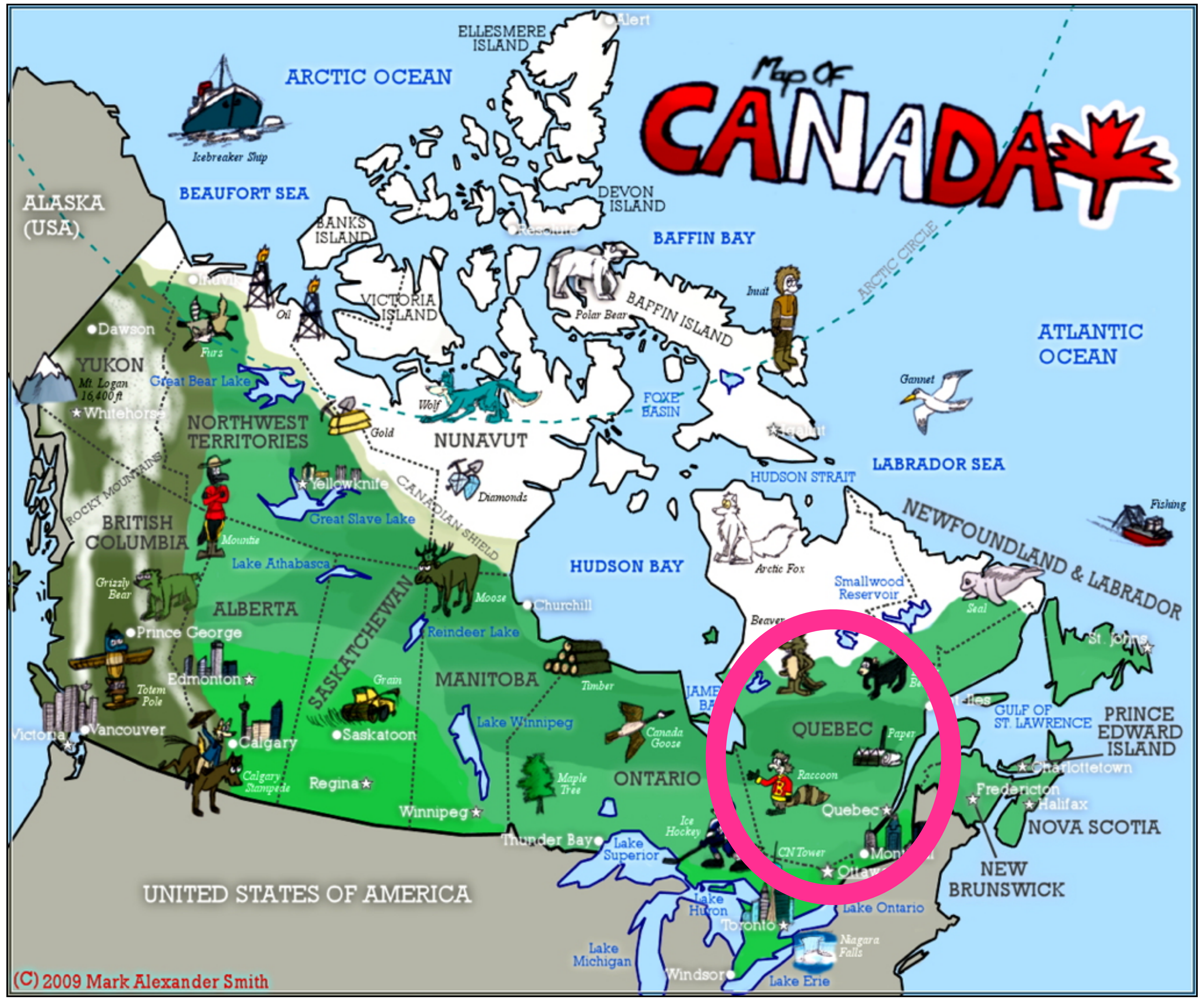
Week 1 Tuesday

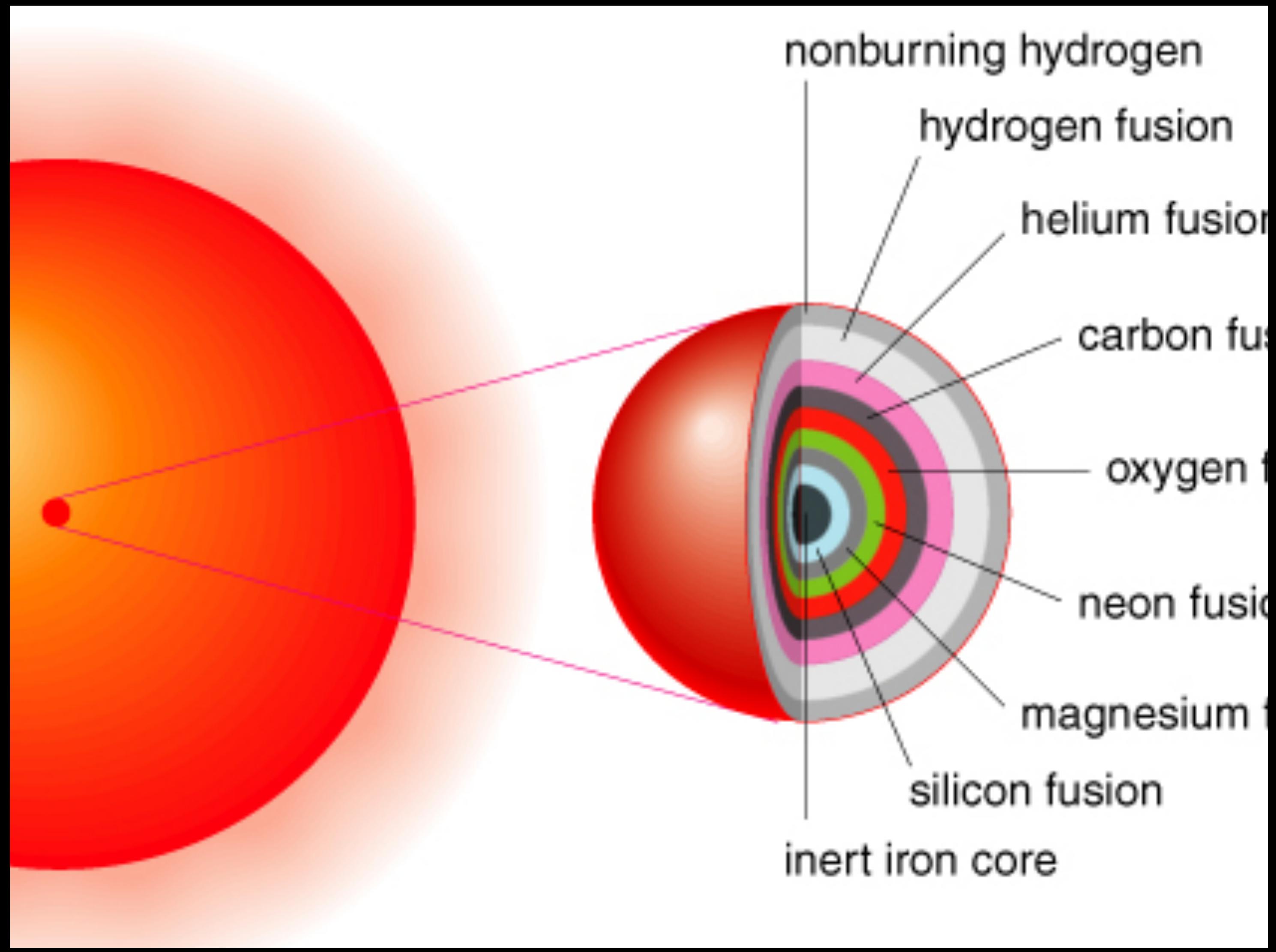
L-1

