Title: Quantum Information 2021/2022

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Collection: Quantum Information 2021/2022

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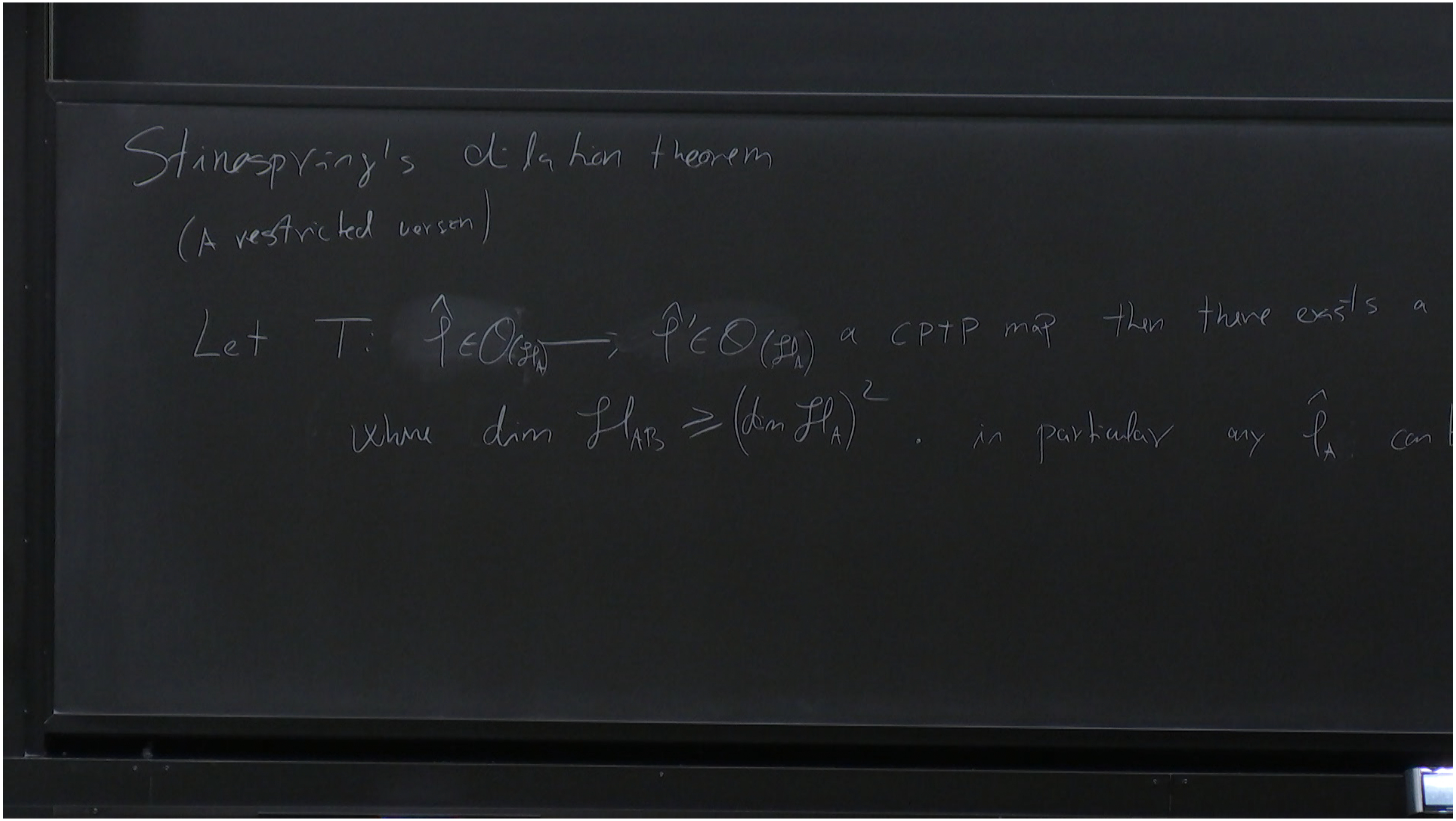
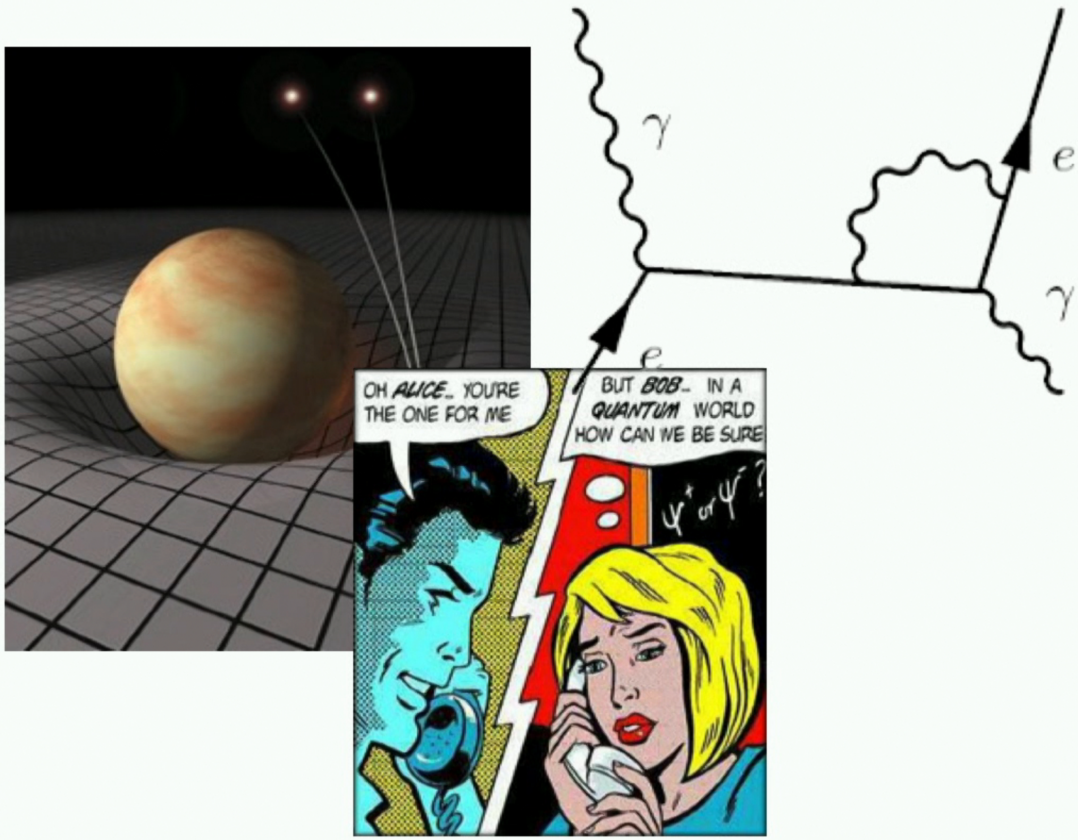

