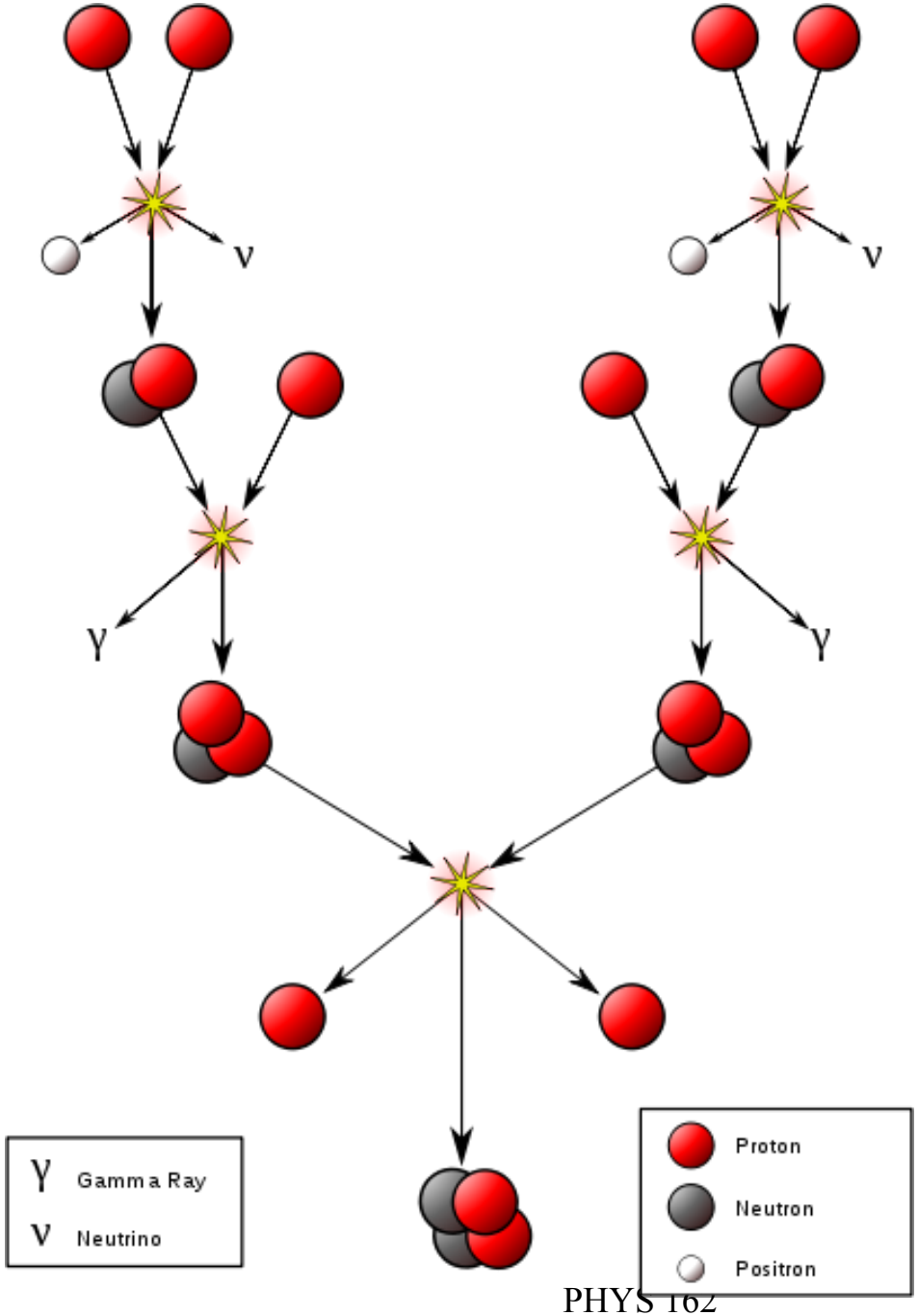
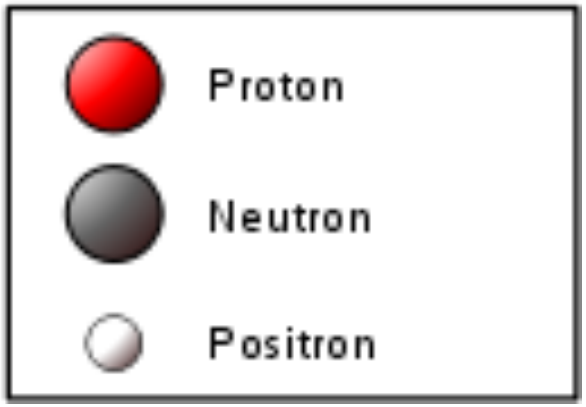
Proton-proton cycle 3 steps