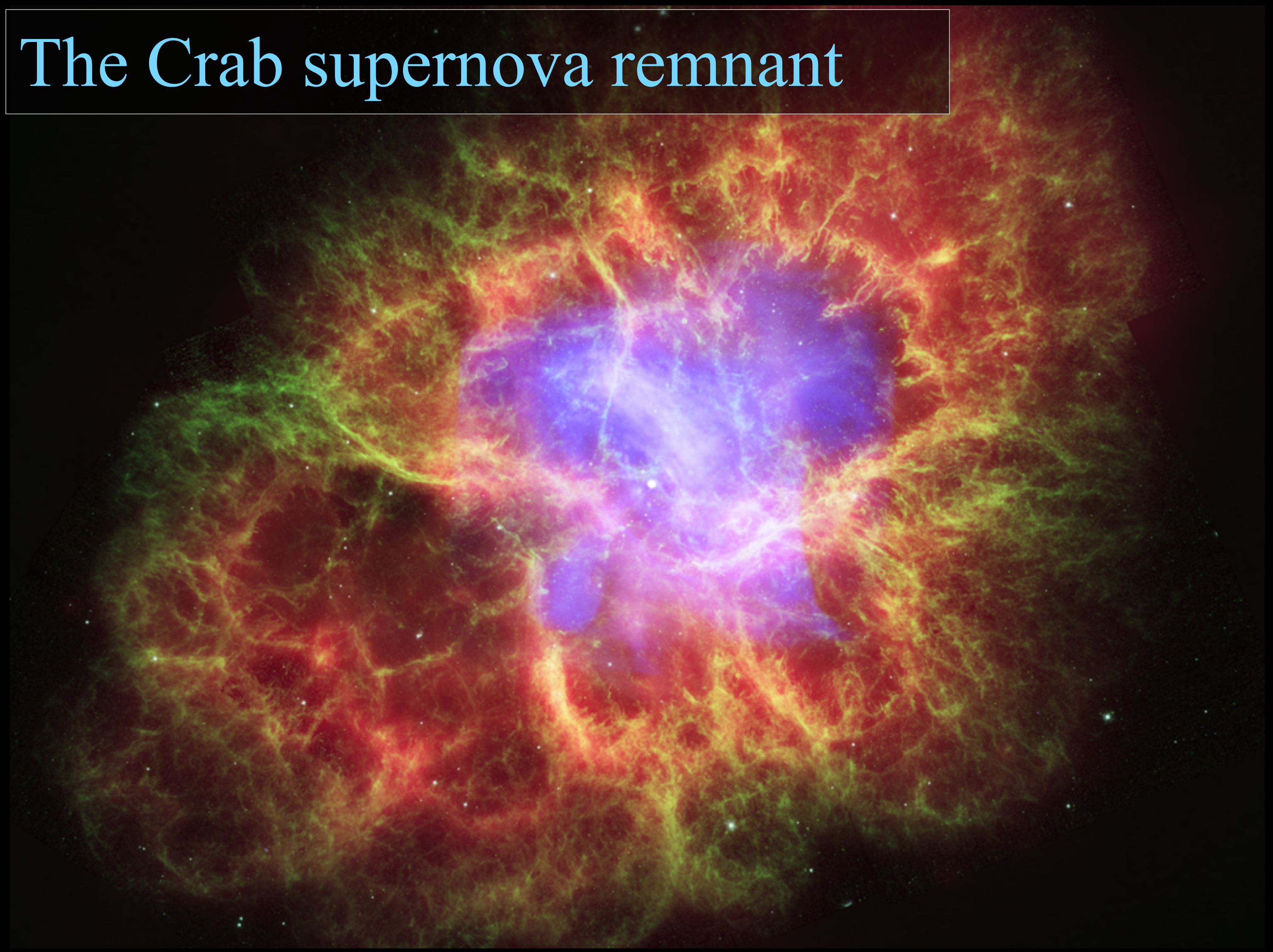
Timescales

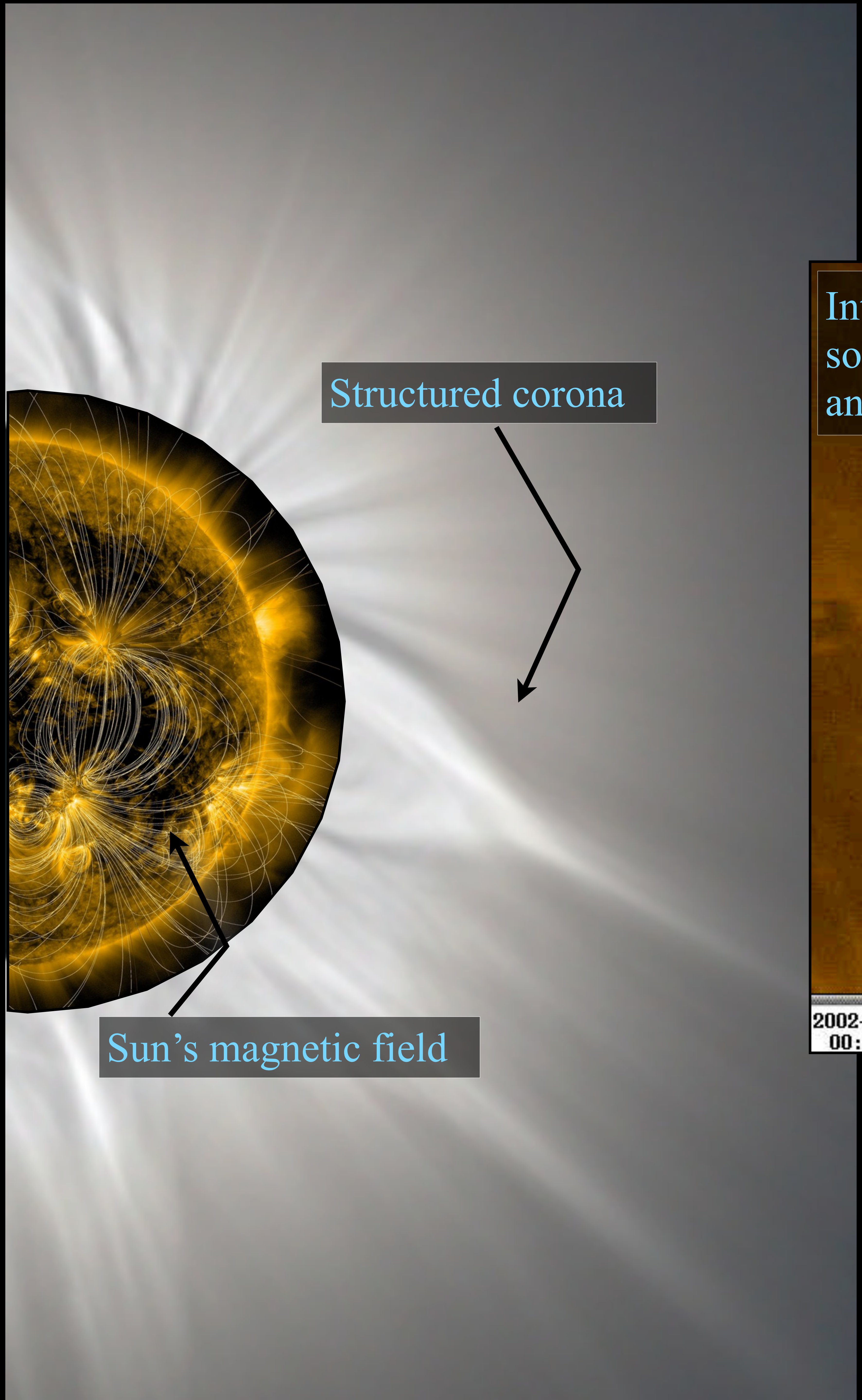
A little bit <canadian> about </canadian> me

