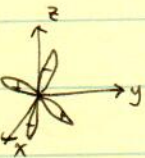


2016/9/18 (9/18). (1).

$$|J_z = \frac{1}{2}\rangle = \frac{1}{\sqrt{3}} \left( |d_{yz} \downarrow\rangle + i |d_{zx} \downarrow\rangle + |d_{xy} \uparrow\rangle \right)$$



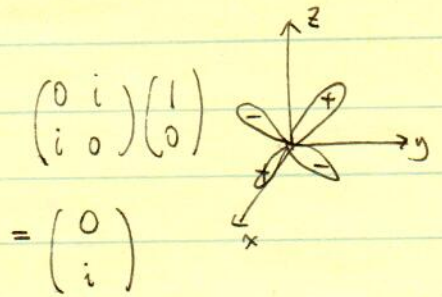
$$P: (x, y, z) \rightarrow (-x + \frac{1}{2}, -y + \frac{1}{2}, z) \times \nu_x$$

$$T: (x, y, z) \rightarrow (x, y, -z) \times i \sigma_y K$$

$$G_x: (x, y, z) \rightarrow (-x + \frac{1}{2}, y + \frac{1}{2}, z) \times i \sigma_x$$

$$S_x = G_y P: (x, y, z) \rightarrow (-x + 1, y, z) \times i \sigma_y \nu_x$$

$$M_z: (x, y, z) \rightarrow (x + \frac{1}{2}, y + \frac{1}{2}, z) \times i \sigma_z \nu_x$$



$$\begin{pmatrix} 0 & i \\ i & 0 \end{pmatrix} \begin{pmatrix} 1 \\ 0 \end{pmatrix} = \begin{pmatrix} 0 \\ i \end{pmatrix}$$

$$PT: (x, y, z) \rightarrow (-x + \frac{1}{2}, -y + \frac{1}{2}, -z) \times i \sigma_y \nu_x K$$

$$\begin{pmatrix} 0 & i \\ -i & 0 \end{pmatrix} \begin{pmatrix} 0 \\ 1 \end{pmatrix} = \begin{pmatrix} i \\ 0 \end{pmatrix}$$

$$PT |J_z = \frac{1}{2}\rangle = \frac{1}{\sqrt{3}} \left( PT |d_{yz} \downarrow\rangle - i PT |d_{zx} \downarrow\rangle + PT |d_{xy} \uparrow\rangle \right)$$

$$= \frac{1}{\sqrt{3}} \left( |-d_{yz} \uparrow, \nu=2\rangle^*_{-x+\frac{1}{2}, -y+\frac{1}{2}, -t} - i |-d_{zx} \uparrow, \nu=2\rangle^*_{-x+\frac{1}{2}, -y+\frac{1}{2}, -t} + |d_{xy} \downarrow, \nu=2\rangle^*_{-x+\frac{1}{2}, -y+\frac{1}{2}, -t} \right)$$

$$= \frac{1}{\sqrt{3}} \left( |-d_{yz} \uparrow, \nu=2, -x+\frac{1}{2}, -y+\frac{1}{2}, -t\rangle^* - i |-d_{zx} \uparrow, \nu=2, -x+\frac{1}{2}, -y+\frac{1}{2}, -t\rangle^* + |d_{xy} \downarrow, \nu=2, -x+\frac{1}{2}, -y+\frac{1}{2}, -t\rangle^* \right)$$

$$G_x PT |J_z = \frac{1}{2}\rangle = \frac{1}{\sqrt{3}} \left( G_x |-d_{yz} \uparrow, \nu=2, -x+\frac{1}{2}, -y+\frac{1}{2}, -t\rangle^* \right. \\ \left. - i G_x |-d_{zx} \uparrow, \nu=2, -x+\frac{1}{2}, -y+\frac{1}{2}, -t\rangle^* \right. \\ \left. + G_x |d_{xy} \downarrow, \nu=2, -x+\frac{1}{2}, -y+\frac{1}{2}, -t\rangle^* \right)$$

$$= \frac{1}{\sqrt{3}} \left( i |-d_{yz} \downarrow, \nu=2, x, -y+1, -t\rangle^* + |d_{zx} \downarrow, \nu=2, x, -y+1, -t\rangle^* \right. \\ \left. - i |d_{xy} \uparrow, \nu=2, x, -y+1, -t\rangle^* \right)$$