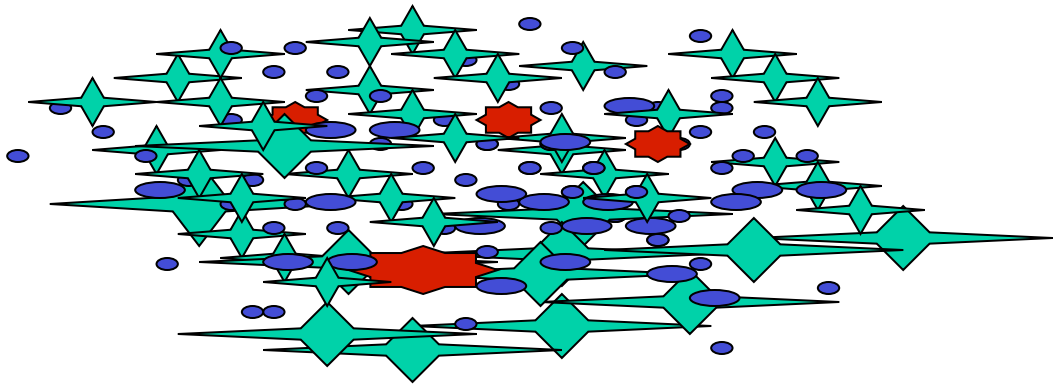
The proton proton chain in action

Proton-proton fusion chain process

1st step: In two separate reactions, 2 protons in each reaction fuse

Layers of the Sun

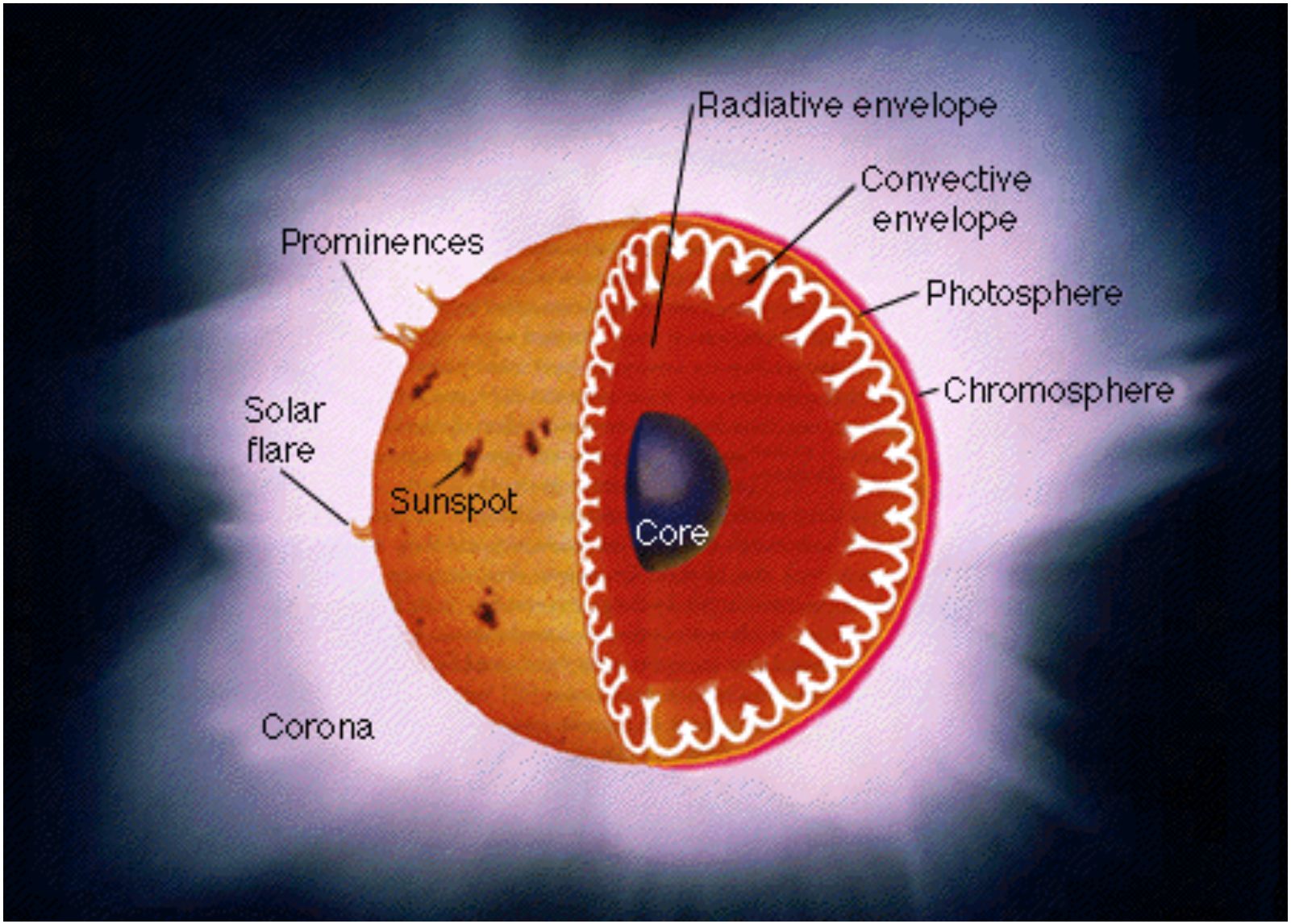
- Mostly Hydrogen with about 25% Helium. Small amounts of heavier elements
- Gas described by Temperature, Pressure, and Density with P= kDT (mostly) - NOT an ideal gas
- Larger temperature near Radius = 0
- Inner radius is a PLASMA - gas where all atoms are ionized. T >100,000 degrees K – and so "free" electrons



