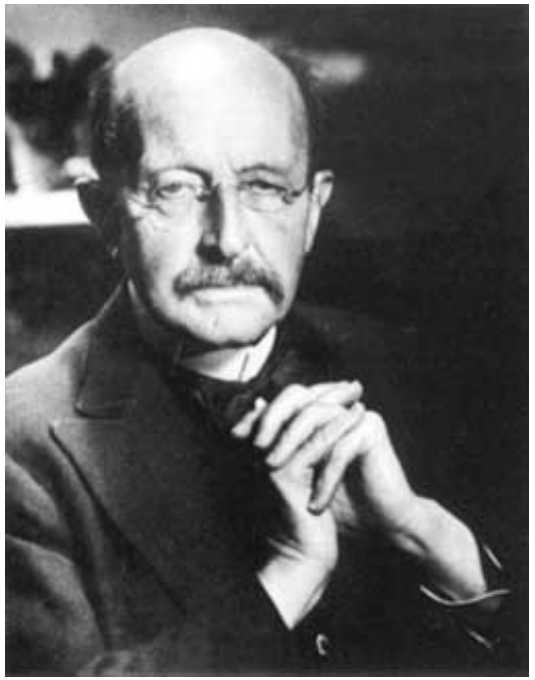
How do atoms persist?



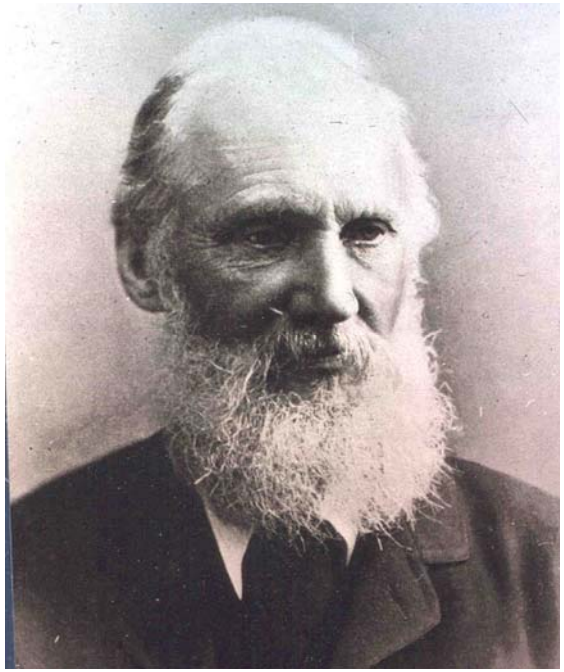
Black-body radiation




Visible light
Intensity
12000K
6000K
3000K
500
1000
2000
3000
Wavelength (nm)

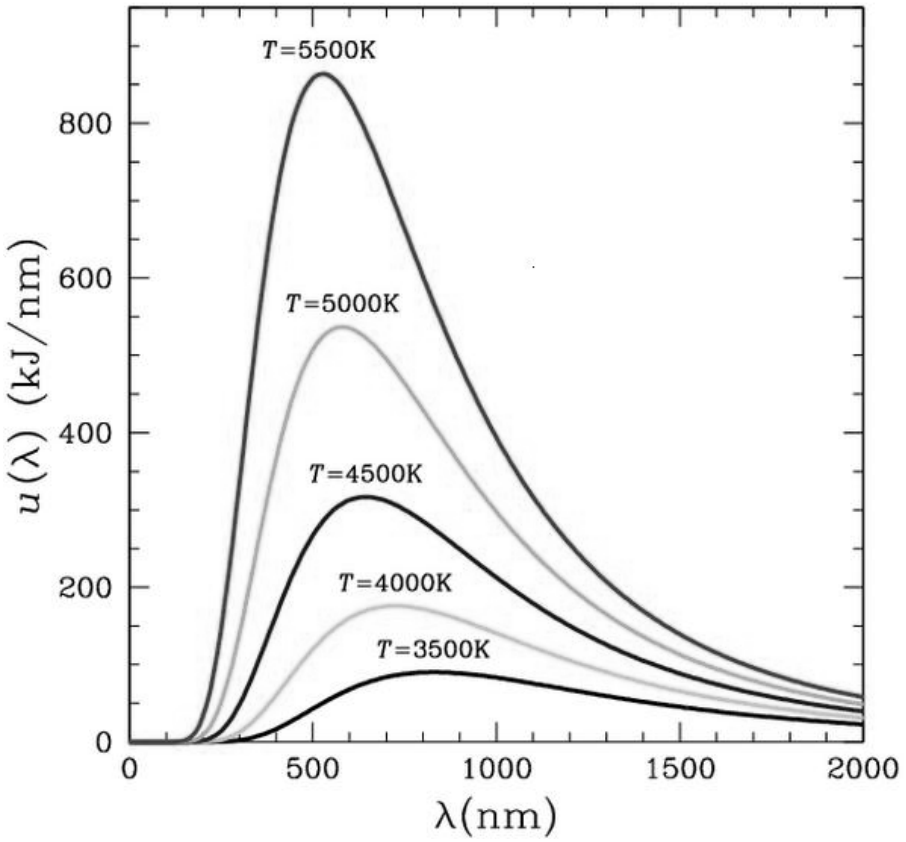


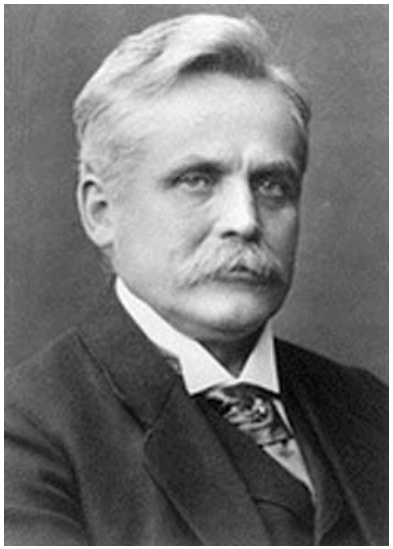
Max Planck



William Thompson
(Lord Kelvin)
1824 - 1907

"In the present state of physical science, therefore, a question of extreme interest arises: Is there any principle on which an absolute thermometric scale can be founded?"



