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Palermo
Spagna
Giappone
Palermo
Londra
Mosca



Istantanea del gruppo al lavoro



blabla



Temi di ricerca



blabla



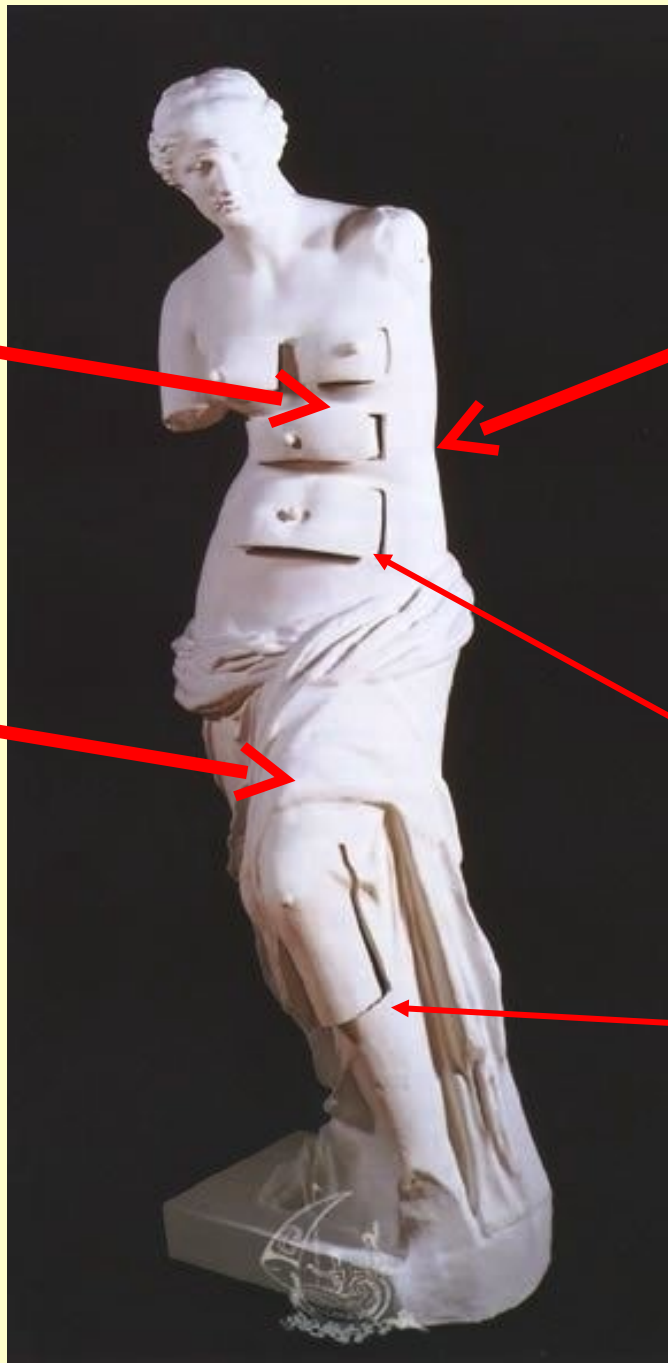
Atomi, molecole,
nanoparticelle
in forti campi
elettromagnetici

Didattica
della Fisica
(AAG)

Tecniche
numeriche
e calcolatori
informatica

Geologia

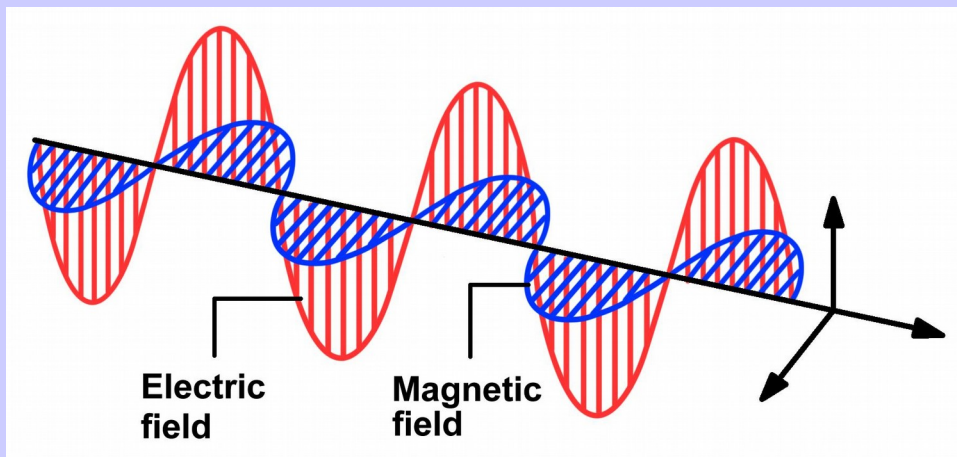
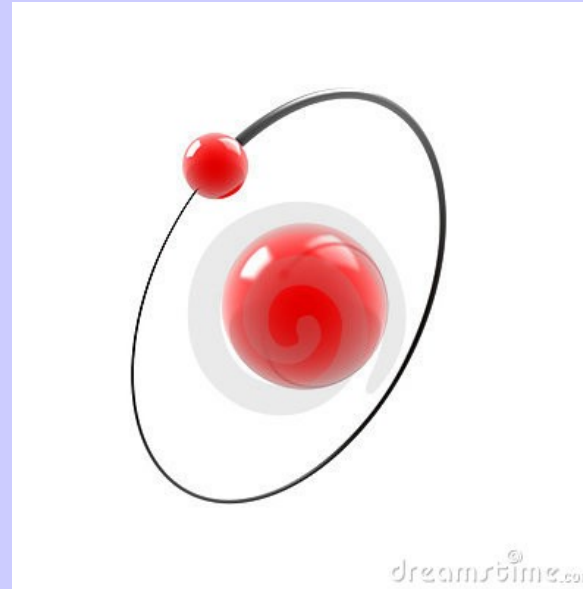
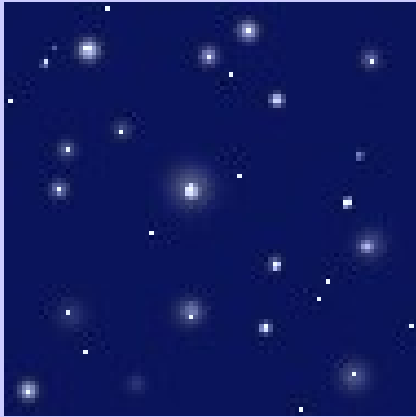
Matematica



Atomi, molecole,
nanoparticelle
in forti campi
elettromagnetici



Il laser è l'oggetto più brillante della galassia



$$a_0 = \frac{\hbar^2}{me^2} = 5.3 \cdot 10^{-9} \text{ cm}$$

$$E = \frac{e}{a_0^2} = 5.1 \cdot 10^9 \text{ V/cm}$$

$$I = 3.5 \cdot 10^{16} \text{ W/cm}^2$$



- ❖ Dinamica di atomi e molecole in presenza di laser
- ❖ Radiazione emessa da atomi e molecole
- ❖ Controllo di processi molecolari con un laser
- ❖ Ionizzazione multifotonica
- ❖ Nanoparticelle (fullerene, nanorings, grafene) in presenza di laser

