

$\frac{dQ}{dt} + \frac{\partial Q}{\partial t}$

$|10\rangle = \frac{1}{\sqrt{2}}(\uparrow\downarrow + \downarrow\uparrow)$
 $|1-1\rangle = \downarrow\downarrow$
 symmetric
 lower energy

singlet
 $i\hbar \frac{\partial \chi}{\partial t} = \hat{H} \chi, \chi(t) = a\chi_+ e^{i\mathbf{B} \cdot \mathbf{t} / \hbar} + b\chi_- e^{-i\mathbf{B} \cdot \mathbf{t} / \hbar}, H = -\vec{\mu} \cdot \vec{B} = -\gamma \vec{S} \cdot \vec{B}$
 $\det(A - \lambda I) = 0, H\psi = E\psi, \chi = a\chi_+ + b\chi_-$

$|S m\rangle = \sum_{m_1+m_2=m} c_{m_1 m_2}^{S S_1 S_2} |S_1 m_1\rangle |S_2 m_2\rangle$

$n=0, l=0, m_l=0, m_j=0, m_s=0$

$\psi_n^0, \psi_n^1 = \sum_{m \neq n} \frac{\langle \psi_m^0 | H' | \psi_n^0 \rangle \psi_m^0}{(E_n^0 - E_m^0)}, E_n^2 = \sum_{m \neq n} \frac{|\langle \psi_m^0 | H' | \psi_n^0 \rangle|^2}{E_n^0 - E_m^0}, E_{\pm}^1 = \frac{1}{2} [W_{aa} + W_{bb} \pm \sqrt{(W_{aa} - W_{bb})^2 + 4|W_{ab}|^2}]$

$j = (l + s),$

fine structure

$\begin{pmatrix} \alpha \\ \beta \end{pmatrix} = E_i \begin{pmatrix} \alpha \\ \beta \end{pmatrix}, W_{ij} = \langle \psi_i^0 | H' | \psi_j^0 \rangle$

$H_{hyd} = \frac{\hbar^2}{2m} \nabla^2 - \frac{e^2}{4\pi\epsilon_0 r}, T = \frac{p^2}{2m} = \frac{\hbar^2}{2m} \frac{d^2}{dx^2}, H_r' = \frac{-p^4}{8m^3 c^2}, E_r^1 = \frac{-1}{2mc^2} [E^2 - 2E$

$\frac{n}{h} - 3], SO: H_{SO}' = \left(\frac{e^2}{4\pi\epsilon_0} \right) \frac{1}{m^2 c^2 r^3} \vec{S} \cdot \vec{L}, E_{SO}^1 = \frac{(E_n)^2}{mc^2} \left\{ \frac{n[j(j+1) - l(l+1) + 3/4]}{l(l+1/2)(l+1)} \right\}, E_{fs}^1 = E_r^1 + E_{SO}^1 = \frac{(E_n)^2}{2mc^2} \left(3 - \frac{4n}{j+1/2} \right)$

$m_j): E_{nj} = \frac{-13.6 \text{ eV}}{n^2} \left[1 + \frac{\alpha^2}{n^2} \left(\frac{n}{j+1/2} - \frac{3}{4} \right) \right], \alpha = \frac{e^2}{4\pi\epsilon_0 \hbar c}$

