Partnerships and Acknowledgements

sunrise.umich.edu

radiojove.gsfc.nasa.gov

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Training Module 0.1

Solar Interior

Prerequisites for Training Modules

1. High School Reading Comprehension and General Science
2. Basic Geometry
3. Electromagnetic Spectrum
4. Speed, Wavelength, Frequency, and Energy of Waves
5. Graphical Interpretation of Data
6. Training Module 0.0

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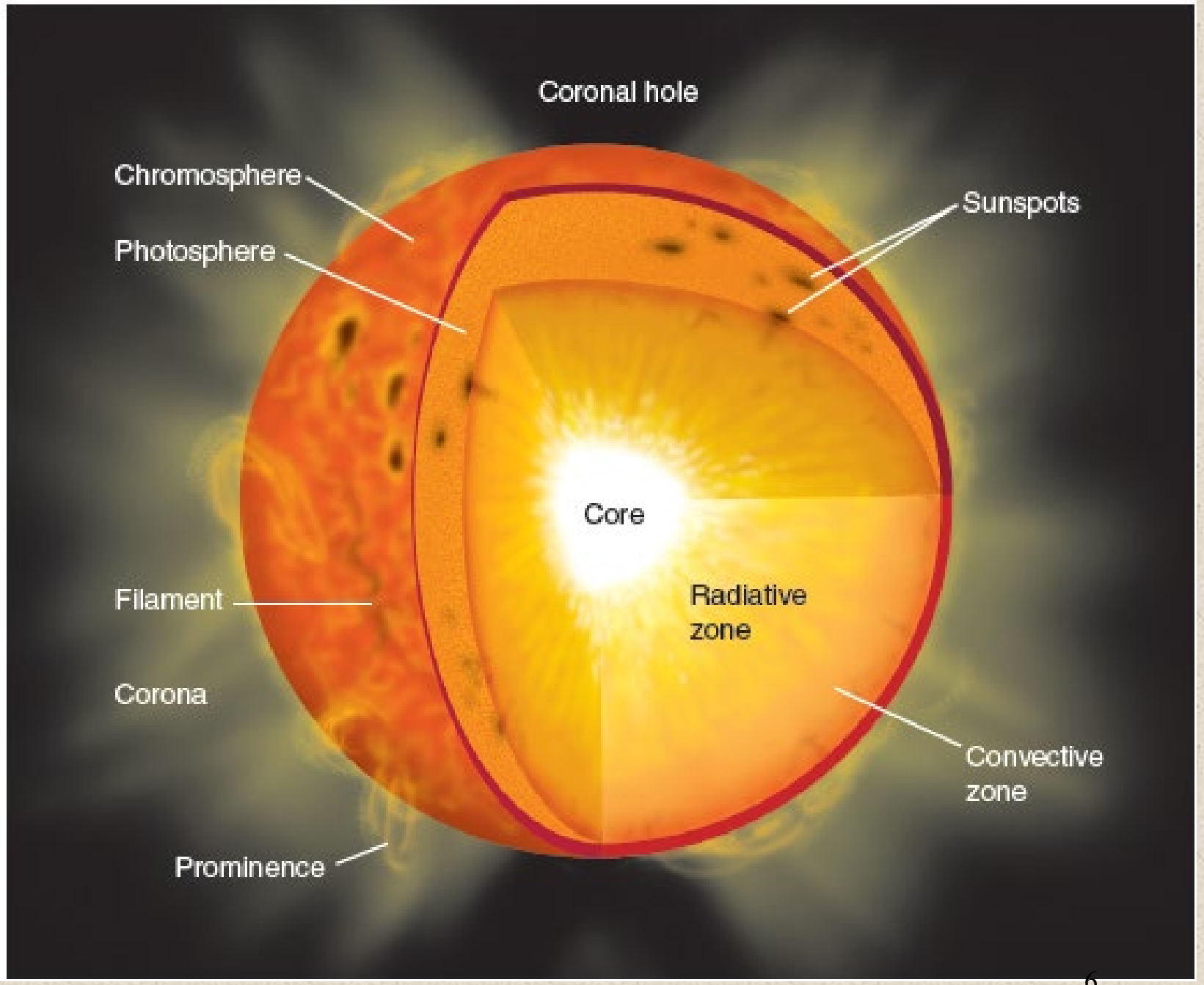
Learning Objectives

1. The structure of the Sun
2. Solar interior layers and processes
3. Nuclear reactions that power the Sun
4. Energy transport mechanisms

