4/22/2013

115 Unraveling open Q systems

1) Motivation for single Q systems

2) QMCWF

3) Ex. Models for dephasing

Schrodinger 1952

“We never experiment with just one electron, or atom, or (small) molecule. In thought experiments, we sometimes assume that we do; this inevitably entails ridiculous consequences.... In the first place, it is fair to say that we are not experimenting with single particles, any more than we can raise ichthysauria in the zoo.”
Welcome to the Infinite You.

You can probably imagine the looks I get when I describe Quantum Jumping to people: it’s a technique for ‘jumping’ into alternate universes, meeting alternate versions of yourself, and using their wisdom and skills to live your ideal life.

The smartest people in the world are trying to tell you something.

First of all, I wouldn’t even dream of telling you about alternate universes and alternate selves if I wasn’t sure of it myself. After all, I’ve told you about my background, and my life’s work in helping people achieve mental and spiritual enlightenment...

And there’s no way I’d throw away a lifetime of credibility and trust by telling you something that wasn’t true.

The real clincher, though, lies in the discoveries of the most intelligent people in the world. Nobel prize winners, professors, quantum physicists—if you can’t trust them, who else is left?

There’s countless other intellectuals that have made discoveries in the possibility of alternate universes, including the world-famous Professor Stephen Hawking, Professor Alan Guth, and even Albert Einstein himself.

If you need more proof, just search Google for scientific theories like String Theory and M-Theory, or watch the film “What The Bleep Do We Know!” Once you do, you’ll be as convinced as I am that alternate universes do indeed exist.
Shelved Optical Electron Amplifier: Observation of Quantum Jumps

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(Received 5 May 1986)

FIG. 2. A typical trace of the 493-nm fluorescence from the 6^2P_{1/2} level showing the quantum jumps after the hollow cathode lamp is turned on. The atom is definitely known to be in the shelf level during the low fluorescence periods.

FIG. 3. Histogram of distribution of dwell times in the shelf level for 203 "off" times. A fitted theoretical (exponential) distribution for a metastable lifetime of 30 sec is superposed on the experimental histogram.

Quantum jumps of light recording the birth and death of a photon in a cavity

Nature 446, 297 (2007) - March 15

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FIG. a and b show the state of the cavity and the detected fluorescence over time.
Now: "Description" of single quantum system

Warning: not unique
∞ ways to unravel density matrix
here: ∞ dynamics

② QM: WF
be in the experiences: perform measurements

after time step dt, toss coin for spin, en

p YES  →

1 - p  No  →

Change of WF by measurement

| i⟩ = |g⟩ stays forever

| i⟩ = |e⟩ photon observed → |g⟩

no photon observed → |e⟩

| i⟩ = \frac{1}{\sqrt{2}} (|g⟩ + |e⟩)

photon obs  → |g⟩

no photon obs

\frac{1}{\sqrt{2}} (|g⟩ + e^{\frac{1}{2}it} |e⟩)

something else

A

B

C
So/So superposition of $|g\rangle$, $|c\rangle$

$\tau^{-1} = 10 \text{ ns}$

1s: no photon observed

$|g\rangle \checkmark$  \hspace{1cm} A

$\alpha |g\rangle \propto \beta |c\rangle$  \hspace{1cm} B

After a long time:

$|g\rangle$

50% of the cases with photon

50% without

A zero measurement modifies the WF!


YES \hspace{1cm} NO
Procedure

1. Compute \( dp = \int dt |\langle e(t), e(0) \rangle|^2 \)
2. \( \varepsilon \leftarrow \text{rand}[0, 1] \)
3. If \( \varepsilon < dp \) then \( |z\rangle \rightarrow |g\rangle \)
4. else \( |z\rangle \rightarrow \frac{\frac{\varepsilon}{2} \mp d t |z\rangle}{\sqrt{1 - dp}} \)
5. goto (2)

Claim: \[ \text{QMCUSF} \equiv OBE \]