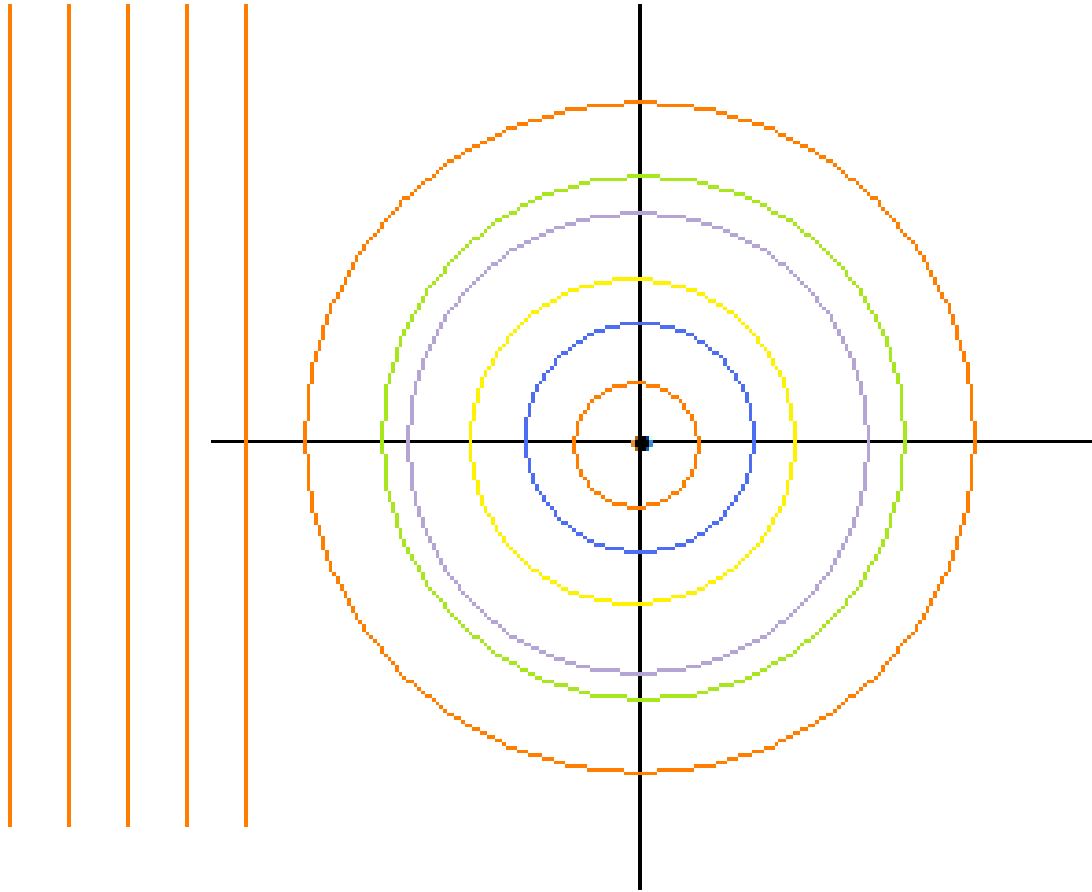


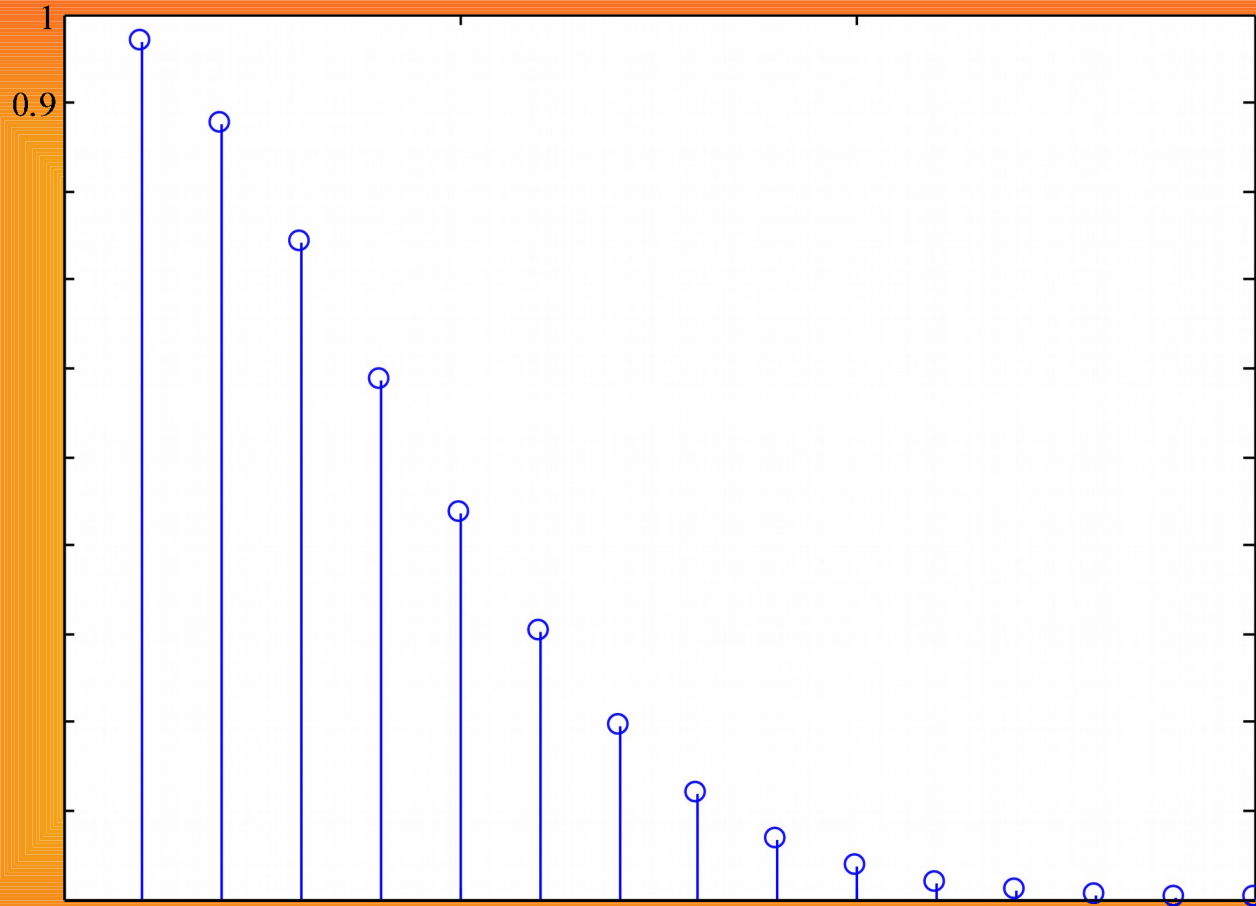
Argomenti

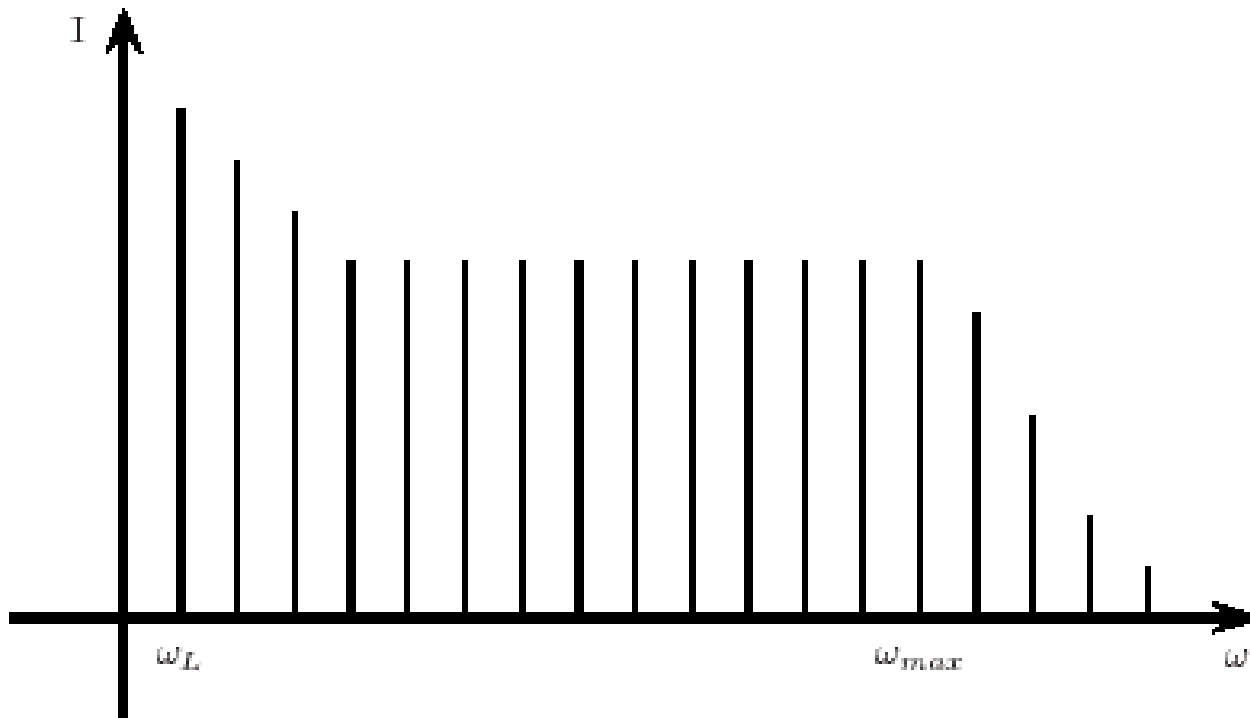
blabla



ω_L

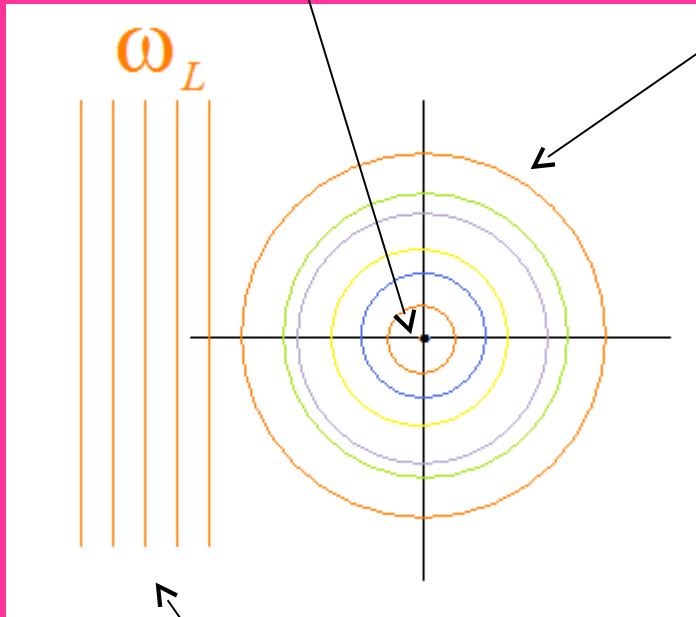






Molecola

Radiazione diffusa

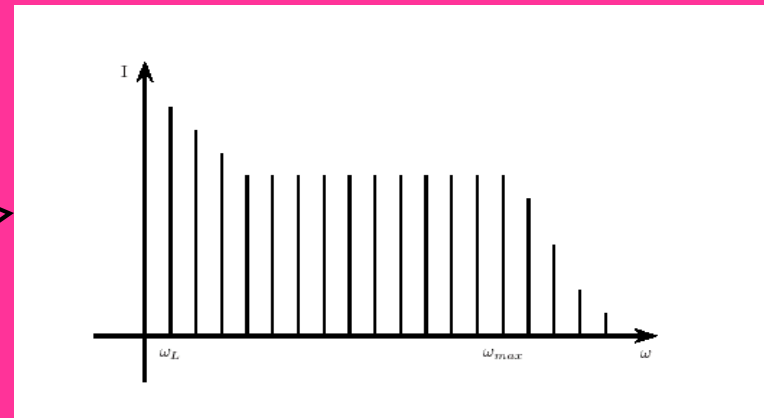


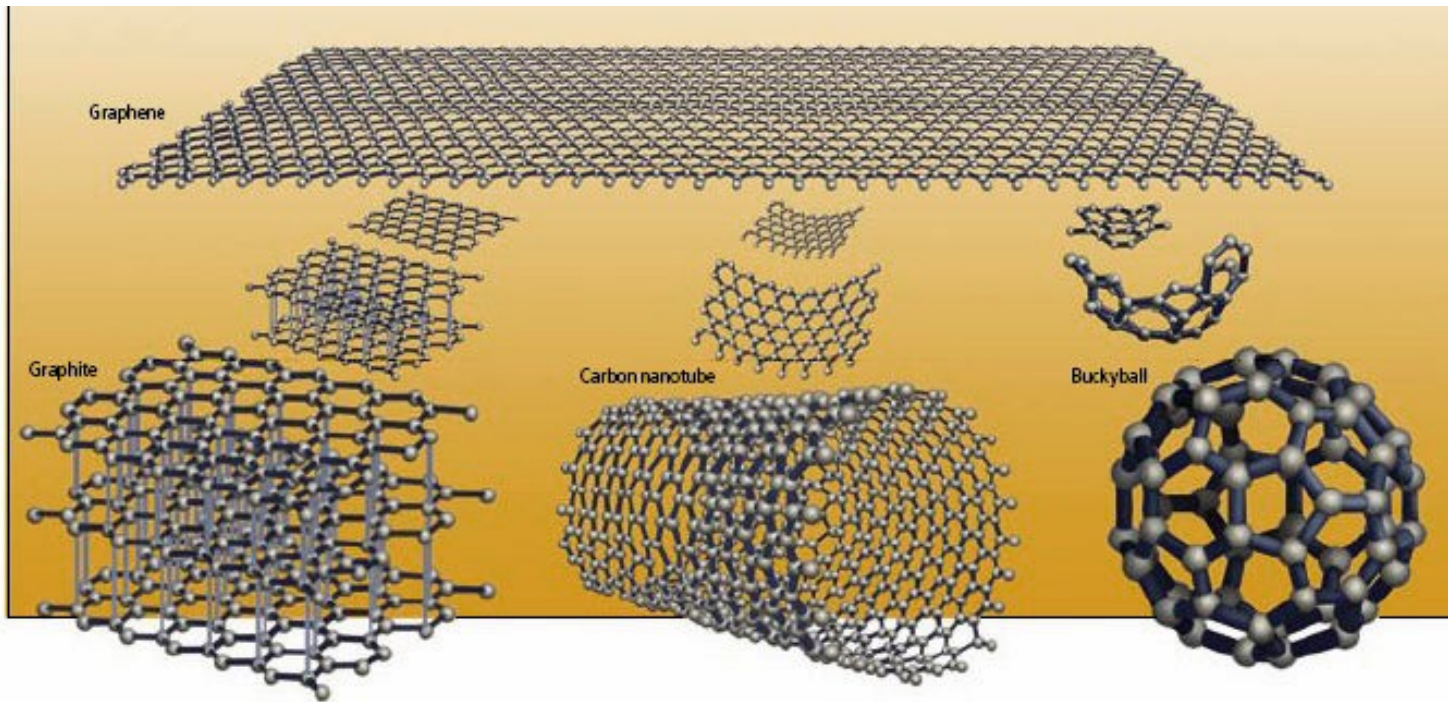
$$P(t) = \frac{2q^2}{3c^3} |\mathbf{a}(t)|^2$$

