# Partículas idênticas & 2ª Quantização

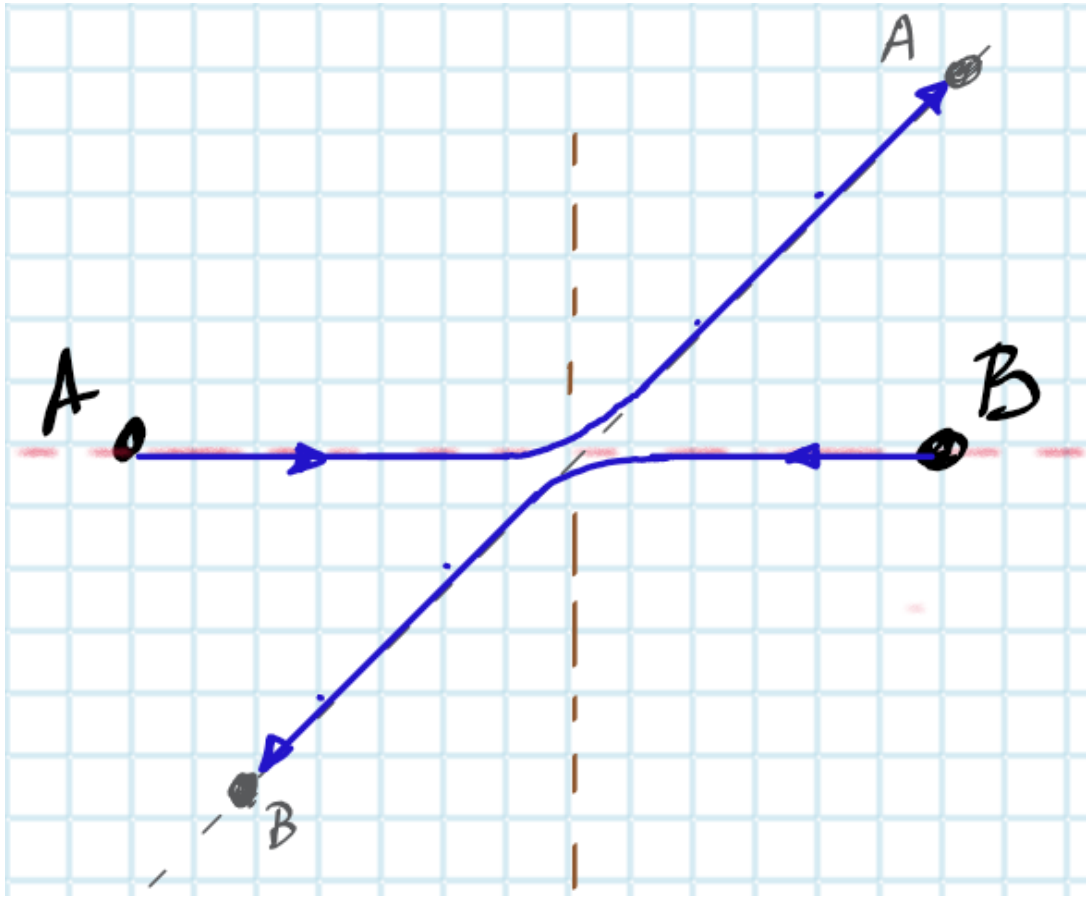
Aula final (extra) – Mec. Quântica Aplicada (2020)
SFI-5774