H (48)

He (4)

electron (56)

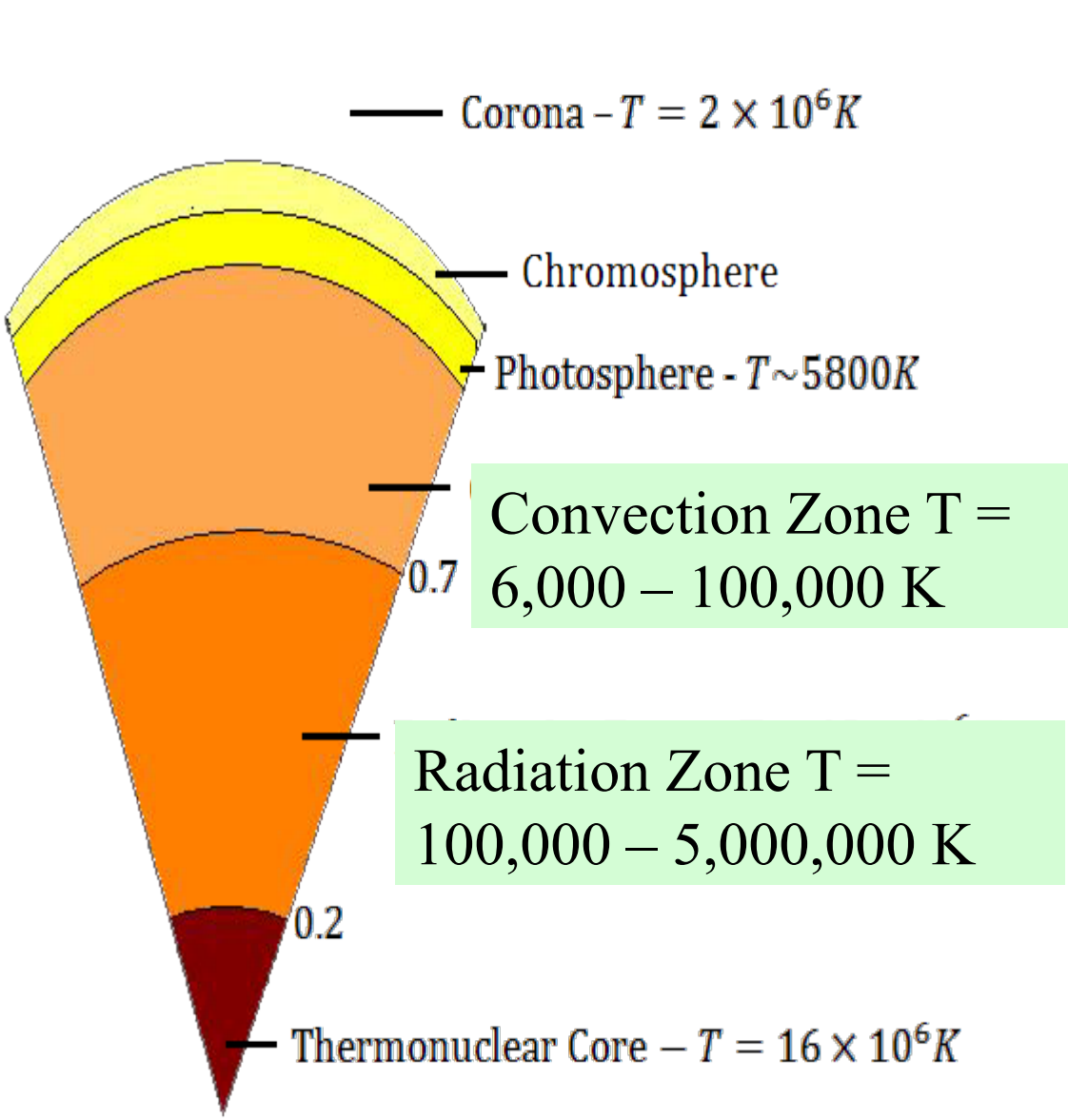

Radiative envelope
Convective envelope
Prominences
Photosphere
Chromosphere
Solar flare
Sunspot
Core
Corona

Equilibrium

Temperature of the Sun is constant for any given radius. It doesn't change as heat flows out