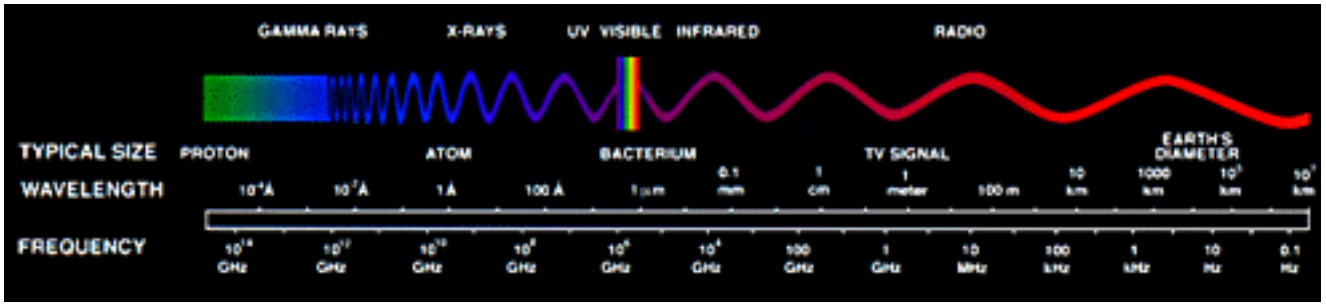


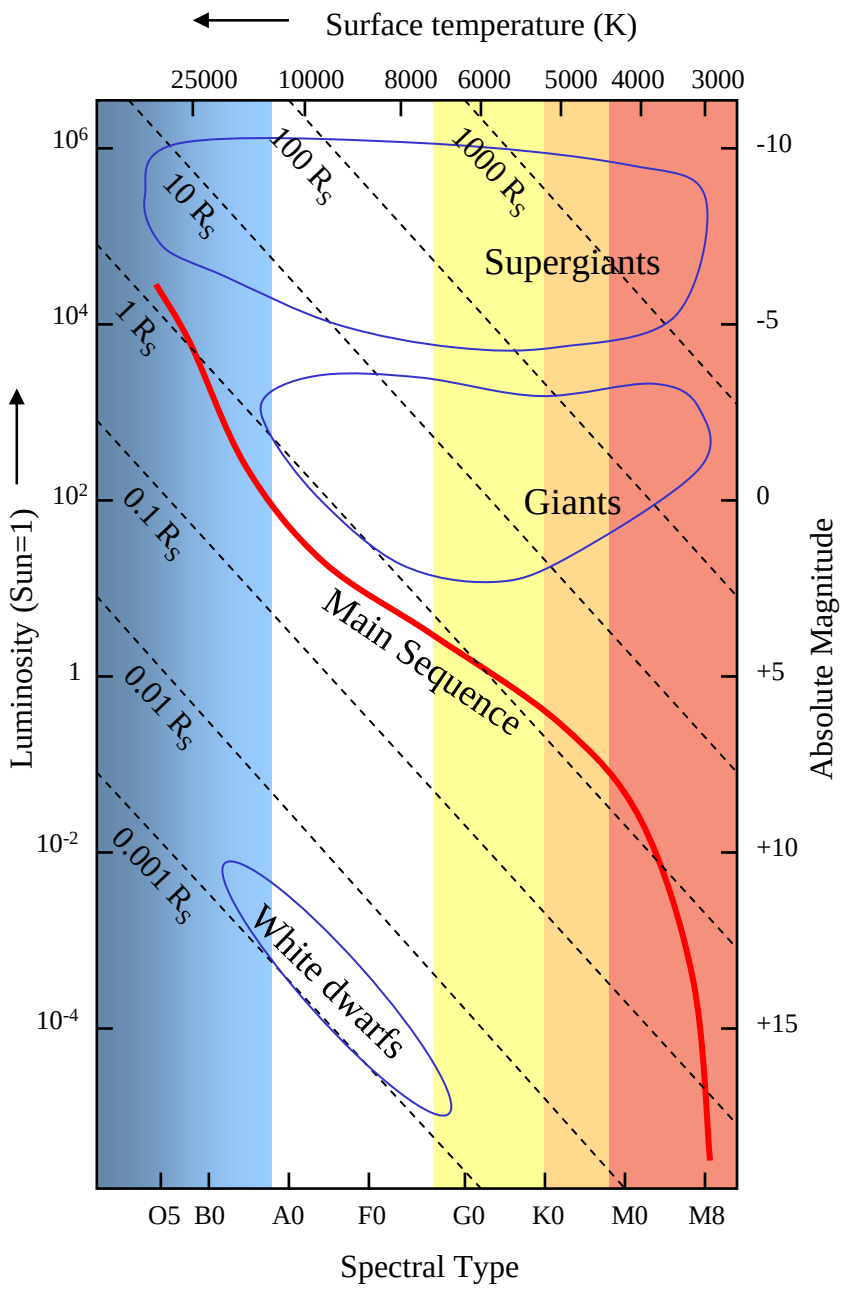
Wien's law

$$\lambda_{\max} T = 2.9 \times 10^{-3}$$

in m

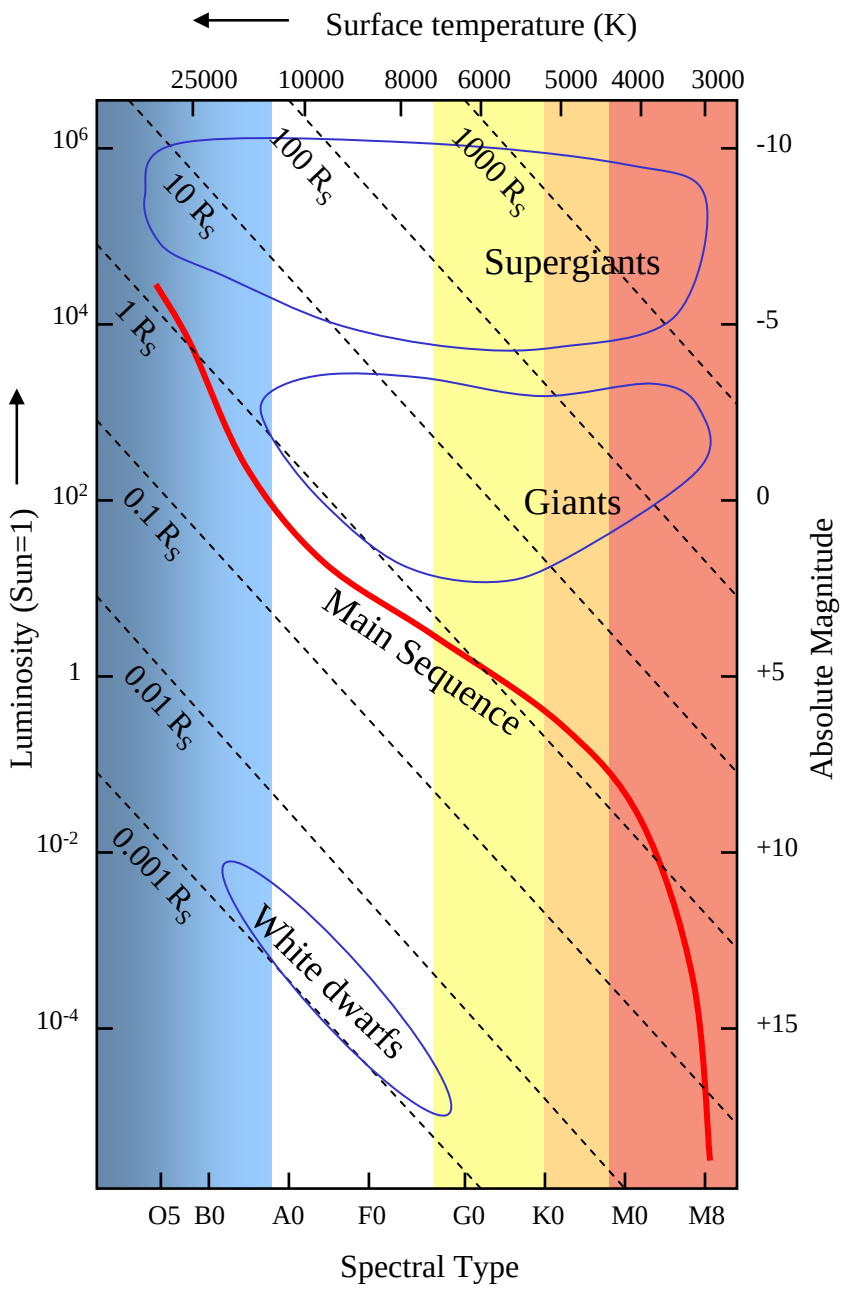
in K





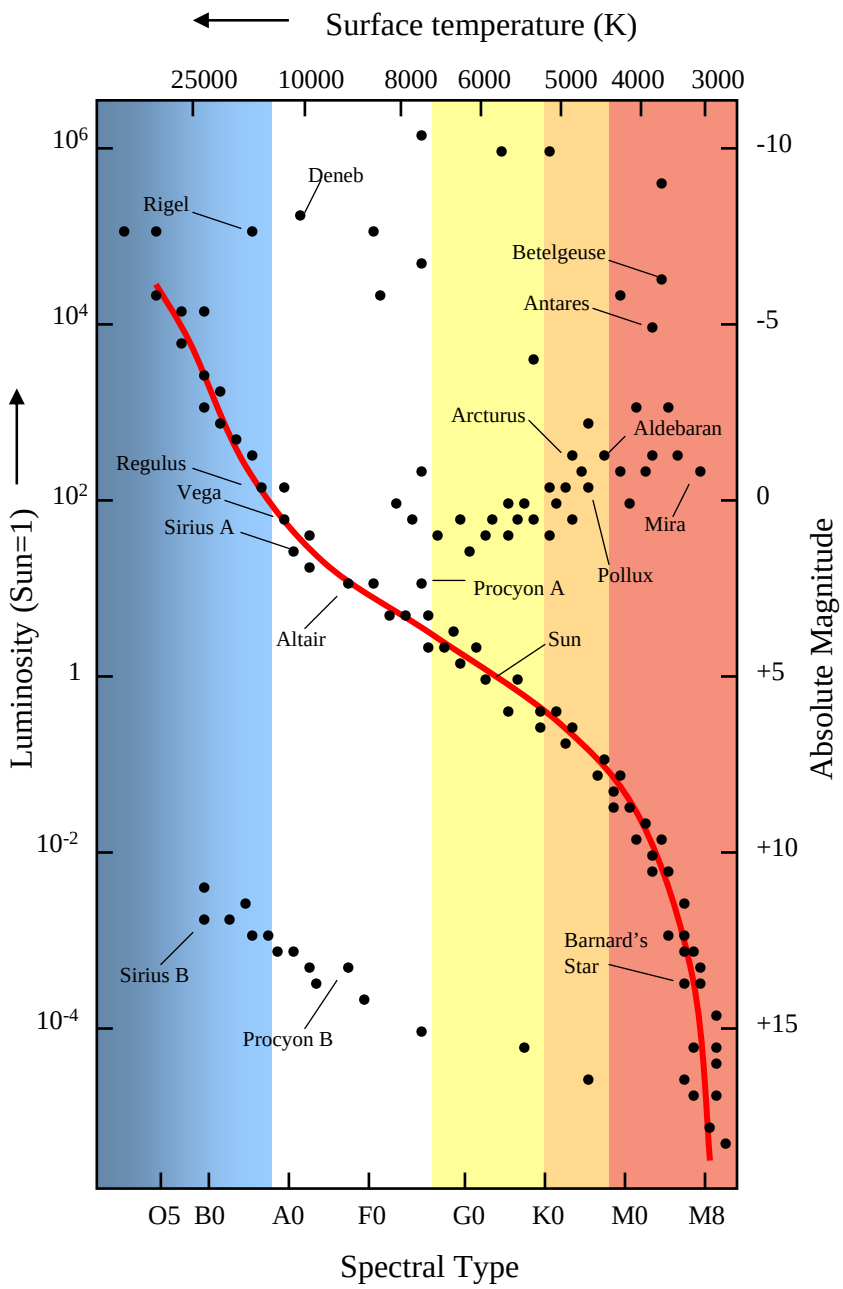
We can plot the **temperature** and **luminosity** of stars on a diagram

Stars don't appear *everywhere*: they group together, and most are found on the **Main Sequence**



Stars found on the **Main Sequence** convert hydrogen into helium.

Stars like the Sun can do this for many billions of years, using the **P-P chain** of nuclear reactions