Stinespring's dilation theorem
(A restricted version)
Let $T: \hat{\rho} \in \mathcal{O}(\mathcal{H}_A) \longrightarrow \hat{\rho}' \in \mathcal{O}(\mathcal{H}_A)$ a CPTP map then there exists a
where $\dim \mathcal{H}_{AB} \geq (\dim \mathcal{H}_A)^2$. in particular any $\hat{\rho}_A$ can

$$|0_{AB}\rangle = |0\rangle_A \otimes |0_B\rangle$$

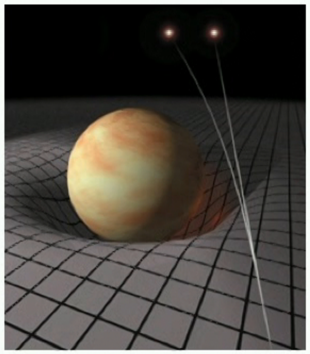
a Hilbert space $\mathcal{H}_{AB}$ such that $T(\hat{\rho}_A) = tr_B\left[\hat{U}_{AB}\,|0_{AB}\rangle\langle 0_{AB}|\,\hat{U}_{AB}\right]$

n be thought of as $\hat{\rho}_A = tr_{AB}\left(|\psi\rangle_{AB}\langle\psi|\right)$