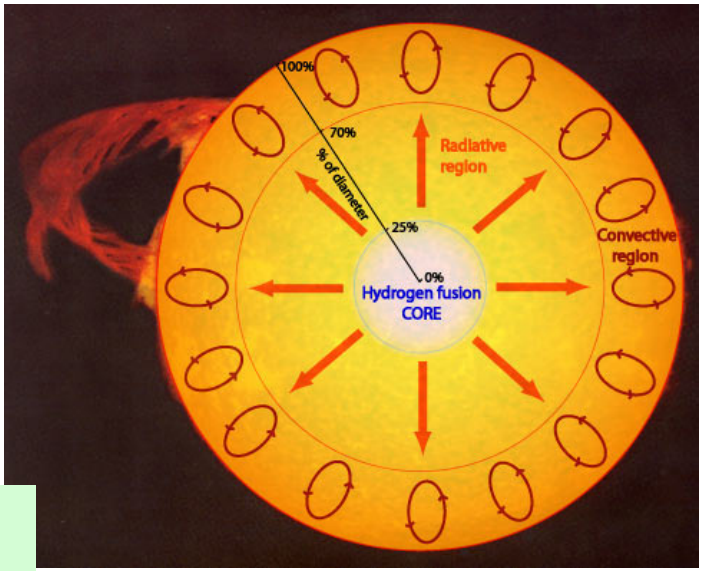
Gravitational Force pulling in BALANCES the gas pressure (Electric force) pushing out

At center : highest gravitational pressure gives the highest temperature



Convection Zone T = 6,000 – 100,000 K

Radiation Zone T = 100,000 – 5,000,000 K



Temp is highest in the core → where nuclear fusion occurs

heat flows outward to surface, then radiated as light to (say) Earth

Core - Center of Sun

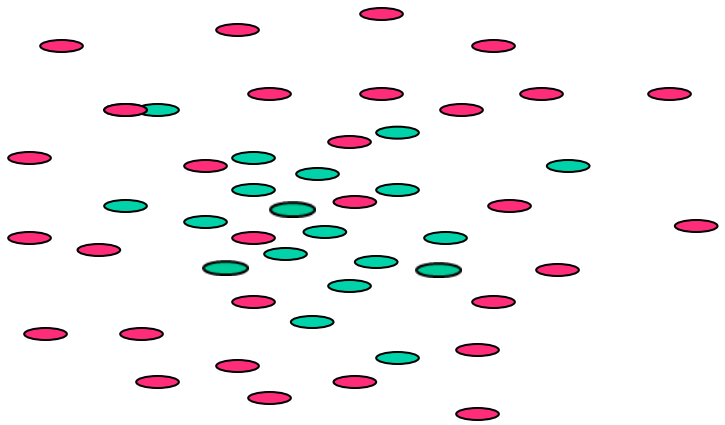
- High temperature ~15,000,000 degrees K
- High density ~ 100 g/cm^3
- Where fusion occurs

  H → He

  …. and heat flows out
- Source of neutrinos

Core - changes with time

- As it is heavier, the Helium which is produced in the fusion reaction tends to “float” to the center.
- For now, the He isn’t burning and there is a mini-core of (mostly) He with reduced fusion