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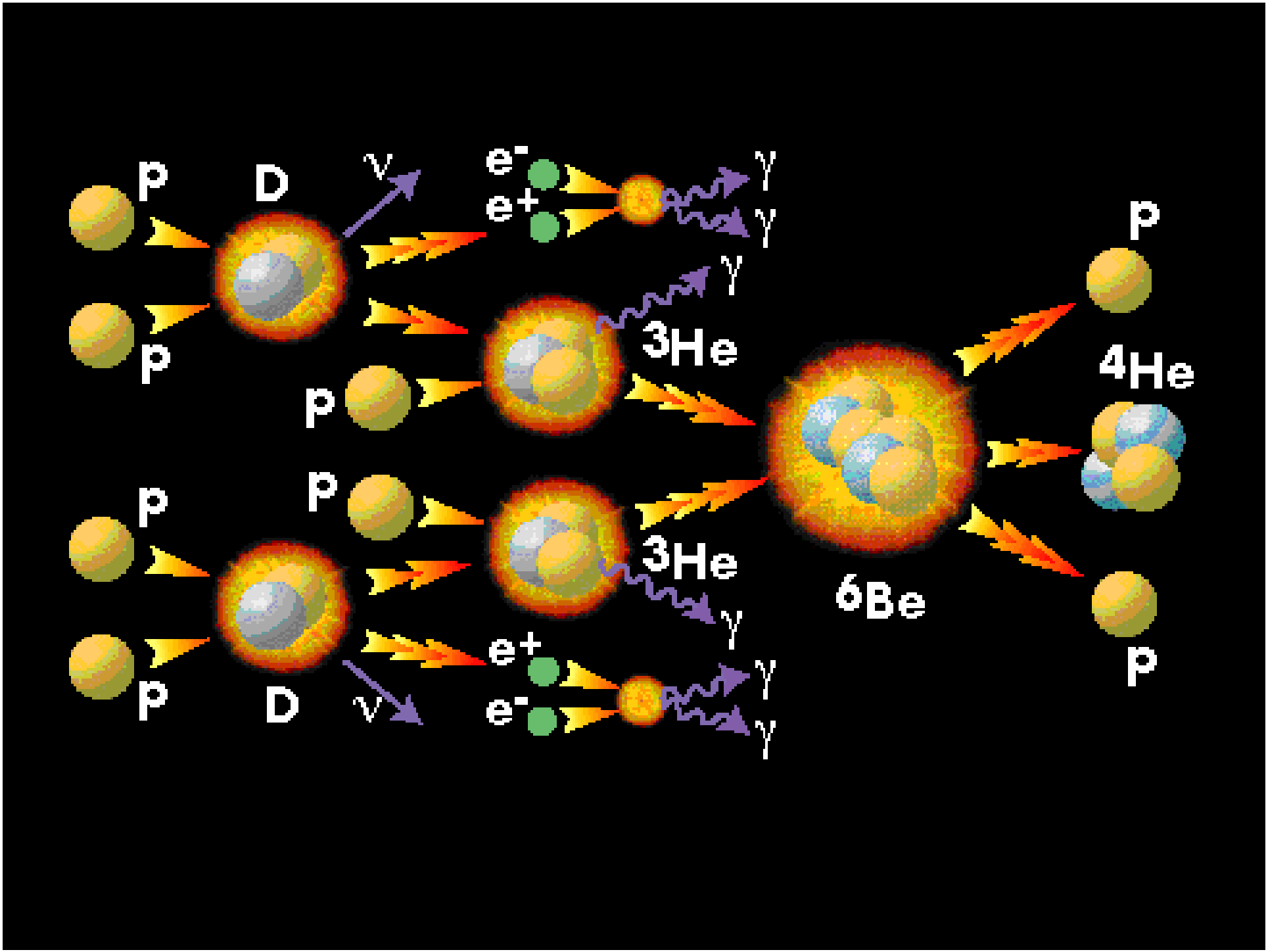