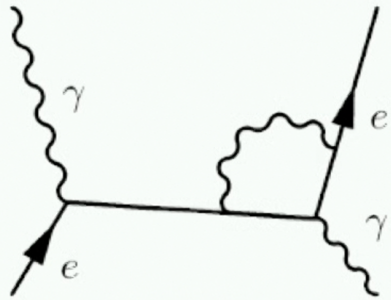
Relativistic Quantum Information



Relativistic Quantum Information



General relativity

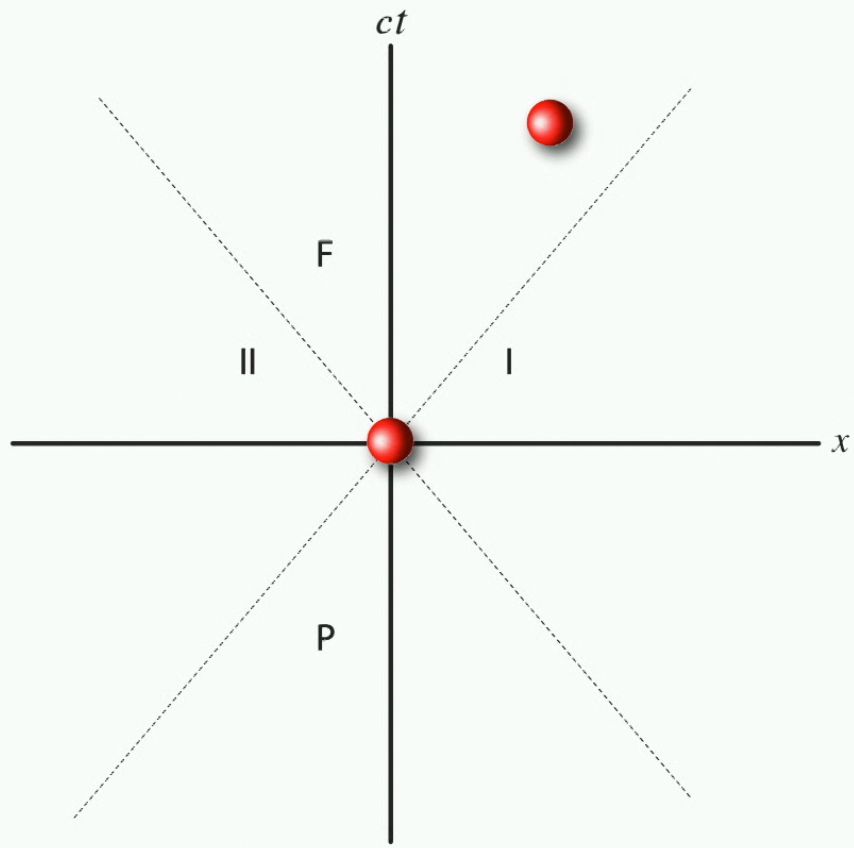


Quantum field theory

Quantum information

- Harness relativistic approaches to "do more" in quantum information processing.

What does it mean to place a qubit on spacetime?



The Measurement problem

Measurements in Quantum Theory

Still an open problem!

Proposal: At least some Measurements can give values (e.g., 42) that we can write on a notepad

In QM, we model that with <u>idealized measurements</u>

Idealized measurements of non-degenerate observables update states through a rank-1 projector on the spectrum of the measured observables

But Quantum to Classical transition? Interpretation?

You could "not care"! And still get rich and famous

Still an open problem!

Measurements in Quantum Theory

How about QFT?

Maybe we want to measure localized observables of the field (e.g., the electric field in my room during the duration of my talk)

If you measure it, it is not unthinkable you get a definite reading (e.g., 42 V/m)

Can you become rich and famous with idealized measurements in QFT?

No idealized measurements?

Rafael Sorkin (1992):

No idealized measurements in QFT?

Impossible Measurements on Quantum Fields*

RAFAEL D. SORKIN

Department of Physics, Syracuse University, Syracuse NY 13244-1130

Abstract

It is shown that the attempt to extend the notion of ideal measurement to quantum field theory leads to a conflict with locality, because (for most observables) the state vector reduction associated with an ideal measurement acts to transmit information faster than light. Two examples of such information-transfer are given, first in the quantum mechanics of a pair of coupled subsystems, and then for the free scalar field in flat spacetime. It is argued that this problem leaves the Hilbert space formulation of quantum field theory with no definite measurement theory, removing whatever advantages it may have seemed to possess vis a vis the sum-over-histories approach, and reinforcing the view that a sum-over-histories framework is the most promising one for quantum gravity.