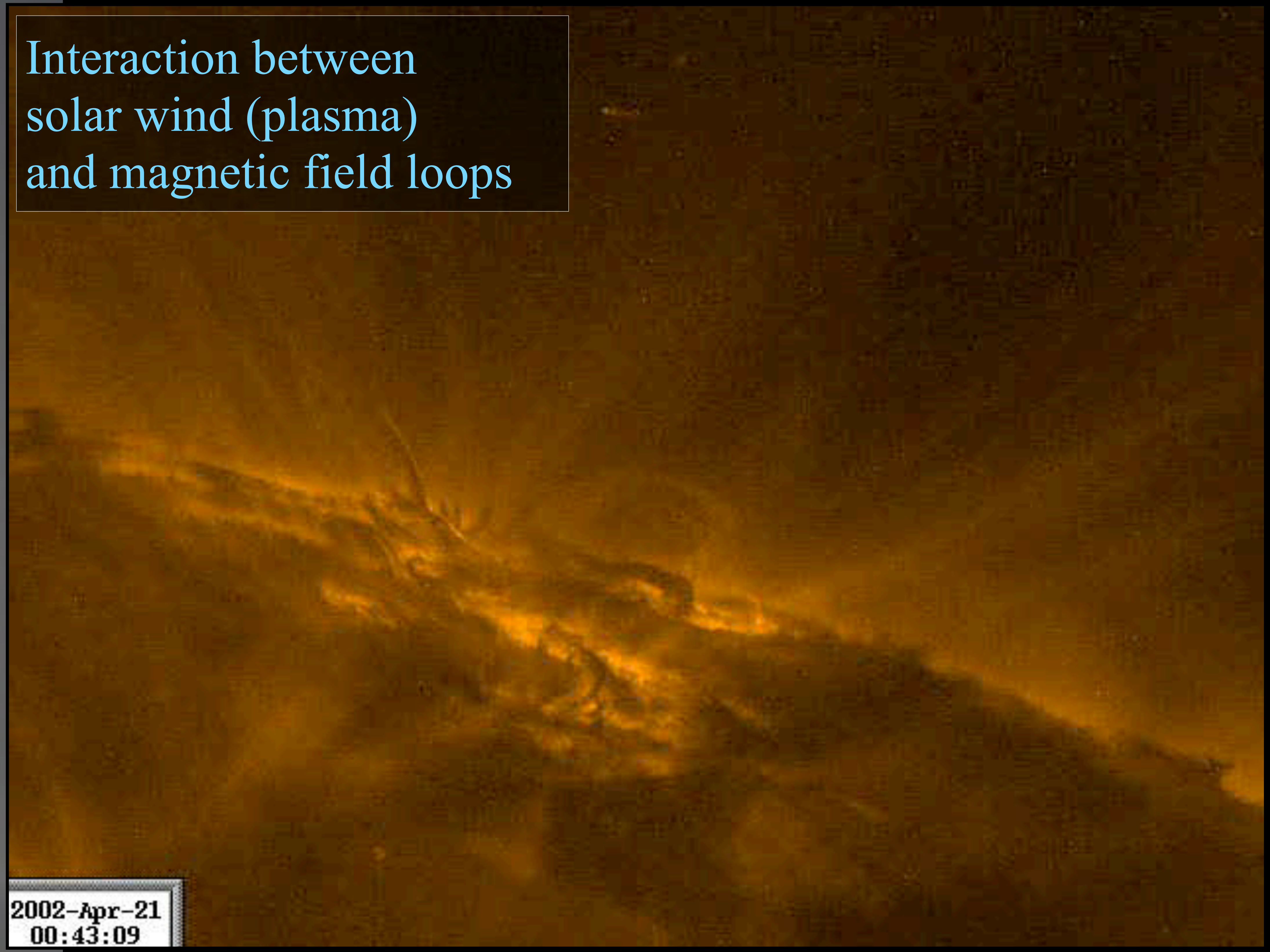


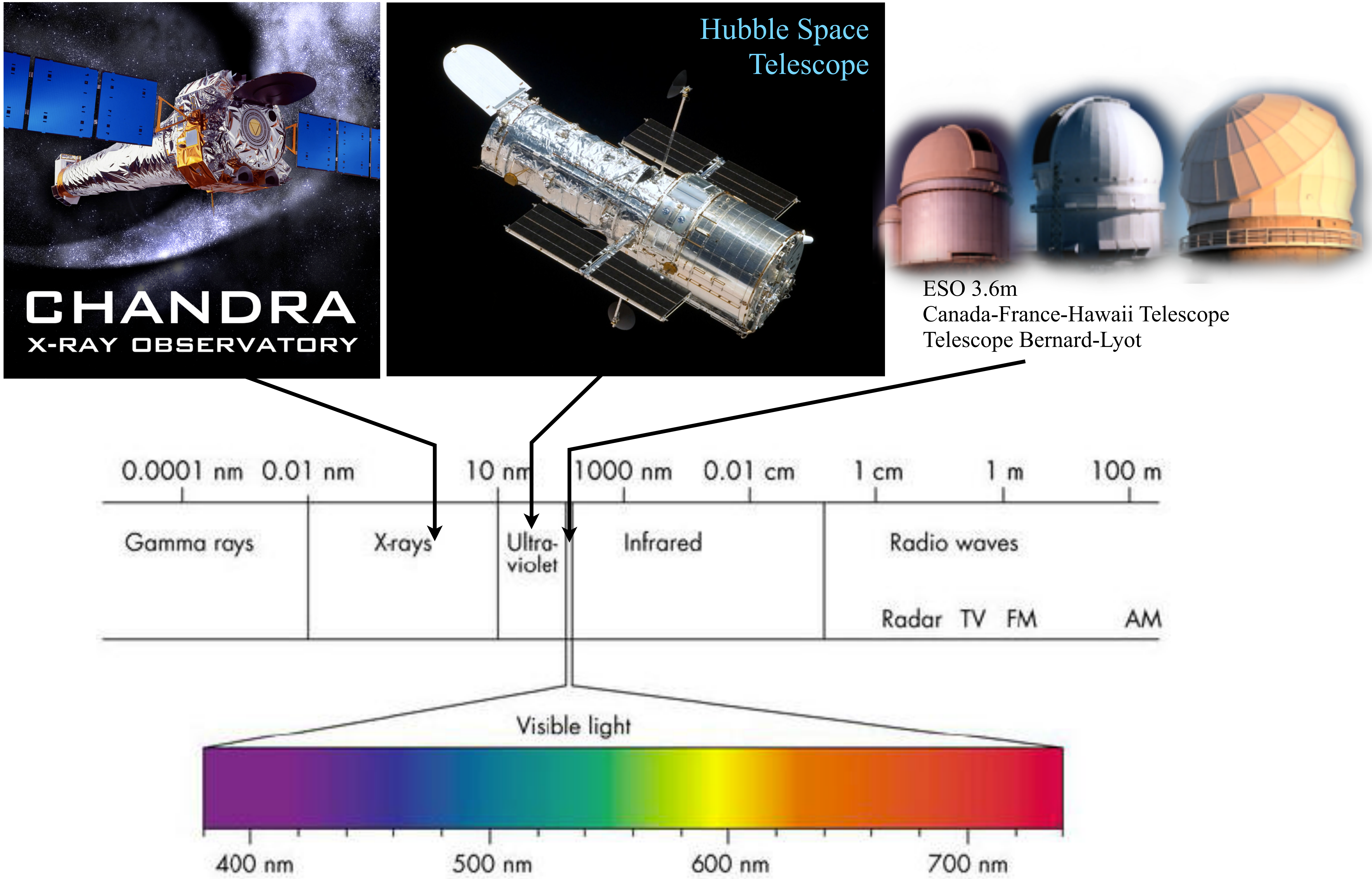

Hot, massive stars in the
star forming region 30 Doradus

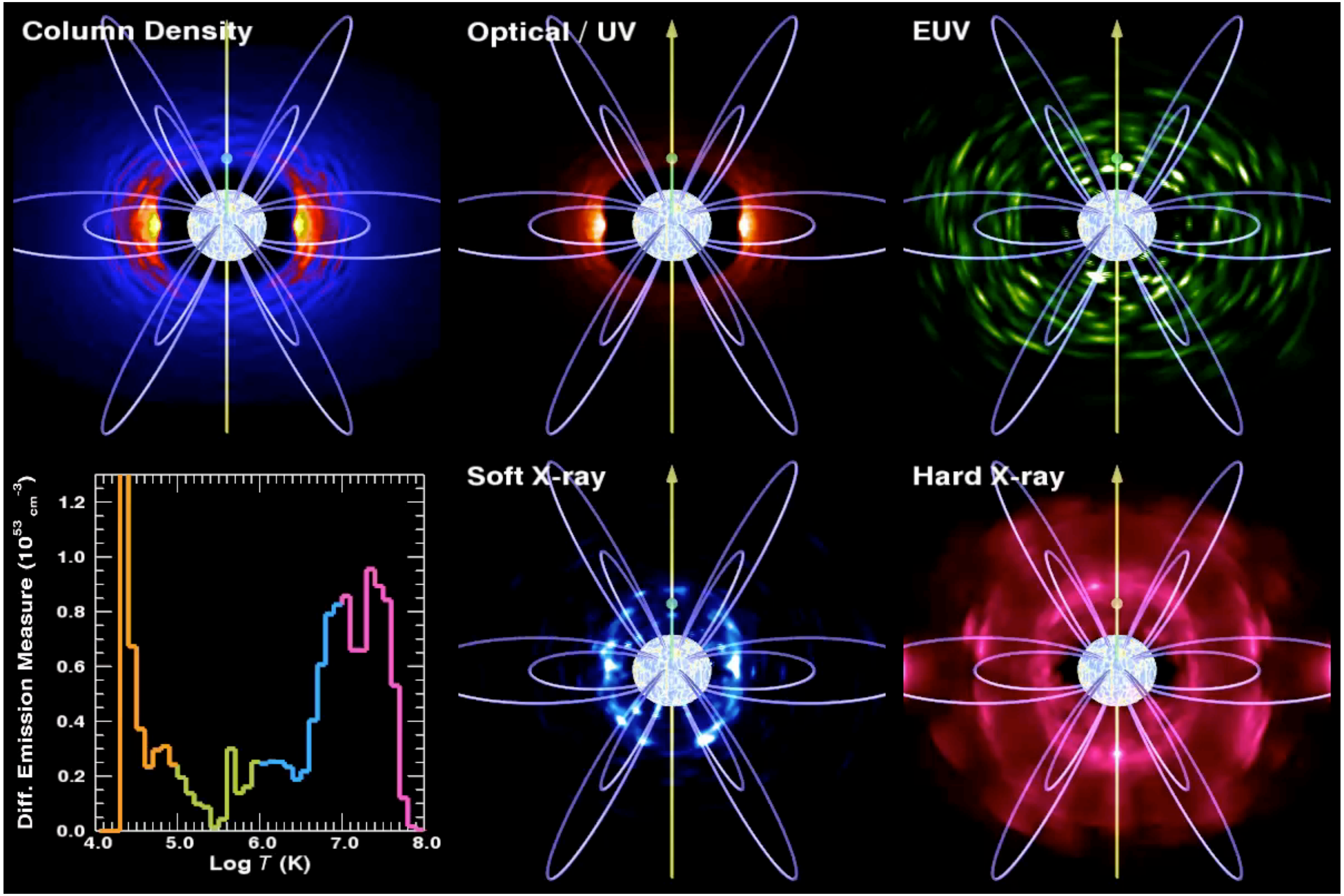



The Crab supernova remnant


Structured corona
Sun’s magnetic field


Interaction between
solar wind (plasma)
and magnetic field loops
2002-Apr-21
00:43:09


CHANDRA
X-RAY OBSERVATORY
Hubble Space
Telescope
ESO 3.6m
Canada-France-Hawaii Telescope
Telescope Bernard-Lyot
0.0001 nm
0.01 nm
10 nm
1000 nm
0.01 cm
1 cm
1 m
100 m
Gamma rays
X-rays
Ultra-
violet
Infrared
Radio waves
Radar
TV
FM
AM
Visible light
400 nm
500 nm
600 nm
700 nm



Column Density
Optical / UV
EUV
Soft X-ray
Hard X-ray
Diff. Emission Measure (10^{53} cm^{-3})
Log T (K)
0.0
0.2
0.4
0.6
0.8
1.0
1.2
4.0
5.0
6.0
7.0
8.0

Scientific goals of this course

Use **physics** to describe the structure and evolution of stars