Sun - Structure

Structure

1. Interior
   a. Core
   b. Radiative Zone
   c. Convection Zone
2. “Surface”
   a. Photosphere
3. Atmosphere
   a. Chromosphere
   b. Transition Zone
   c. Corona

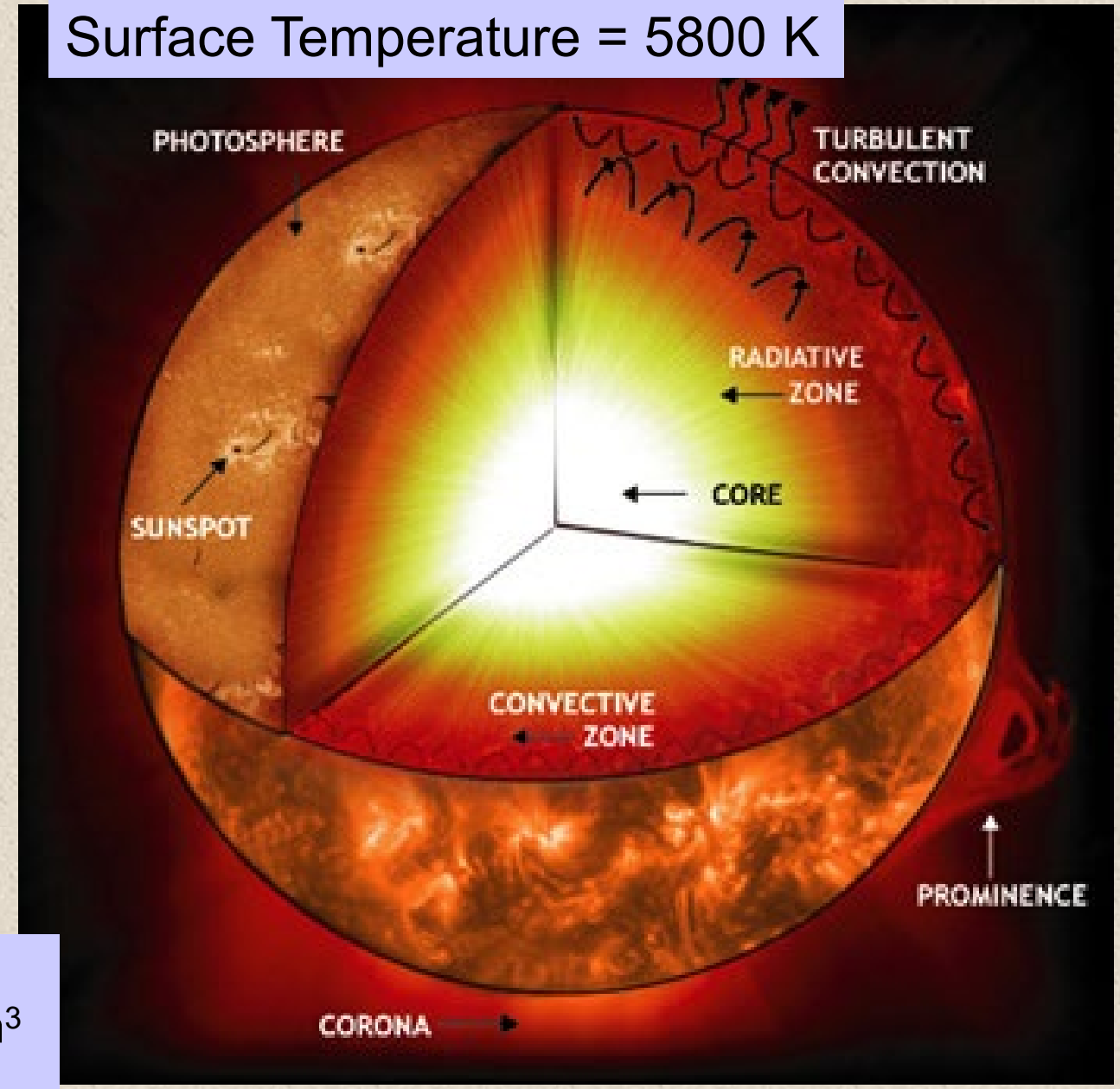


Sun Interior

Interior

a. Core – Nuclear Reactions
b. Radiative Zone – energy transport
c. Convection Zone – energy transport