No idealized measurements?

Rafael Sorkin (1992):

No idealized measurements in QFT?

Argues that idealized measurements are incompatible with causality

Two examples:

Example 1: Two-Qubit system

Consider a state: $|0_A 0_B\rangle$

1-Perform local Unitary on A

2-Make an idealized Bell measurement projecting on to $\frac{1}{\sqrt{2}}(|0_A 0_B\rangle + |1_A 1_B\rangle)$

3-Expectation of observable on B gains information about the unitary on A

Surprised?

No idealized measurements?

Rafael Sorkin (1992):

No idealized measurements in QFT?

Argues that idealized measurements are incompatible with causality

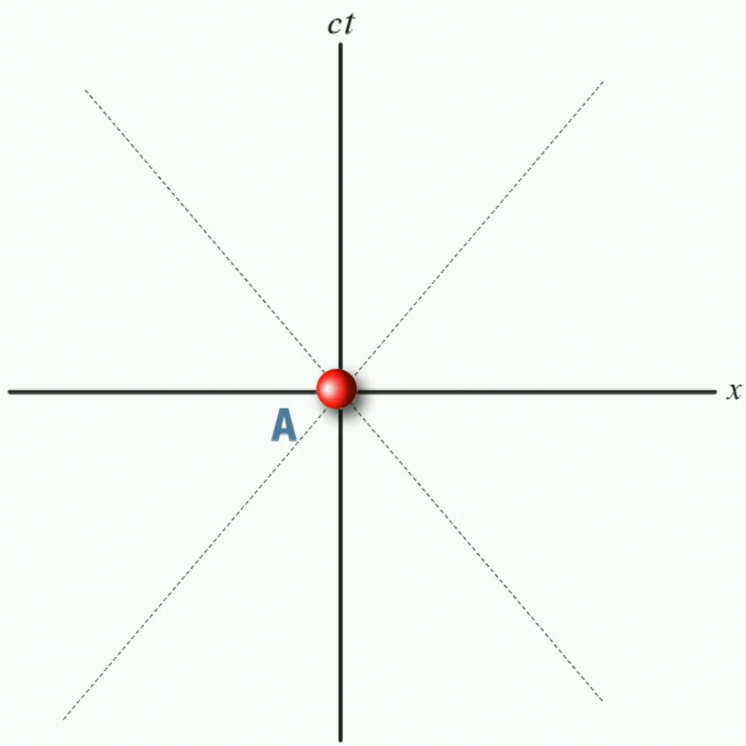
Two examples:

Example 2: Quantum Field

Consider a state: $\hat{\rho}$

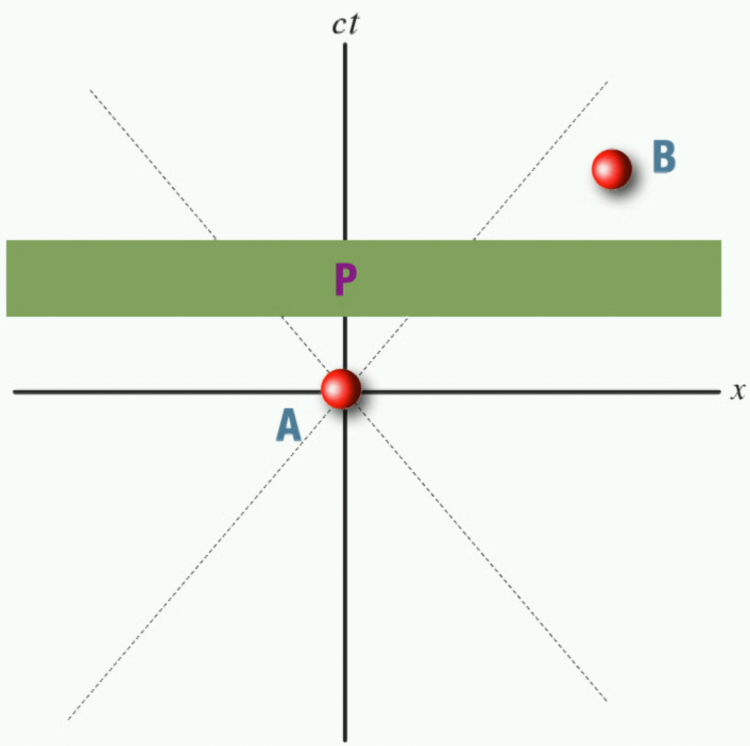
No idealized measurements?