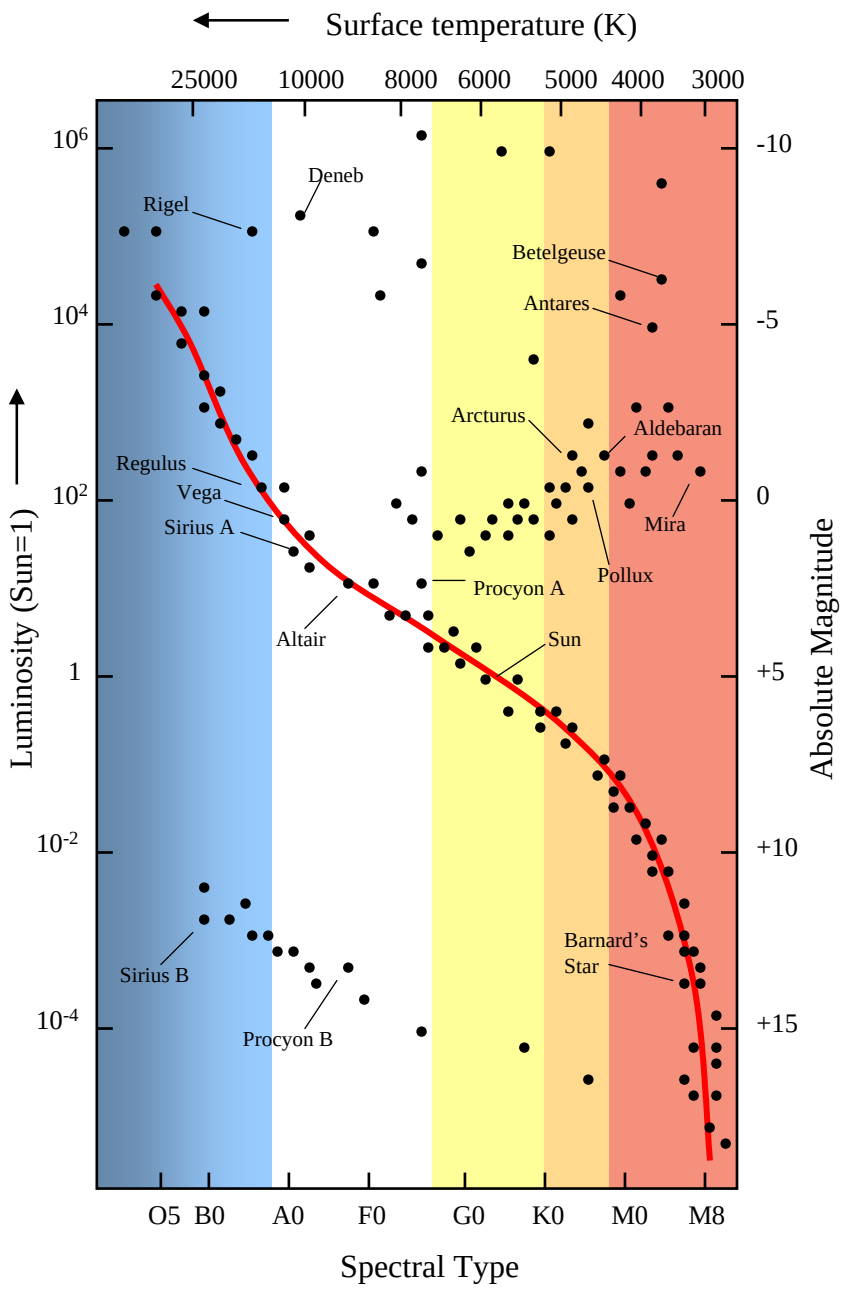
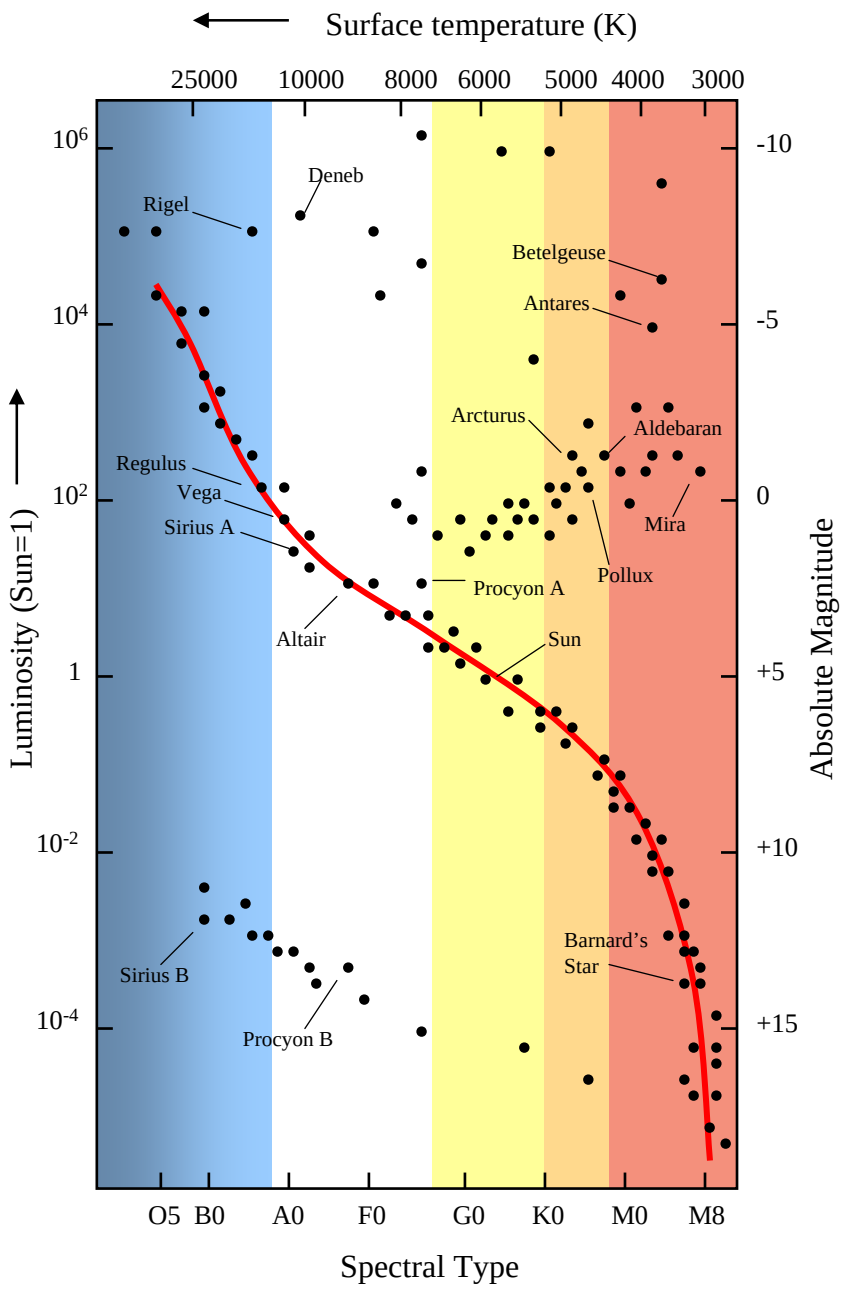

