ASTR705 ISM
Midterm
Due Friday, 3/3, in class

Instructions: Work on this on your own! Feel free to use any reference materials, including anything found online. 50pt total.

1) HI! (22pt)
a) (3pt) Even in an environment where collisions are unimportant, why may we still get H I 21 cm line emission? Back up your answer with equations.

b) (2pt) Calculate the average lifetime of an H I atom in the $F = 1$ state in years.

c) (3pt) Is stimulated emission important for H I? Back up your answer with equations.

d) (2pt) Would your answer for c) also apply to OH fine-structure transitions near 1700 MHz? Why or why not?

e) (4pt) Determine the relationshiop between the optical depth and the column density for the WNM and CNM at line center. Assume they have linewidths of $\sigma_V = 5$ and 20 $\mathrm{km\,s^{-1}}$, respectively.

f) (4pt) If observing at $(\ell, b) = (30^\circ,\ 0^\circ)$ in the direction of a bright extragalactic continuum source (i.e., an AGN), draw the H I spectrum for all H I along the line of sight. Assume the continuum brightness temperature is 1000 K and the H I spin temperature is 100 K. Use axes in units of brightness temperature versus velocity. Do not remove the background intensity (plot T^{ON}).

g) (4pt) If observing at $(\ell, b) = (30^\circ,\ 0^\circ)$ in the direction of a faint extragalactic continuum source, draw the H I spectrum for all H I along the line of sight. You can assume the continuum brightness temperature is 10 K and the H I spin temperature is 100 K. Again, use axes in units of brightness temperature versus velocity. Do not remove the background intensity.

2) CO! (28pt)

a) (3pt) For a 20 K cloud, compare the $J = 2$ and $J = 1$ level populations of ^{13}CO. State all assumptions.

b) (2pt) For this same cloud, what is the thermal broadening of ^{12}CO in km/s?

c) (3pt each) Write the equation of radiative transfer for the scenario where you are observing:
i) "on source" in the direction of a ^{12}CO cloud,
ii) "off source", not through the cloud, and
iii) on-off (simplified).
You may assume the Rayleigh-Jeans limit applies (even though we know it isn't a great approximation for CO) and use terms in temperatures. Be sure to include a background term in all relevant equations.

d) (4pt each) You are observing at $(\ell, b) = (30\,^{\circ},0\,^{\circ})$. On a single set of axes, draw on-off for the following observations:
i) ^{12}CO $J = 1 - 0$ of the 20 K molecular cloud **at a Galactocentric radius of 5 kpc.**
ii) ^{13}CO $J = 1 - 0$ of a 20 K molecular cloud at a Galactocentric radius of 5 kpc.
iii) ^{12}CO $J = 2 - 1$ of a 20 K molecular cloud at a Galactocentric radius of 5 kpc (consult your answer for part a)).
As before, plot units of brightness temperature versus velocity. Assume a flat rotation curve. State all assumed temperature values. Pay close attention to the peak line heights and velocities.

e) (2pt) If the off-source direction has a term with $T_{\rm BG}$ and the on-source direction has a term with $T_{\rm BG}e^{-\tau_\nu}$, why is the on-off spectrum at 0 K at velocities way lower or higher than that of the cloud?