1-Perform local Unitary on a field observable localized around A



No idealized measurements?

3-Expectation of local observables on B gains information about the unitary on A



So what's the plan?

People kept using such idealized measurements (actively and by assumption)

People in RQI followed two paths:

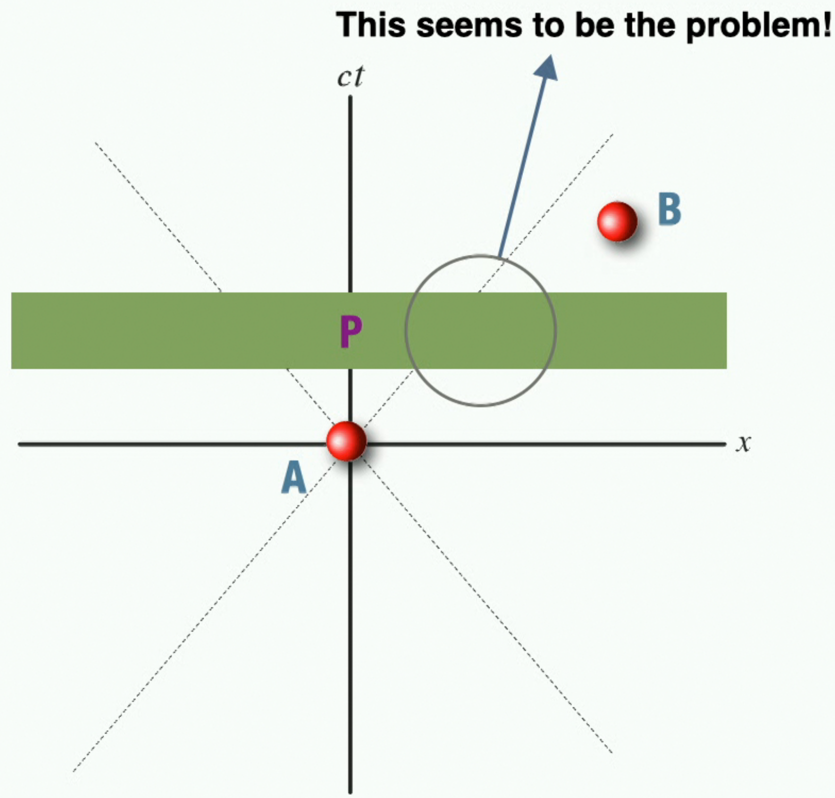
Particle detectors

More on this later!

Localized idealized measurements

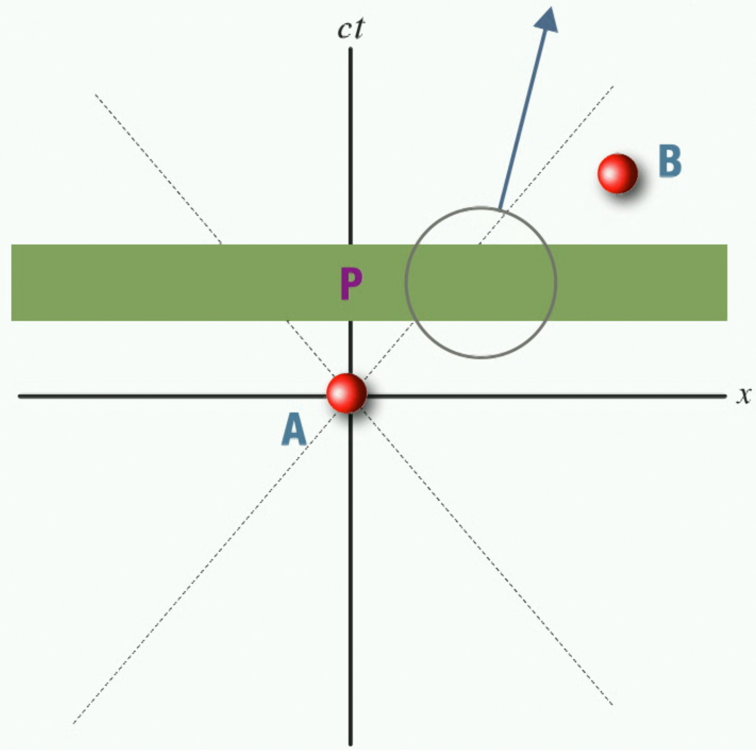
Is this okay?