- How are properties (density, pressure, temperature, etc) distributed inside of stars
- If we take a star of a certain — say mass — what will the surface properties be like?
- As time goes by, what happen to stars?

Skills goals of this course

Practice understanding new things and figuring things out

Practice science computing, including numerical calculations and graphs

Practice producing deliverables (papers, reports, etc)

My role: Keep your eyes on the price

Before class

Review of concepts

Readings

In class

Lecture

Notebook

Outside of class

Complete notebook

Additional assignment

Your portfolio

Grading scheme

Portfolio: 60%
Mid-term (oral): 20%
Final (oral): 20%

A	4.00
B	3.00
C	2.00
D	1.00
F	0.00

Textbooks

Policies

Code of conduct

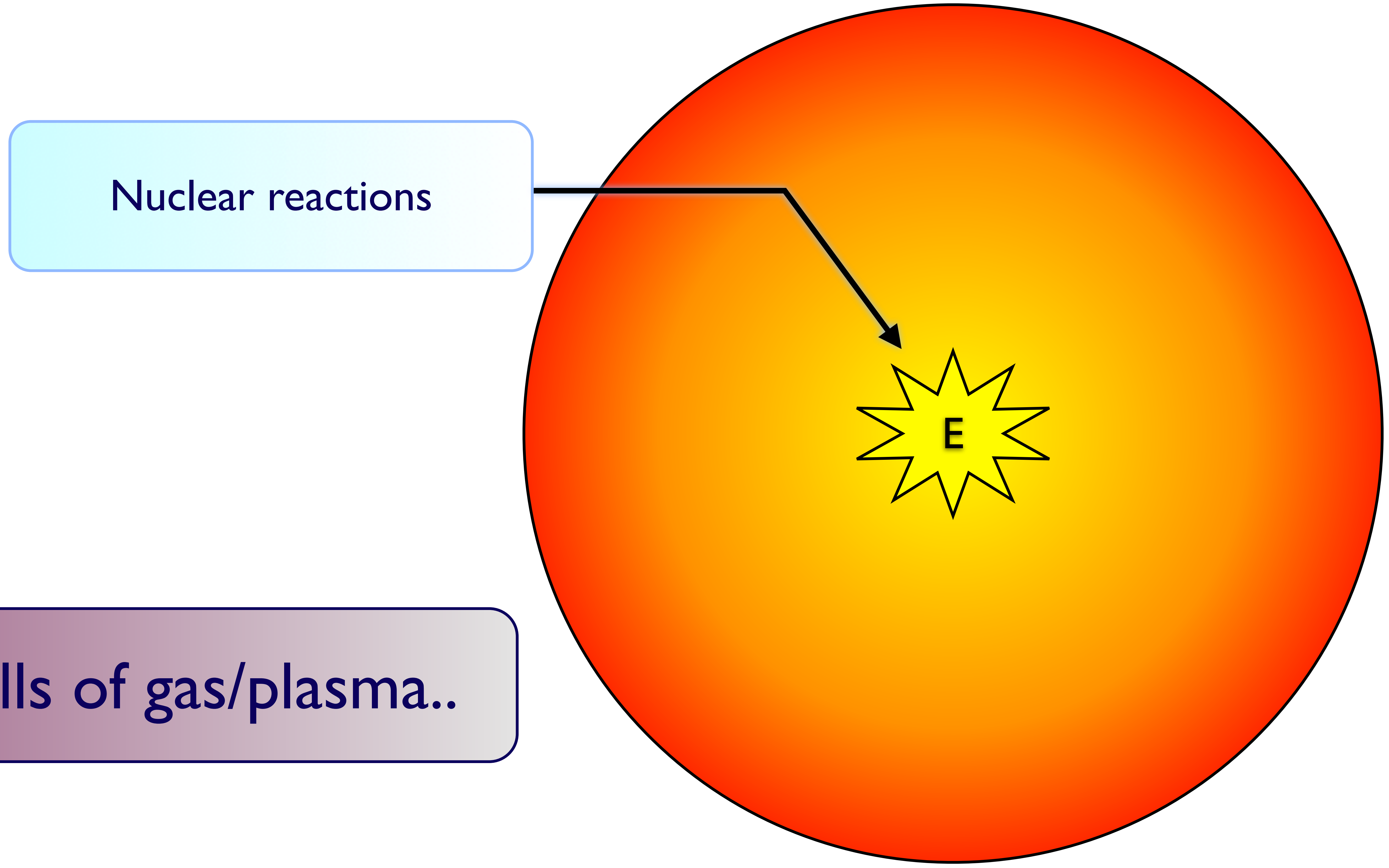
What is a star ?