# Dirac Fermions in AFM semimetal.

2016/9/18 (2)

(2).

$$G_x PT | J_z = \frac{1}{2} \rangle = \frac{1}{\sqrt{3}} \left( i | -d_{yz} \downarrow, \nu=2, x, -y+1, -t \rangle^* + | d_{zx} \downarrow, \nu=2, x, -y+1, -t \rangle^* - i | -d_{xy} \uparrow, \nu=2, x, -y+1, -t \rangle^* \right).$$

$$G_x | J_z = \frac{1}{2} \rangle = \frac{1}{\sqrt{3}} \left( G_x | d_{yz} \downarrow \rangle + i G_x | d_{zx} \downarrow \rangle + G_x | d_{xy} \uparrow \rangle \right) \\ = \frac{1}{\sqrt{3}} \left( i | d_{yz} \uparrow, \nu=1, -x+\frac{1}{2}, y+\frac{1}{2}, t \rangle - | -d_{zx} \uparrow, \nu=1, -x+\frac{1}{2}, y+\frac{1}{2}, t \rangle + i | -d_{xy} \downarrow, \nu=1, -x+\frac{1}{2}, y+\frac{1}{2}, t \rangle \right)$$

$$PT G_x | J_z = \frac{1}{2} \rangle = \frac{1}{\sqrt{3}} \left( -i PT | d_{yz} \uparrow, \nu=1, -x+\frac{1}{2}, y+\frac{1}{2}, t \rangle - PT | -d_{zx} \uparrow, \nu=1, -x+\frac{1}{2}, y+\frac{1}{2}, t \rangle - i PT | -d_{xy} \downarrow, \nu=1, -x+\frac{1}{2}, y+\frac{1}{2}, t \rangle \right)$$

$$= \frac{1}{\sqrt{3}} \left( +i | -d_{yz} \downarrow, \nu=2, x, -y, -t \rangle^* + | d_{zx} \downarrow, \nu=2, x, -y, -t \rangle^* - i | -d_{xy} \uparrow, \nu=2, x, -y, -t \rangle^* \right)$$



2016 / 9 / 18 / 92 (3)

$$PT | J_z = \frac{1}{2} \rangle = \frac{1}{\sqrt{3}} \left( | -d_{yz} \uparrow, \nu=2, -x+\frac{1}{2}, y+\frac{1}{2}, -t \rangle^* - i | -d_{zx} \uparrow, \nu=2, -x+\frac{1}{2}, -y+\frac{1}{2}, -t \rangle^* - | d_{xy} \downarrow, \nu=2, -x+\frac{1}{2}, -y+\frac{1}{2}, -t \rangle^* \right)$$

$$S_x PT | J_z = \frac{1}{2} \rangle = \frac{1}{\sqrt{3}} \left( S_x | -d_{yz} \uparrow, \nu=2, -x+\frac{1}{2}, -y+\frac{1}{2}, -t \rangle^* - i S_x | -d_{zx} \uparrow, \nu=2, -x+\frac{1}{2}, -y+\frac{1}{2}, -t \rangle^* - S_x | d_{xy} \downarrow, \nu=2, -x+\frac{1}{2}, -y+\frac{1}{2}, -t \rangle^* \right)$$

$$= \frac{1}{\sqrt{3}} \left( + | +d_{yz} \downarrow, \nu=2, x+\frac{1}{2}, -y+\frac{1}{2}, -t \rangle^* + i | d_{zx} \downarrow, \nu=2, x+\frac{1}{2}, -y+\frac{1}{2}, -t \rangle^* + | +d_{xy} \uparrow, \nu=2, x+\frac{1}{2}, -y+\frac{1}{2}, -t \rangle^* \right)$$

$$S_x | J_z = \frac{1}{2} \rangle = \frac{1}{\sqrt{3}} \left( S_x | d_{yz} \downarrow \rangle + i S_x | d_{zx} \downarrow \rangle + S_x | d_{xy} \uparrow \rangle \right)$$

$$= \frac{1}{\sqrt{3}} \left( | d_{yz} \uparrow, \nu=2, -x+1, y, t \rangle + i | -d_{zx} \uparrow, \nu=2, -x+1, y, t \rangle - | -d_{xy} \downarrow, \nu=2, -x+1, y, t \rangle \right)$$