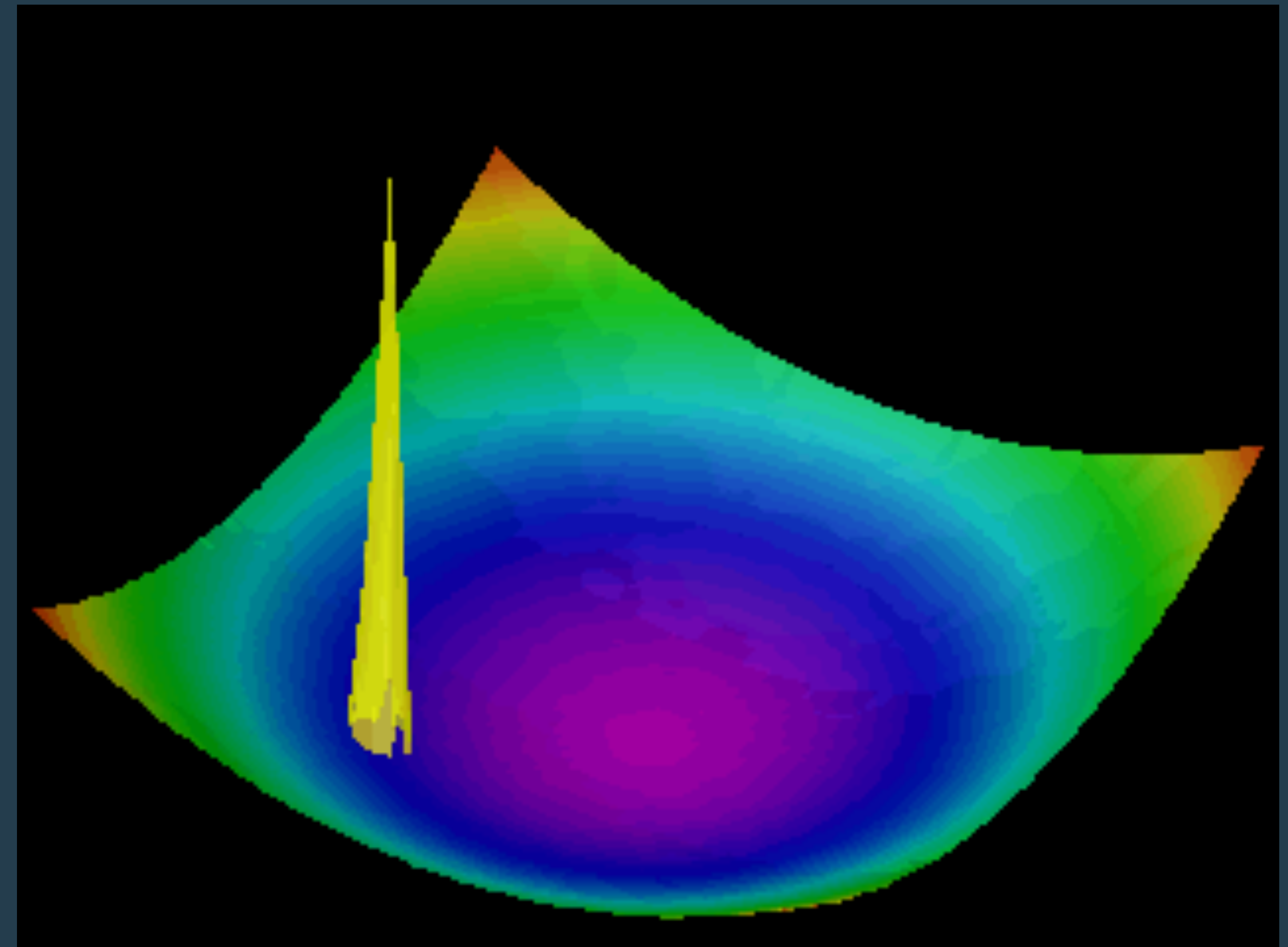
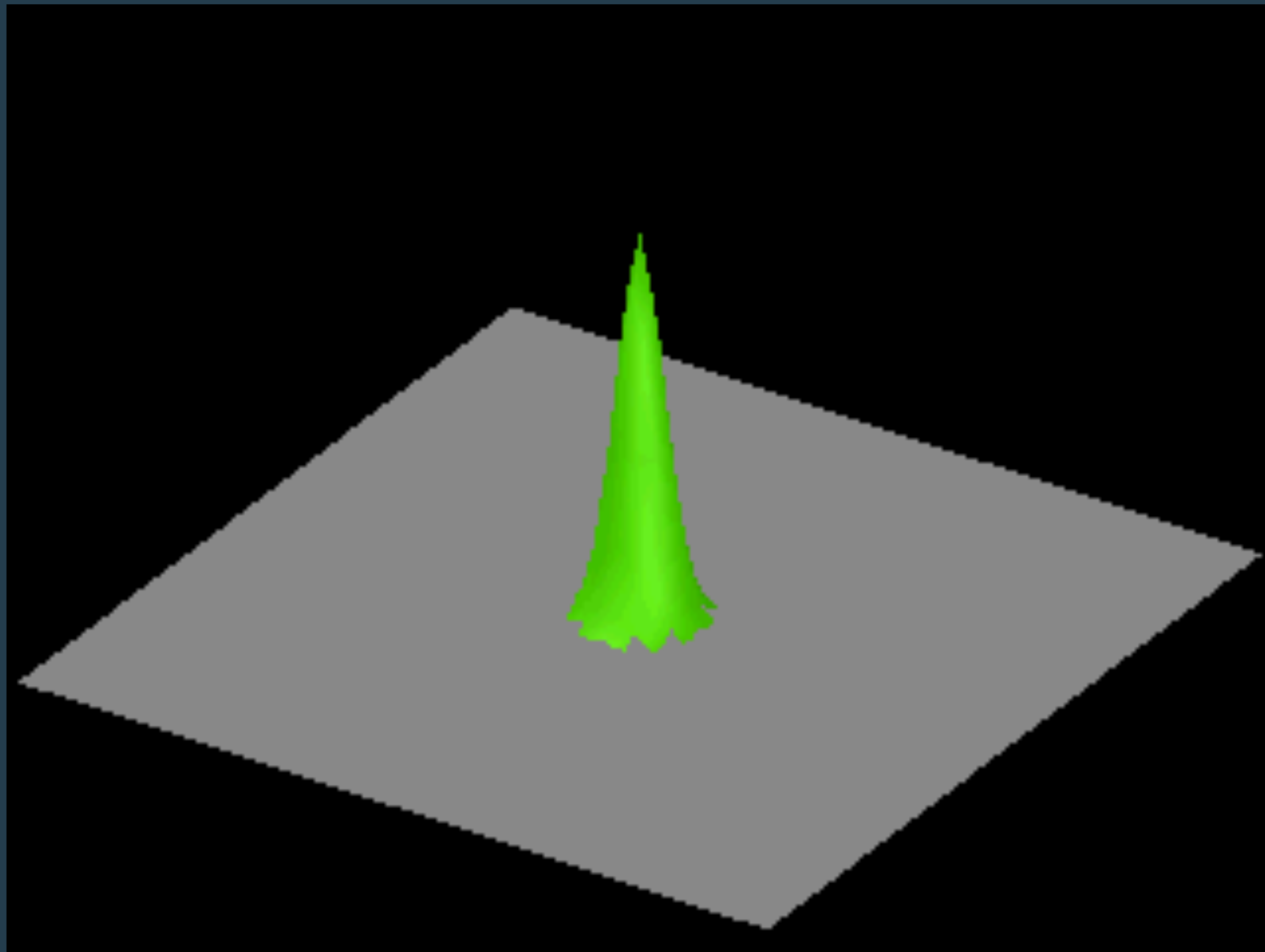
$\Xi: H_z' = \frac{e}{2m} (\vec{L} + 2\vec{S}) \cdot \vec{B}_{ext}, \mu_B = \frac{e\hbar}{2m}$

