Assignment #7: due June 26

1. **Thermal instability**

   Consider a simplified model for the heating and cooling of the ISM, in which the only source of cooling is C^+ fine structure emission, with a cooling rate

   $$\Lambda = 3 \times 10^{-27} \exp\left(-\frac{92}{T}\right) n^2 \,\mathrm{erg\,s^{-1}\,cm^{-3}}, \tag{1}$$

   and the only source of heating is photoelectric heating, with a heating rate

   $$\Gamma = 6 \times 10^{-26} n \,\mathrm{erg\,s^{-1}\,cm^{-3}}. \tag{2}$$

   (a) Show that in this model, thermal equilibrium is impossible for $n < 20\,\mathrm{cm^{-3}}$, irrespective of the value of T.

   (b) Find the equilibrium temperature of the gas when $n = 100\,\mathrm{cm^{-3}}$.

   (c) Find the temperature T_c at which the gas first becomes unstable to the isobaric thermal instability. Is there any temperature at which the gas is isochorically unstable?

2. **Heating**

   (a) The heating rate from photoelectric dust emission on the diffuse ISM is given by

   $$\frac{\Gamma}{n_H} = 1.4 \times 10^{-26} \frac{\mathrm{erg}}{\mathrm{s}} \left(\frac{n_{photon}}{3 \times 10^{-3}\mathrm{cm^{-3}}}\right) \frac{<\sigma_{abs}>}{10^{-21}\mathrm{cm^2}} \frac{<Y>}{0.1} \frac{E_{net}}{1\mathrm{eV}} \tag{3}$$

   where σ_{abs} is the dust photoabsorption cross section, $< Y >$ is the averaged photoelectric yield and E_{net} is the net energy released.

   Another possible heating source for HI clouds is cosmic ray heating. The cosmic ray ionisation rate ζ_{CR} is of order $\sim 10^{-16}\ \mathrm{s^{-1}}$ and the energy deposited by cosmic rays is

   $$E_h = 6.5\mathrm{eV} + 24.4\mathrm{eV}\left(\frac{\mathrm{x_e}}{\mathrm{x_e} + 0.07}\right)^{1/2} \tag{4}$$

   where $x_e \equiv n_e/n_H$ is the ratio of electrons to hydrogen atoms. Which of these heating mechanisms will be the most significant.

   (b) The contribution of X-rays to the local radiation field is not a dominant one, but nonetheless, X-rays emitted by compact objects or interstellar plasma may still impinge on neutral regions. The photo-absorption cross section for an H nucleon is $\sim 4 \times 10^{-22}\ \mathrm{cm^2}$. Describe how X-rays will penetrate neutral clouds.