

Measurement Problem and Quantum Gravity

Conference in Foundations of Physics- IPM-Tehran

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December 20, 2017

IPM

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The Measurement Problem

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- Failure Of Classical Physics at Micro Scales \implies Emergence Of Quantum Physics \implies Expected To Be the More Complete Theory (Correspondence Principle)
- "We have defined "apparatus" as a physical object which is governed, with sufficient accuracy, by classical mechanics... Thus quantum mechanics occupies a very unusual place among physical theories: *it contains classical mechanics as a limiting case* [correspondence principle], yet at the same time **it requires this limiting case for its own formulation**".

(Quantum Mechanics, Landau and Lifshitz, pp.2-3)

The Measurement Paradox

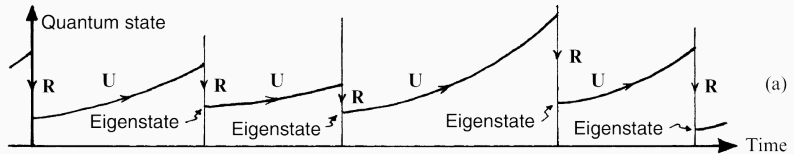
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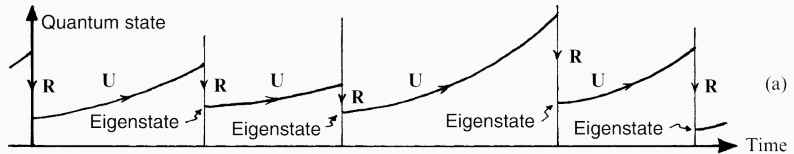
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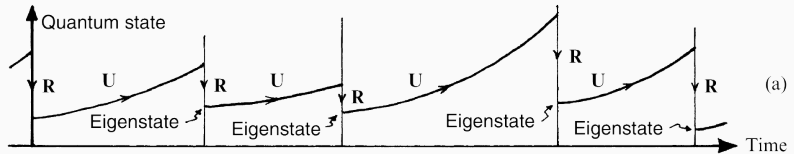
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- **Superposition** and **Unitary** both can not be saved.

- There is no clear boundary between classical measuring device and quantum system.

Other statements

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- Classical objects (solutions of classical equations) are required in formulation of a Quantum theory: **BACKGROUND DEPENDENCE**

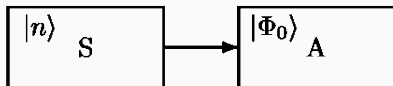
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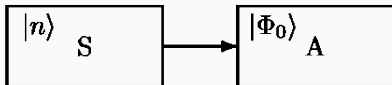
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- Classical objects (solutions of classical equations) are required in formulation of a Quantum theory: **BACKGROUND DEPENDENCE**
- Quantum system in classical background or environment.
- **R** process (Using Born rule) : Pure State \implies Mixed State

Mathematical Statement



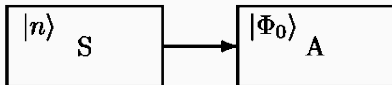
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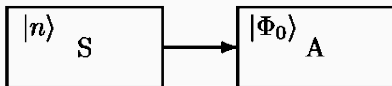
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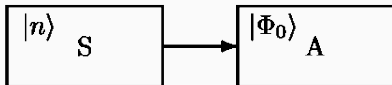
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- Density Matrix:

$$\rho_{\text{pure}} = \sum_{ij} c_i c_j |i\rangle\langle j| |\Phi_i\rangle\langle \Phi_j| \xrightarrow{\text{collapse}} \rho_{\text{mixed}} = \sum_i |c_i|^2 |i\rangle\langle i| |\Phi_i\rangle\langle \Phi_i|$$

Main Attitudes Toward The Problem

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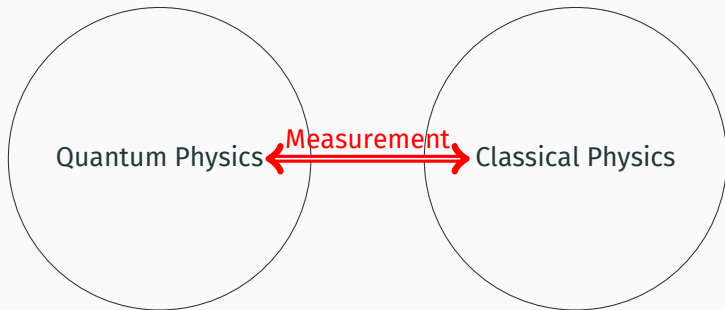
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- (IV) Current Quantum Theory is an **approximation** to more complete theory.