$E_z^1 = \langle n, l, j, m_j | H_z' | n, l, j, m_j \rangle \Rightarrow E_z^1 = \mu_B \left[1 + \frac{j(j+1) - l(l+1) + 3/4}{2j(j+1)} \right] B_{ext} m_j \leftarrow \textcircled{ii}, E_{tot}(Zeek) = \textcircled{i} + \textcircled{ii}$

$E_{n, m_l, m_s} = \frac{-13.6 \text{ eV}}{n^2} + \mu_B B_{ext} (m_l + 2m_s) \leftarrow \textcircled{iii}, E_{fs}^1 = \frac{13.6 \text{ eV} \alpha^2}{n^3} \left\{ \frac{3}{4n} - \left[\frac{l(l+1) - m_l m_s}{l(l+1/2)(l+1)} \right] \right\} \leftarrow \textcircled{iv}, E_{tot}(Stark) = \textcircled{iii} + \textcircled{iv}$

$m_j), H' = H_z' + H_{fs}' = \frac{e\hbar}{2m} B_{ext} (m_l + 2m_s) + \frac{13.6 \text{ eV} \alpha^2}{64} \left(3 - \frac{8}{j+1/2} \right)$

$\int_a^b f \frac{dg}{dx} dx = \int_a^b f g' dx$
 $\int_{-\infty}^{\infty} e^{-abx^2} dx = \sqrt{\frac{\pi}{a}}$
 $e^{\pm i\theta} = \cos \theta \pm i \sin \theta$
 $\cos \theta = \frac{1}{2} (e^{i\theta} + e^{-i\theta})$
 $\sin \theta = \frac{1}{2i} (e^{i\theta} - e^{-i\theta})$



Michielson and De Raedt, 2012