Reading assignments scattered throughout the course:

We will come up with a list of the physical properties of stars **that are measurable**.

A star is:

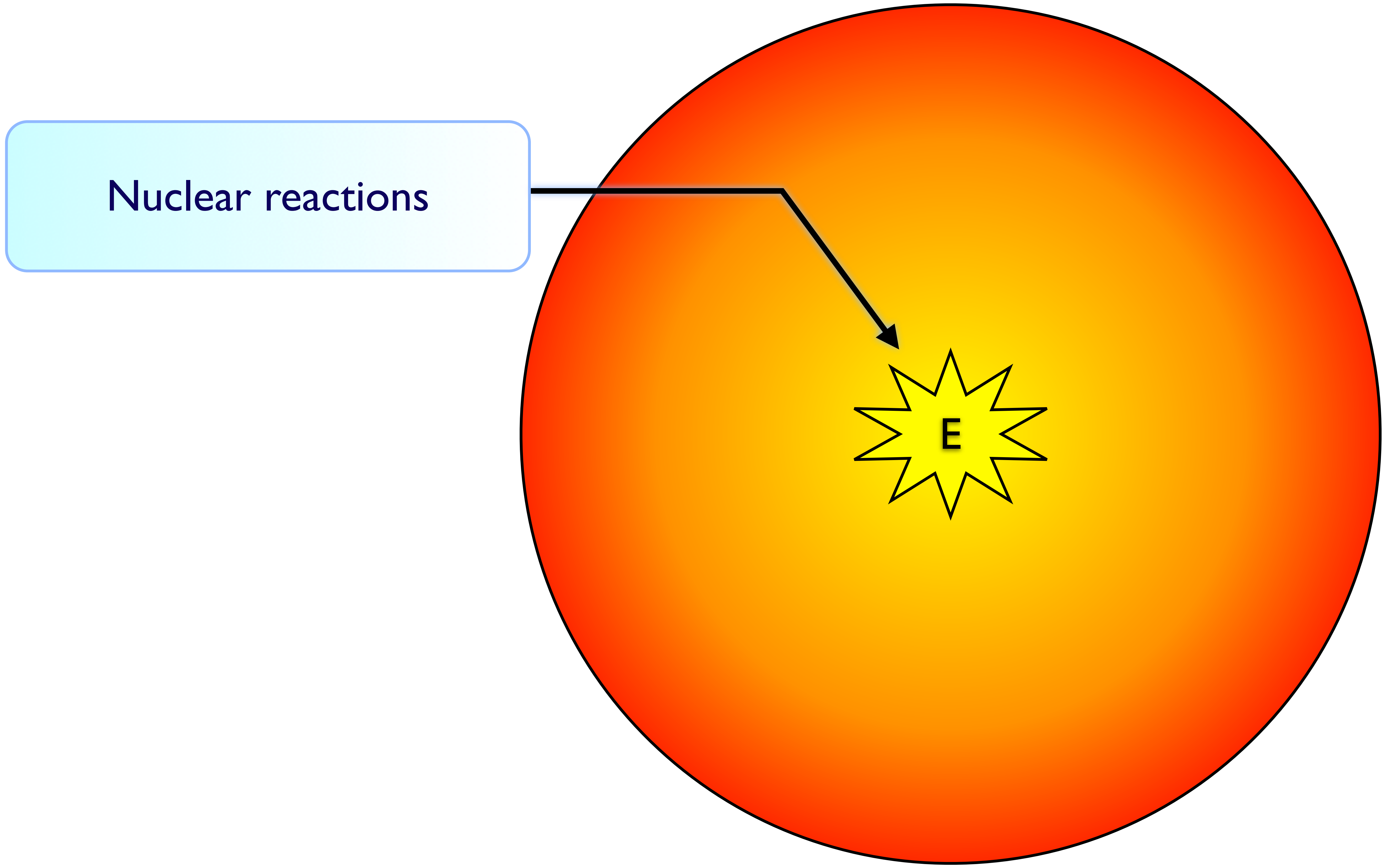
Self-gravitating celestial object, in which there is, or once was, sustained **thermonuclear fusion** of hydrogen in their core.



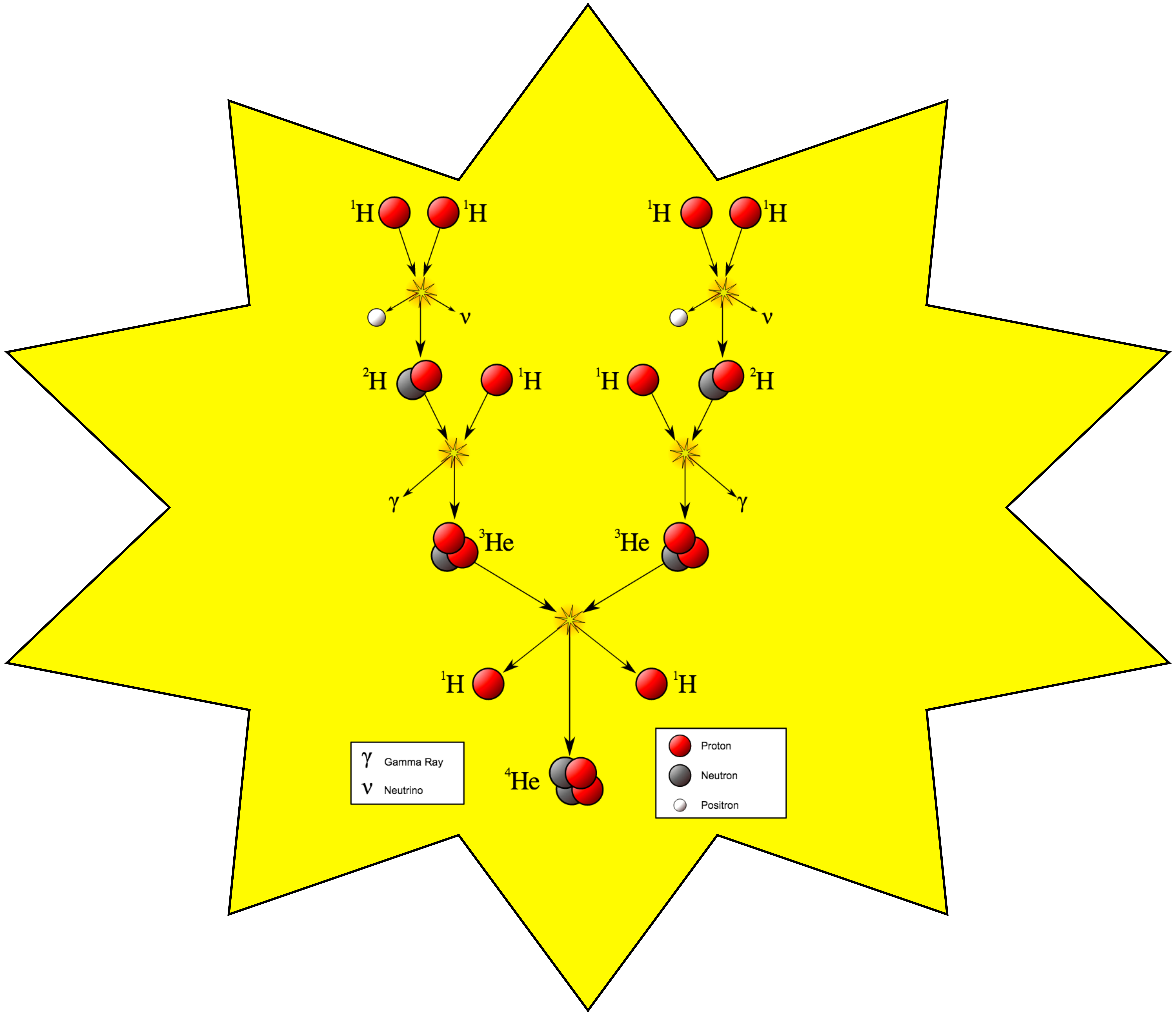
Big balls of gas/plasma..

