Title: What is a quantal reality?

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Abstract: I will rephrase the question, "What is a quantal reality?" as "What is a quantal history?" (the word history having here the same meaning as in the phrase sum-over-histories). The answer I will propose modifies the rules of logical inference in order to resolve a contradiction between the idea of reality as a single history and the principle that events of zero measure cannot happen (the Kochen-Specker paradox being a classic expression of this contradiction). The so-called measurement problem is then solved if macroscopic events satisfy classical logic, and this can in principle be decided by a calculation. The resulting conception of reality involves neither multiple worlds nor external observers. It is therefore suitable for quantum gravity in general and causal sets in particular.

Quantum Gravity and Quantal Reality

We still haven't learned how to think clearly about the quantum world in itself, without reference to "observers" and other external agents.

Because of this we don't really know how to think about the Planckian regime where quantum gravity is expected to be most relevant.

Without an observer-free notion of reality, how does one give meaning to superluminal causation or its absence in a causal set?

We all employ intuitive pictures in our work, but we lack a coherent descriptive framework to answer: **What is a quantal reality?**

My main purposes are to

- propose a (family of possible) answer(s)
- explain how the "measurement problem" can be posed and plausibly solved

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Histories (the kinematic input)

In the classical era it was easy to say what a possible reality was.

Examples: GR (a 4-geometry), Brownian motion (a single worldline)

We could survey all the possible realities, and state the dynamical laws that further circumscribed them (ie the equations of motion or field equations.)

Such a possible reality is what I will mean by a **history** (as in Σ/hist)

Ω = space of all histories.

Event = subset of Ω (eg "It rained all day yesterday").

Coevent = ϕ (defined here for future reference)

(It answers every possible question of the form "Did this event happen?" "Will that event happen?")

(It's higher order: a "predicate of predicates")

Classically "existence" corresponds to a single history. Quantally it ou[...] quantal history, but what exactly should this mean?

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Anhomomorphic logic grows out of the path-integral. What does the path-integral really compute? The probability of a succession of "position events" can be written directly as a path-integral.

The resulting expression makes sense for any event (set of histories) This **q-measure** μ or "decoherence functional" is what the p.i. computes!

Mathematically can view QM as level two measure theory. (ongoing test at IQC?)

μ can't be interpreted as a probability in general because of interference.

In general we don't know what μ means. (From histories standpoint, this *is* the problem of quantum interp.)

I propose to interpret μ in terms of a Preclusion Postulate

$$\mu(E) = 0 \Rightarrow E \text{ does not happen} \quad [\phi(E) = 0]$$

Call such a coevent ϕ preclusive

(cf Cournot's principle)

The idea is that the whole dynamical content of the quantal formalism reduces to this preclusion rule (with approx preclusion if need be).

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Mathematically can view QM as level two measure theory. (ongoing test a IQC)

μ can't be interpreted as a probability in general because of interference.

In general we don't know what μ means. (From histories standpoint, this is the problem of quantum interp.)

I propose to interpret μ in terms of a Preclusion Postulate

$$\mu(E) = 0 \Rightarrow E \text{ does not happen} \quad [\phi(E) = 0]$$

Call such a coevent ϕ preclusive

(cf Cournot's principle)

The idea is that the whole dynamical content of the quantal formalism reduces to this preclusion rule (with approx preclusion if need be).

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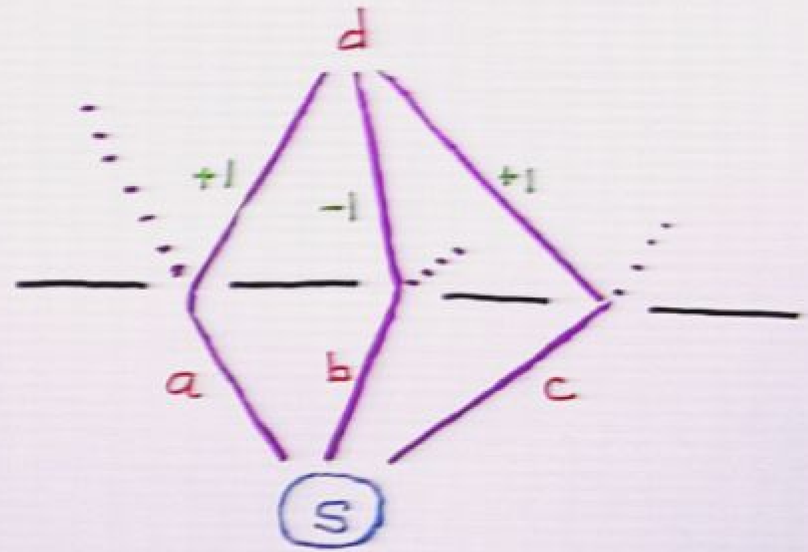