Localized idealized measurements



Localized idealized measurements

This seems to be the problem!



A naive read of Sorkin's paper may suggest so….

Localized idealized measurements

Impossible measurements revisited

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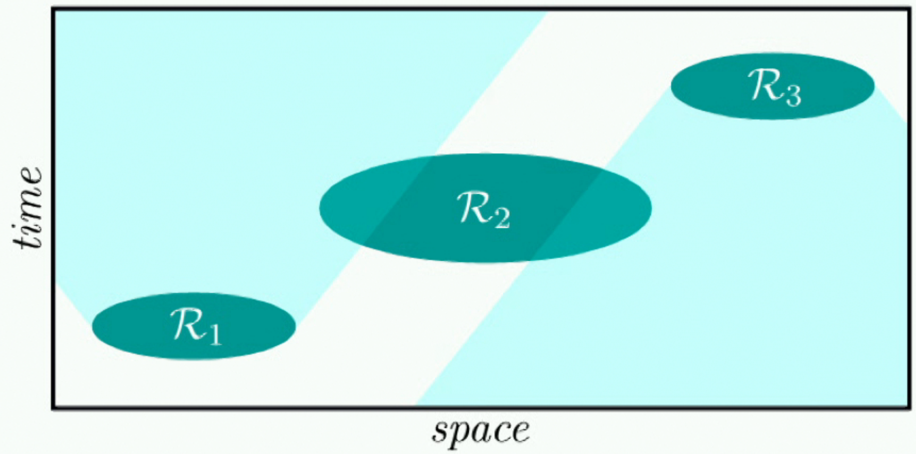
School of Theoretical Physics, Dublin Institute for Advanced Studies, 10 Burlington Road, Dublin 4, Ireland
(Dated: December 16, 2019)



Localized idealized measurements?

Foundations of Physics, Vol. 25, No. 1, 1995

More Ado about Nothing

Michael Redhead[1]

Received February 9, 1994

In this paper questions about vacuum fluctuations in local measurements, and the correlations between such fluctuations, are discussed. It is shown that maximal correlations always exist between suitably chosen local projection operators associated with spacelike separated regions of space-time, however far apart these regions may be. The connection of this result with the well-known Fregenhagen bound showing exponential decay of correlations with distance is explained, and the relevance of the discussion to the question "What do particle detectors detect?" is addressed.

Localized idealized measurements?

Foundations of Physics, Vol. 25, No. 1, 1995

Theorem 1. If $P \in R(O)$, then P is an infinite-dimensional projector.

Proof. This follows directly from the result of Driessler[7] which states that the quasi-local algebra associated with an unbounded wedge of space-time is a type III factor. Now any bounded region is internal to some wedge, so by isotony $R(O)$ is a subalgebra of some wedge algebra. So the projectors in $R(O)$ are identified with some of the projectors in the wedge algebra. But in a type III factor *all* the projectors are infinite-dimensional. So all the projectors in $R(O)$ are infinite-dimensional.

A PVM over a bounded region of spacetime cannot be finite-rank!

No localized idealized measurements

So... Now what?

W. E. Lamb, Anti-Photon

Abstract

It should be apparent from the title of this article that the author does not like the use of the word “photon”, which dates from 1926. In his view, there is no such thing as a photon. Only a comedy of errors and historical accidents led to its popularity among physicists and optical scientists. I admit that the word is short and convenient. Its use is also habit forming. Similarly, one might find it convenient to speak of the “aether” or “vacuum” to stand for empty space, even if no such thing existed. There are very good substitute words for “photon”, (e.g., “radiation” or “light”), and for “photonics” (e.g., “optics” or “quantum optics”). Similar objections are possible to use of the word “phonon”, which dates from 1932.

electrons, neutrinos of finite rest mass, or helium atoms can, under suitable conditions, be considered to be particles, since their theories then have viable non-relativistic and non-quantum limits. This paper outlines the main features of the quantum theory of radiation and indicates how they can be used to treat problems in quantum optics.