$$\frac{dS}{d\omega} = \frac{4q^2}{3c^3} |\mathbf{a}(\omega)|^2$$

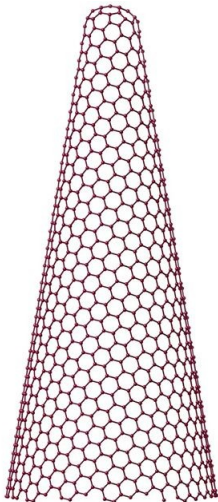
Laser

Spettro artistico





Allotropi del carbonio

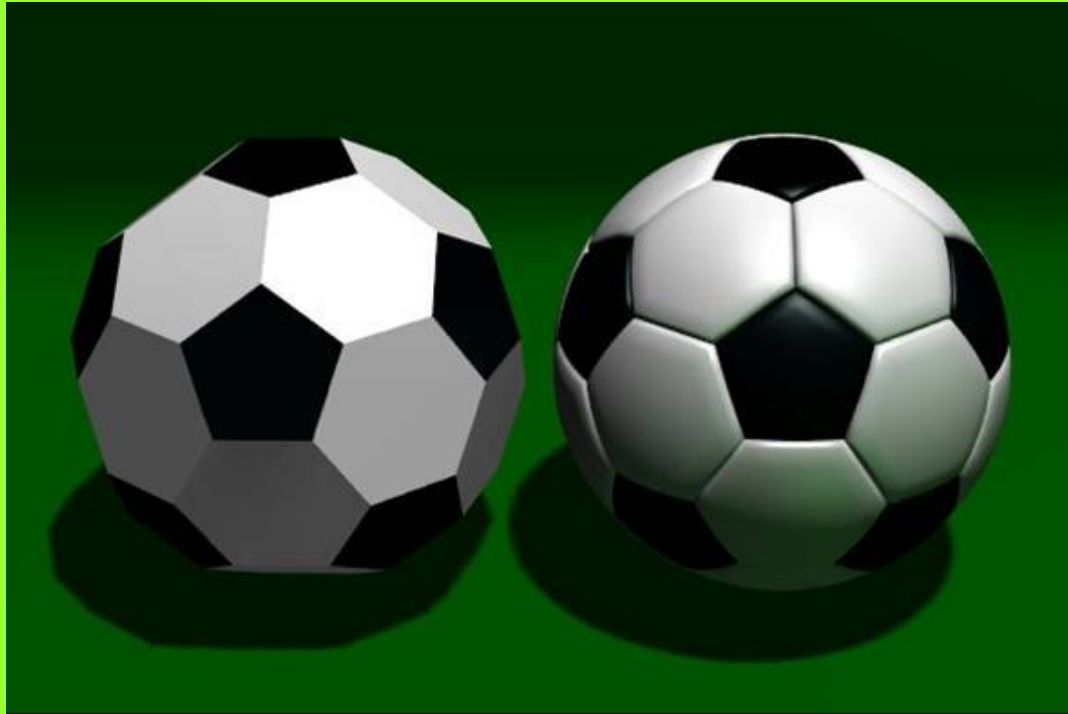


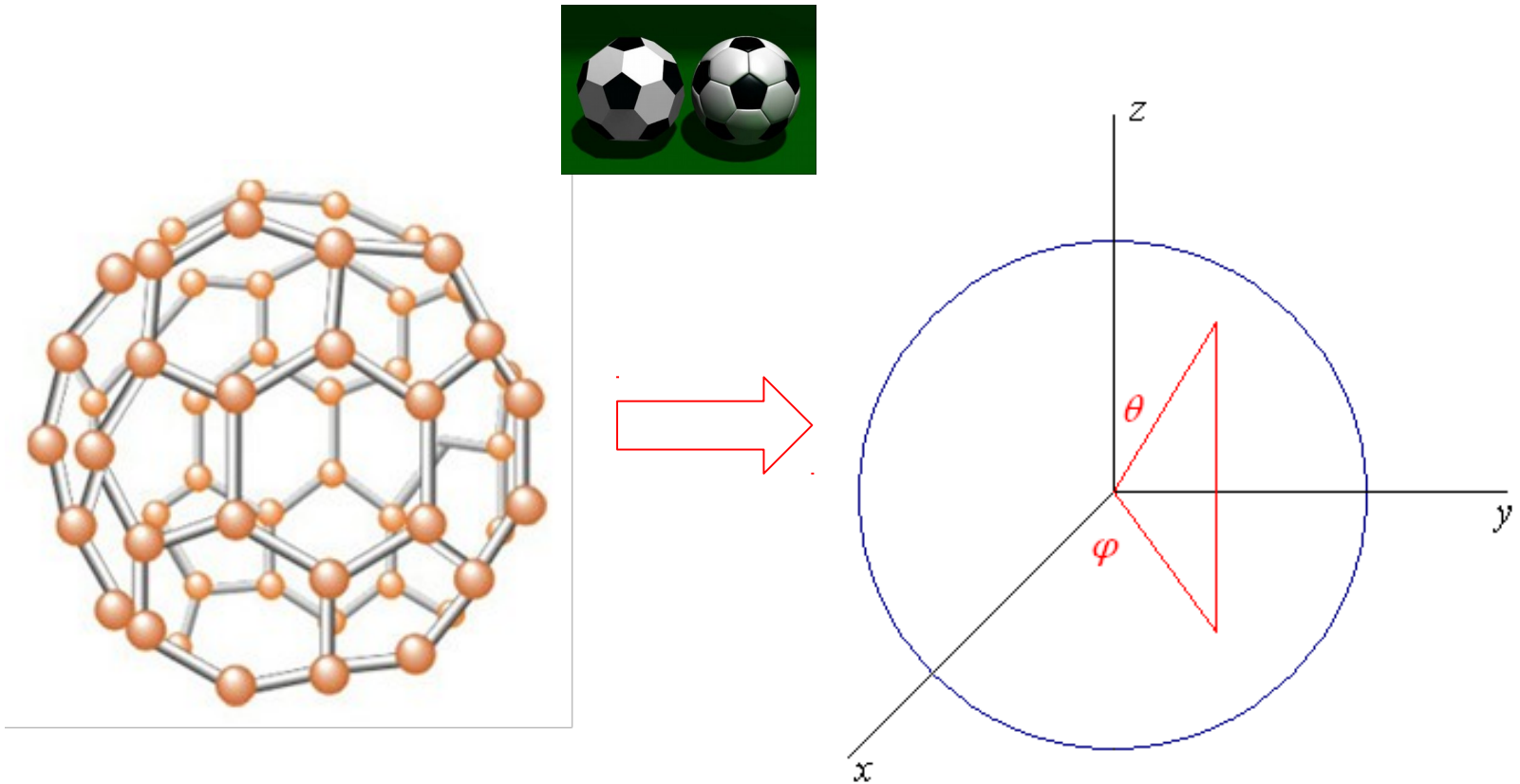
Wow Il nanocorno



blabla

Fullerene





Occorre gente con fantasia



$$\hat{H} = \frac{\hbar^2}{2I} \hat{L}^2 + V_L f(t) \cos \vartheta \sin(\omega_L t)$$

$$\tau = \omega_L t$$

$$\hat{L}^2 |\ell, m\rangle = \ell(\ell + 1) |\ell, m\rangle$$

$$\Omega_L = \frac{V_L}{\hbar \omega_L}$$

$$|\ell, m\rangle \Leftrightarrow Y_{\ell, m}(\vartheta, \varphi)$$

$$\delta_\ell = \frac{\omega_\ell}{\omega_L}$$

$$\omega_\ell = \frac{\hbar}{2I} \ell(\ell + 1)$$

$$\delta_{\ell+1, \ell} = \delta_{\ell+1} - \delta_\ell$$

$$i\hbar \frac{\partial}{\partial t} |t\rangle = \hat{H} |t\rangle$$

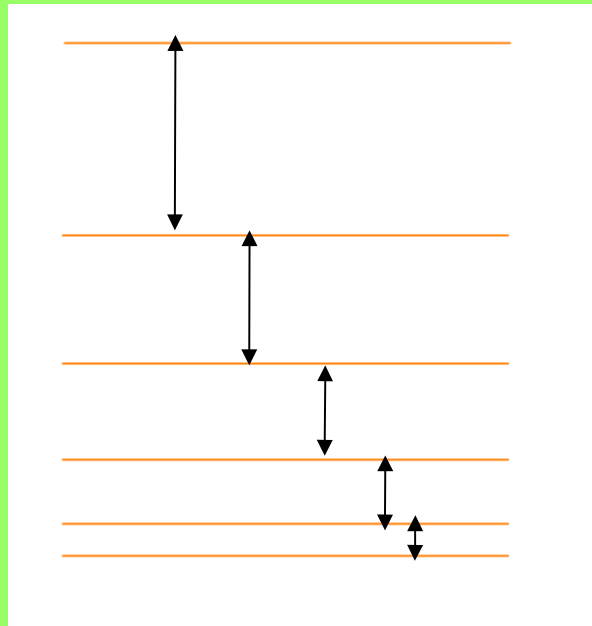
$$|t\rangle = \sum_{\ell=\Lambda}^{\infty} c_\ell |\ell, 0\rangle$$

Ma la fantasia deve essere messa all'opra.

Occorre gente che sappia fare modelli

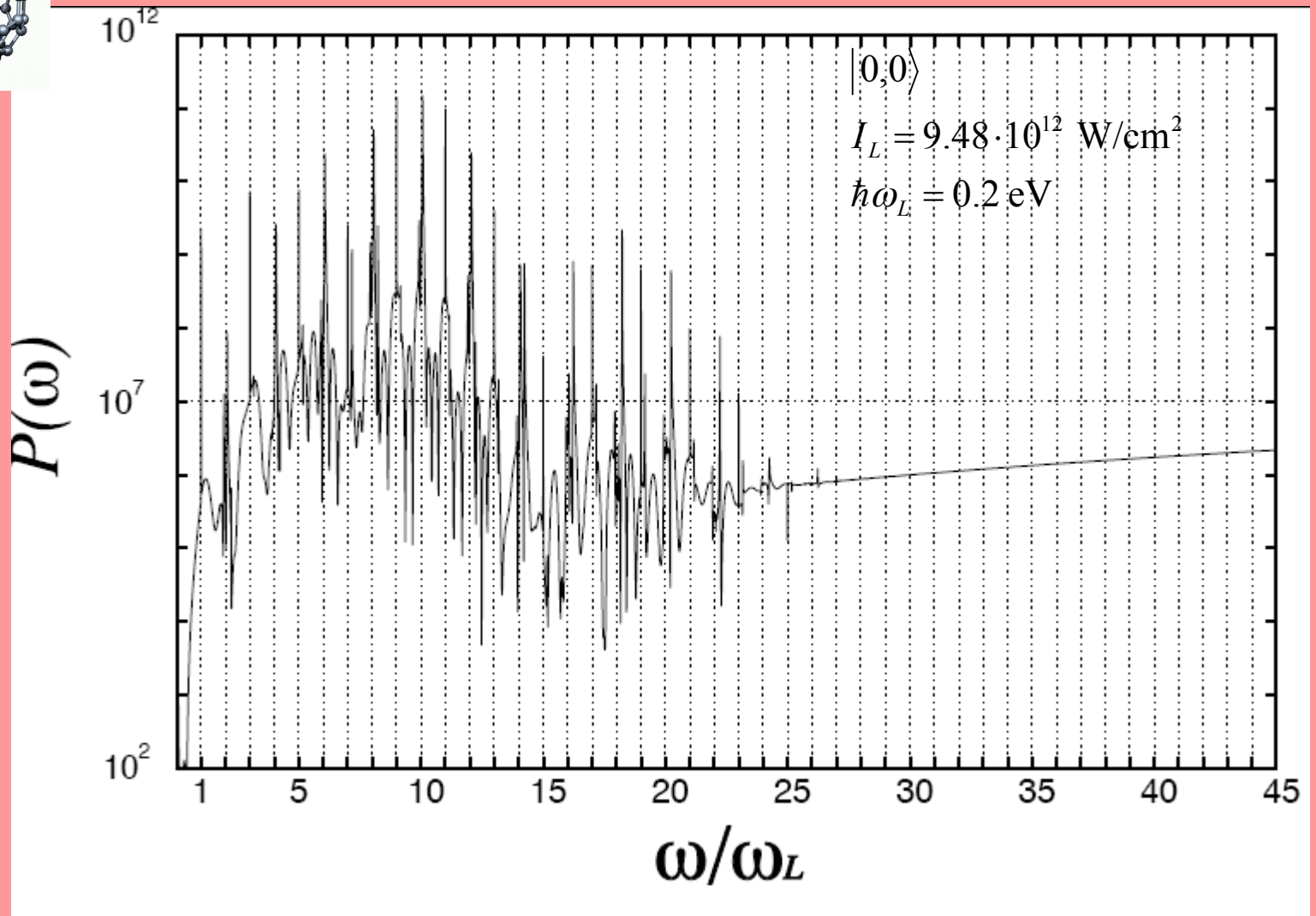
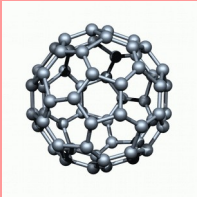


