

## AST 300B – Spring 2018

### In-class/Take-home Problems Due: Monday Apr 2

34. 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  $n_{\text{crit}} = (1 + n_\gamma)A_{21}/\gamma_{21}$ , where  $n_\gamma$  is equal to the ratio of stimulated to spontaneous de-excitation rates that you derived in Problem 32. In this problem, we shall explore the relative importance of radiative rates vs. collisional de-excitation.

- What are the units of the critical density,  $n_{\text{crit}}$ ?
- 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  $n_{\text{crit}}$ .
- What is this fraction equal to when  $n_c = n_{\text{crit}}$ . Interpret.
- What is the limit of this fraction in the high density limit ( $n_c \gg n_{\text{crit}}$ )? 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?
- What is the limit of this fraction in the low density limit ( $n_c \ll n_{\text{crit}}$ )?

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

- 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  $f_{21}^{\text{rad}}$ ? Convert all Einstein B terms to Einstein As in your expression.
- What are the limits of  $f_{21}^{\text{rad}}$  at low and high density ( $n_c$ )?
- Define the “multi-level critical density”  $(n_{\text{crit}})_{21}$  as the density at which  $f_{21}^{\text{rad}} = 1/2$ . What is the equation for  $(n_{\text{crit}})_{21}$ ? How is this different from the 2 level definition in Problem 35?