2016/9/18/ 2 (4)

$$PTS_x |J_z = \frac{1}{2}\rangle = \frac{1}{\sqrt{3}} \left( PT |d_{yz} \uparrow, \nu=2, -x+1, y, t\rangle - i PT |d_{zx} \uparrow, \nu=2, -x+1, y, t\rangle \right. \\ \left. - PT |d_{xy} \downarrow, \nu=2, -x+1, y, t\rangle \right)$$

$$= \frac{1}{\sqrt{3}} \left( - |d_{yz} \downarrow, \nu=2, x-\frac{1}{2}, -y+\frac{1}{2}, -t\rangle^* + i |d_{zx} \downarrow, \nu=2, x-\frac{1}{2}, -y+\frac{1}{2}, -t\rangle^* \right. \\ \left. - |d_{xy} \uparrow, \nu=2, x-\frac{1}{2}, -y+\frac{1}{2}, -t\rangle^* \right)$$

$$= \frac{1}{\sqrt{3}} \left( |d_{yz} \downarrow, \nu=2, x-\frac{1}{2}, -y+\frac{1}{2}, -t\rangle^* + i |d_{zx} \downarrow, \nu=2, x-\frac{1}{2}, -y+\frac{1}{2}, -t\rangle^* \right. \\ \left. + |d_{xy} \uparrow, \nu=2, x-\frac{1}{2}, -y+\frac{1}{2}, -t\rangle^* \right)$$

$$PT |J_z = \frac{1}{2}\rangle = \frac{1}{\sqrt{3}} \left( |d_{yz} \uparrow, \nu=2, -x+\frac{1}{2}, -y+\frac{1}{2}, -t\rangle^* - i |d_{zx} \uparrow, \nu=2, -x+\frac{1}{2}, -y+\frac{1}{2}, -t\rangle^* \right. \\ \left. - |d_{xy} \downarrow, \nu=2, -x+\frac{1}{2}, -y+\frac{1}{2}, -t\rangle^* \right)$$

$$M_z PT |J_z = \frac{1}{2}\rangle = \frac{1}{\sqrt{3}} \left( \overset{M_z}{\checkmark} |d_{yz} \uparrow, \nu=2, -x+\frac{1}{2}, -y+\frac{1}{2}, -t\rangle^* - i |d_{zx} \uparrow, \nu=2, -x+\frac{1}{2}, -y+\frac{1}{2}, -t\rangle^* \right. \\ \left. - \cancel{M_z} |d_{xy} \downarrow, \nu=2, -x+\frac{1}{2}, -y+\frac{1}{2}, -t\rangle^* \right)$$



~~ok, ok, ok, ok, ok~~

~~ok, ok, ok, ok, ok~~

2016/9/18 1% (5)

$$M_z PT |J_z = \frac{1}{2}\rangle = \frac{1}{\sqrt{3}} \left( i | -d_{yz} \uparrow \nu=1, -x+1, -y+1, -t \rangle^* + | -d_{zx} \uparrow, \nu=1, -x+1, -y+1, -t \rangle^* + i | d_{xy} \downarrow, \nu=1, -x+1, -y+1, -t \rangle^* \right)$$

$$M_z |J_z = \frac{1}{2}\rangle = \frac{1}{\sqrt{3}} \left( M_z |d_{yz} \downarrow\rangle + i M_z |d_{zx} \downarrow\rangle + M_z |d_{xy} \uparrow\rangle \right) \\ = \frac{1}{\sqrt{3}} \left( -i |d_{yz} \downarrow \nu=2, x+\frac{1}{2}, y+\frac{1}{2}, t\rangle + |d_{zx} \downarrow \nu=2, x+\frac{1}{2}, y+\frac{1}{2}, t\rangle + i |d_{xy} \uparrow \nu=2, x+\frac{1}{2}, y+\frac{1}{2}, t\rangle \right)$$

$$PT M_z |J_z = \frac{1}{2}\rangle = \frac{1}{\sqrt{3}} \left( i PT |d_{yz} \downarrow \nu=2, x+\frac{1}{2}, y+\frac{1}{2}, t\rangle + PT |d_{zx} \downarrow \nu=2, x+\frac{1}{2}, y+\frac{1}{2}, t\rangle - i PT |d_{xy} \uparrow \nu=2, x+\frac{1}{2}, y+\frac{1}{2}, t\rangle \right)$$