Events $da,\ db,\ dc,\ da+db,\ \ldots,\ d$

Write $da = A,\ db = B,\ dc = C$, then $d = A+B+C$

preclusions $A+B,\ B+C$

$\mu(d) = \mu(A+B+C) > 0$ but $\mu(A+B) = 0 = \mu(B+C)$

These are all intrinsic events, not "measured events"

Classically: $A+B$ and $B+C$ cannot happen, but A+B+C can!

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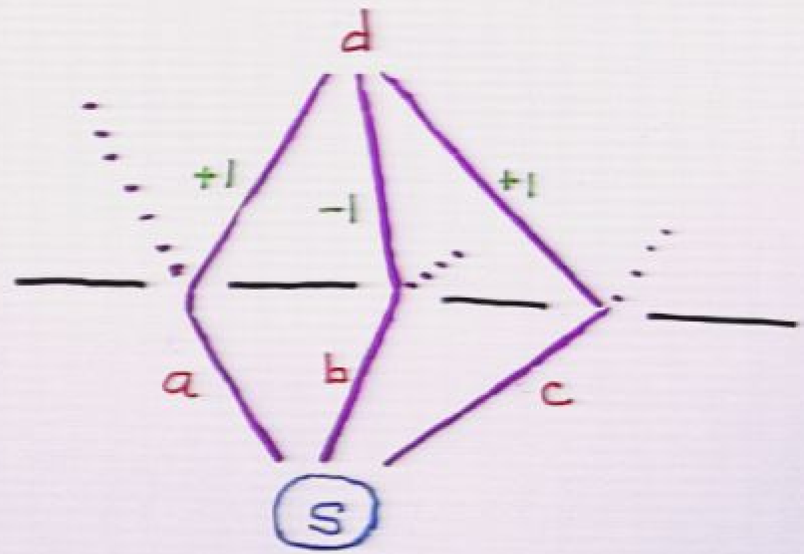

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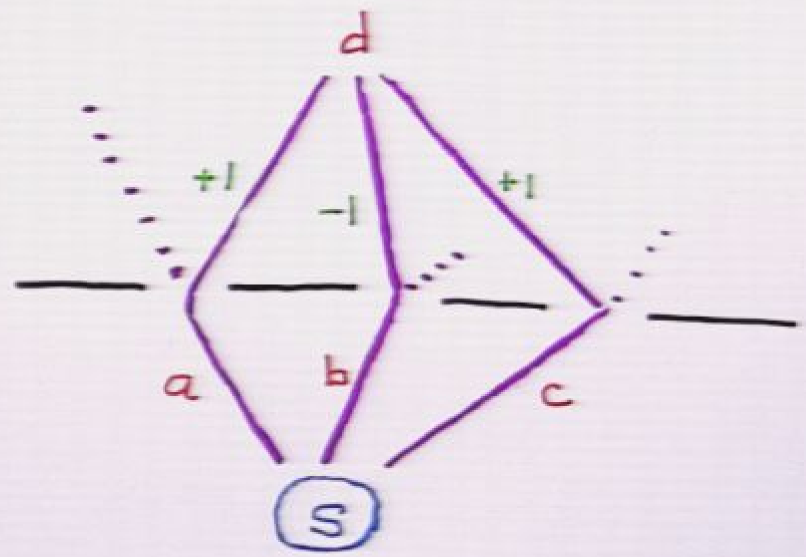