p
p
D
γ
e-
e+
γ
γ
γ
3He
p
p
p
p
3He
γ
6Be
p
4He
p
e+
e-
γ
γ
D
ν



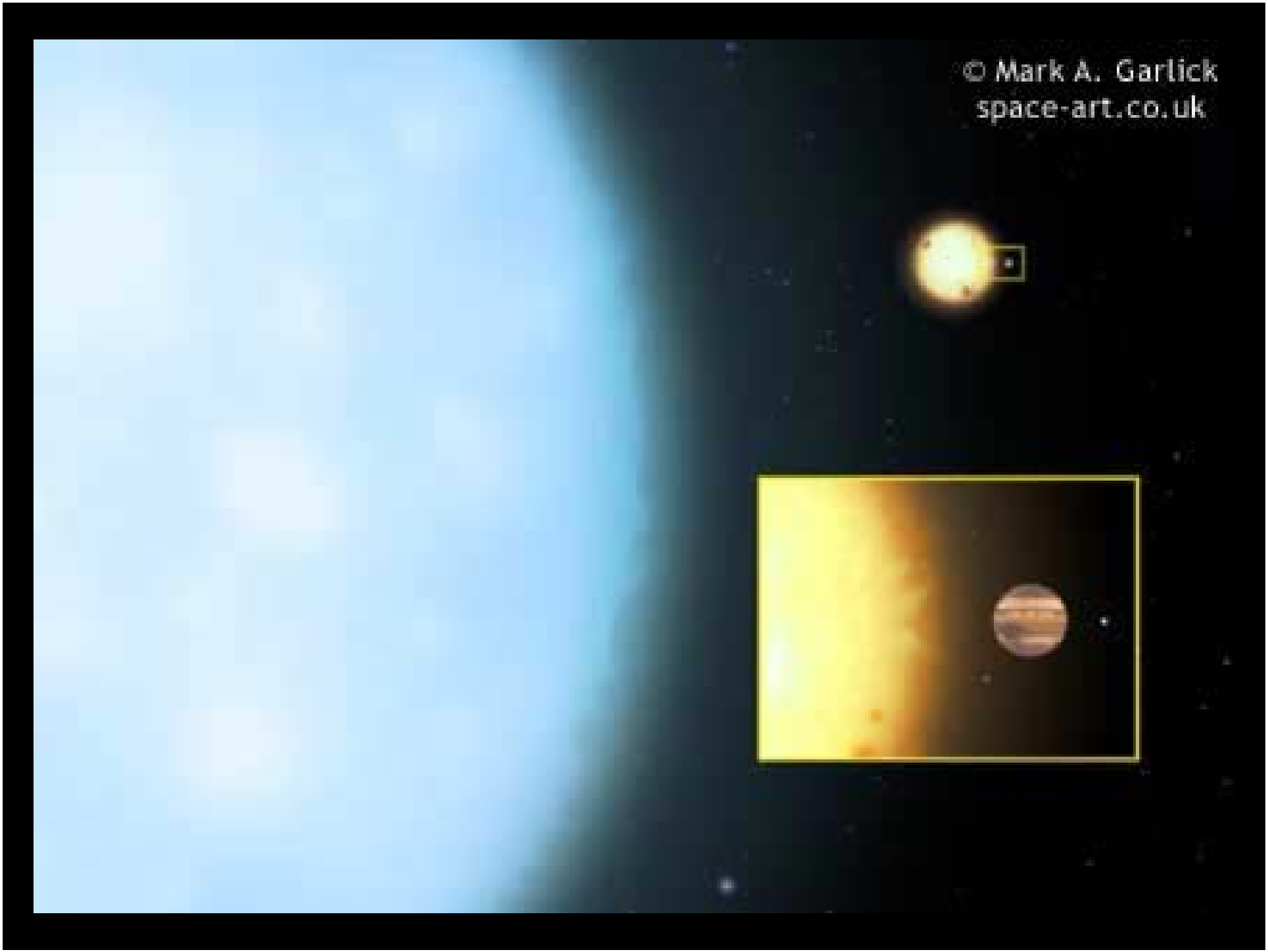
Stars found on the **Main Sequence** convert hydrogen into helium.