$$4\ {}^{1}H \rightarrow {}^{4}He + \text{energy}$$

Nuclear physics



$$4\ {}^{1}H \rightarrow {}^{4}He + \text{energy}$$

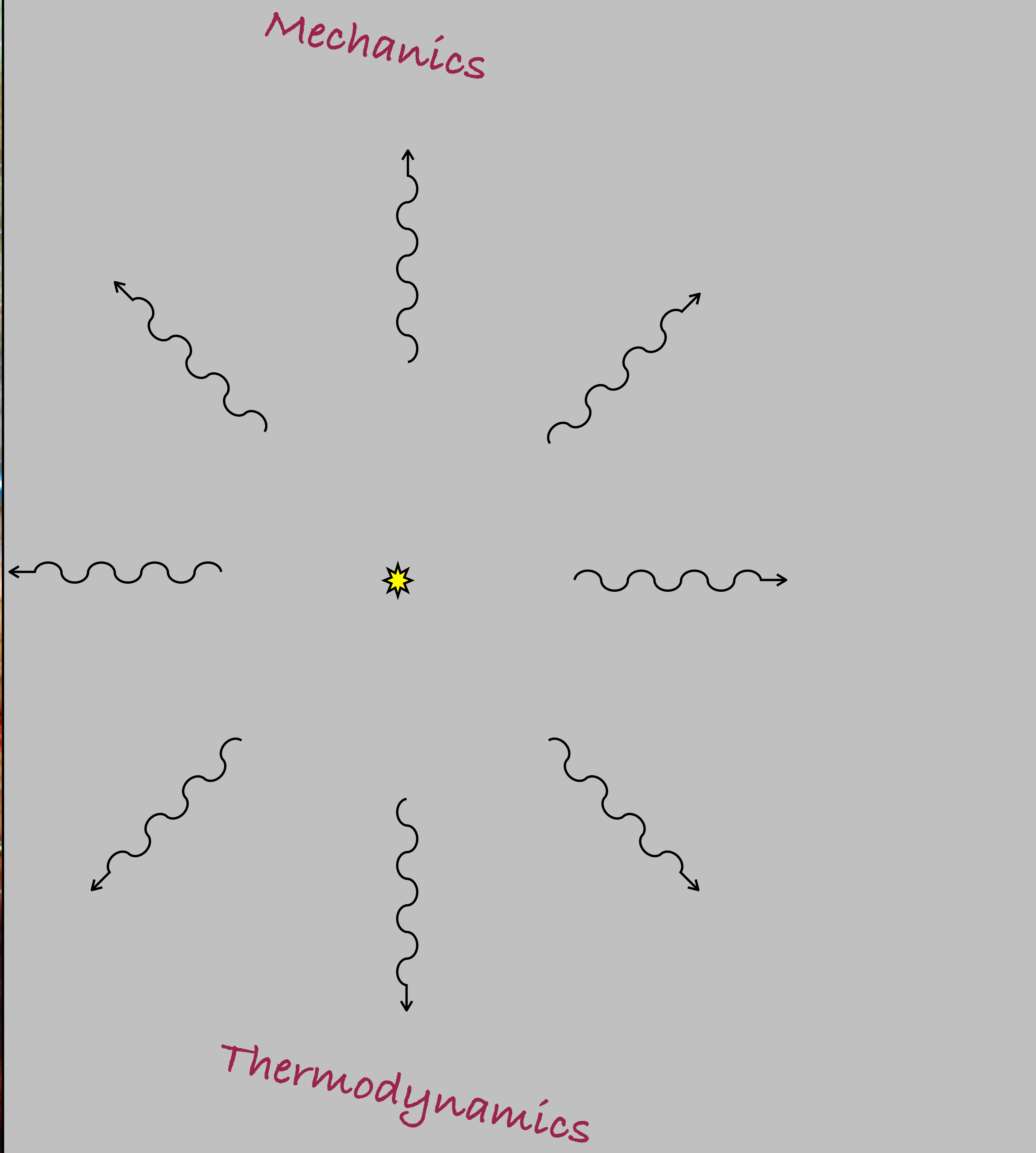


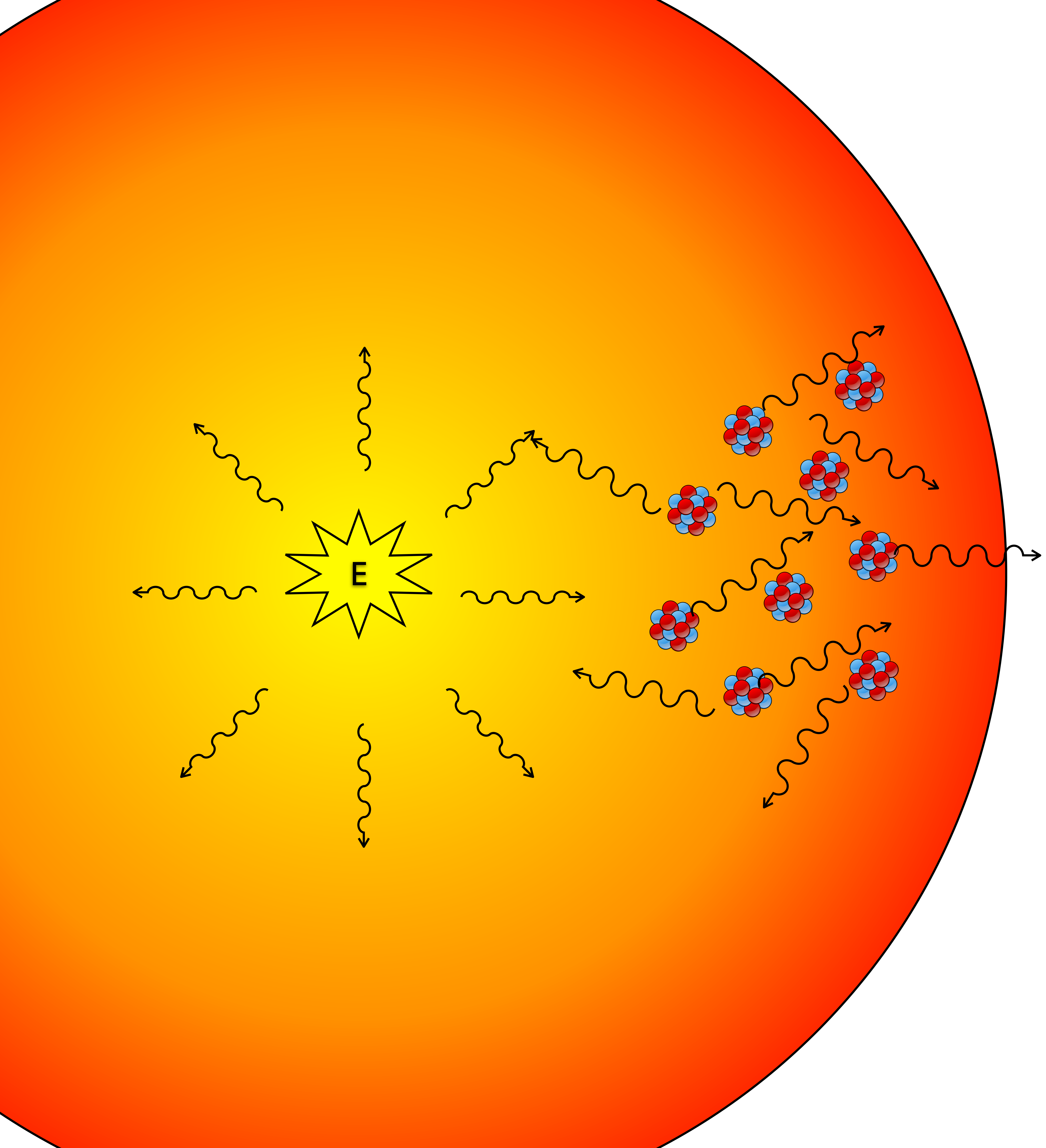
Nuclear physics

Electromagnetism

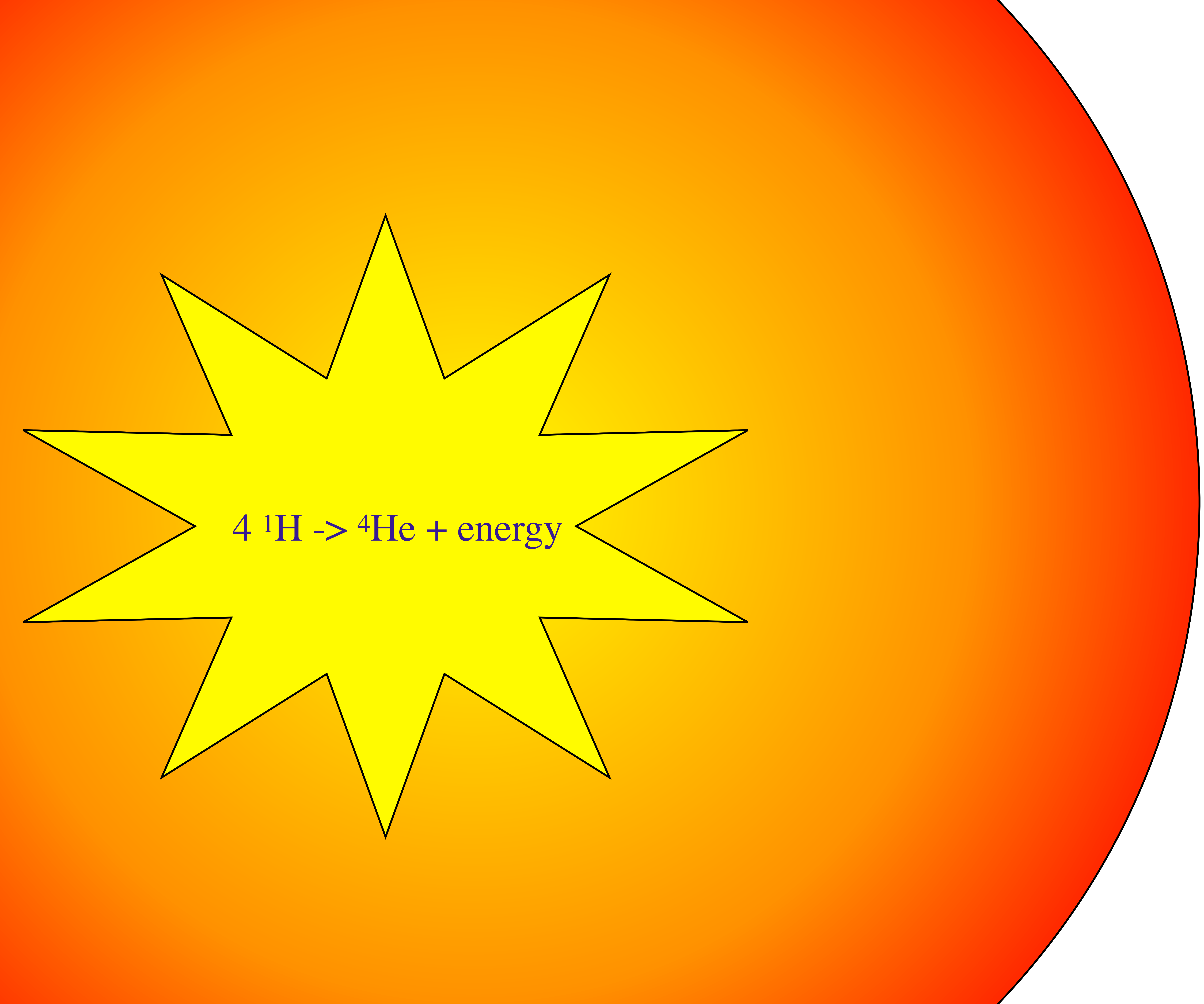
Quantum


Gravitational collapse

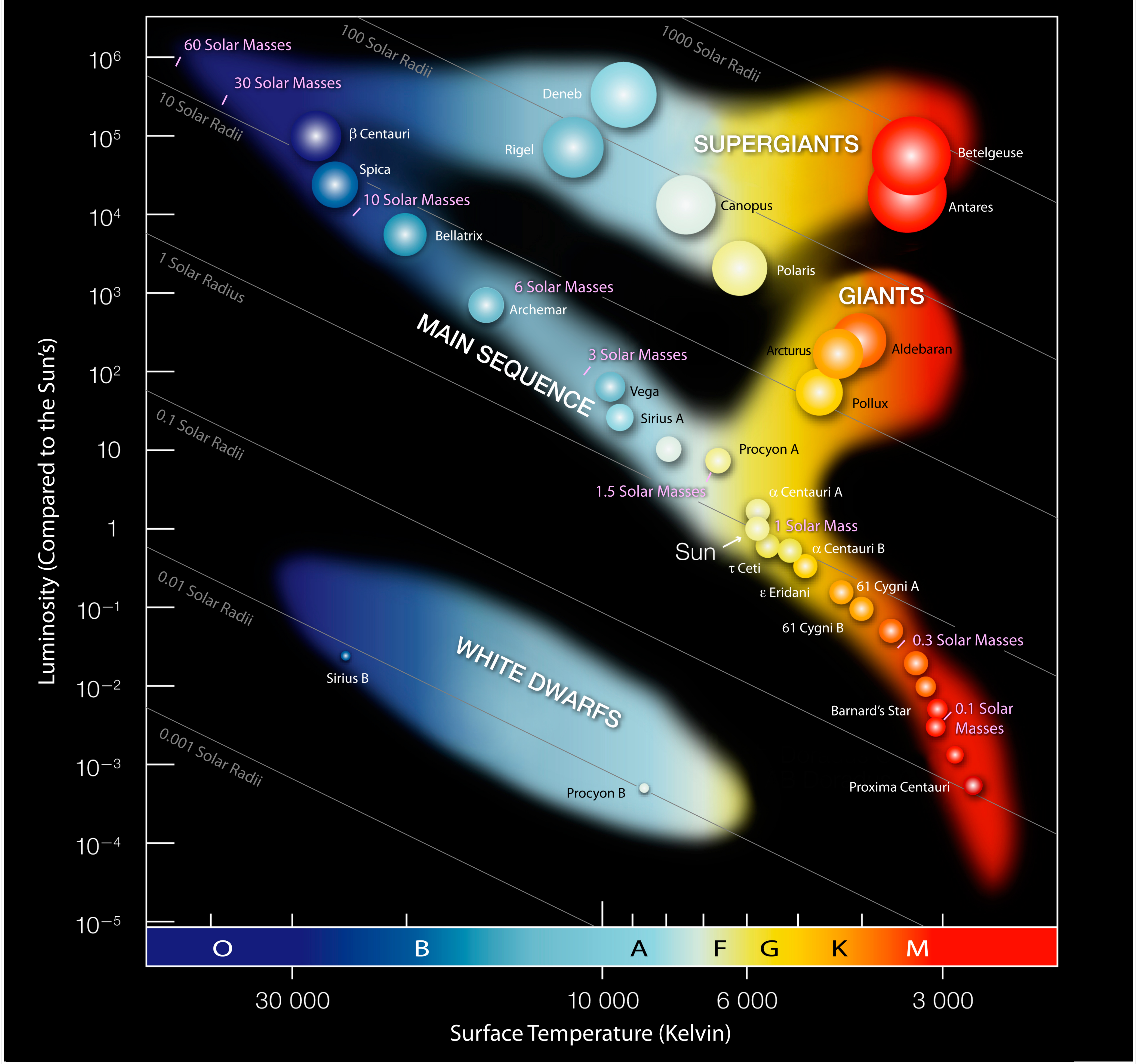

Mechanics
Thermodynamics



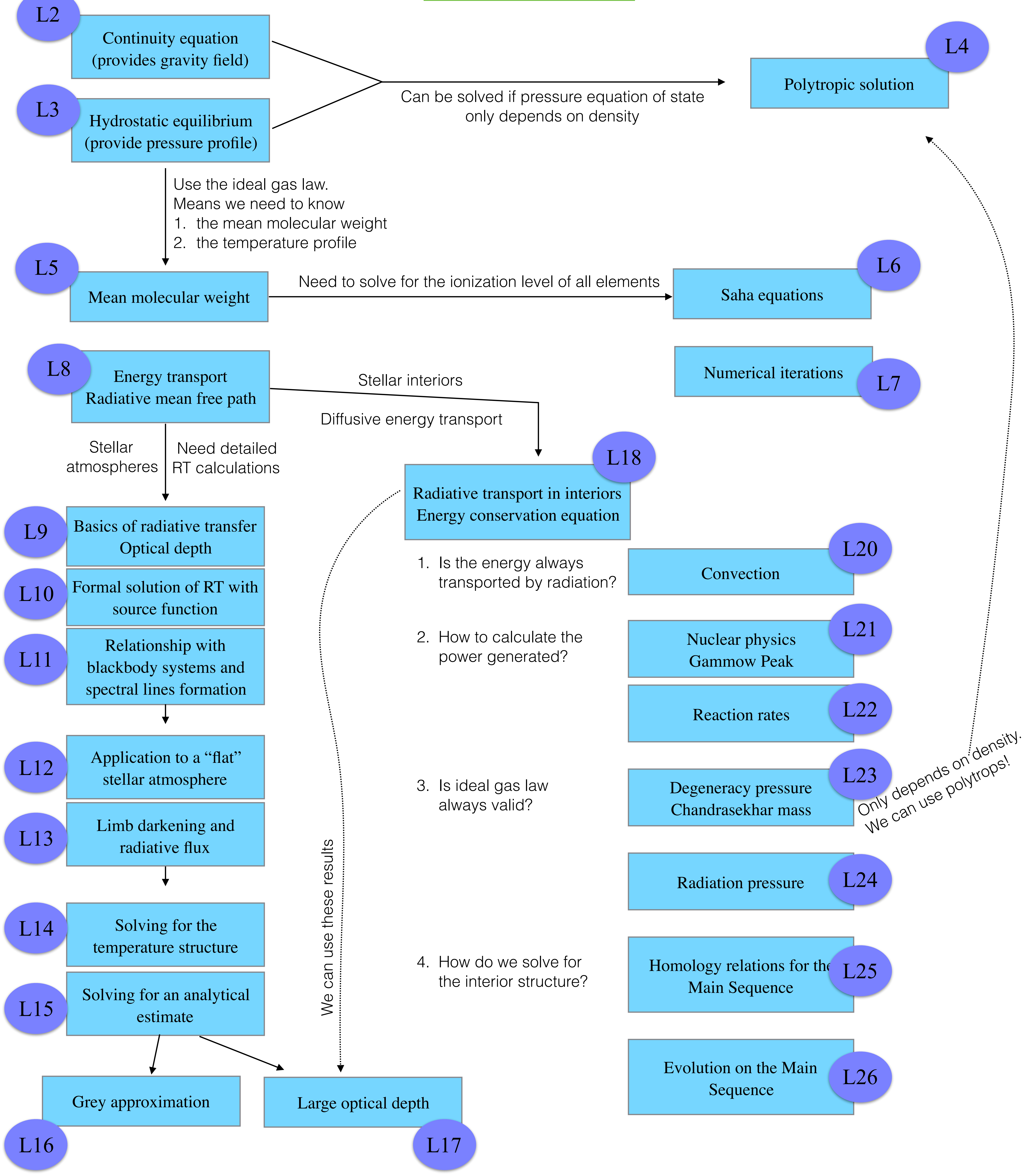
Radiative Transport


4 ¹H -> ⁴He + energy

H-R DIAGRAM


Luminosity (Compared to the Sun's)
10^6
10^5
10^4
10^3
10^2
10
1
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
60 Solar Masses
30 Solar Masses
10 Solar Masses
6 Solar Masses
3 Solar Masses
1.5 Solar Masses
1 Solar Mass
0.3 Solar Masses
0.1 Solar Masses
100 Solar Radii
1000 Solar Radii
10 Solar Radii
1 Solar Radius
0.1 Solar Radii
0.01 Solar Radii
0.001 Solar Radii
SUPERGIANTS
GIANTS
MAIN SEQUENCE