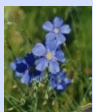
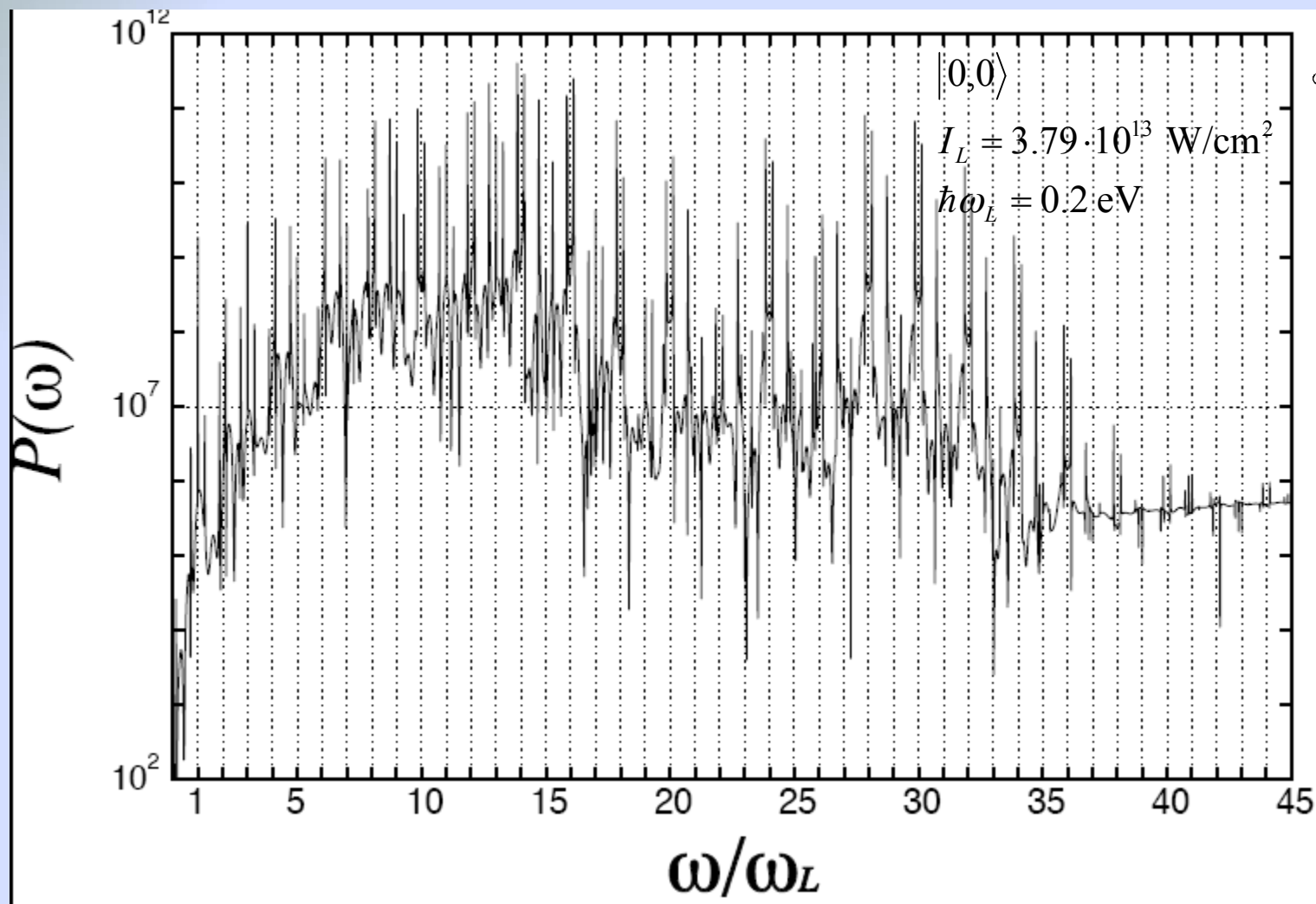
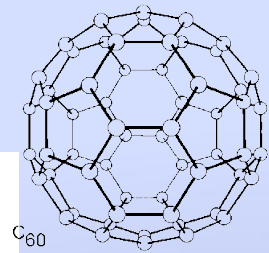
$$\left\{ \begin{array}{l} ic'_\Lambda = \delta_\Lambda c_\Lambda + \Omega_L \frac{\Lambda + 1}{\sqrt{(2\Lambda + 1)(2\Lambda + 3)}} \sin(\tau) c_{\Lambda + 1} \\ ic'_{l > \Lambda} = \delta_l c_l + \Omega_L \left\{ \frac{l c_{l-1}}{\sqrt{(2l - 1)(2l + 1)}} + \frac{(l + 1) c_{l+1}}{\sqrt{(2l + 1)(2l + 3)}} \right\} \sin(\tau) \end{array} \right.$$