Quantum-Classical relation

- Classical Physics isn't a limit of Quantum Physics!
- The main problem is with unclear Quantum-Classical boundary



For complete resolution of measurement problem we need a general theory of classical and quantum physics

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Quantum-Classical Theory

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- Main aspect of classical world \implies Gravity (Quantum-Gravity Theory)

Quantum Gravity problems

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- **Semiclassical Approximation?** $G_{\mu\nu} = 8\pi\langle T_{\mu\nu}\rangle$

QFT in accelerated frames

The distinction between quantum and statistical fluctuation only is possible in preferred references in absences of gravitational fields.

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- \implies Statistical Interpretation \implies Hidden variables.

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- Quantum fluctuations \implies Statistical fluctuations $T_H = \frac{\kappa}{2\pi}$
- pure state \implies mixed state \implies Information paradox
- "Unusual causal structure of the black hole is serving as a kind of microscope for looking at the structure of the quantum field theory vacuum "

L.Smolin [1].

Information Vs Measurement Paradox!

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- Information paradox: **R** process: pure state \implies mixed state
- Quantum system interact with a **classical** gravitational background.

General Attitudes to information paradox

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- (III) Statistical interpretations of Quantum fields.(In fact similar to Hawking early suggestion)

Penrose Model for state reduction

- Minimal Quantum Gravity for state reduction

$$i\hbar \frac{\partial \Psi(\mathbf{X}, t)}{\partial t} = - \sum_{i=1}^N \frac{\hbar^2}{2m_i} \nabla_i^2 \Psi(\mathbf{X}, t) - G \sum_{i=1}^N m_i \Phi(x_i, t) \Psi(\mathbf{X}, t)$$
$$\nabla^2 \Phi(x, t) = 4\pi G \int d^{3N} X' |\Psi(\mathbf{X}', t)|^2 \sum_{j=1}^N m_j \delta(\mathbf{x} - \mathbf{x}'_j)$$

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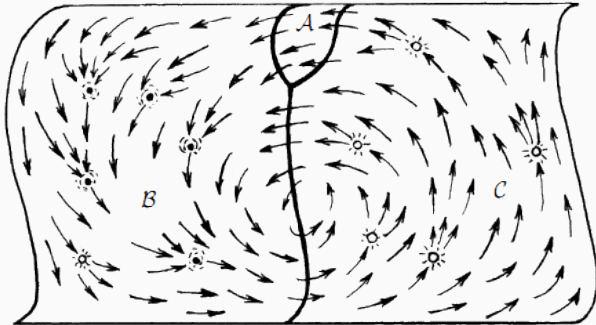
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- Collapse time: $T_G = \frac{\hbar}{E_G}$

- Objective Reduction is an approximation to the full theory.
- Semiclassical is an approximation to the full theory.



Total *phase space* volume of QG is conserved

'tHooft deterministic Quantum (Gravity)

- The fundamental degrees of freedom of nature (at Planck scale) are classical and deterministic.

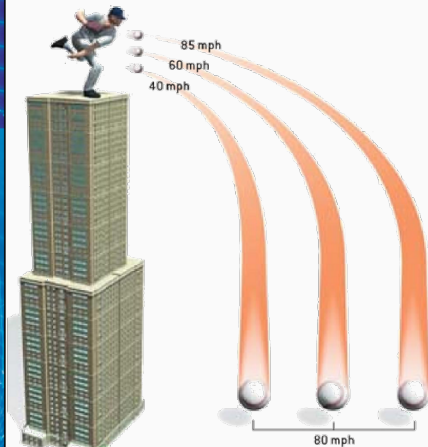
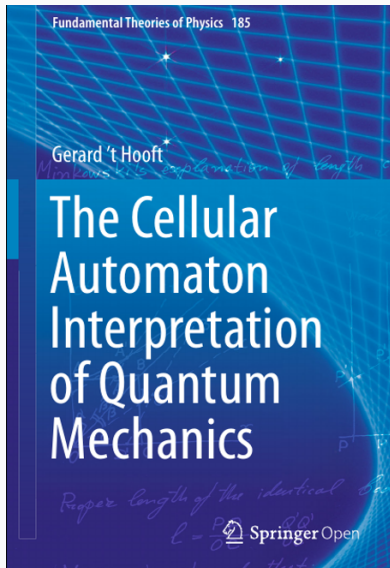
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- Fundamental Variables \implies dissipation (Information loss provided by gravity) \Rightarrow Equivalent classes \Rightarrow Hilbert space
- Holography example: A classical theory with gravity within a volume \mathbf{V} can be formulated as a quantum theory with the degrees of freedom living on the boundary \mathbf{A} .

'tHooft deterministic Quantum (Gravity)



Conclusion

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- General relativity and quantum theory are only approximations (limits) to the as-yet unknown deterministic quantum theory of gravity.
- "The ultimate explanation of quantum mechanics will also require the complete solution of the quantum gravity problem."

Avicenna the philosopher said to a Sufi :

“ What would there be to be seen if there were nobody present to see it?”

the Sufi answered :

”What could not be seen, if there were a seer present to see it?”

Thank You

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Some references are: [1, 2, 3, 4, 5, 6]



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