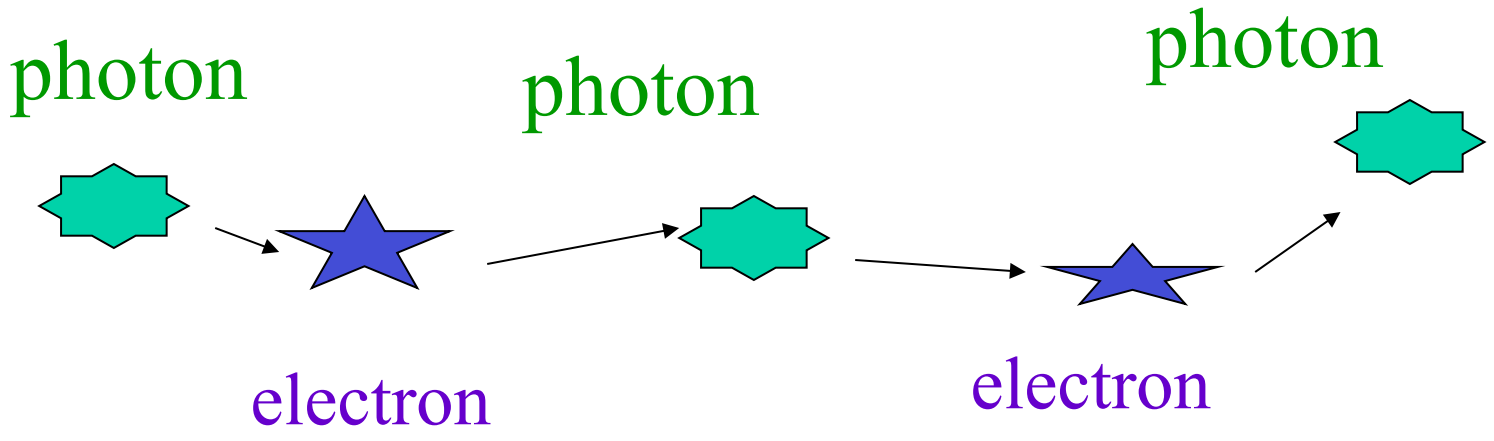


Red=H

green=He

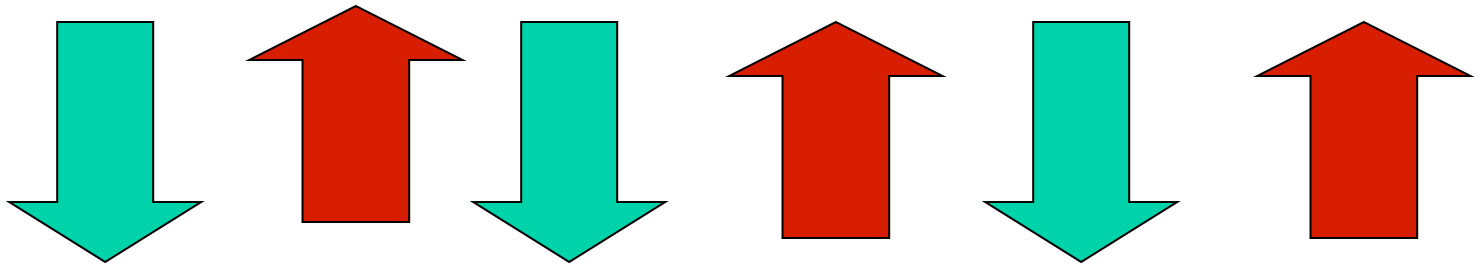
Radiation Layer

- Temperature 100,000 to 5,000,000 degrees (plasma)
- No fusion
- Electrons are not in atoms very, very opaque
- Energy transferred by absorption and re-radiation of light