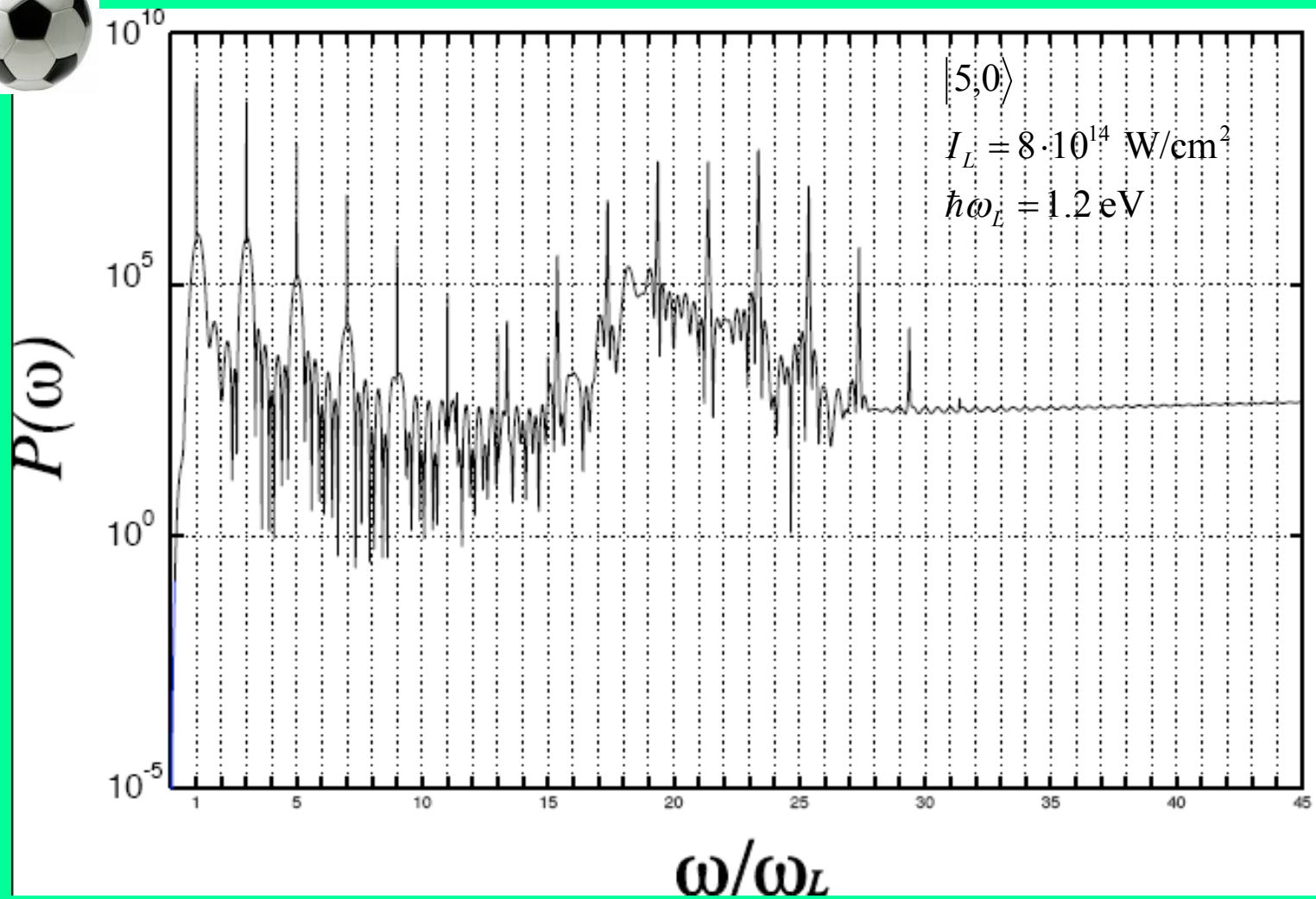


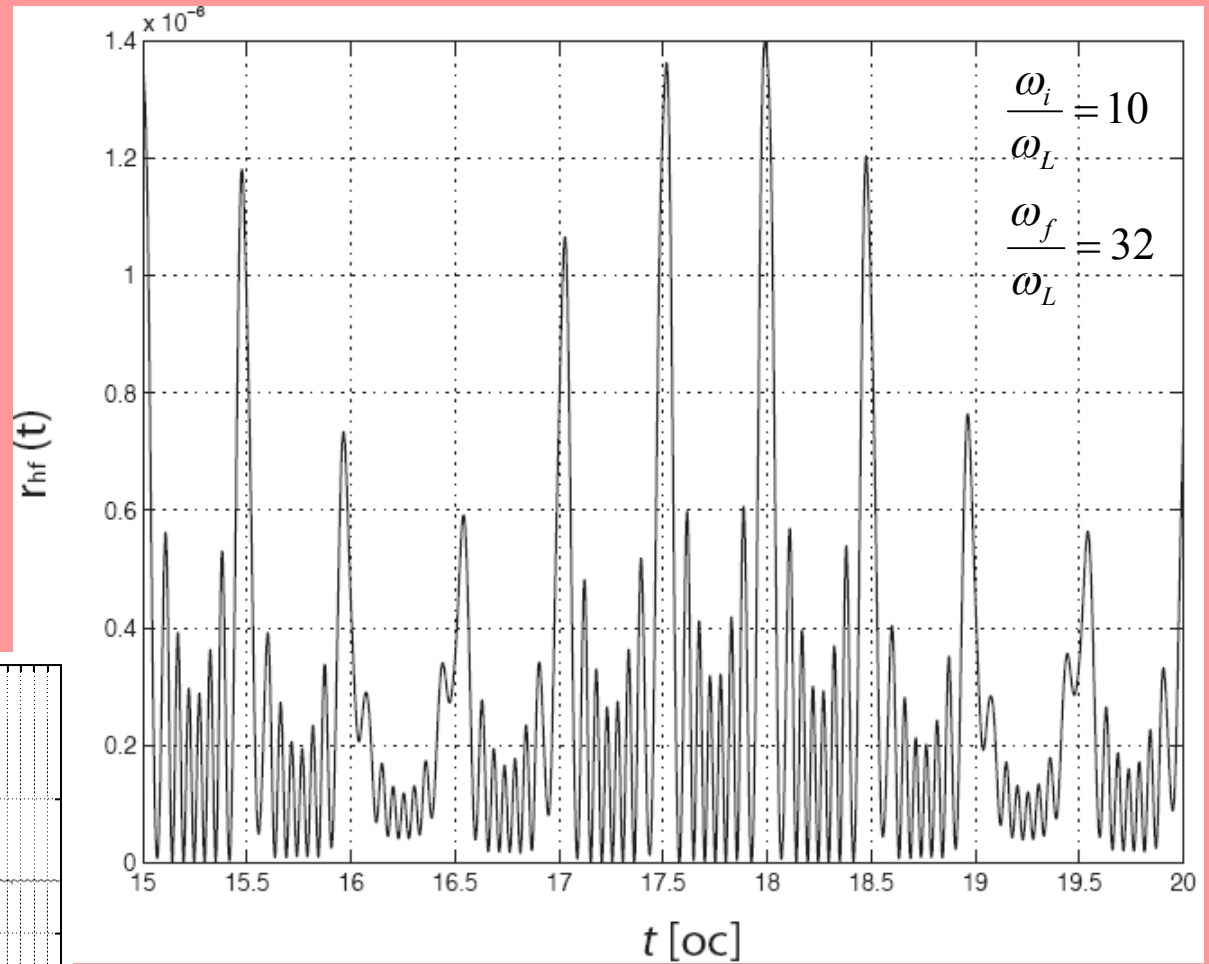
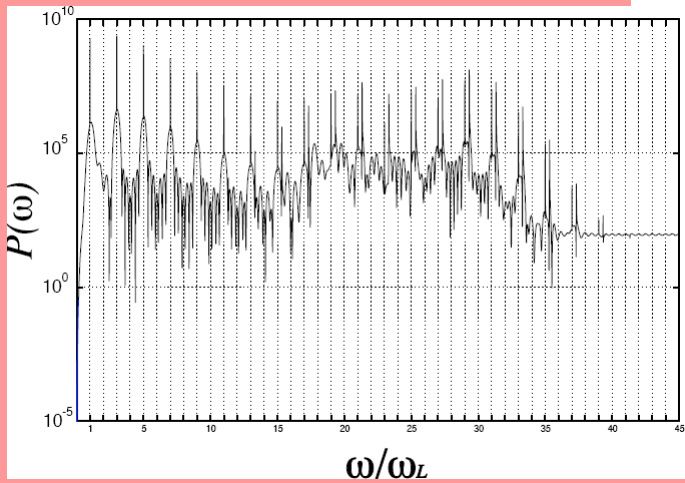
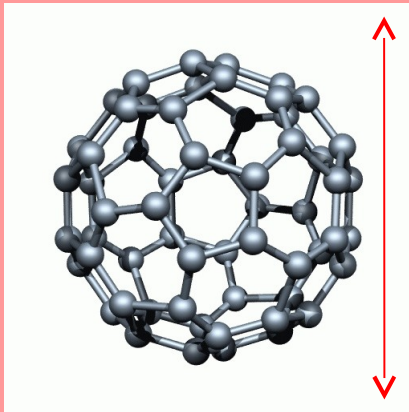
Occorre gente che sappia vedere quanto fa











$$r(t) = \int_{\omega_i}^{\omega_f} r(\omega) \exp(-i\omega t) d\omega$$



Molecola diatomica in un campo laser



Hamiltoniana completa

$$\hat{H} = -\frac{\hbar^2}{2M} (\nabla_{\mathbf{R}_1}^2 + \nabla_{\mathbf{R}_2}^2) - \frac{\hbar^2}{2m} (\nabla_{\mathbf{r}_1}^2 + \nabla_{\mathbf{r}_2}^2) + U(\mathbf{R}_1, \mathbf{R}_2, \mathbf{r}_1, \mathbf{r}_2) + V(\mathbf{R}_1, \mathbf{R}_2, \mathbf{r}_1, \mathbf{r}_2, t)$$

$$U(\mathbf{R}_1, \mathbf{R}_2, \mathbf{r}_1, \mathbf{r}_2) = -\sum_{i,j=1}^2 \frac{e^2}{|\mathbf{r}_i - \mathbf{R}_j|} + \frac{e^2}{|\mathbf{r}_1 - \mathbf{r}_2|} + \frac{e^2}{|\mathbf{R}_1 - \mathbf{R}_2|}$$

$$V(\mathbf{R}_1, \mathbf{R}_2, \mathbf{r}_1, \mathbf{r}_2, t) = e(-\mathbf{R}_1 - \mathbf{R}_2 + \mathbf{r}_1 + \mathbf{r}_2) \cdot \mathbf{E}(t)$$

Occorre gente che sappia approssimare





nuclei classici



$$i\hbar \frac{\partial}{\partial t} \varphi(x, t) = H_{(1/2)c}(t) \varphi(x, t)$$

$$M \frac{d^2 R_i}{dt^2} = F_{ie}(t) + F_{ij}(t) + eE(t)$$

$$H_{(1/2)c}(t) \cong -\frac{\hbar^2}{2m} \frac{\partial^2}{\partial x^2} + eE(t)x - \frac{e^2}{\sqrt{a^2 + [R_1(t) - x]^2}} - \frac{e^2}{\sqrt{a^2 + [R_2(t) - x]^2}}$$

$$F_{ie}(t) = -\int \frac{e^2 [x - R_i(t)] \varphi(x, t)^2}{\{A + [x - R_i(t)]^2\}^{3/2}} dx$$

$$F_{ij}(t) = \frac{e^2 [R_i(t) - R_j(t)]}{\{A_n + [R_i(t) - R_j(t)]^2\}^{3/2}}$$

Equazione di Schroedinger per l'elettrone

Equazione di Newton per inuclei

Hamiltoniana

Interazione electrone-nucleo

Interazione nucleo-nucleo



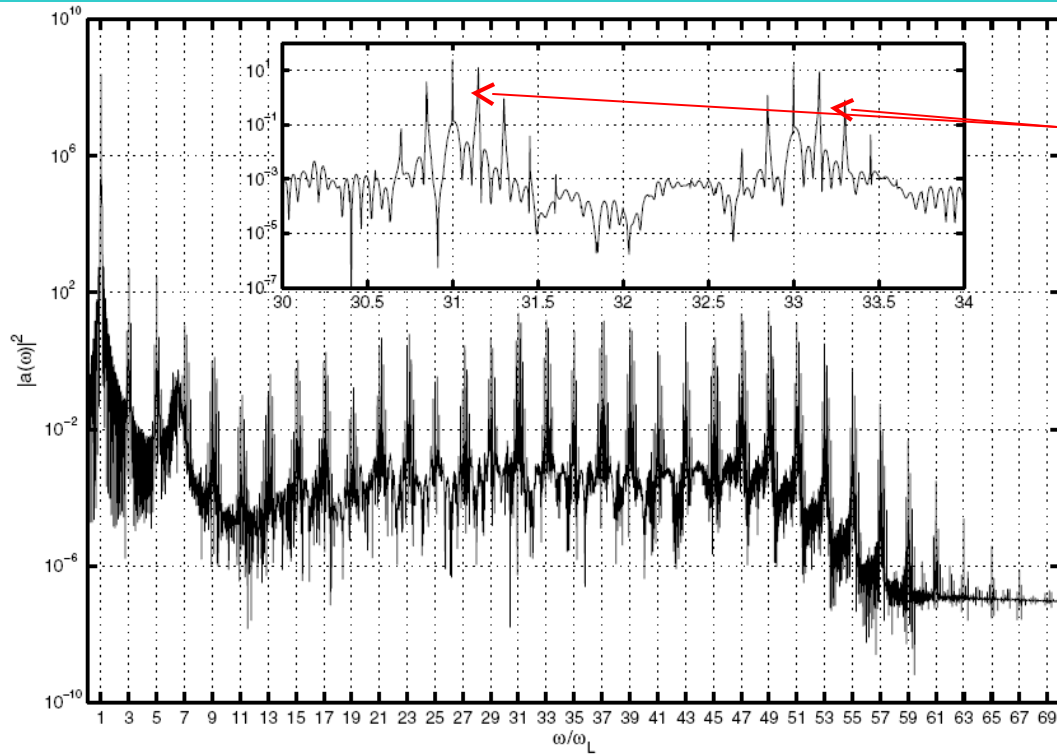
**Occorre gente che non si
spaventi davanti al calcolo
numerico**



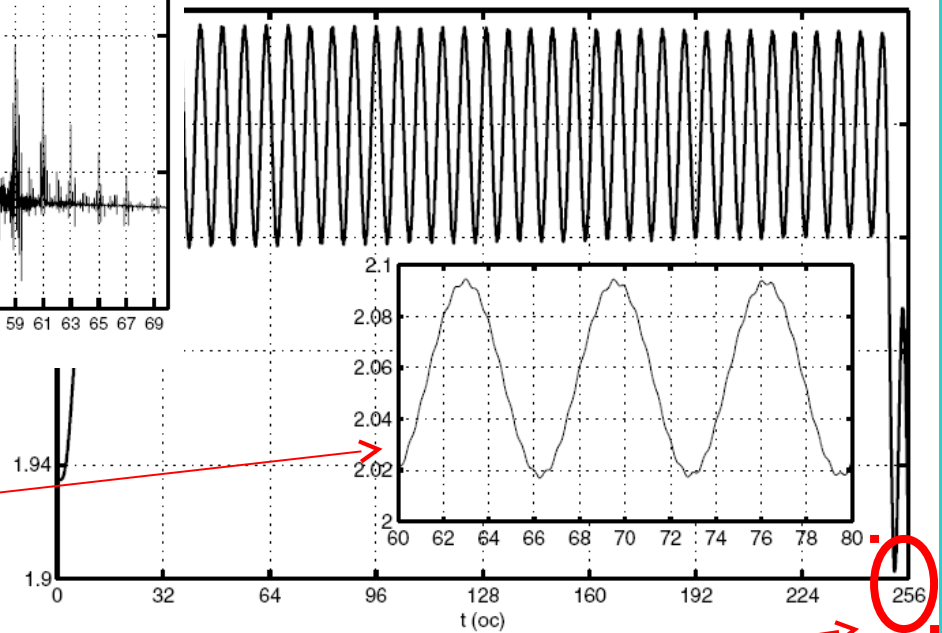
$$I_L = 5 \cdot 10^{14} \text{ W/cm}^2$$