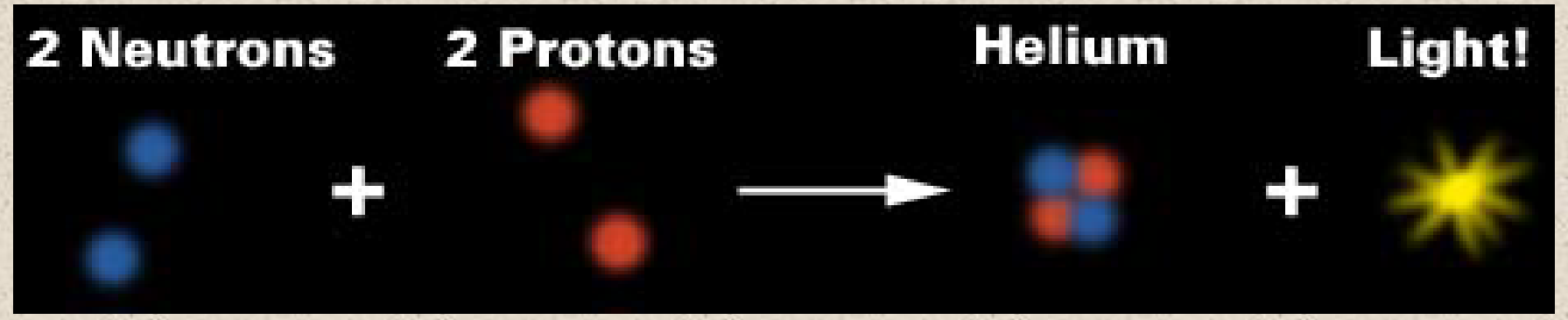
d. Force Balance
Outward Pressure vs. Inward Gravity (keeps it stable)



Interior Density = 150 g/cm^3
Photosphere Density = 0.0000002 g/cm^3
Average = 1.4 g/cm^3