$$= \frac{1}{\sqrt{3}} \left( i | -d_{yz} \uparrow \nu=1, -x, -y, -t \rangle^* + | -d_{zx} \uparrow \nu=1, -x, -y, -t \rangle^* + i | d_{xy} \downarrow \nu=1, -x, -y, -t \rangle^* \right)$$

$$= \frac{1}{\sqrt{3}} \left( -i |d_{yz} \uparrow \nu=1, -x, -y, -t\rangle^* - |d_{zx} \uparrow \nu=1, -x, -y, -t\rangle^* + i |d_{xy} \downarrow \nu=1, -x, -y, -t\rangle^* \right)$$

Phase slips in 2D spin superfluidity.

Section 4.13

2016/9/18 10: (6).

$$|J_z = -\frac{1}{2}\rangle = \frac{1}{\sqrt{3}} \left( |d_{yz}\uparrow\rangle - i |d_{zx}\uparrow\rangle - |d_{xy}\downarrow\rangle \right)$$

$$PT |J_z = -\frac{1}{2}\rangle = \frac{1}{\sqrt{3}} \left( PT |d_{yz}\uparrow\rangle + i PT |d_{zx}\uparrow\rangle - PT |d_{xy}\downarrow\rangle \right)$$

$$= \frac{1}{\sqrt{3}} \left( -|d_{yz}\downarrow, \nu=2, -x+\frac{1}{2}, -y+\frac{1}{2}, -t\rangle^* - i |d_{zx}\downarrow, \nu=2, -x+\frac{1}{2}, -y+\frac{1}{2}, -t\rangle^* - |d_{xy}\uparrow, \nu=2, -x+\frac{1}{2}, -y+\frac{1}{2}, -t\rangle^* \right)$$

$$= \frac{1}{\sqrt{3}} \left( |d_{yz}\downarrow, \nu=2, -x+\frac{1}{2}, -y+\frac{1}{2}, -t\rangle^* + i |d_{zx}\downarrow, \nu=2, -x+\frac{1}{2}, -y+\frac{1}{2}, -t\rangle^* - |d_{xy}\uparrow, \nu=2, -x+\frac{1}{2}, -y+\frac{1}{2}, -t\rangle^* \right)$$

$$G_x PT |J_z = -\frac{1}{2}\rangle = \frac{1}{\sqrt{3}} \left( G_x |d_{yz}\downarrow, \nu=2, -x+\frac{1}{2}, -y+\frac{1}{2}, -t\rangle^* \right.$$

$$+ i G_x |d_{zx}\downarrow, \nu=2, -x+\frac{1}{2}, -y+\frac{1}{2}, -t\rangle^* \left. - G_x |d_{xy}\uparrow, \nu=2, -x+\frac{1}{2}, -y+\frac{1}{2}, -t\rangle^* \right)$$

$$= \frac{1}{\sqrt{3}} \left( i |d_{yz}\uparrow, \nu=2, x, -y+1, -t\rangle^* \right.$$

$$- |d_{zx}\uparrow, \nu=2, x, -y+1, -t\rangle^* \left. - i |d_{xy}\downarrow, \nu=2, x, -y+1, -t\rangle^* \right)$$

$$= \frac{1}{\sqrt{3}} \left( i |d_{yz}\uparrow, \nu=2, x, -y+1, -t\rangle^* + |d_{zx}\uparrow, \nu=2, x, -y+1, -t\rangle^* + i |d_{xy}\downarrow, \nu=2, x, -y+1, -t\rangle^* \right)$$



2016/9/18 (2) (1).

$$G_x |J_z = -\frac{1}{2}\rangle = \frac{1}{\sqrt{3}} (G_x |d_{yz} \uparrow\rangle - i G_x |d_{zx} \uparrow\rangle - G_x |d_{xy} \downarrow\rangle)$$

$$= \frac{1}{\sqrt{3}} \left( i |d_{yz} \downarrow, \nu=1, -x+\frac{1}{2}, y+\frac{1}{2}, t\rangle + |-d_{zx} \downarrow, \nu=1, -x+\frac{1}{2}, y+\frac{1}{2}, t\rangle \right. \\ \left. - i |-d_{xy} \uparrow, -x+\frac{1}{2}, y+\frac{1}{2}, t\rangle \right)$$