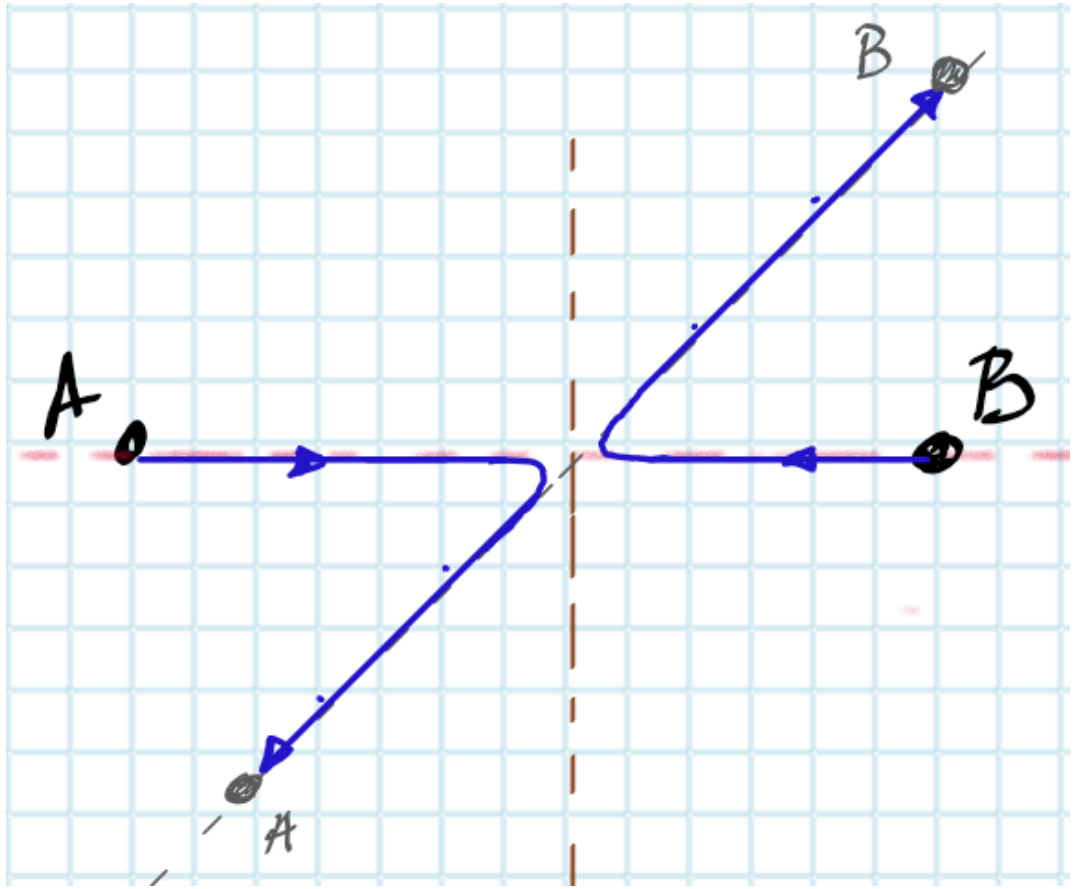
(SRM)