Nuclear Fusion

Basic Reaction $4H \rightarrow He + Energy!$



Net Reaction

$4H \rightarrow He + 2e^{+} + 2\gamma + 2\nu$

$4H \rightarrow He + 7\gamma + 2\nu$

e^{+} = positron

γ = gamma ray

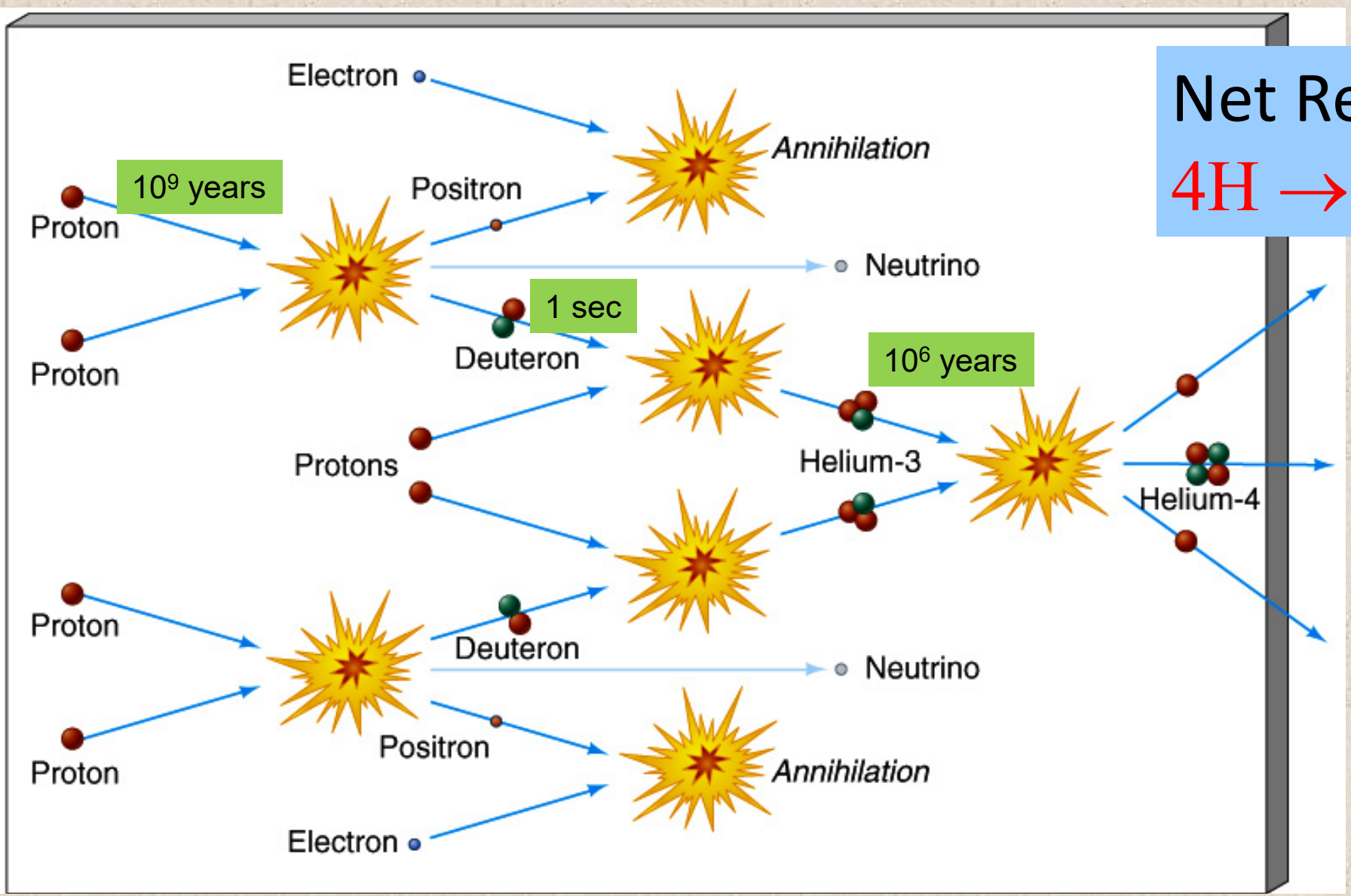
ν = neutrino

Requirements: High Temperature, High Pressure

Sun's Core: 15 million K

100-200 billion atmospheres!

Proton-Proton Chain Timescales



Net Reaction

$$4H \rightarrow He + 7\gamma + 2\nu$$

Nuclear Energy

Energy from the Nuclear "furnace"