$$PT G_x |J_z = -\frac{1}{2}\rangle = \frac{1}{\sqrt{3}} \left( -i PT |d_{yz} \downarrow, \nu=1, -x+\frac{1}{2}, y+\frac{1}{2}, t\rangle \right. \\ \left. + PT |-d_{zx} \downarrow, \nu=1, -x+\frac{1}{2}, y+\frac{1}{2}, t\rangle \right. \\ \left. + i PT |-d_{xy} \uparrow, -x+\frac{1}{2}, y+\frac{1}{2}, t\rangle \right)$$

$$= \frac{1}{\sqrt{3}} \left( -i |-d_{yz} \uparrow, \nu=2, x, -y, -t\rangle^* + |d_{zx} \uparrow, \nu=2, x, -y, -t\rangle^* \right. \\ \left. - i |-d_{xy} \downarrow, \nu=2, x, -y, -t\rangle^* \right)$$

$$= \frac{1}{\sqrt{3}} \left( i |d_{yz} \uparrow, \nu=2, x, -y, -t\rangle^* + |d_{zx} \uparrow, \nu=2, x, -y, -t\rangle^* \right. \\ \left. + i |d_{xy} \downarrow, \nu=2, x, -y, -t\rangle^* \right).$$

2016/9/18/2 (8).

$$S_x P T |J_z = -\frac{1}{2}\rangle = \frac{1}{\sqrt{3}} \left( S_x |d_{yz} \downarrow, \nu=2, -x+\frac{1}{2}, -y+\frac{1}{2}, -t\rangle^* \right. \\ \left. + i S_x |d_{zx} \downarrow, \nu=2, -x+\frac{1}{2}, -y+\frac{1}{2}, -t\rangle^* \right. \\ \left. - S_x |d_{xy} \uparrow, \nu=2, -x+\frac{1}{2}, -y+\frac{1}{2}, -t\rangle^* \right)$$

$$= \frac{1}{\sqrt{3}} \left( |d_{yz} \uparrow, \nu=1, x+\frac{1}{2}, -y+\frac{1}{2}, -t\rangle^* \right. \\ \left. + i |-d_{zx} \uparrow, \nu=1, x+\frac{1}{2}, -y+\frac{1}{2}, -t\rangle^* \right. \\ \left. + |-d_{xy} \downarrow, \nu=1, x+\frac{1}{2}, -y+\frac{1}{2}, -t\rangle^* \right)$$

$$S_x |J_z = -\frac{1}{2}\rangle = \frac{1}{\sqrt{3}} \left( S_x |d_{yz} \uparrow\rangle - i S_x |d_{zx} \uparrow\rangle - S_x |d_{xy} \downarrow\rangle \right)$$

$$= \frac{1}{\sqrt{3}} \left( -|d_{yz}, \downarrow, \nu=2, -x+1, y, t\rangle \right. \\ \left. + i |-d_{zx} \downarrow, \nu=2, -x+1, y, t\rangle - |-d_{xy} \uparrow, \nu=2, -x+1, y, t\rangle \right)$$

$$P T S_x |J_z = -\frac{1}{2}\rangle = \frac{1}{\sqrt{3}} \left( -P T |d_{yz}, \downarrow, \nu=2, -x+1, y, t\rangle \right.$$

$$\left. - i P T |-d_{zx} \downarrow, \nu=2, -x+1, y, t\rangle + P T |d_{xy} \uparrow, \nu=2, -x+1, y, t\rangle \right)$$

$$= \frac{1}{\sqrt{3}} \left( -|-d_{yz} \uparrow, \nu=1, x-\frac{1}{2}, -y+\frac{1}{2}, -t\rangle^* \right.$$

$$\left. - i |d_{zx} \uparrow, \nu=1, x-\frac{1}{2}, -y+\frac{1}{2}, -t\rangle^* - |d_{xy} \downarrow, \nu=1, x-\frac{1}{2}, -y+\frac{1}{2}, -t\rangle^* \right)$$



2016/9/18 / 2 (9).