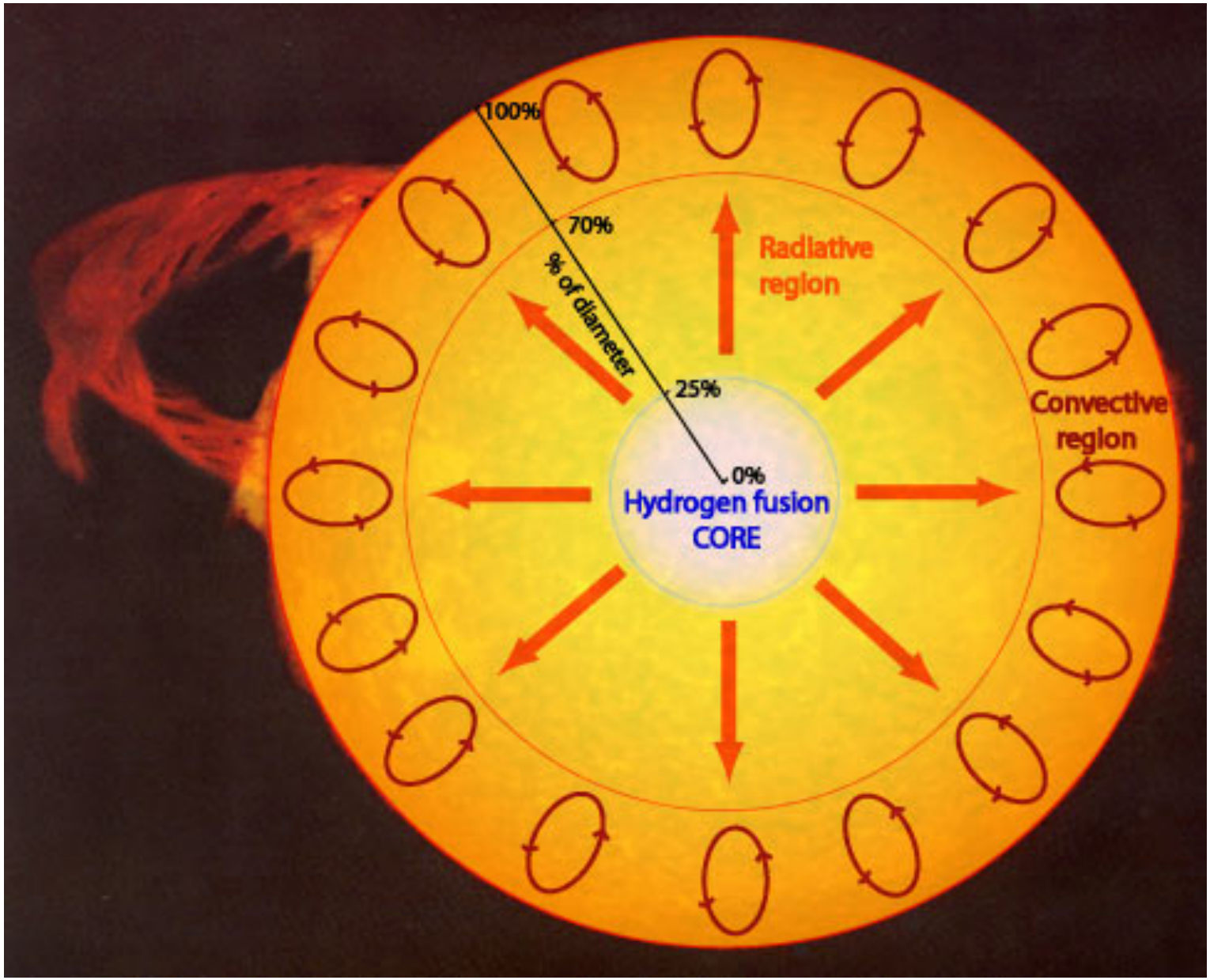


Convection Layer

- Temperature 6,000 to 100,000 degrees
- No fusion
- Electrons in atoms → less opaque
- Energy transferred through convection. Movement of gas to/from surface ("hot" air rises) "mechanical"

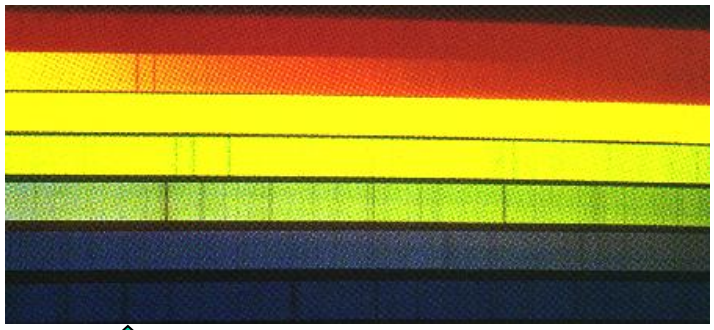


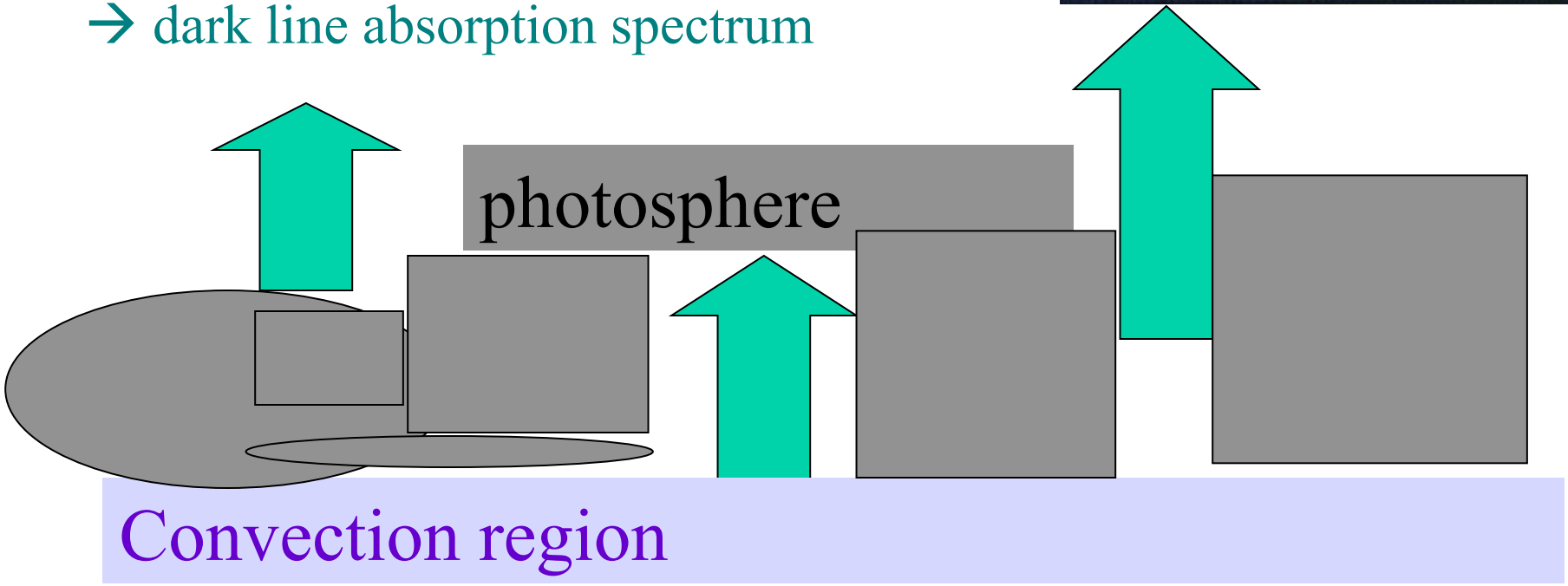
Convection and Radiation layers differ on how heat is transferred