$4H \rightarrow He + neutrinos + Energy$

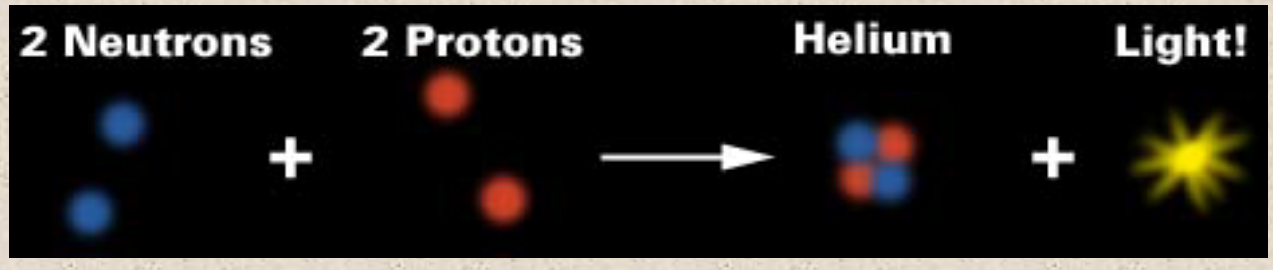
Mass of 4 H atoms = 6.693×10^{-27} kg
- Mass of He atom = 6.645×10^{-27} kg
Mass Lost = 0.048×10^{-27} kg

$E = mc^2$

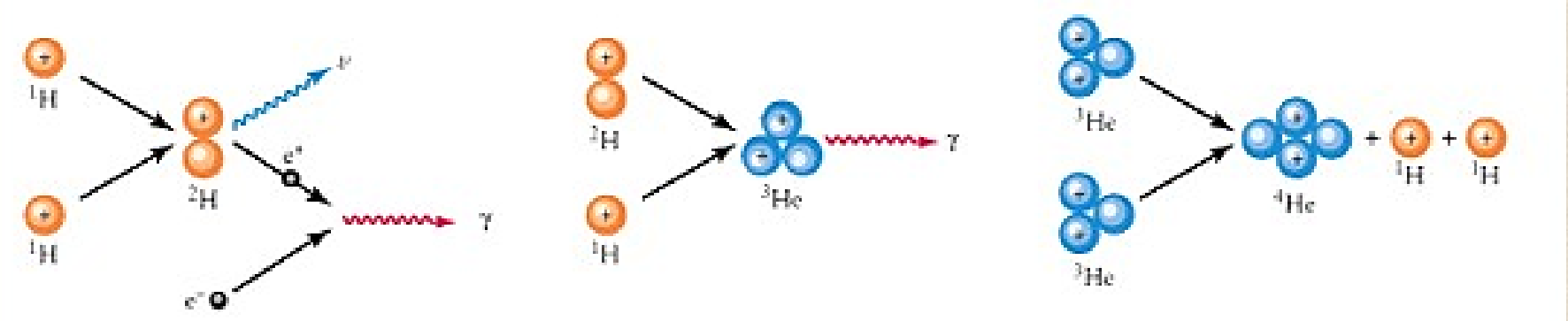
$= (0.048 \times 10^{-27} \text{ kg}) \times (3 \times 10^{8} \text{ m/s})^2$

Energy = 4.3×10^{-12} Joules

Basic Reaction $4H \rightarrow He + Energy!$



600 million metric tons of Hydrogen are converted into Helium EACH second inside the Sun!!!