# Problema de interesse (passos p/ resolução)

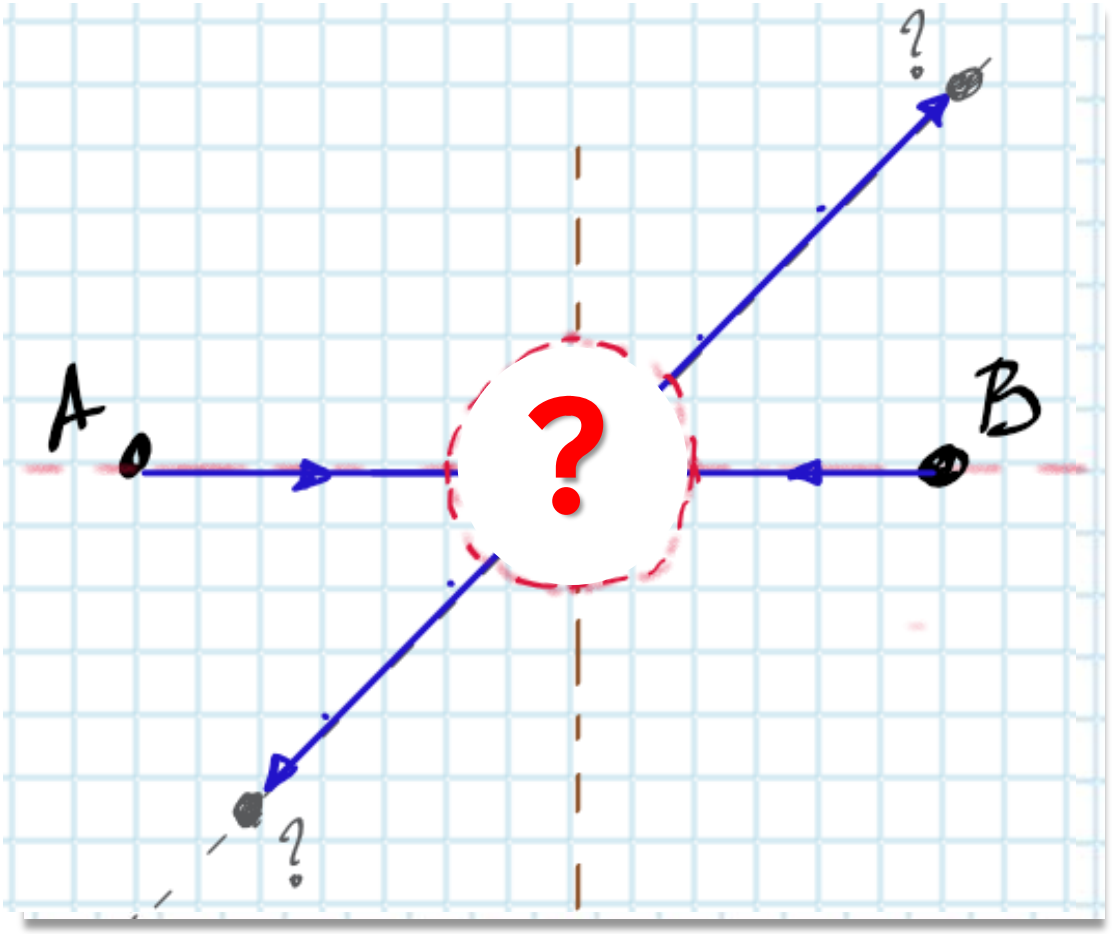
- **Quais os estados permitidos** (*autofunção & autovalores*)?
  - Encontrar estados estacionários (diagonalização)
- **Qual a distribuição das partículas nesses estados**?
  - Distribuição (mecânica) estatística quântica
  - Probabilidade de transições
- **Como as partículas respondem a estímulos externos**?
  - Interações e probabilidades de transições