$$\hbar\omega_L = 2 \text{ eV}$$

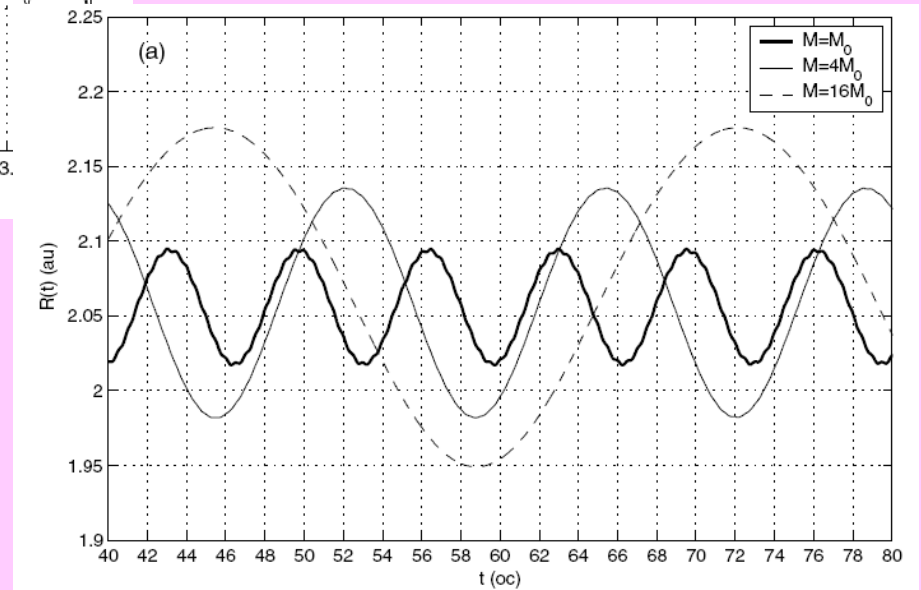
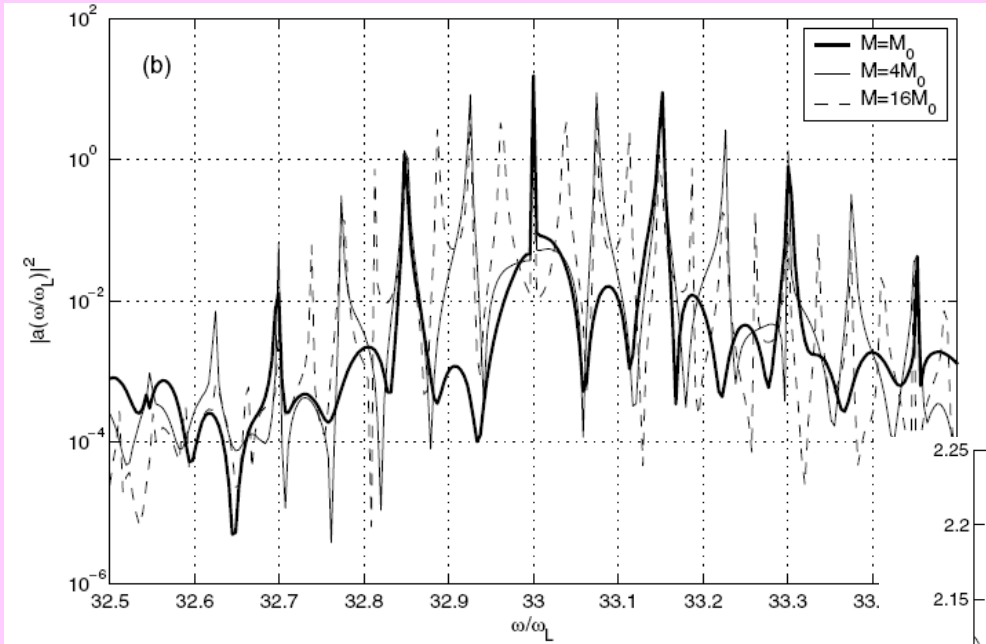
Compaiono righe satelliti



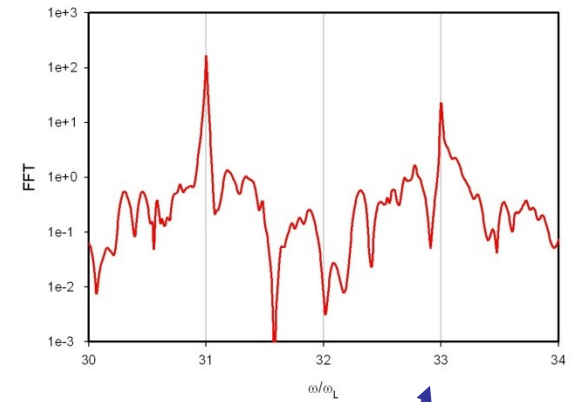
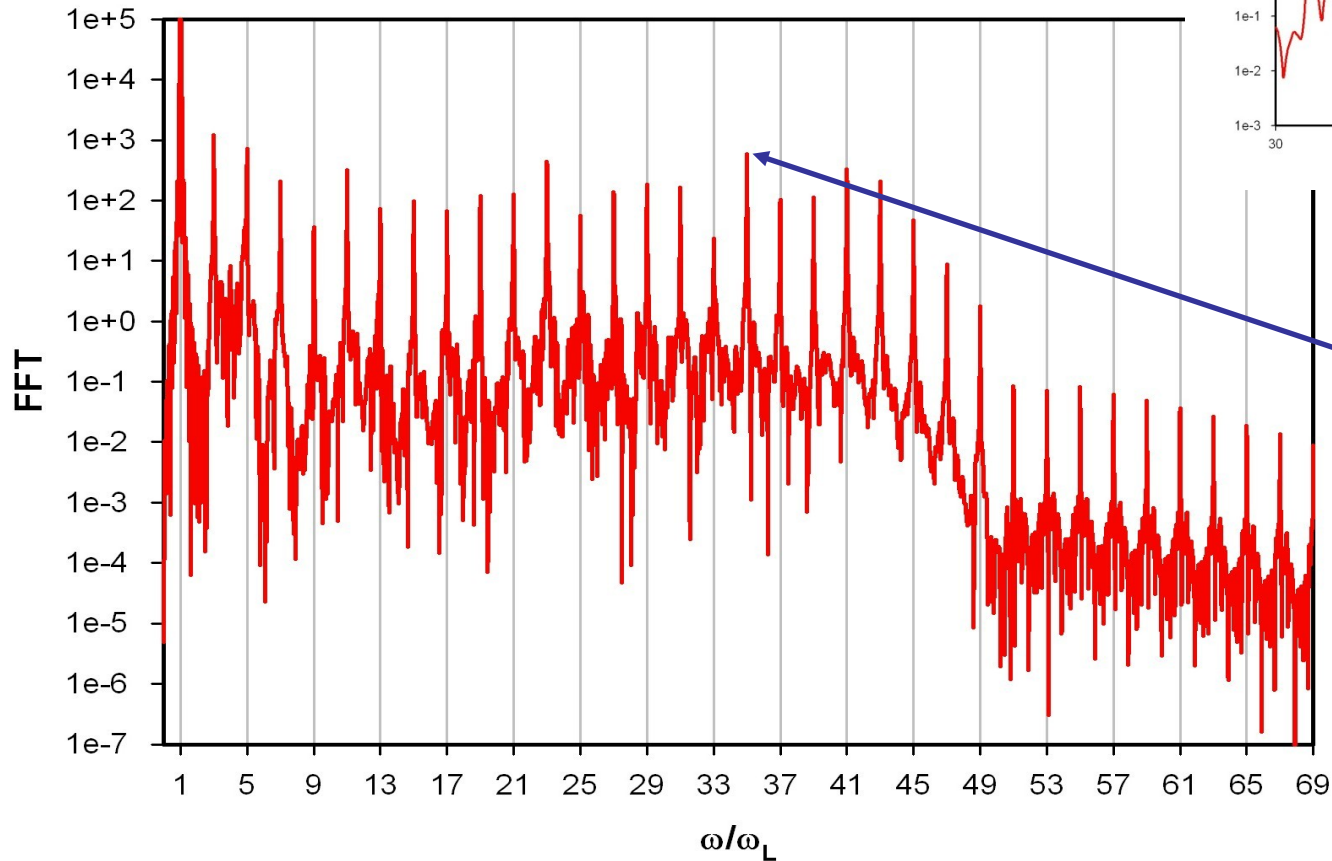
La spaziatura fra i picchi è pari alla frequenza di oscillazione dei nuclei



