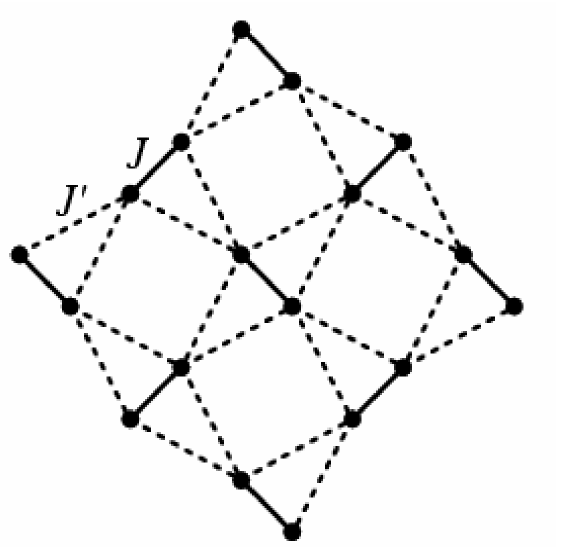
Tutorial : Shastry-Sutherland model I

[1] Show that the direct product of the dimer singlet

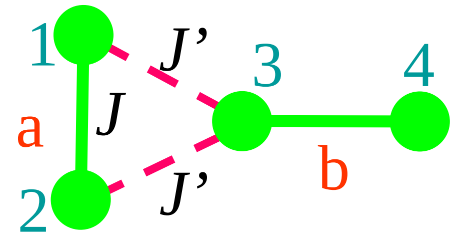
$$\left|\Psi_s\right\rangle = \otimes_i \left|s\right\rangle_i$$

is an eigenstate of the Shastry-Sutherland Hamiltonian irrespectrive of the value of J'/J.



Tutorial: Shastry-Sutherland model II

[2] Consider two orthogonal dimers.
Show that



$$J'(\mathbf{s}_1+\mathbf{s}_2)\cdot\mathbf{s}_3\left|s_a\right\rangle\left|t_{mb}\right\rangle = 0 \quad (m=1,0,-1)$$

$$J'(\mathbf{s}_1+\mathbf{s}_2)\cdot\mathbf{s}_3\left|t_1\right\rangle_a\left|s\right\rangle_b = \frac{J'}{2}\left(\left|t_1\right\rangle_a\left|t_0\right\rangle_b - \left|t_0\right\rangle_a\left|t_1\right\rangle_b\right)$$

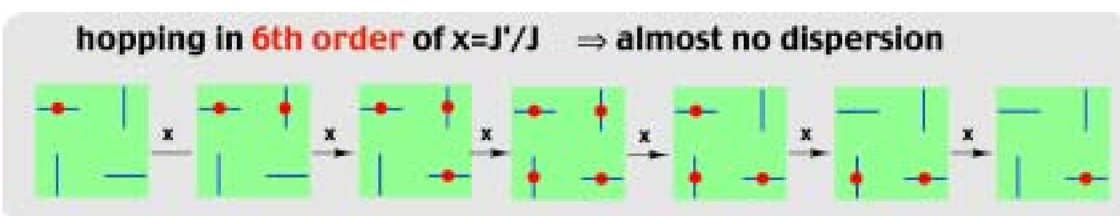
$$\left|s\right\rangle = \frac{1}{\sqrt{2}}\left(\left|\uparrow\downarrow\right\rangle - \left|\downarrow\uparrow\right\rangle\right)$$

$$\left|t_1\right\rangle = \left|\uparrow\uparrow\right\rangle$$

$$\left|t_0\right\rangle = \frac{1}{\sqrt{2}}\left(\left|\uparrow\downarrow\right\rangle + \left|\downarrow\uparrow\right\rangle\right)$$

$$\left|t_{-1}\right\rangle = \left|\downarrow\downarrow\right\rangle$$

Explain the difference between this and the result for a frustrated ladder.



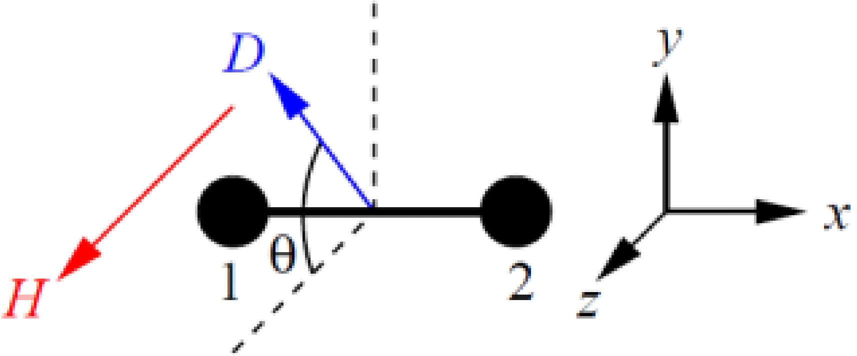
Tutorial : single dimer with the DM interaction

[3] consider a dimer with exchange and DM interaction in a magnetic field.

$$H = J\,\mathbf{S}_1 \cdot \mathbf{S}_2 + \mathbf{D} \cdot (\mathbf{S}_1 \times \mathbf{S}_2) - g\mu_B H \left(S_1^z + S_2^z\right) \qquad D << J$$

Let us define the uniform and the staggered moment as

$$\mathbf{m}_{\mathrm{u}} = \frac{\langle \mathbf{S}_1 + \mathbf{S}_2 \rangle}{2}, \quad \mathbf{m}_{\mathrm{s}} = \frac{\langle \mathbf{S}_1 - \mathbf{S}_2 \rangle}{2}$$



Derive the following to the lowest order in D.

$$\mathbf{m}_{\mathrm{s}} = \frac{g\mu_B}{2J^2}(\mathbf{D} \times \mathbf{H})$$

Tutorial : NMR detection of DM interaction

[4] In the previous question, suppose magnetic ions have NMR active nuclei with isotropic on-site hyperfine coupling *A*. Describe the angle dependence of the NMR shift. What is the distinctive feature compared with the ordinary shift due to uniform susceptibility.