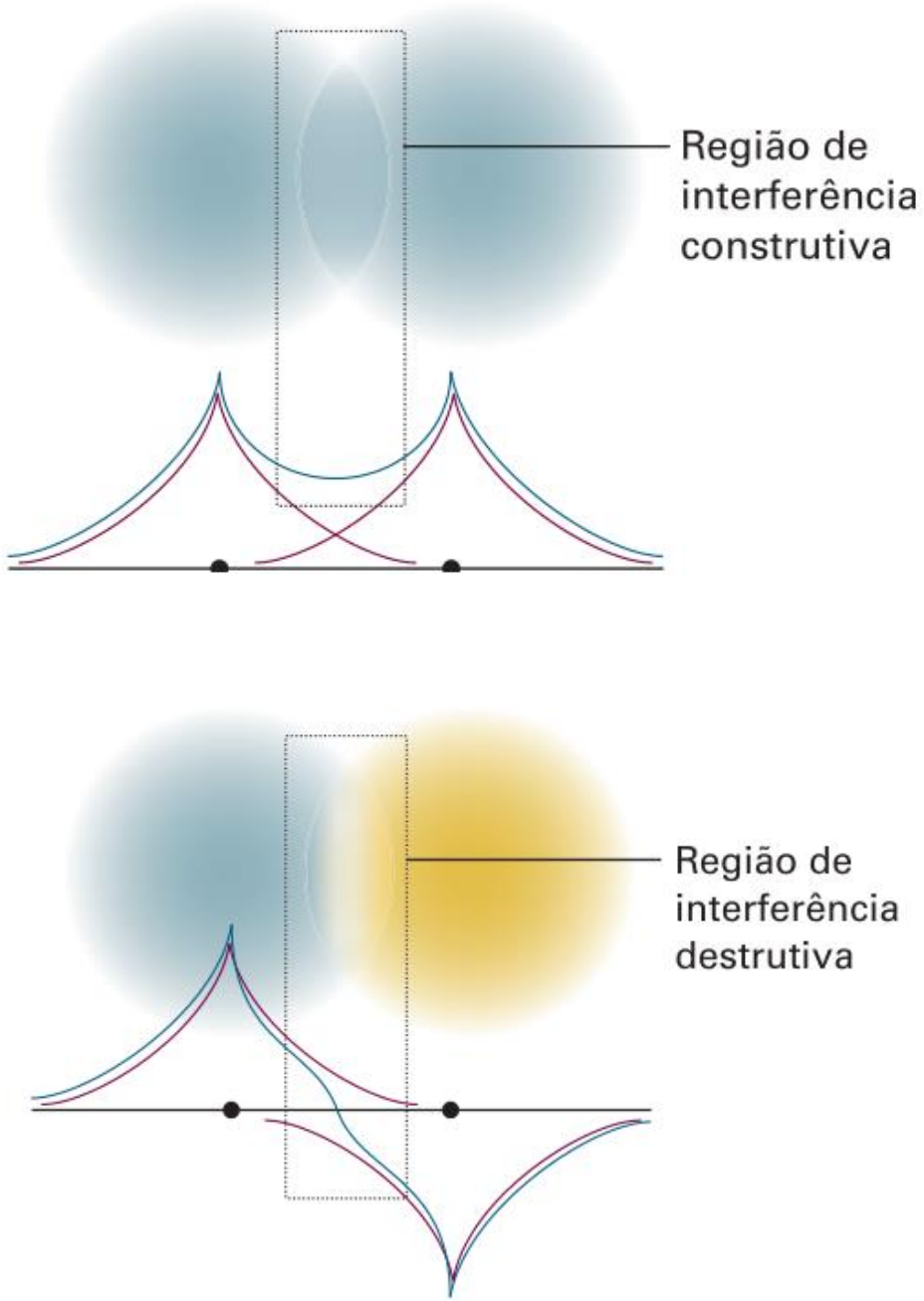
# Partículas idênticas



# Partículas idênticas





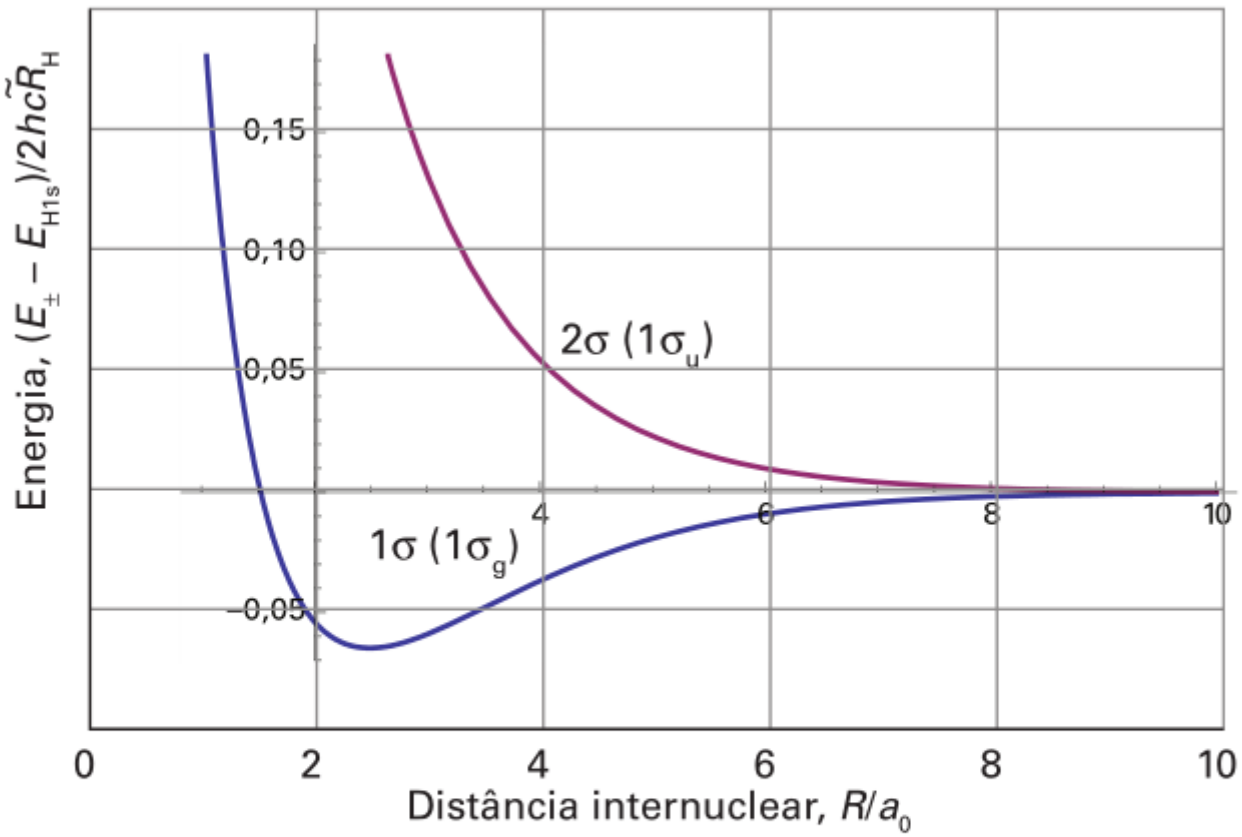
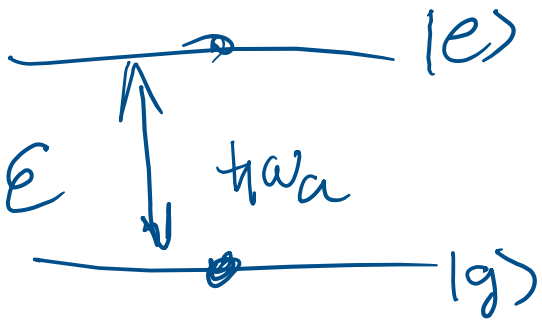




**Figura 10B.6** As curvas da energia potencial molecular calculadas do íon do hidrogênio molecular, mostrando a variação da energia dos orbitais ligantes e antiligantes quando o