1D modello 1D per vari isotopi molecolari



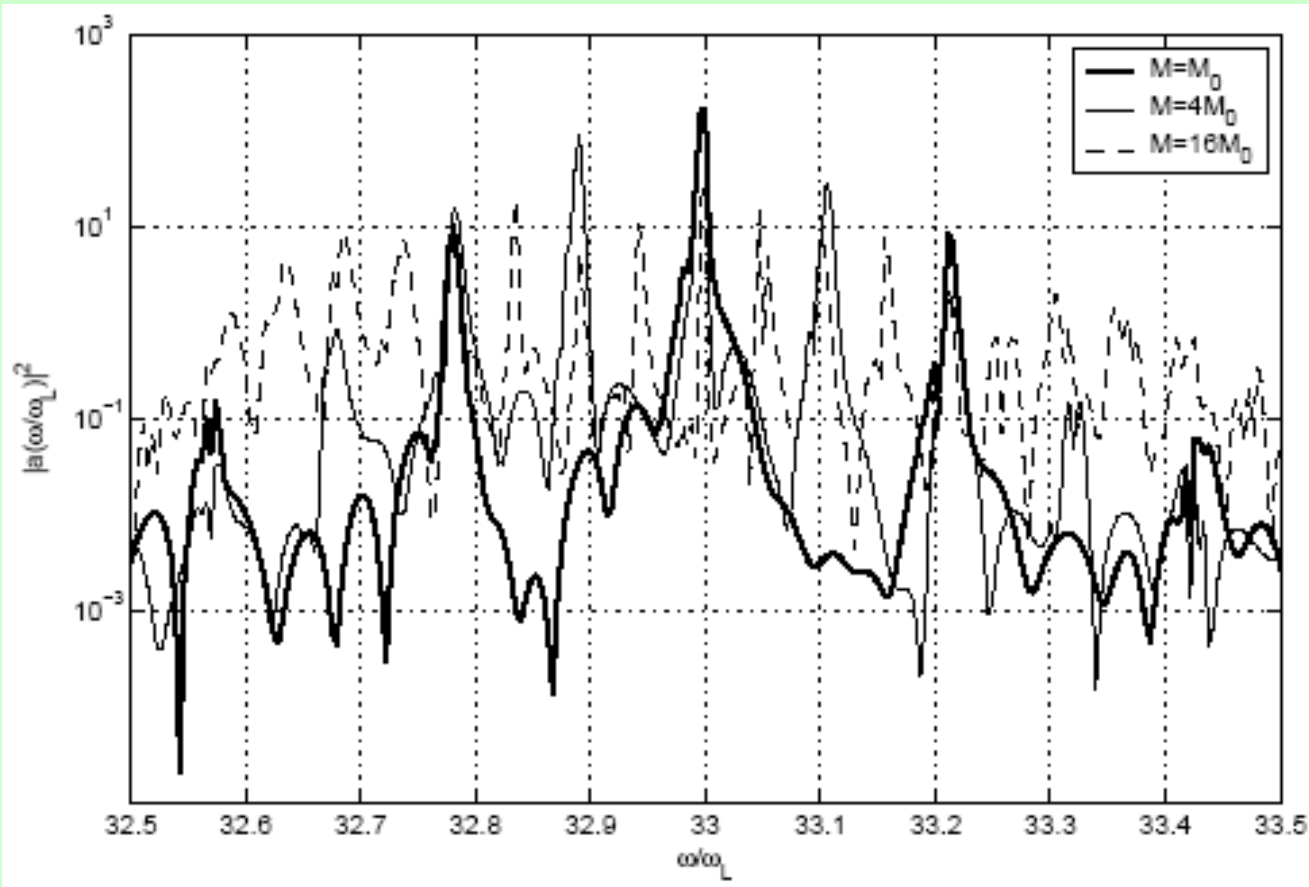
Nuclei fissi: spettro per $M=M_0$



Nessun picco laterale



Equazione di Schroedinger in 3D



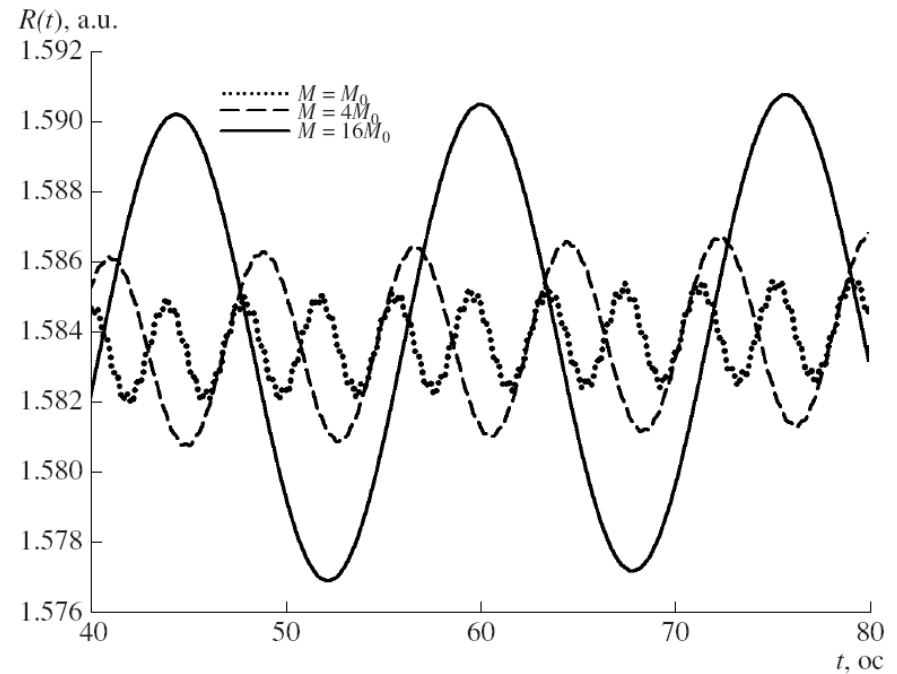
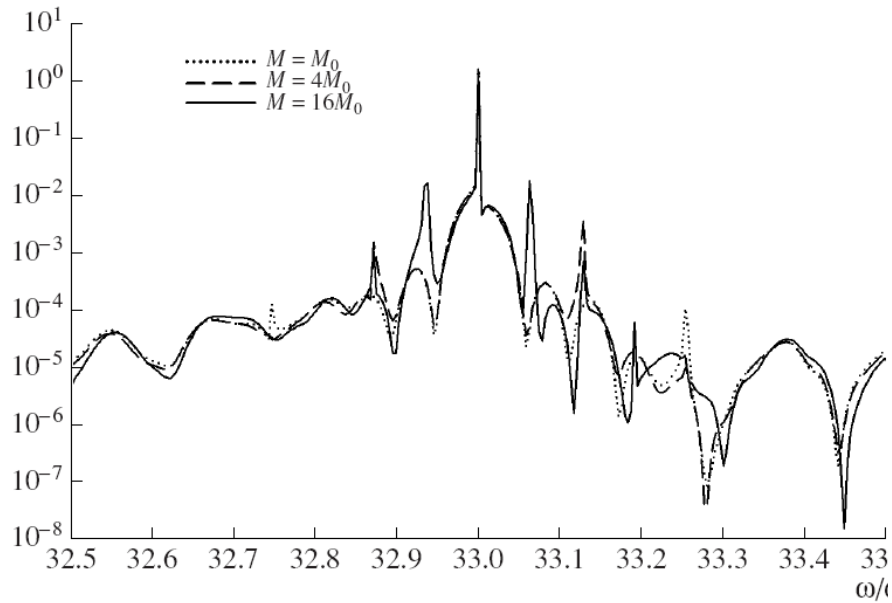
**Occorre
gente che
sappia
controllare**

$$\omega_N \propto 1/\sqrt{M}$$





1D semiclassical model for various H₂ molecular isotopes



1D full quantum calculations for H_2^+



Conceptual considerations suggest the use of a full quantal calculation for the molecule.

$$i\hbar \frac{\partial}{\partial t} \psi(R, x, t) = H(t) \psi(R, x, t)$$

$$E(t) = E_0(t) \sin \omega_L t$$

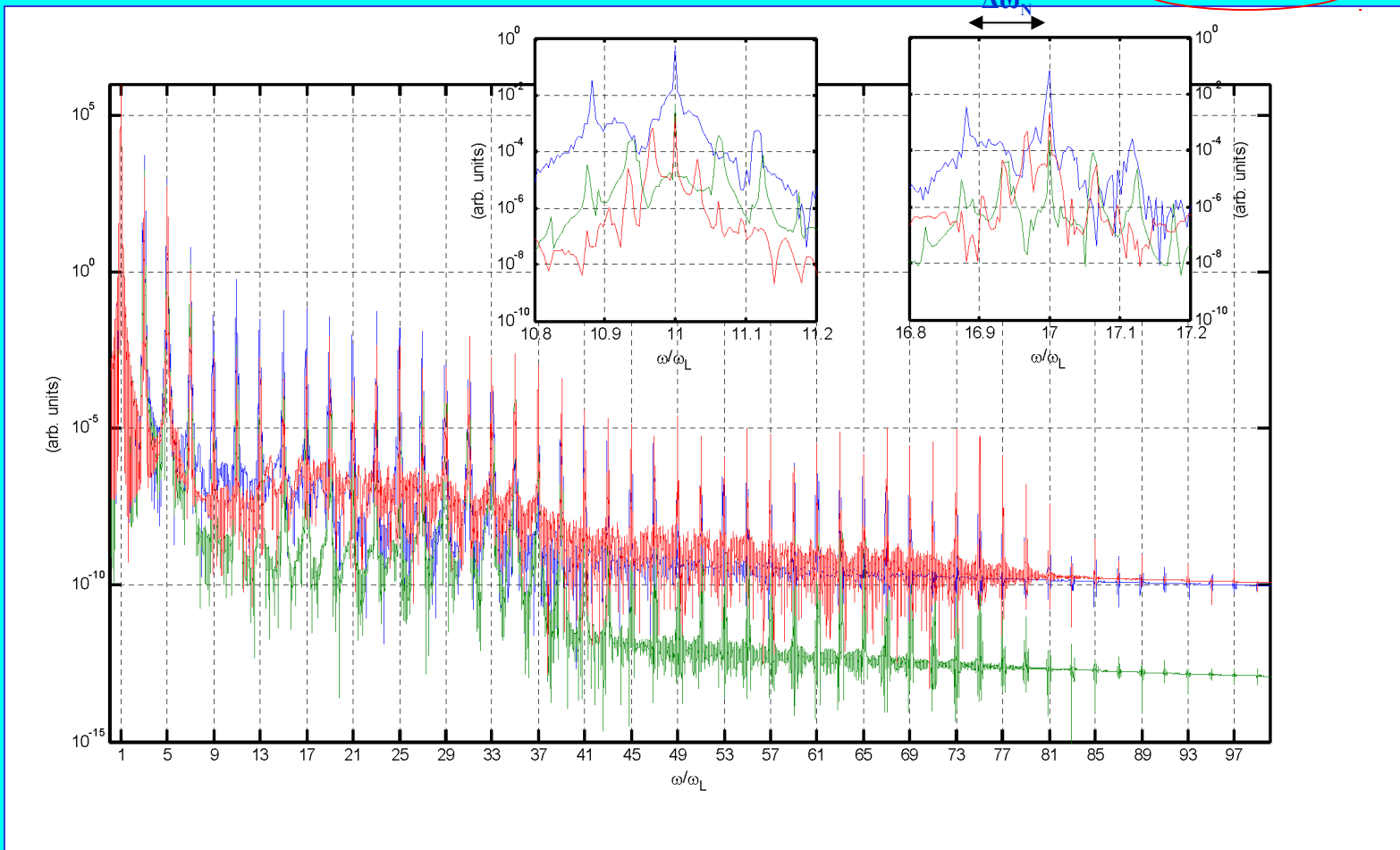
$$H(t) \cong -\frac{\hbar^2}{M} \frac{\partial^2}{\partial R^2} + \frac{e^2}{\sqrt{a_N^2 + R^2}} - \frac{\hbar^2}{2m} \frac{\partial^2}{\partial x^2} + eE(t)x - \frac{e^2}{\sqrt{a^2 + \left(\frac{R}{2} + x\right)^2}} - \frac{e^2}{\sqrt{a^2 + \left(\frac{R}{2} - x\right)^2}}$$



$$I_L = 1 \cdot 10^{14} \text{ W/cm}^2$$

$$\lambda = 780 \text{ nm} \Rightarrow \hbar\omega_L = 1.6 \text{ eV}$$

$$\tau = 256 \text{ fs}$$



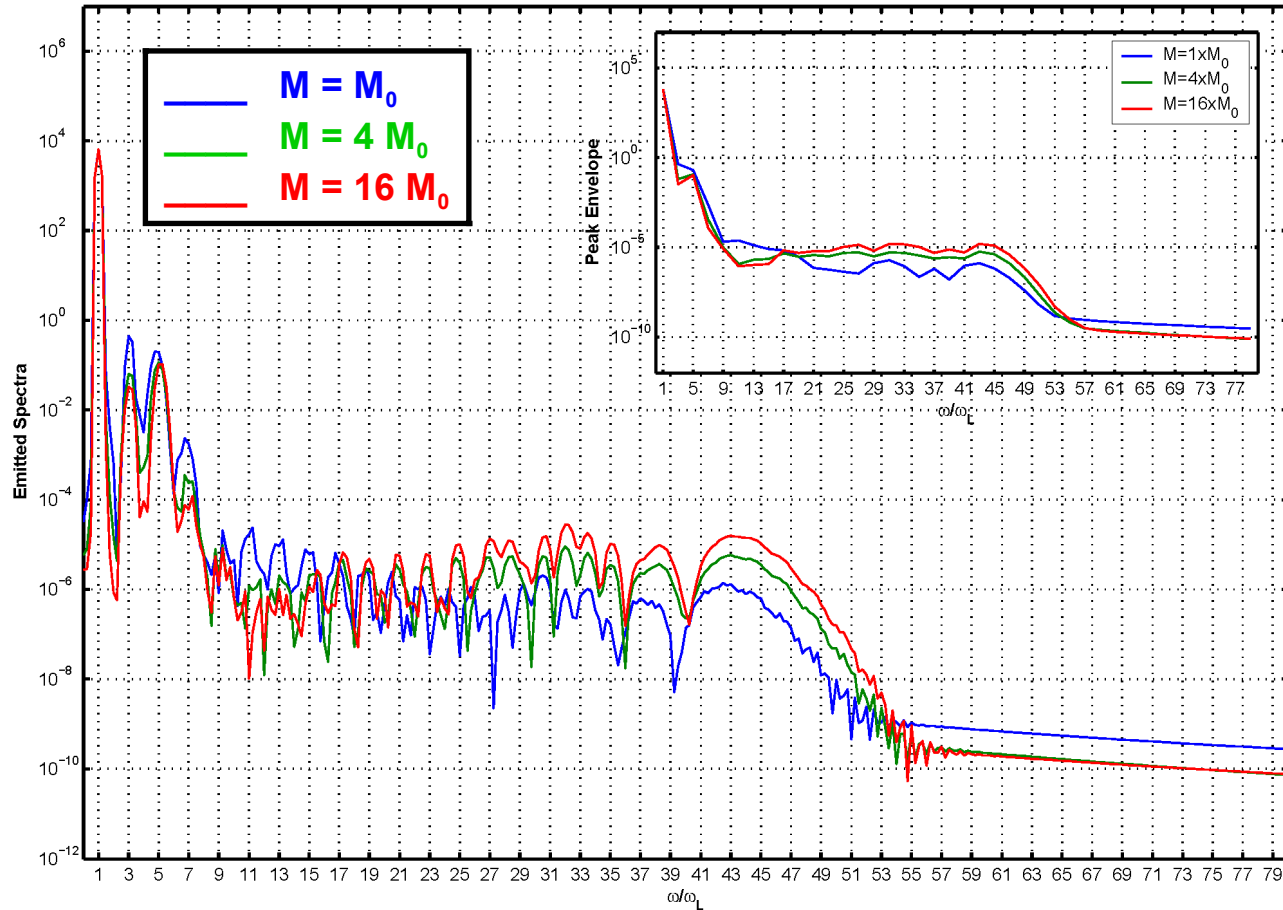
$$\omega_N \propto 1/\sqrt{M}$$

- $M = M_0$
- $M = 4 M_0$
- $M = 16 M_0$



1D full-quantum model for various H_2^+ isotopes

$T = 4$ o.c.