Hotter stars burn their hydrogen much faster, via the **CNO Cycle**



Stars on the **Main Sequence** turn hydrogen into helium.

Blue stars are much hotter than the Sun, and use up their hydrogen in a few million years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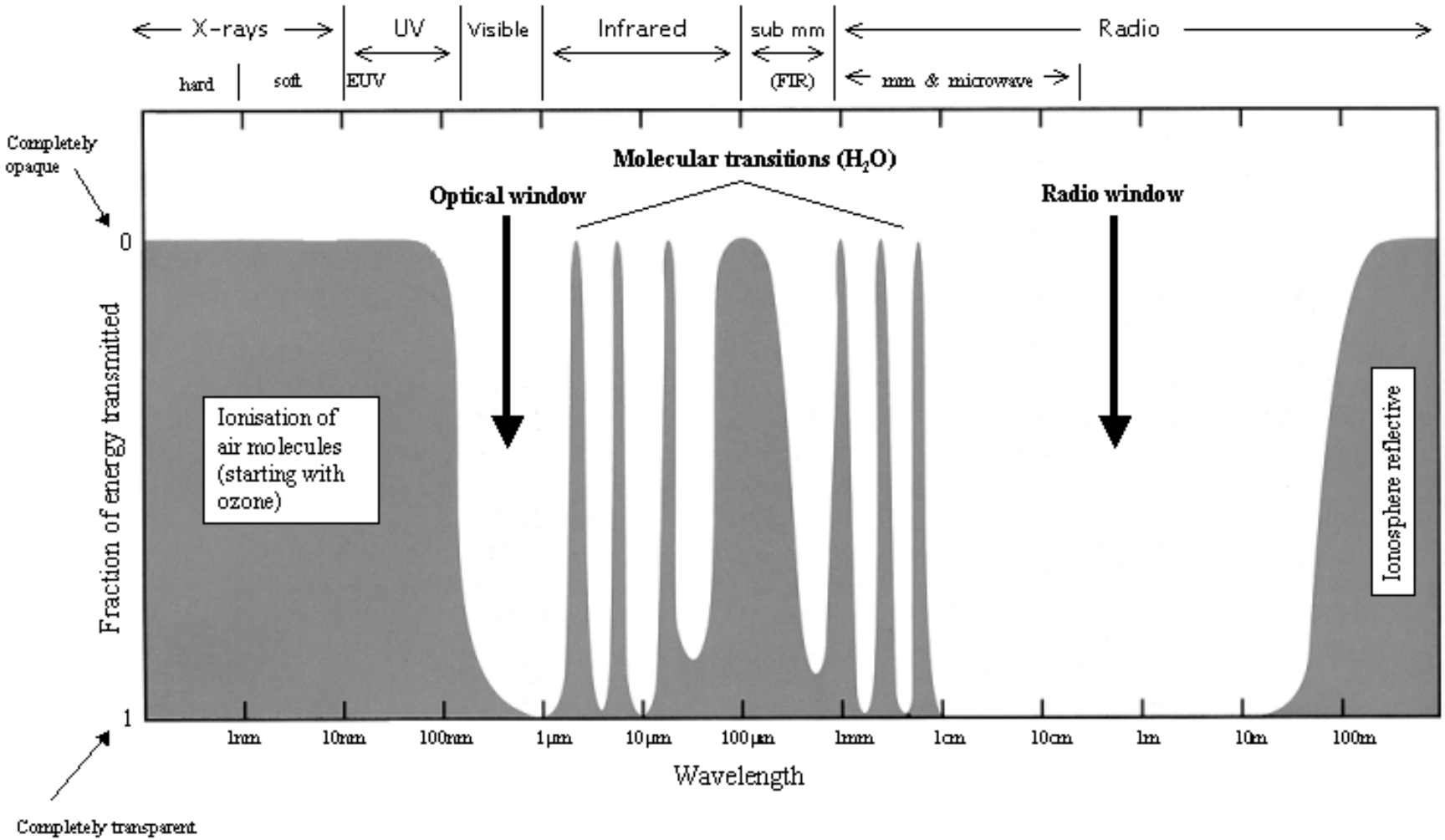
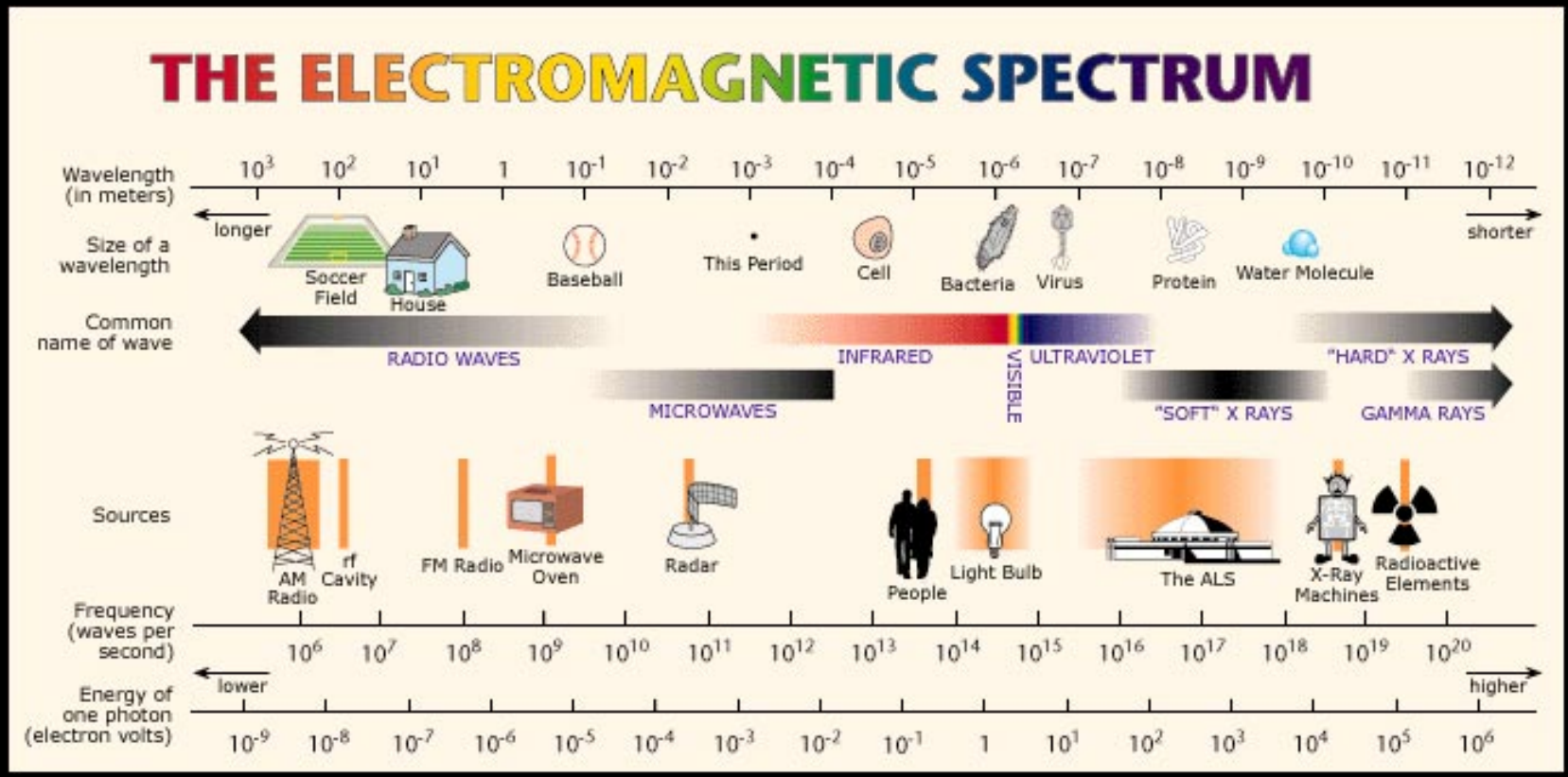
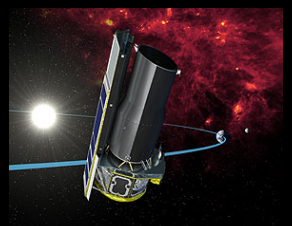
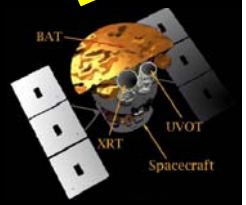
space-art.co.uk


X-rays
hard
soft
UV
EUV
Visible
Infrared
sub mm
(FIR)
Radio
mm & microwave
Completely opaque
0
1
Fraction of energy transmitted
Molecular transitions (H_2O)
Optical window
Radio window
Ionisation of air molecules (starting with ozone)
Ionosphere reflective
1nm
10nm
100nm
1μm
10μm
100μm
1mm
1cm
10cm
1m
10m
100m
Wavelength
Completely transparent







Temperature: 3K 100K 5000K 10^{5}K 10^{7}K 10^{9}K