Stellar Astrophysics, Fall 2024

Problem Set VII

Deadline: 5PM of Thursday, December 5, 2024

1. **Temperature dependence of fusion reactions (10%).** The flux of energetic neutrinos from ^{8}B decay in branch III of the proton-proton chain is very dependent on the central temperature of the Sun. Show that the rate of the reaction producing ^{8}B,

$$p + {}^7\mathrm{Be} \rightarrow {}^8\mathrm{B} + \gamma,$$

   is approximately proportional to T^{14}, when the temperature T is near to 1.2×10^7 K.

2. **Photodisintegration of nuclei (15%).** The photodisintegration of nuclei plays an increasingly important role as a star evolves and as the temperature at its center increases.

   (a) (10%) Derive an expression for the number density of photons with an energy above 9.98 MeV in a gas at temperature T. Recall the Planck's formula for the photon flux density in the frequency range ν to $\nu + \mathrm{d}\nu$

$$F_\nu \mathrm{d}\nu = \frac{2\pi\nu^2}{c^2} \frac{h\nu}{e^{h\nu/kT} - 1} \mathrm{d}\nu,$$

   and assume that $kT \ll 9.98$ MeV, the minimum energy needed to eject a ^{4}He nucleus from a ^{28}Si nucleus.

   (b) (5%) Estimate the fractional change in the number of such photons that occurs when the temperature rises from 10^9 K to 4×10^9 K.