comprimento da ligação varia. A notação alternativa dos orbitais é explicada mais adiante.




$$\hat{\mathcal{H}} = \sum_k \hbar\omega_k \hat{a}_k^\dagger \hat{a}_k + \dots$$

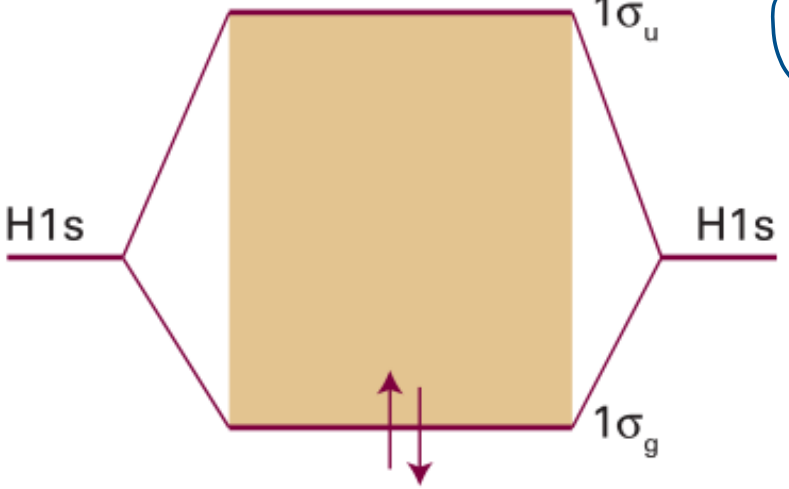
Jaynes-Cummings

$$\hat{\mathcal{H}} = \hbar\omega_c \hat{a}^\dagger \hat{a} + \frac{\hbar\omega_a}{2}\hat{\sigma}_z + \frac{\hbar\Omega}{2}(\dots)$$