Stellar Structure
A peek inside a star!

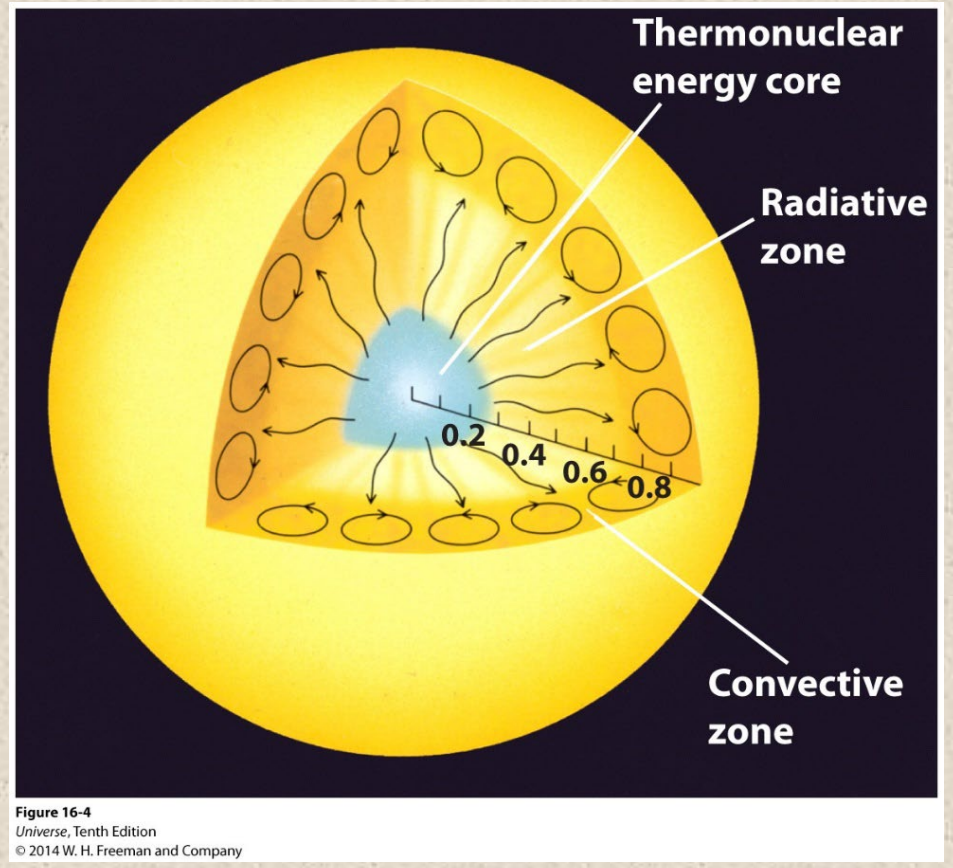
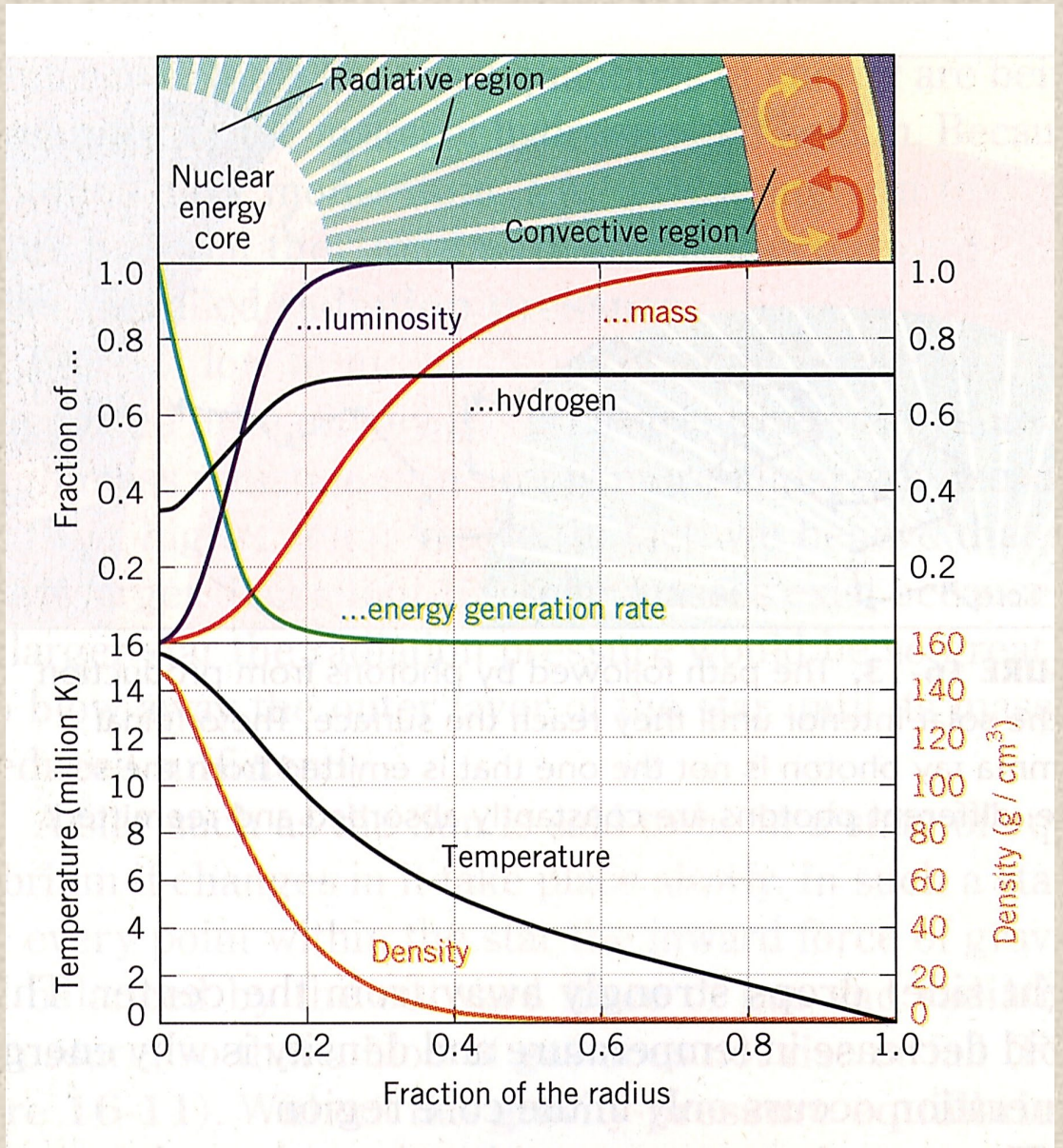


