AST 300B – Spring 2019

In-class/Take-home Problems Due: Monday Mar 25

28. Consider a 2 level system with a single collisional partner with density n_c and a "critical density" that includes stimulated emission from a background radiation field given by $n_{crit} = (1 + n_\gamma)A_{21}/\gamma_{21}$, where n_γ is equal to the ratio of stimulated to spontaneous de-excitation rates that you derived in Problem 26. In this problem, we shall explore the relative importance of radiative rates vs. collisional de-excitation.

a. What are the units of the critical density, n_{crit}?
b. What is an expression for the fractional rate of radiative transitions from level 2 compared to the total de-excitation rate (by all mechanisms) from level 2? Simplify your answer to an expression with only n_c and n_{crit}.
c. What is this fraction equal to when $n_c = n_{crit}$. Interpret.
d. What is the limit of this fraction in the high density limit ($n_c >> n_{crit}$)? In this limit, forbidden line transitions in HII regions are said to be "quenched". What does this mean in terms of observing the forbidden line and why?
e. What is the limit of this fraction in the low density limit ($n_c << n_{crit}$)?

29. Now consider a 3 level system with a single collisional partner with density n_c. Radiative transitions are only allowed from level 2 → 1 and from level 1 → 0. Assume $A_{20} \sim 0$.

a. What is an expression for the fractional rate of radiative transitions from level 2 compared to the total de-excitation rate (by all mechanisms) from level 2, denoted by f_{21}^{rad}? Convert all Einstein B terms to Einstein As in your expression.
b. What are the limits of f_{21}^{rad} at low and high density (n_c)?
c. Define the "multi-level critical density" $(n_{crit})_{21}$ as the density at which $f_{21}^{rad} = ½$. What is the equation for $(n_{crit})_{21}$? How is this different from the 2 level definition in Problem 28?