$$|J_z = \frac{1}{2}\rangle = \frac{1}{\sqrt{3}} \left( |d_{yz} \downarrow\rangle + i |d_{zx} \downarrow\rangle + |d_{xy} \uparrow\rangle \right)$$

$$G_x |J_z = \frac{1}{2}\rangle = \frac{1}{\sqrt{3}} \left( G_x |d_{yz} \downarrow\rangle + i G_x |d_{zx} \downarrow\rangle + G_x |d_{xy} \uparrow\rangle \right)$$

$$= \frac{1}{\sqrt{3}} \left( i |d_{yz}, \downarrow, \nu=1, -x+\frac{1}{2}, y+\frac{1}{2}, t\rangle - |-d_{zx} \downarrow, \nu=1, -x+\frac{1}{2}, y+\frac{1}{2}, t\rangle \right. \\ \left. + i |-d_{xy} \uparrow, \nu=1, -x+\frac{1}{2}, y+\frac{1}{2}, t\rangle \right)$$

$$G_x^2 |J_z = \frac{1}{2}\rangle = \frac{1}{\sqrt{3}} \left( i G_x |d_{yz}, \downarrow, \nu=1, -x+\frac{1}{2}, y+\frac{1}{2}, t\rangle \right. \\ \left. + G_x |d_{zx} \downarrow, \nu=1, -x+\frac{1}{2}, y+\frac{1}{2}, t\rangle \right. \\ \left. + i G_x |-d_{xy} \uparrow, \nu=1, -x+\frac{1}{2}, y+\frac{1}{2}, t\rangle \right)$$

$$= \frac{1}{\sqrt{3}} \left( - |d_{yz}, \downarrow, \nu=1, x, y+1, t\rangle - i |d_{zx} \downarrow, \nu=1, x, y+1, t\rangle \right. \\ \left. - |d_{xy}, \uparrow, \nu=1, x, y+1, t\rangle \right)$$

$$G_x^3 |J_z = \frac{1}{2}\rangle = -e^{iky} |J_z = \frac{1}{2}\rangle$$

2016/9/18/2 (10)

$$|J_z = -\frac{1}{2}\rangle = \frac{1}{\sqrt{3}} \left( |d_{yz} \uparrow\rangle - i |d_{zx} \uparrow\rangle - |d_{xy} \downarrow\rangle \right)$$

$$G_x |J_z = -\frac{1}{2}\rangle = \frac{1}{\sqrt{3}} \left( G_x |d_{yz} \uparrow\rangle - i G_x |d_{zx} \uparrow\rangle - G_x |d_{xy} \downarrow\rangle \right)$$

$$= \frac{1}{\sqrt{3}} \left( i |d_{yz} \uparrow, \nu=1, -x+\frac{1}{2}, y+\frac{1}{2}, t\rangle + |-d_{zx} \uparrow, \nu=1, -x+\frac{1}{2}, y+\frac{1}{2}, t\rangle \right. \\ \left. - i |-d_{xy} \downarrow, \nu=1, -x+\frac{1}{2}, y+\frac{1}{2}, t\rangle \right)$$

$$G_x^2 |J_z = -\frac{1}{2}\rangle = \frac{1}{\sqrt{3}} \left( i G_x |d_{yz} \uparrow, \nu=1, -x+\frac{1}{2}, y+\frac{1}{2}, t\rangle \right.$$

$$+ G_x |-d_{zx} \uparrow, \nu=1, -x+\frac{1}{2}, y+\frac{1}{2}, t\rangle$$

$$\left. - i G_x |-d_{xy} \downarrow, \nu=1, -x+\frac{1}{2}, y+\frac{1}{2}, t\rangle \right)$$

$$= \frac{1}{\sqrt{3}} \left( - |d_{yz}, \uparrow, \nu=1, +x, y+1, t\rangle + i |d_{zx}, \uparrow, \nu=1, x, y+1, t\rangle \right. \\ \left. + |d_{xy}, \uparrow, \nu=1, x, y+1, t\rangle \right)$$

$$G_x^2 |J_z = -\frac{1}{2}\rangle = -e^{ik_y} |J_z = -\frac{1}{2}\rangle$$



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2016/9/18/2 (11).