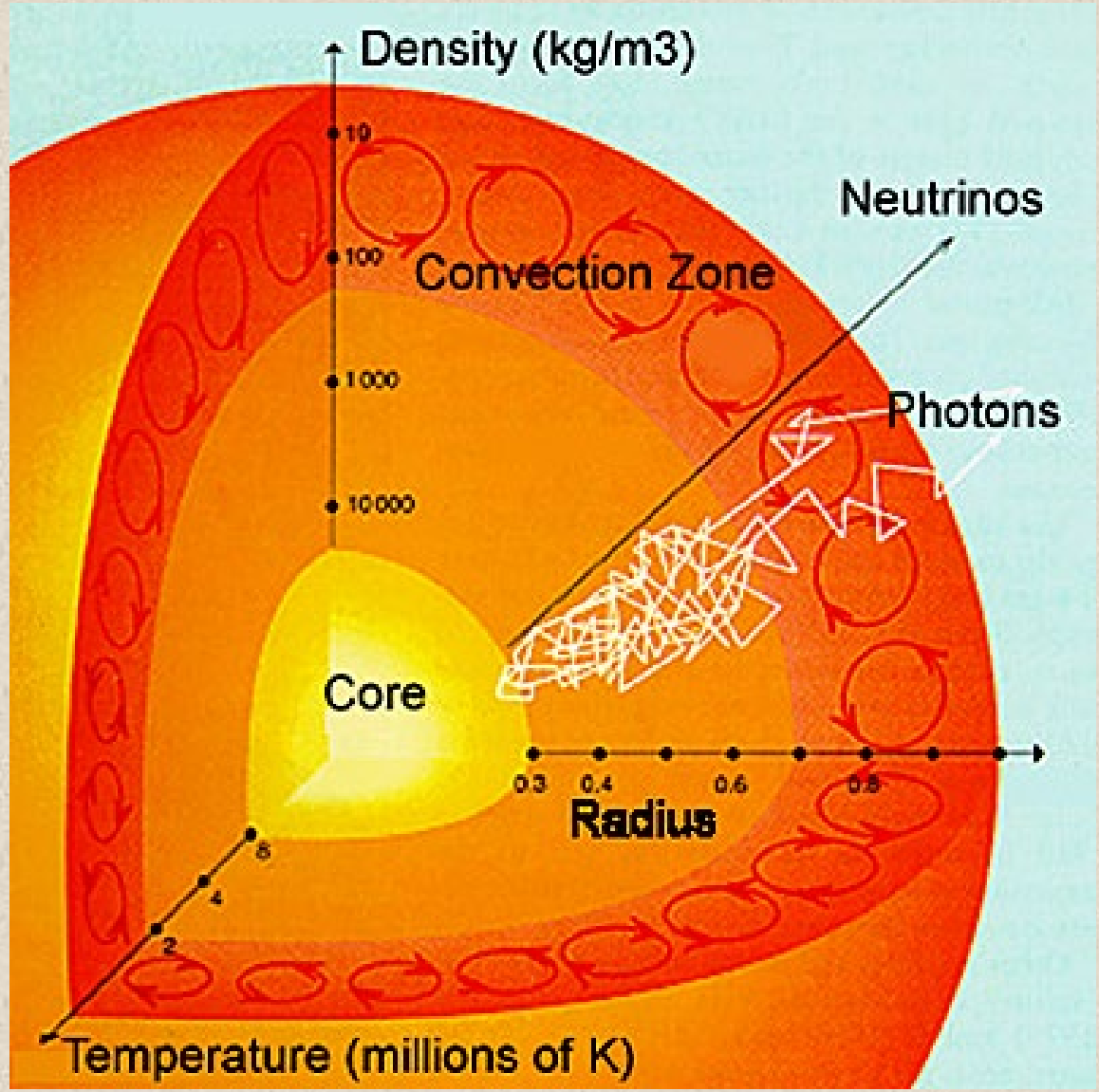
Figure 16-4
Universe, Tenth Edition



Radiation and Convection Zones

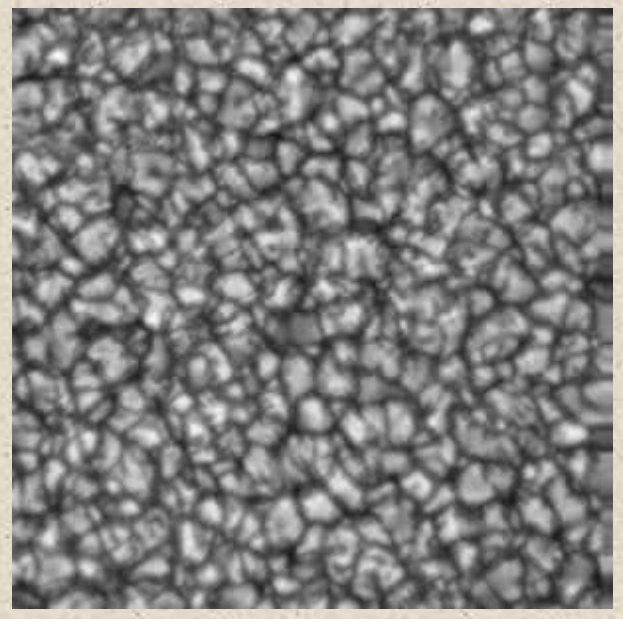
Energy from the core is transported through the radiation zone by a random walk of photons as they are absorbed and emitted. The overall "flow" of energy is outward.

As the temperature decreases outward convection becomes the more efficient mode of energy transport.