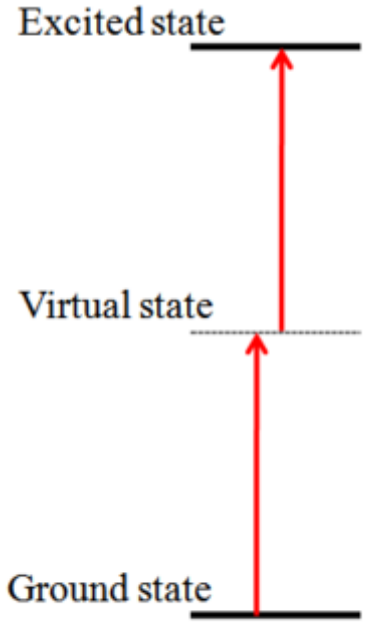
(comp.) (Rabi)

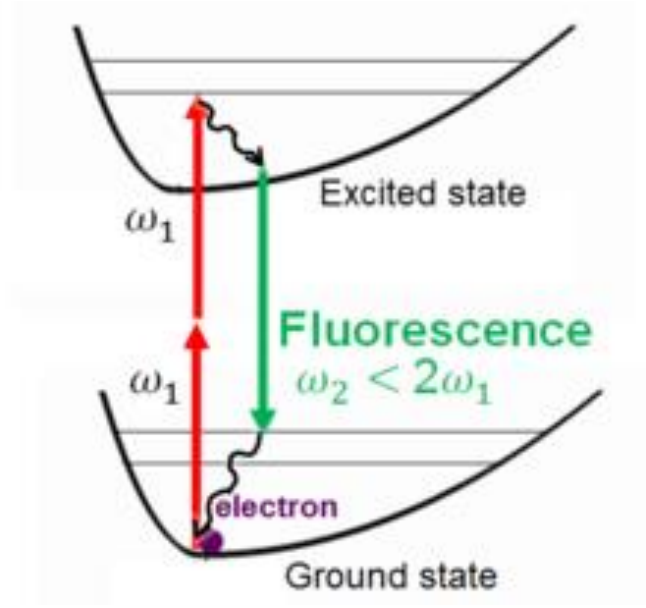
$$+ \frac{\hbar\Omega}{2}\left( a\sigma_+ + a^\dagger\sigma_- \right) \leftarrow$$

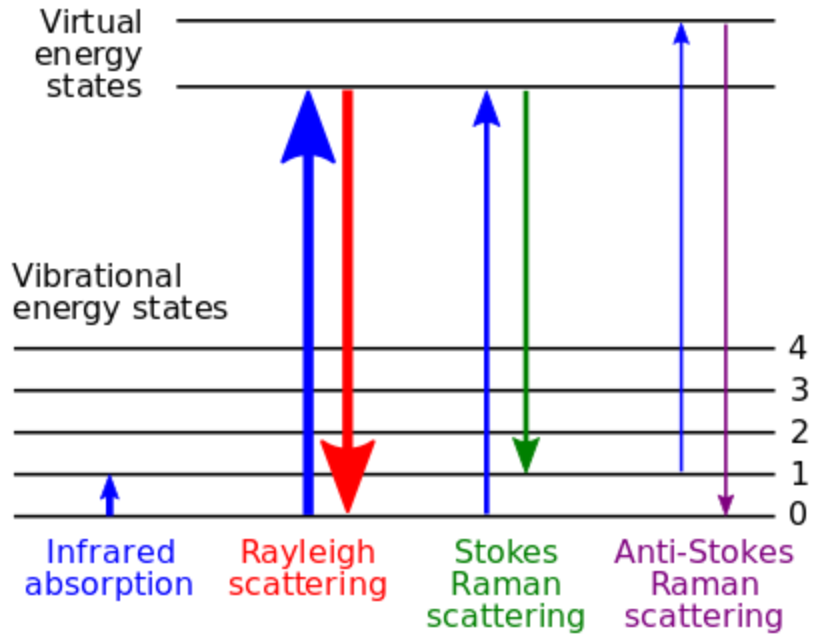
$a\sigma_+$ $\sigma_+ + a^\dagger\sigma_-$