$$|J_z = \frac{1}{2}\rangle = \frac{1}{\sqrt{3}} (|d_{yz} \downarrow\rangle + i |d_{zx} \downarrow\rangle + |d_{xy} \uparrow\rangle)$$

$$S_x |J_z = \frac{1}{2}\rangle = \frac{1}{\sqrt{3}} (S_x |d_{yz} \downarrow\rangle + i S_x |d_{zx} \downarrow\rangle + S_x |d_{xy} \uparrow\rangle)$$

$$= \frac{1}{\sqrt{3}} (|d_{yz} \uparrow, \nu=2, -x+1, y, t\rangle + i |-d_{zx} \uparrow, \nu=2, -x+1, y, t\rangle \\ - |d_{xy} \downarrow, \nu=2, -x+1, y, t\rangle)$$

$$= \frac{1}{\sqrt{3}} (|d_{yz} \uparrow, \nu=2, -x+1, y, t\rangle - i |d_{zx} \uparrow, \nu=2, -x+1, y, t\rangle \\ + |d_{xy} \downarrow, \nu=2, -x+1, y, t\rangle)$$

$$S_x^2 |J_z = \frac{1}{2}\rangle = \frac{1}{\sqrt{3}} (-|d_{yz} \downarrow, \nu=1, x, y, t\rangle + i |-d_{zx} \downarrow, \nu=1, x, y, t\rangle \\ - |d_{xy} \uparrow, \nu=1, x, y, t\rangle)$$

$$S_x^2 |J_z = \frac{1}{2}\rangle = -|J_z = \frac{1}{2}\rangle$$

$$S_x |J_z = \frac{1}{2}\rangle = \pm i |J_z = \frac{1}{2}\rangle.$$

2016/9/18/2 (12)

$$|J_z = \frac{1}{2}\rangle = \frac{1}{\sqrt{3}} (|d_{yz} \downarrow\rangle + i|d_{zx} \downarrow\rangle + |d_{xy} \uparrow\rangle)$$

$$M_z |J_z = \frac{1}{2}\rangle = \frac{1}{\sqrt{3}} (-i|d_{yz} \downarrow, \nu=2, x+\frac{1}{2}, y+\frac{1}{2}, t\rangle$$

$$|d_{zx} \downarrow, \nu=2, x+\frac{1}{2}, y+\frac{1}{2}, t\rangle + i|d_{xy} \uparrow, \nu=2, x+\frac{1}{2}, y+\frac{1}{2}, t\rangle)$$

$$M_z^2 |J_z = \frac{1}{2}\rangle = \frac{1}{\sqrt{3}} (-|d_{yz} \downarrow, \nu=1, x+1, y+1, t\rangle - i|d_{zx} \downarrow, \nu=1, x+1, y+1, t\rangle - |d_{xy} \uparrow, \nu=1, x+1, y+1, t\rangle)$$

$$M_z^2 |J_z = \frac{1}{2}\rangle = -e^{ik_x} e^{iky} |J_z = \frac{1}{2}\rangle$$



2016/9/18/2 (13).

$$G_x \left( \left| J_z = \frac{1}{2}, x, y, t, \nu=1 \right\rangle + \left| J_z = \frac{1}{2}, x+\frac{1}{2}, y+\frac{1}{2}, t, \nu=1 \right\rangle \right. \\ \left. + \left| J_z = \frac{1}{2}, x, y, t, \nu=2 \right\rangle + \left| J_z = \frac{1}{2}, x+\frac{1}{2}, y+\frac{1}{2}, t, \nu=2 \right\rangle \right)$$

$$= i \left| J_z = -\frac{1}{2}, -x+\frac{1}{2}, y+\frac{1}{2}, t, \nu=1 \right\rangle + i \left| J_z = -\frac{1}{2}, -x, y+1, t, \nu=1 \right\rangle \\ + i \left| J_z = -\frac{1}{2}, -x+\frac{1}{2}, y+\frac{1}{2}, t, \nu=2 \right\rangle + i \left| J_z = -\frac{1}{2}, -x, y+1, t, \nu=2 \right\rangle$$

$$G_x^2 |\psi\rangle = \left( - \left| J_z = \frac{1}{2}, x, y+1, t, \nu=1 \right\rangle - \left| J_z = \frac{1}{2}, x+\frac{1}{2}, y+\frac{3}{2}, t, \nu=1 \right\rangle \right. \\ \left. - \left| J_z = \frac{1}{2}, x, y+1, t, \nu=2 \right\rangle - \left| J_z = \frac{1}{2}, x+\frac{1}{2}, y+\frac{3}{2}, t, \nu=2 \right\rangle \right)$$