Proof: Show \( S(t) = |z(t)\rangle \langle z(t)| \)

\[
\rho(t + dt) = dp \langle g|g\rangle + (1 - dp) \frac{e^{-i H dt|\psi\rangle\langle\psi|e + i H^\dagger dt}}{1 - dp} \\
\approx dp \langle g|g\rangle + (1 - i H dt)\rho(t)(1 + i H^\dagger dt) \\
\approx dp \langle g|g\rangle + \rho(t) - i(H\rho(t) - \rho(t)H^\dagger)dt \\
= \Gamma dt \langle e|\rho(t)|e\rangle \langle g|g\rangle + \rho(t) - i dt [H_0, \rho(t)] - \frac{\Gamma}{2} dt \langle e|\rho(t)|e\rangle \langle e|\rho(t)|e\rangle \langle e|\rho(t)|e\rangle \langle e|\rho(t)|e\rangle \rangle \\
= \Gamma dt \langle e|\rho(t)|e\rangle \langle g|g\rangle + \rho(t) - i dt [H_0, \rho(t)] - \frac{\Gamma}{2} dt \langle e|\rho(t)|e\rangle \langle e|\rho(t)|e\rangle \langle e|\rho(t)|e\rangle \langle e|\rho(t)|e\rangle \rangle \\
\]

Writing this as a coarse-grained differential equation, taking the limit of small \( dt \), we find
\[
\frac{d}{dt} \rho(t) \approx \rho(t + dt) - \rho(t) \\
= -i \left[H_0, \rho(t)\right] - \frac{\Gamma}{2} (\langle e|\rho(t)|e\rangle \langle e|\rho(t)|e\rangle \langle e|\rho(t)|e\rangle \langle e|\rho(t)|e\rangle) + \Gamma \langle g|e|\rho(t)|e\rangle \langle e|g \rangle \\
\]

This is the optical Bloch equation.
Extensions:

- Polarization
  - If photon is detected
  - Second random η determines $\delta^+, \delta^-, \Pi$

- Recoil: Random number for direction $\approx \frac{q_i}{p_i} \rightarrow \text{recoil}$

General QPC CLF:

$$\mathbf{\hat{S}} = -i[H_S, \mathbf{\hat{S}}] + \sum_{k} \epsilon_{ik} \mathbf{\hat{S}}_{ik} - \frac{i}{2} [\mathbf{\hat{J}}_{x}, \mathbf{\hat{J}}_{y}] - \frac{i}{2} [\mathbf{\hat{J}}_{y}, \mathbf{\hat{J}}_{x}]$$

$$H = H_0 - \frac{i}{2} \sum_{k} \mathbf{\hat{J}}_{x} \mathbf{\hat{J}}_{y}$$
General QMCWF Procedure:

1. Compute \( dp = \sum_k dp_k \), and \( dp_k = dt \langle \psi | \hat{L}_k^\dagger \hat{L}_k | \psi \rangle \)

2. Let \( 0 \leq \epsilon \leq 1 \) be a uniformly distributed random number.

3. If \( \epsilon < dp \) then \( |\psi\rangle \leftarrow \frac{L_k |\psi\rangle}{\sqrt{dp_k/dt}} \) with \( k \) randomly chosen with probability \( dp_k/dp \).

4. Else \( |\psi\rangle \leftarrow \frac{e^{-iHdt}}{\sqrt{1-dp}} |\psi\rangle \).

5. Go to 1.

Spontaneous em.: \( L = \sqrt{\Gamma} \sigma \)
Dephasing

\[ S(\tau) = \begin{bmatrix} a & b \\ b^* & c \end{bmatrix} \]

\[ S(t) = \begin{bmatrix} 1 - c e^{-t/T_1} & b e^{-t/T_2} \\ b^* e^{-t/T_2} & c e^{-t/T_1} \end{bmatrix} \]

- \( T_1 \): energy loss
- \( T_2 \): dephasing, loss of coherence, phase damping

HW #6, Problem 2:
3 examples of \( T_2 \) processes:
- random plan
- elastic collision projects onto \( |c\rangle \)
- random plan flips \( |c\rangle \rightarrow -|c\rangle \)

Dipole moment
elastic cell in leg > random phase flip

see Wiki for animations

Discussion

Which model is correct?
All or none?

Freedom of interpretation arises from unitary degree of freedom how the photon is detected

\[ S(t) \rightarrow U \rightarrow S(t+dr) \]

let X end W