# Processos de 2-fótons



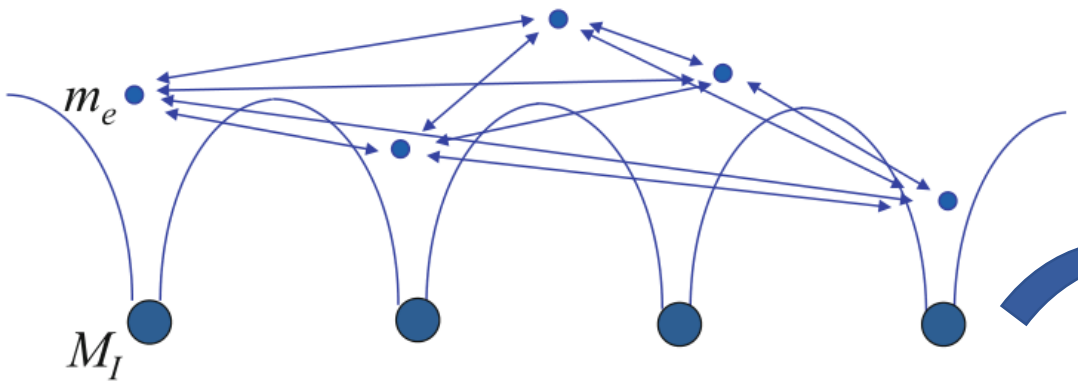




Imagens Wikipedia

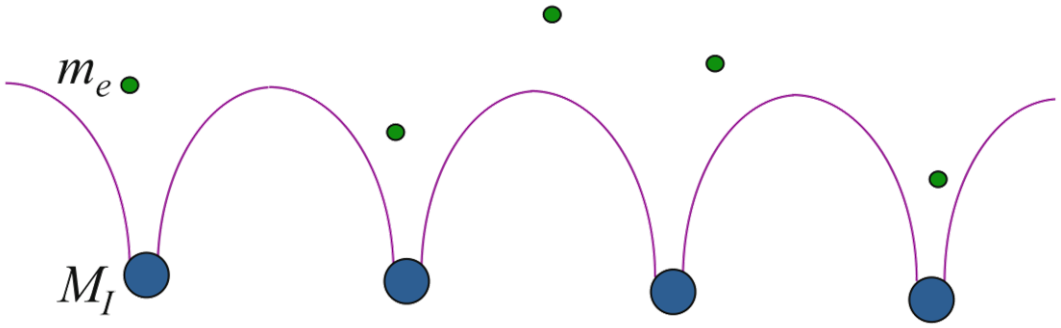
# Many-body problem

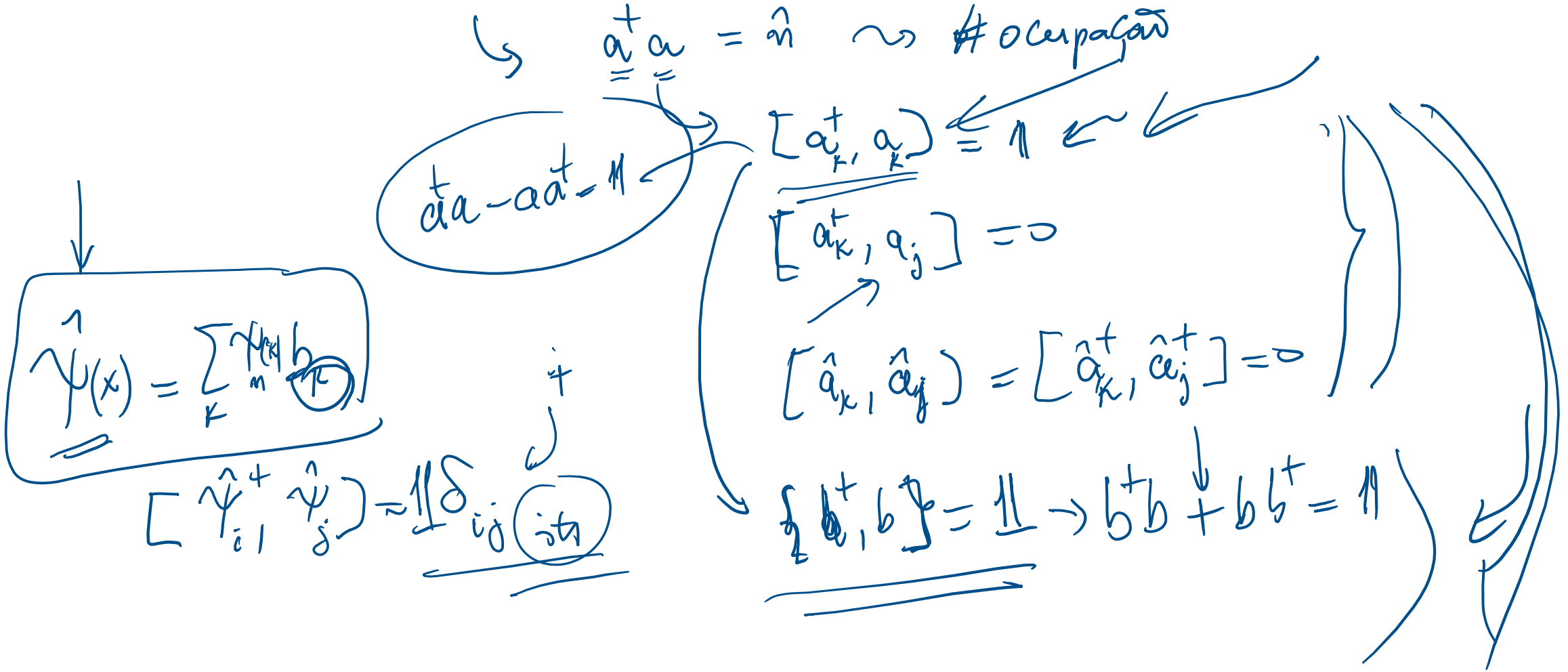
$$\mathscr{H} = \sum_i \frac{\mathbf{p}_i^2}{2m_e} - \sum_{i,I} \frac{Z_I e^2}{|\mathbf{r}_i - \mathbf{R}_I|} + \frac{1}{2}\sum_{i,j} \frac{e^2}{|\mathbf{r}_i - \mathbf{r}_j|} + \sum_I \frac{\mathbf{P}_I^2}{2M_I} + \frac{1}{2}\sum_{I,J} \frac{Z_I Z_J e^2}{|\mathbf{R}_I - \mathbf{R}_J|}$$




Sistema de muitas partículas interagentes

Sistema de quase-partículas não interagentes




↳ $a^\dagger a = \hat{n}$ ⇝ #ocupação
$a^\dagger a - a a^\dagger = \mathbb{1}$
$[a_k^\dagger, a_k] = \mathbb{1}$
$[a_k^\dagger, a_j] = 0$
$[\hat{a}_k, \hat{a}_j] = [\hat{a}_k^\dagger, \hat{a}_j^\dagger] = 0$
$\{b^\dagger, b\} = \mathbb{1} \to b^\dagger b + b b^\dagger = \mathbb{1}$
$\hat{\psi}(x) = \sum_k \varphi_m(x) b_m$
$[\hat{\psi}_i^\dagger, \hat{\psi}_j] = \mathbb{1}\delta_{ij}$
ith
jth