I, II

$A, \tilde{A}$ $\quad B, \tilde{B}$

$$C = AB + A\tilde{B} + \tilde{A}B - \tilde{A}\tilde{B}$$

$$\langle C \rangle = \underbrace{\langle AB \rangle} + \langle A\tilde{B} \rangle + \langle \tilde{A}B \rangle - \langle \tilde{A}\tilde{B} \rangle$$

$$\langle C^2 \rangle = \underbrace{A^2 B^2}_{1} + \underbrace{A^2 \tilde{B}^2}_{1} + \tilde{A}^2 B^2 + \tilde{A}^2 \tilde{B}^2$$

+ linear in $A, \tilde{A}, B, \tilde{B}$ and linear squares

$\langle A \rangle = \langle \tilde{A} \rangle = \langle B \rangle = \langle \tilde{B} \rangle = 0$

$$- \langle [A, \tilde{A}][B, \tilde{B}] \rangle$$

$$C^2 = 4 + [A, \tilde{A}][B, \tilde{B}]$$

$A = \sigma_1 \qquad \bar{A} = \sigma_2 \qquad B = \Sigma_1 \qquad \bar{B} = \Sigma_2$

$$\hat{C}^2 = 4 + 4\,\sigma_3 \Sigma_3$$

If we take $|+\rangle|\uparrow\rangle$ or $|-\rangle|\downarrow\rangle$

Then $C^2 |\ \rangle = 8 |\ \rangle$

$$C\,? \longrightarrow \alpha |+\rangle|\uparrow\rangle + \beta |-\rangle|\downarrow\rangle$$

$\alpha = e^{-i\pi/8}$ $\qquad \beta = e^{+i\pi/8}$

$$C\left(\alpha |+\rangle|\uparrow\rangle \pm \beta |-\rangle|\downarrow\rangle\right) = -2\sqrt{2}\ (\quad)$$

That will give $\langle C \rangle = -2\sqrt{2}$

Class.

$$A\,(\underbrace{B + B'}_{(2,\,0,\,-2)}) + A'(B - B')$$

$$(\pm)\,(2,\,0,\,-2) \qquad \pm 2 \quad (B - B')$$

$$= \pm 2,\ 0$$

$$-2 < \langle c \rangle < 2$$

$$\langle c \rangle = 2\sqrt{2}$$

Problem

A, B   A, $\bar{B}$

Assumption in Bell's pf
is that in exp A, $\bar{B}$
that $\bar{B}$ has the same value
as it would have if I
measured B rather than
$\bar{B}$.

Counterfactual argument
In exp A, B, $\bar{B}$ still has a value
which would be what I get if
I had measured $\bar{B}$.

Hardy's chain

In Bell the q states which are non-classical are max entangled

$$e^{-i\pi/8} |+,\uparrow\rangle + e^{i\pi/2} |-,\downarrow\rangle$$

If $A = +$ then $B = \uparrow$ Prob $1/2$
" $A = -$ then $B = \downarrow$ Prob $1/2$

Max entangled

$$|\psi\rangle = \sin\theta\,|+;\uparrow\rangle + \sin\theta\,|-\uparrow\rangle + \sqrt{\cos 2\theta}\,|-\downarrow\rangle$$

I   +1 e-state

A: $|+\rangle$

B: $\dfrac{|+\rangle + |-\rangle}{\sqrt{2}}$

II   +1 e-state.

C: $|\uparrow\rangle$

D: $\dfrac{2\sin\theta\,|\uparrow\rangle + \sqrt{\cos 2\theta}\,|\downarrow\rangle}{\sqrt{1+2\sin^2\theta}}$

A, B, C, D all are 2 level ? ± 1 value.

a   If measure A and find +1   "   +1

B   If measur B   "   "   +1

C   "   C   "   "   +1

D   "   D   "   "   +1

a $\Rightarrow$ C true   C $\Rightarrow$ B true   B $\Rightarrow$ D true; A $\not\Rightarrow$ D $\theta \sim 0$

almost always!

If θ small prob of $\emptyset$

$$\simeq \frac{4\sin^2\theta}{\sqrt{1+2\sin^2\theta}} \ll 1 \text{ if } \theta \simeq 0$$

If θ small, $|\psi\rangle \simeq |-\downarrow\rangle$
$= |-\rangle|\downarrow\rangle$

Prob $a \simeq \sin^2\theta$

Both $\dfrac{D \text{ is true} + D \text{ false}}{\text{in Q.M.}}$

Note this violation occurs most strongly for unentangled state what defines Q.M. ?

even entanglement does not completely characterize Q.M.

?

Q.M. is weird from classical point of view