WHITE DWARFS
Deneb
Rigel
β Centauri
Spica
Bellatrix
Archemar
Canopus
Polaris
Betelgeuse
Antares
Arcturus
Aldebaran
Pollux
Vega
Sirius A
Procyon A
α Centauri A
Sun
α Centauri B
τ Ceti
ε Eridani
61 Cygni A
61 Cygni B
Barnard's Star
Proxima Centauri
Sirius B
Procyon B
O
B
A
F
G
K
M
30 000
10 000
6 000
3 000
Surface Temperature (Kelvin)

Course “Storyboard”



The whole course in a nutshell!

$$M_r(r) \quad P(r) \quad L_r(r) \quad T(r)$$

$$\rho(r) \quad \mu(r) \quad \epsilon_{\mathrm{nuc}}(r) \quad \kappa_R(r)$$

Continuity equation

$$\frac{dM_r(r)}{dr} = 4\pi r^2 \rho(r)$$

Hydrostatic equilibrium

$$\frac{dP(r)}{dr} = -\rho(r)\frac{GM_r(r)}{r^2}$$

Radiative energy transport

$$\frac{dT(r)}{dr} = -\frac{3\kappa_R(r)\rho(r)}{64\pi\sigma}\frac{L_r(r)}{r^2 T(r)^3}$$

(Or = to convection transport)

Energy source

$$\frac{dL_r(r)}{dr} = 4\pi r^2 \rho(r)\epsilon(r)$$

Ideal gas law

$$P(r) = \frac{\rho(r)}{\mu(r)} kT(r)$$

(Or = to degeneracy pressure)

Mean molecular weight

$$\mu(r) = f(\mathrm{comp}, T(r), P(r))$$

Mean Rossland opacity

$$\kappa_R(r) = f(\mathrm{comp}, T(r), P(r))$$

Nuclear rates

$$\epsilon_{\mathrm{nuc}}(r) = f(\mathrm{comp}, T(r), P(r))$$

Timescales

Where does the energy come from?

Luminosity (energy lost by the Sun per second)

$L_\odot \sim 10^{26}$ joule/s (or watts)

On the board: calculating the life-time of the Sun (considering that it looses 10^{26} joules per second through radiation) if:

* the Sun was powered by chemical reactions?
* the Sun was powered by gravitational contraction? (Kelvin-Helmholtz timescale)
* the Sun was powered by nuclear reaction? (Nuclear timescale)

On the board: How quickly would a star readjust its structure if something was to change? (Hydro timescale)

==> Conclusion: Quasi-equilibrium system.