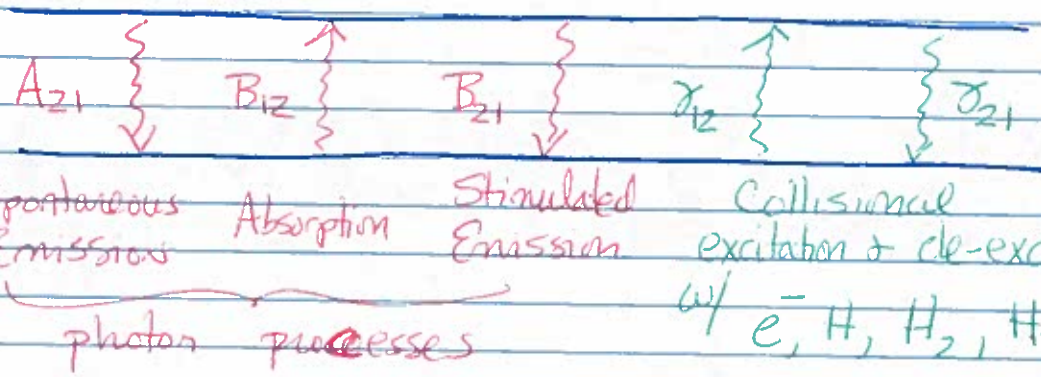
Bound - Bound Transitions

ASTR 300B

Consider 2 Bound States

There are 3 Radiative ways to populate/de-populate and 2 collisional ways to populate/de-populate



Let's analyse the rate at which level 2 changes:

Spontaneous Emission

$$\frac{dn_2}{dt} = -n_2 A_{21}$$

$[cm^{-3} \cdot s^{-1}]$ $[cm^{-3}]$

← Einstein A give rate of spontaneous decay $[s^{-1}]$

*Note $1/A_{21}$ is a lifetime

Photon Processes

Stimulated Emission

$$\frac{dn_2}{dt} = -n_2 B_{21} \cdot u_\nu$$

$[cm^{-3} \cdot s^{-1}]$ $[cm^{-3}]$ $[erg \cdot cm^{-3} \cdot s^{-2}]$ $[erg \cdot cm^{-3} \cdot Hz^{-1}]$

← Einstein B coefficient

(Note! It is also possible to define $B_{21} \cdot \bar{J}_\nu$ where J_ν is the mean specific intensity)

* depends on energy density of photons at frequency $h\nu = h\nu_{21}$

Absorption (from level 1 to 2)

$$\frac{dn_2}{dt} = +n_1 B_{12} \cdot u_\nu$$

[Same units as B_{21}]

number density of colliding particles (e^-, H, H_2, He, etc.)

Collisional De-excitation $\frac{dn_2}{dt} = -n_2 n_c \gamma_{21}$ ← Collision Rate

$cm^{-3}\cdot s^{-1}$ cm^{-3} cm^{-3} $cm^3\cdot s^{-1}$

$\gamma_{21} = \langle \sigma v \rangle$ ← averaged over the colliding particle velocity (or energy) distribution.

σ: collisional cross-section cm^2; v: velocity of colliding particles cm/s; $\gamma_{21} = cm^3\cdot s^{-1}$

Collisional Excitation $\frac{dn_2}{dt} = n_1 n_c \gamma_{12}$

$cm^{-3}\cdot s^{-1}$ cm^{-3} cm^{-3} $cm^3\cdot s^{-1}$

Combining ways to populate and depopulate n_2:

$$\frac{dn_2}{dt} = n_1 n_c \gamma_{12} + n_1 B_{12} u_\nu - n_2 n_c \gamma_{21} - n_2 A_{21} - n_2 B_{21} u_\nu$$

In statistical Equilibrium $\frac{dn_2}{dt} = 0$

$$n_1 (n_c \gamma_{12} + B_{12}\cdot u_\nu) = n_2 (n_c \gamma_{21} + A_{21} + B_{21}\cdot u_\nu)$$

$\Rightarrow$ We can only Determine ratio of n_2/n_1

NOTE: Einstein As & Bs are related AND
γ_{12} is related to γ_{21} AND
n_2/n_1 is given by Boltzmann's Equation
We shall derive these relations in the next lectures ...