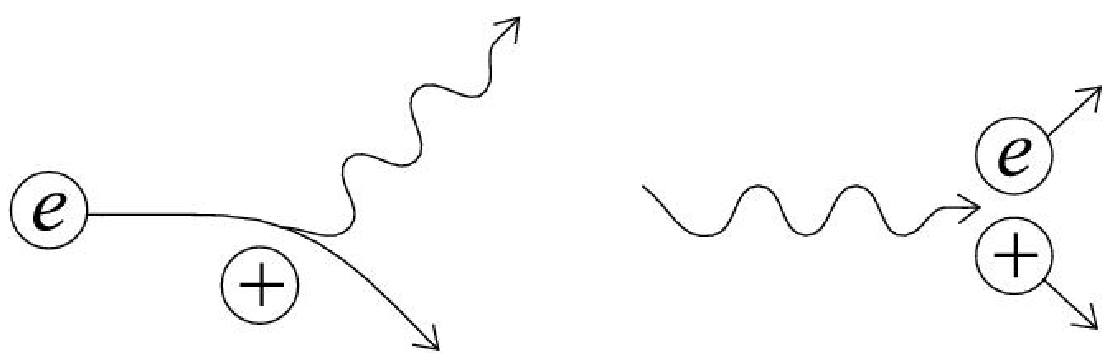
Outline

- Hand in, go over homework problems 3.2, 3.4
- Opacity
- Scaling relations on the main sequence

Opacity

How can a photon scatter (lose energy or be absorbed)?

- Thomson scattering
- Interaction with an atom
  - Bound-bound absorption - electron stays bound
  - Bound-free absorption - (electron is ejected = photoionization)
- Free-free absorption – photon absorbed by electron+ion, but electron is not bound. Different from Thomson scattering since ion can help satisfy momentum conservation and allow absorption.
- (Free-free emission = bremsstrahlung)



Opacity

- Calculation of bound-bound absorption is a huge pain because it depends on details of atomic structure and varies wildly with energy.
- Bound-free and free-free absorption are approximately described by Kramer's law $\kappa \propto \rho\, T^{-7/2}$. Kramer's law is only an approximation that holds over a limited range in temperature and density, but is often used in modeling stellar structure.
- Thomson scattering has a constant cross-section, but we need to know the number density of free electrons.

$$n_e = n_H + 2 n_{He} + \sum \frac{A}{2} n_A = \frac{\rho}{m_H}\left(X + \frac{2}{4} Y + \frac{1}{2} Z \right) = \frac{\rho}{2 m_H}(1+X)$$

$$\kappa = \frac{n_e \sigma_T}{\rho} = \frac{\sigma_T}{2 m_H}(1+X) = (1+X)\, 0.2\, \mathrm{cm}^2\, \mathrm{g}^{-1}$$

Scaling Relations

- Assume $P(r) \propto r^{\beta}$, same for $T(r)$, $M(r)$, $\rho(r)$.
- Then $dP/dr \propto P/r$.
- Derive relations under different assumptions for equation of state and opacity.

$$\frac{dP(r)}{dr} = \frac{-GM(r)\rho(r)}{r^2} \qquad \frac{dT(r)}{dr} = \frac{-3L(r)\kappa(r)\rho(r)}{16\pi r^2 a c T^3(r)}$$

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

Scaling Relations

$$\frac{L}{L_\odot} \approx .23 \left(\frac{M}{M_\odot} \right)^{2.3} \qquad (M < .43 M_\odot)$$

$$\frac{L}{L_\odot} = \left(\frac{M}{M_\odot} \right)^{4} \qquad (.43 M_\odot < M < 2 M_\odot)$$

$$\frac{L}{L_\odot} \approx 1.5 \left(\frac{M}{M_\odot} \right)^{3.5} \qquad (2 M_\odot < M < 20 M_\odot)$$

$$\frac{L}{L_\odot} \approx 3200 \frac{M}{M_\odot} \qquad (M > 20 M_\odot)$$

Homework

- For next class:
  - Problem 3-5