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$$S_x \left( \left| J_z = \frac{1}{2}, x, y, t, \nu=1 \right\rangle + \left| J_z = \frac{1}{2}, x+\frac{1}{2}, y+\frac{1}{2}, t, \nu=1 \right\rangle \right. \\ \left. + \left| J_z = \frac{1}{2}, x, y, t, \nu=2 \right\rangle + \left| J_z = \frac{1}{2}, x+\frac{1}{2}, y+\frac{1}{2}, t, \nu=2 \right\rangle \right) \\ = \left( - \left| J_z = -\frac{1}{2}, -x+1, y, t, \nu=2 \right\rangle - \left| J_z = -\frac{1}{2}, -x+\frac{1}{2}, y+\frac{1}{2}, t, \nu=2 \right\rangle \right. \\ \left. - \left| J_z = -\frac{1}{2}, -x+1, y, t, \nu=1 \right\rangle - \left| J_z = -\frac{1}{2}, -x+\frac{1}{2}, y+\frac{1}{2}, t, \nu=1 \right\rangle \right)$$

$$S_x^2 ( ) = \left( - \left| J_z = \frac{1}{2}, x, y, t, \nu=1 \right\rangle - \left| J_z = \frac{1}{2}, x+\frac{1}{2}, y+\frac{1}{2}, t, \nu=1 \right\rangle \right. \\ \left. - \left| J_z = \frac{1}{2}, x, y, t, \nu=2 \right\rangle - \left| J_z = \frac{1}{2}, x+\frac{1}{2}, y+\frac{1}{2}, t, \nu=2 \right\rangle \right).$$

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$$M_z \left( \left| J_z = \frac{1}{2}, x, y, t, \nu=1 \right\rangle + \left| J_z = \frac{1}{2}, x+\frac{1}{2}, y+\frac{1}{2}, t, \nu=1 \right\rangle \right. \\ \left. + \left| J_z = \frac{1}{2}, x, y, t, \nu=2 \right\rangle + \left| J_z = \frac{1}{2}, x+\frac{1}{2}, y+\frac{1}{2}, t, \nu=2 \right\rangle \right)$$

$$= \left( i \left| J_z = \frac{1}{2}, x+\frac{1}{2}, y+\frac{1}{2}, t, \nu=2 \right\rangle + i \left| J_z = \frac{1}{2}, x+1, y+1, t, \nu=2 \right\rangle \right.$$

$$\left. i \left| J_z = \frac{1}{2}, x+\frac{1}{2}, y+\frac{1}{2}, t, \nu=1 \right\rangle + i \left| J_z = \frac{1}{2}, x+1, y+1, t, \nu=1 \right\rangle \right).$$

$$M_z^{\pm}(\cdot) = \left( - \left| J_z = \frac{1}{2}, x+1, y+1, t, \nu=1 \right\rangle - \left| J_z = \frac{1}{2}, x+\frac{3}{2}, y+\frac{3}{2}, t, \nu=1 \right\rangle \right. \\ \left. - \left| J_z = \frac{1}{2}, x+1, y+1, t, \nu=2 \right\rangle - \left| J_z = \frac{1}{2}, x+\frac{3}{2}, y+\frac{3}{2}, t, \nu=2 \right\rangle \right).$$



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$$\left( \cos \frac{\theta}{2} |J_z = \frac{1}{2}\rangle + \sin \frac{\theta}{2} e^{i\phi} |J_z = -\frac{1}{2}\rangle \right)$$

$$G_x \left( \cos \frac{\theta}{2} |J_z = \frac{1}{2}\rangle + \sin \frac{\theta}{2} e^{i\phi} |J_z = -\frac{1}{2}\rangle \right)$$

$$= \cos \frac{\theta}{2} i |J_z = -\frac{1}{2}, -x+\frac{1}{2}, y+\frac{1}{2}, t\rangle + \sin \frac{\theta}{2} e^{i\phi} i |J_z = \frac{1}{2}, -x+\frac{1}{2}, y+\frac{1}{2}, t\rangle$$

$$G_x^2(\ ) = -\cos \frac{\theta}{2} |J_z = \frac{1}{2}, x, y+1, t\rangle - \sin \frac{\theta}{2} e^{i\phi} |J_z = -\frac{1}{2}, x, y+1, t\rangle.$$

$$\theta \rightarrow \pi - \theta$$

$$\phi \rightarrow \phi + \pi$$