Photosphere

- Sun → gas cloud → no true surface
  Light we see comes from a 200 km fairly transparent region → photosphere and top of convection region
- Temperature 4,500-6,000
- Photosphere cooler than convection region
  → dark line absorption spectrum





Outer Atmosphere

- Surface of the Sun → hot, turbulent with electric/magnetic storms which throw out energetic particles
- CHROMOSPHERE

  low density, high T

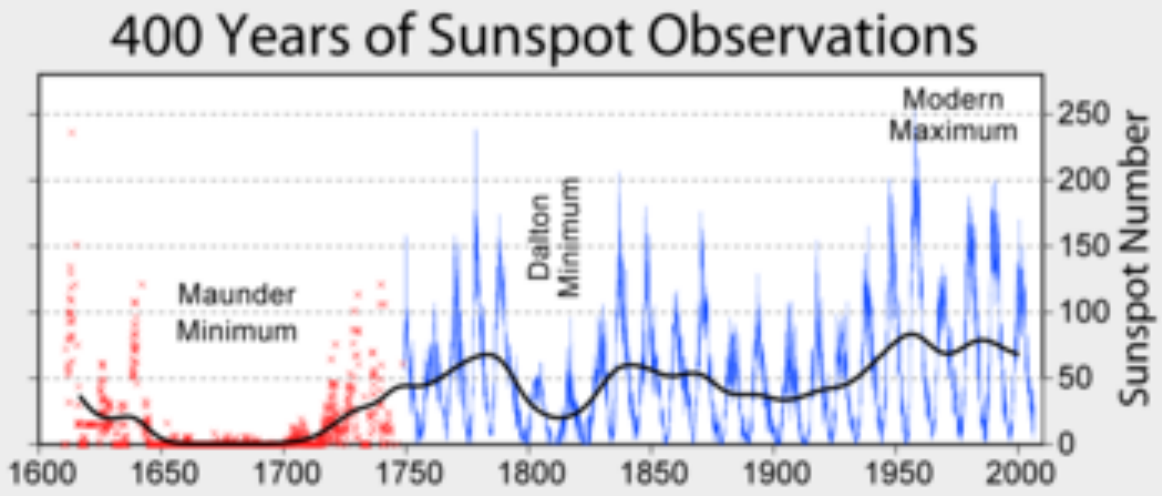
  glows red (H atom) → seen in eclipse
- CORONA

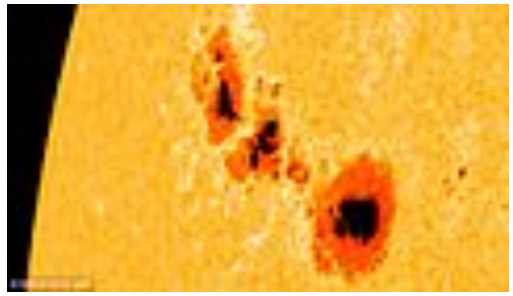
  even lower density and higher T (over 1,000,000 degrees)
- SOLAR WIND

  protons escaping Sun's gravity so large velocity. Can interact in Earth's atmosphere

