Homework 3

Please use Jupyter notebook to complete this assignment.

1. [CII]158μm line (4 points)

The [CII]158μm fine-structure line is a two-level system, as shown in Fig. 17.3 in Draine's book. Calculate the level population (ratio of upper-level to lower level) numerically and plot it as a function of hydrogen number density ($n_{\rm H}$) at six different temperatures T =30, 100, 300, 1000, 3000, and 10000 K (similar to Fig. 17.4).

2. Thermal equilibrium in the diffuse ISM (4 points)

In the diffuse ISM, the primary cooling mechanism is the [CII]158μm fine-structure line, while the primary heating mechanism is the photoelectric heating, which, to first order, has the following heating rate per volume

$$\Gamma_{\rm pe} = 2 \times 10^{-26} n_{\rm H} \text{ erg s}^{-1} \text{ cm}^{-3}.$$

In thermal equilibrium (i.e., cooling balances heating), plot the gas temperature T as a function of $n_{\rm H}$ (show both axes in log scales). Set the density range between 10^{-2} cm^{-3} to 10^{3} cm^{-3}

3. The two-phase ISM (2 points)

Following (2), plot the gas pressure P as a function of $n_{\rm H}$ (show both axes in log scales) and determine the range of pressure that allows an ISM with two thermally stable phases in pressure equilibrium with each other. Express the pressure as $P/k_{\rm B}$ in units of [K cm^{-3}], where $k_{\rm B}$ is the Boltzmann constant.

4. Density diagnostics (4 points)

Use a three-level model to calculate the line ratio [OII]3729.8/[OII]3727.1 and plot it as a function of $n_e T_4^{1/2}$ (as Fig. 18.4). You can find all the relevant atomic data in the Appendix.