$$I_L = 2 \cdot 10^{14} \text{ W/cm}^2$$

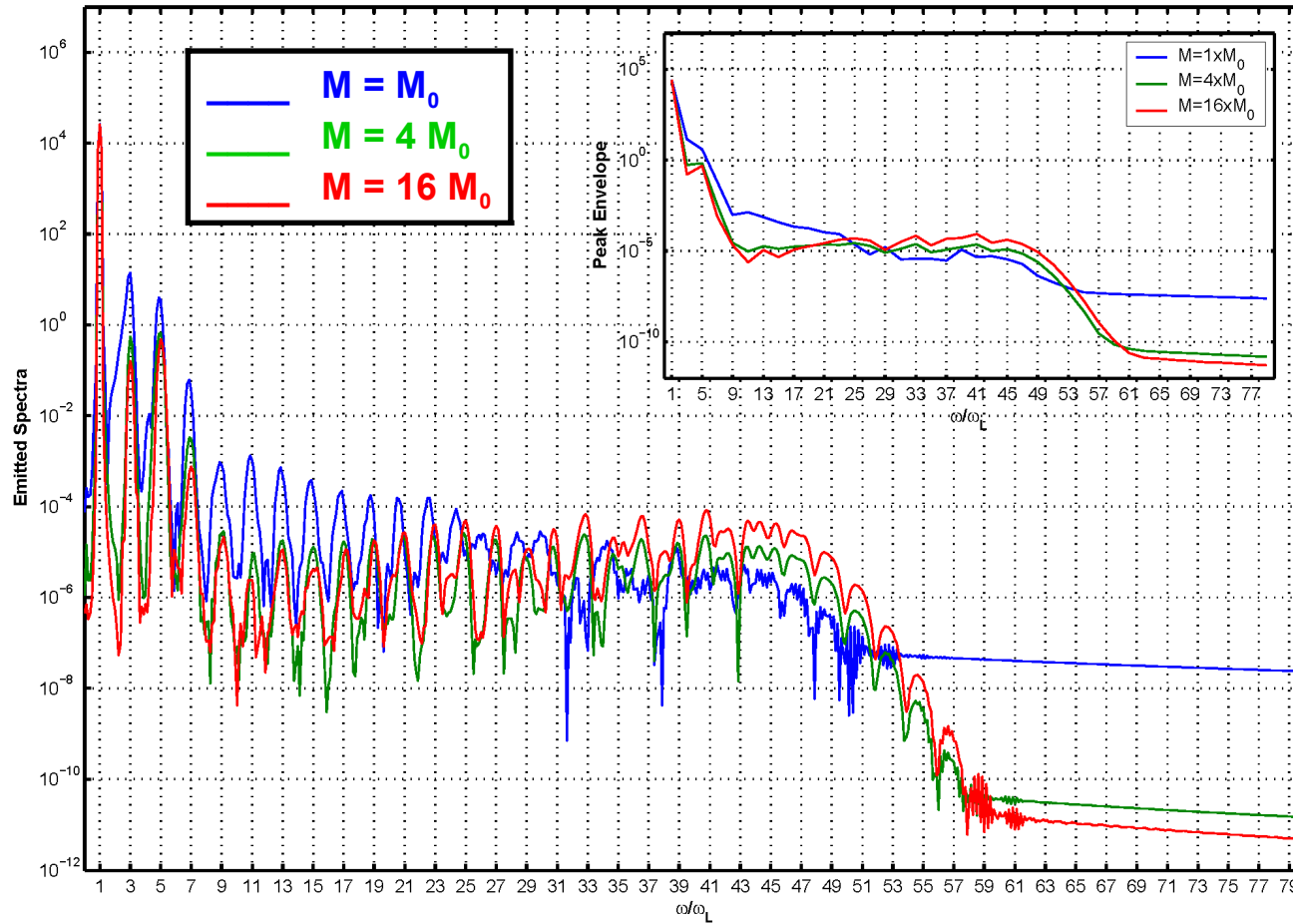
$$\lambda = 780 \text{ nm}$$

**For short pulses
heavy nuclei win**



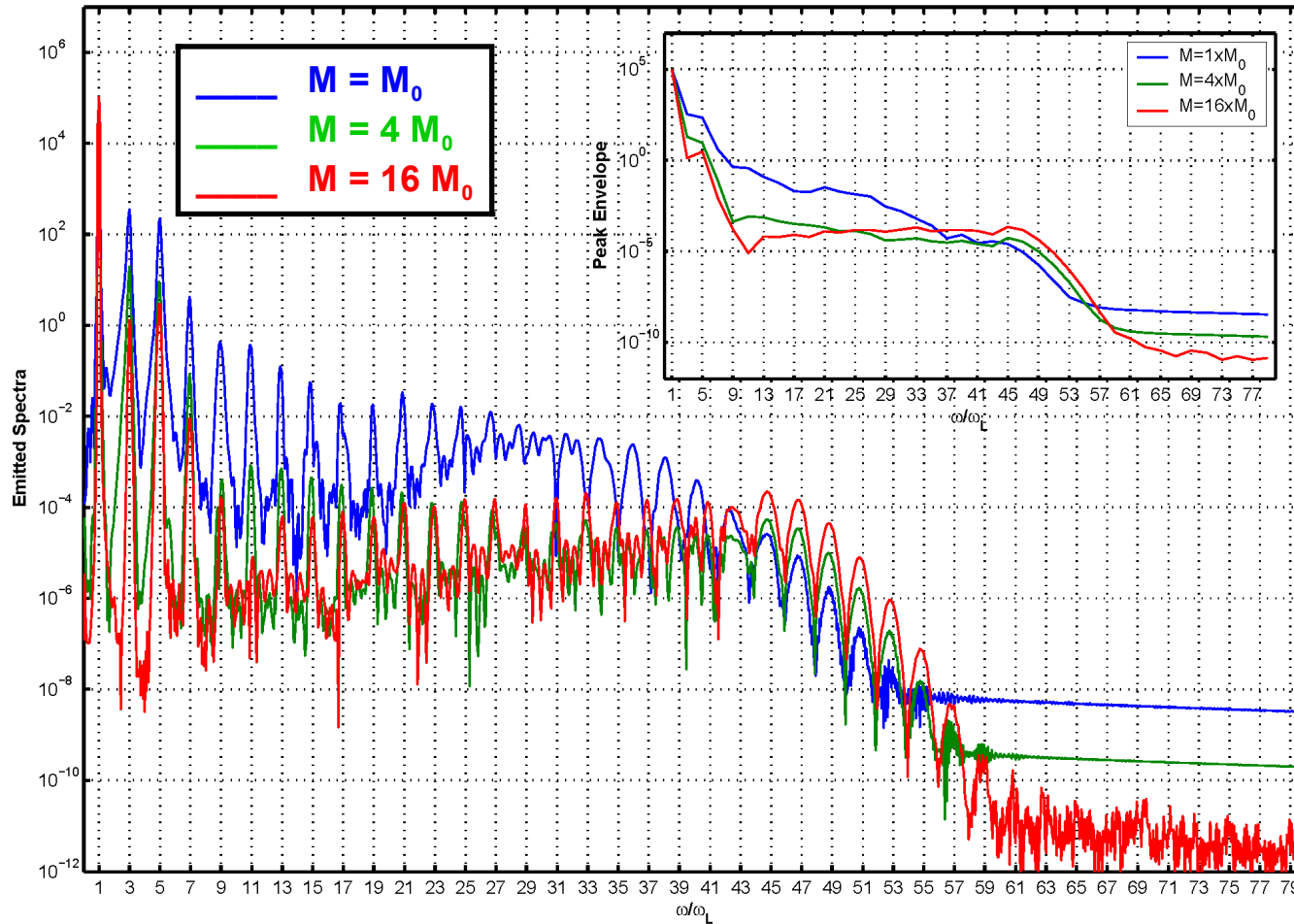
1D full-quantum model for various H_2^+ molecular isotopes

$T = 8 \text{ o.c.}$



1D full-quantum model for various H_2^+ molecular isotopes

$T = 16 \text{ o.c.}$

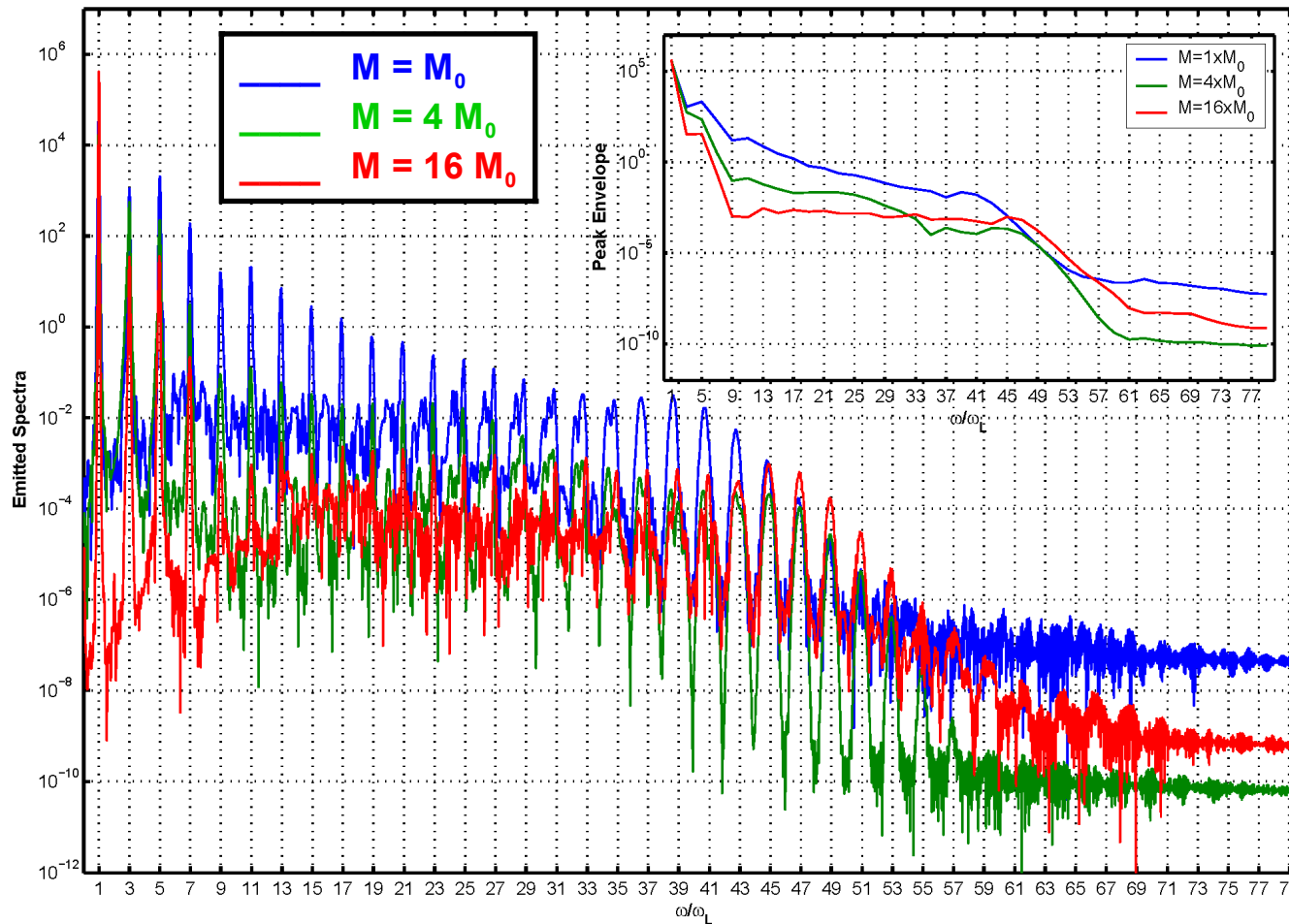


For long pulse
light nuclei win



1D full-quantum model for various H_2^+ molecular isotopes

$T = 32 \text{ o.c.}$



1D full-quantum model for various H_2^+ isotopes

$T = 64 \text{ o.c.}$

