Class 25
The Structure of the Sun

- Basic structure of the Sun
- Hydrostatic equilibrium
- Surface phenomena
I : The structure of the Sun

- Core (R<0.25R\textsubscript{Sun})
  - Extremely hot (1.5x10\textsuperscript{7} K at center)
  - Extremely dense (1.6x10\textsuperscript{5} kg/m\textsuperscript{3})
  - Site of energy generation (thermonuclear fusion)
  - More next class...
- Radiative zone (0.25R\textsubscript{Sun} → 0.7R\textsubscript{Sun})
  - Energy transported outwards by radiative diffusion
  - Essentially, photons “random walk” their way outwards
  - Takes about 170,000 years for energy to leak out!
- Convective zone (0.7R\textsubscript{Sun} → R\textsubscript{Sun})
  - Temperature low enough (below 2x10\textsuperscript{6}K) that some combined hydrogen nuclei form.
  - Gas become much more effective at absorbing radiation... chokes radiative diffusion process
  - Energy transport continues via convection
- Photosphere, chromosphere and corona
  - More later...
II: Hydrostatic equilibrium

- What supports the Sun against collapsing in its own gravitational field?
  - Consider any slab of gas in the Sun... it is in equilibrium (i.e., zero net force) when

\[
\frac{dp}{dr} = -\rho \frac{GM(< r)}{r^2}
\]

- This is the equation of **hydrostatic equilibrium**
- Quick note (beyond ASTR120 level)... the actual equation for a spherical object like the Sun is

\[
\frac{dp}{dr} = -\rho \frac{GM(< r)}{r^2}
\]
III : Surface phenomena

- Outer regions of the Sun (above convective zone) consists of three layers
  - Bottom layer : Photosphere
    - Visible surface of Sun
    - Top of the convective zone; T=5800K
    - Can see convective cells
  - Next : Chromosphere
    - Region of hotter gas
    - Temperature increases with height
    - Displays spicules
  - Finally : the Corona
    - Very hot gas (million K or more); emits X-rays
    - Most likely heated by phenomena associated with magnetic fields
In this narrow transition region between the chromosphere and corona, the temperature rises abruptly by about a factor of 100.
Many important phenomena are driven by magnetic fields...

- Sunspots
  - Regions where magnetic fields pierce the photosphere

- Prominences, flares and coronal mass ejections...
  - Explosive events associated with the unraveling of a stressed, twisted magnetic field
  - Can send bursts of high-energy particles into space... can be problem for satellites and astronauts

Magnetic phenomena have an 11 year cycle associated with the solar dynamo
Bright areas lie on top of sunspot groups

Coronal loops

Image of the Earth (superimposed for scale)
(a) A coronal mass ejection

(b) Two to four days later