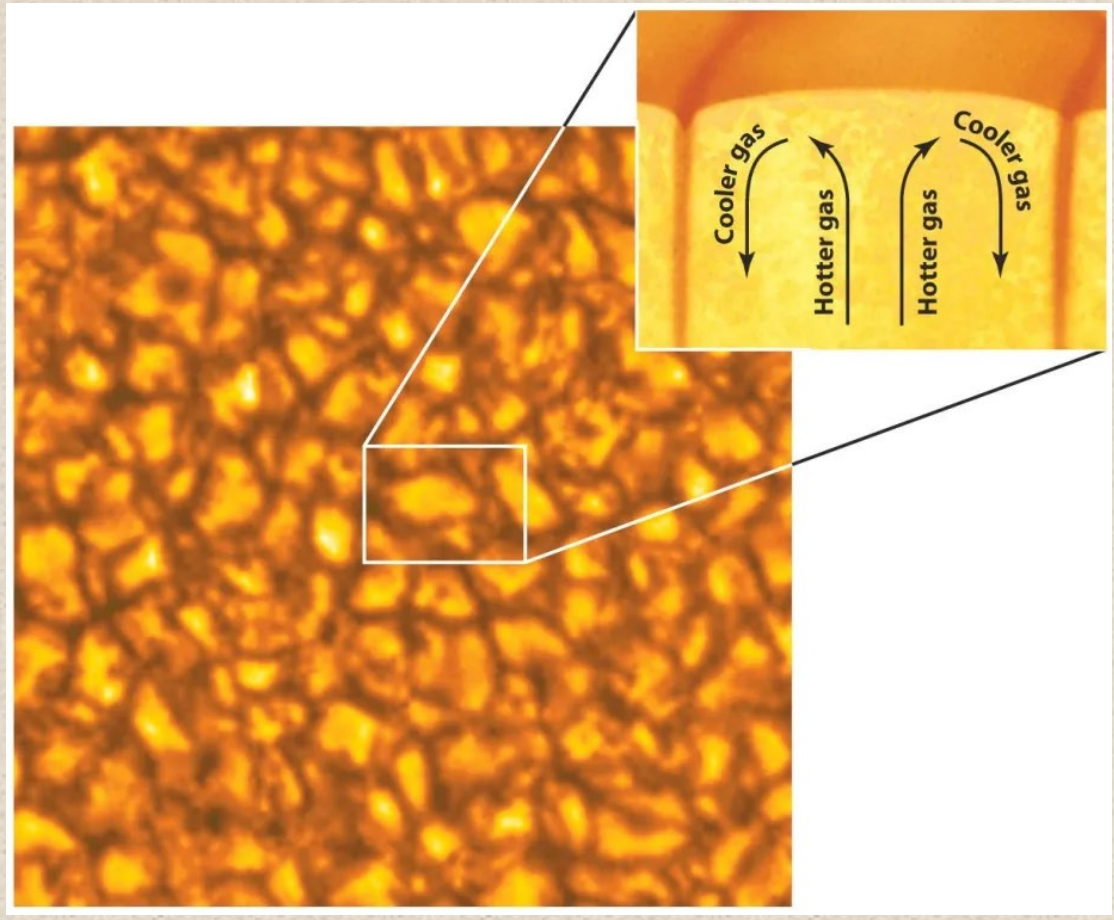


Credit: http://www.solarsystemcentral.com/

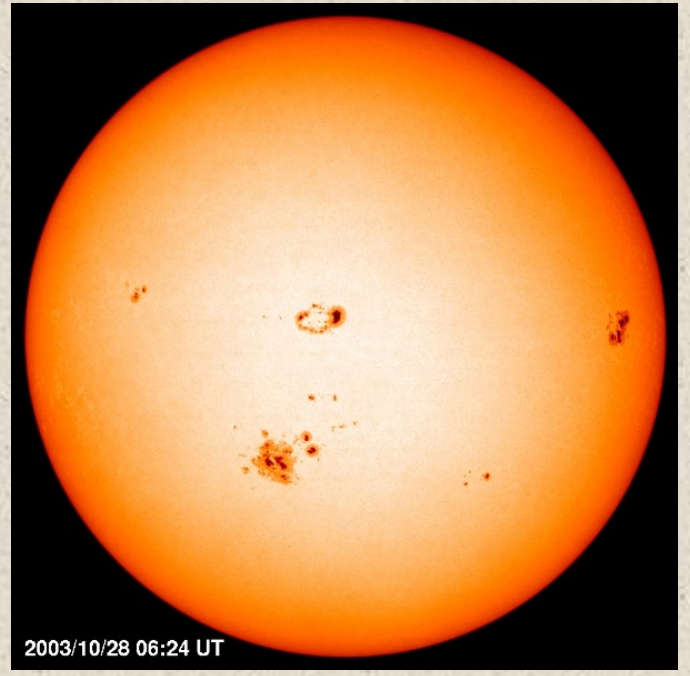
Photosphere



27x27 Mm² field,
35 minutes



Credit: Patrick Hall, York University



SOHO, NASA & ESA

Photosphere Granulation – bubbles of gas rising and sinking near the surface caused by convection

Resources

NASA Marshall Space Flight Center Solar Physics
https://solarscience.msfc.nasa.gov/

NASA Solar and Heliospheric Observatory (SOHO)
https://soho.nascom.nasa.gov/home.html

NOAA Space Weather Prediction Center
https://www.swpc.noaa.gov/
Australian Space Weather Forecasting Center
https://www.sws.bom.gov.au/Educational/2/1

Space weather:
https://spaceweather.com/
https://swe.ssa.esa.int/current-space-weather
https://www.swpc.noaa.gov/