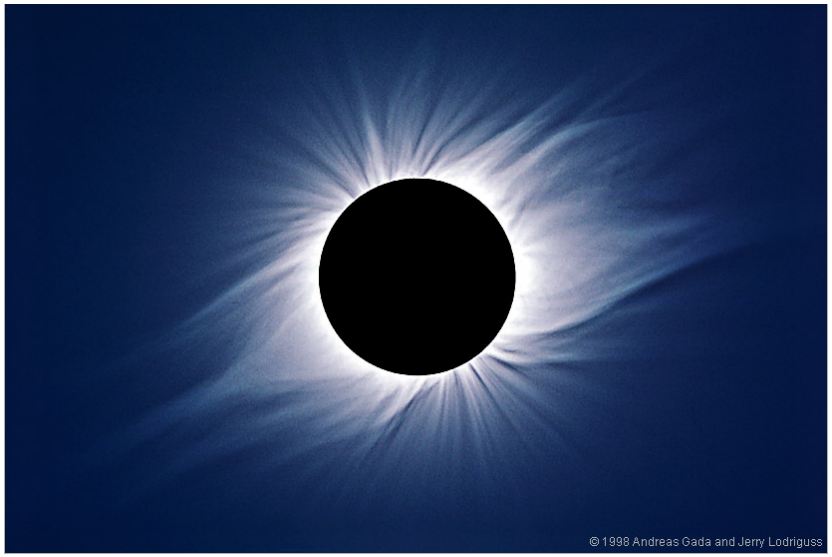
Sunspots

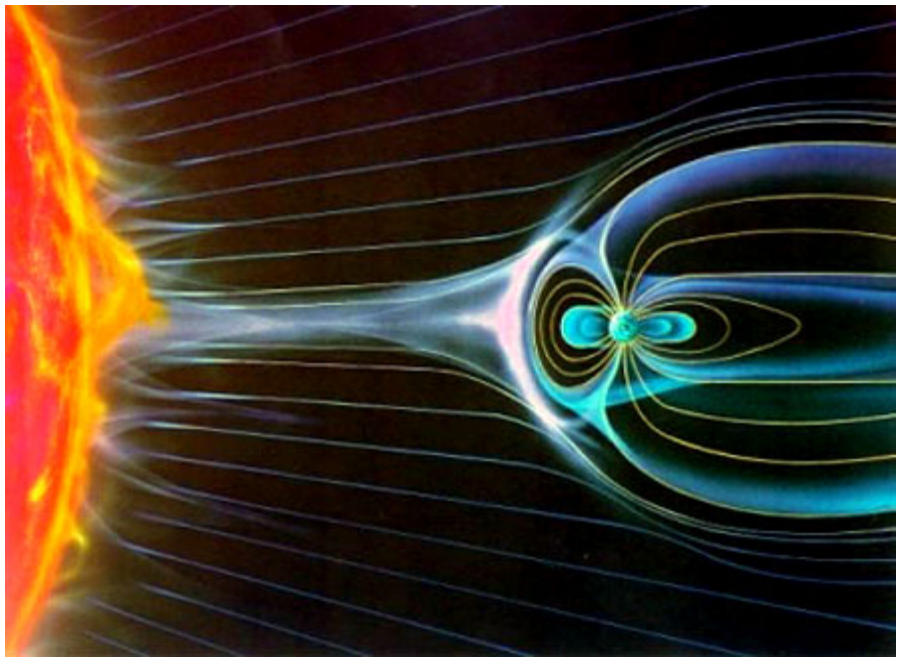
- Intense magnetic fields which inhibited convection currents to the surface → appear darker as at lower temperature
- Solar storms/flares often associated with sunspots
- Had been observed prior to Galileo's time (and without telescopes) – Galileo gets credit as he had best explanation
- Sunspot activity varies with time. 11 year cycle plus variation over hundreds (thousands) of years – change in Solar energy output





Outer Atmosphere





- Can see during eclipses. Interactions of solar wind with Earth's magnetic field and atmosphere causes Aurora Borealis

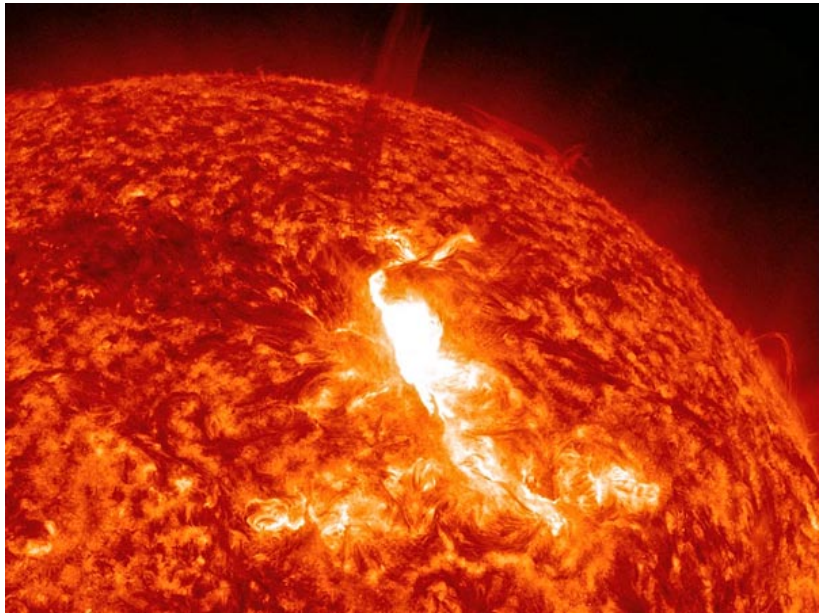
Aurora Borealis – Northern Lights

seen at high latitudes as magnetic fields are lower in the atmosphere.

rarely seen in DeKalb. Photos are from Alaska and Maine

Solar Storms

- Large eruptions from Sun's surface are called "flares" or "storms"
- Will increase flow of charged particles to Earth, increase Northern Lights, and have (some) radiation impact (plane flights, on space station, radio signals)
- Large one in January 2012
- Had been possible explanation for "global warming" - CLOUD expt. At CERN found no evidence….



Test 1 Guide for short answer questions

- Motion of Sun, stars, planets through sky vs seasons
- Galileo's astronomical observations
- Kepler's Laws of planetary motion
- Newton's Laws of motion (mostly F=ma) and gravity!
- How light is produced (accelerated charge) plus discrete vs. continuous spectra - absorption vs. emission Doppler Effect
- Nuclear reactions in the Sun : p-p cycle
- Layers in the Sun
- 4 forces with examples