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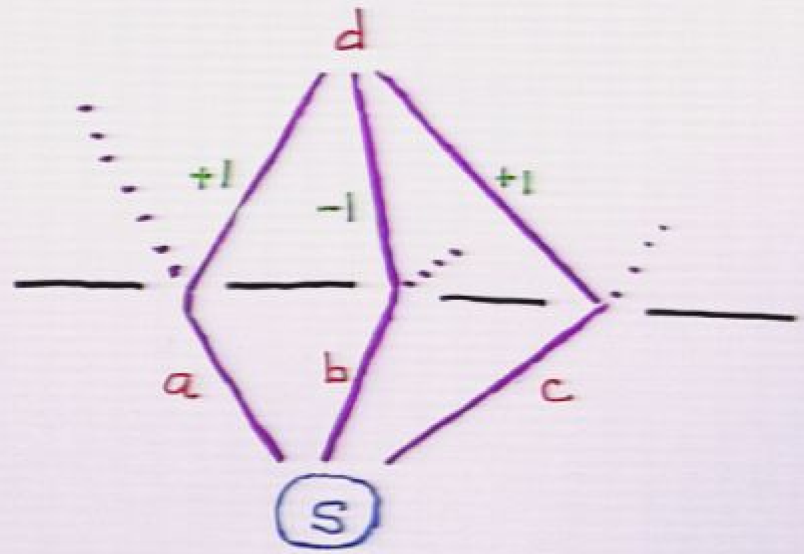

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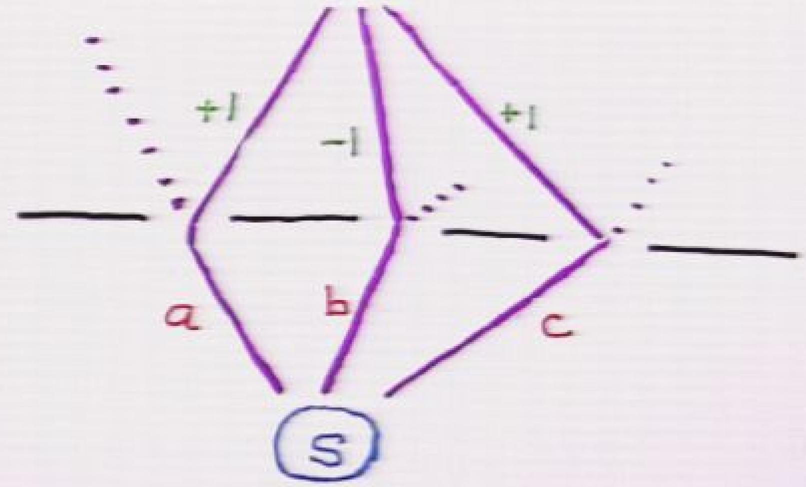

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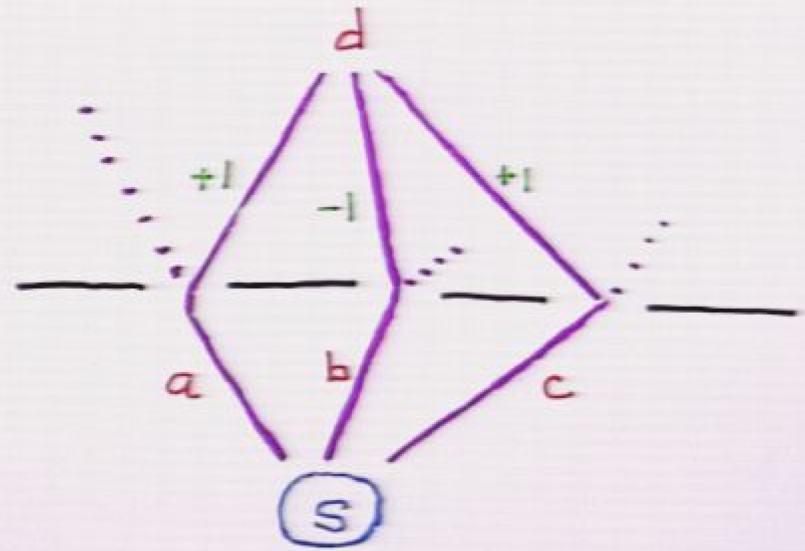

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Let us retain preclusion unchanged

Logical inference (deduction) is special case of dynamics
(Kepler's laws to forecast eclipses)
(logic concerns events, not strings of words)

Logic has been "ossified" like geometry was. Should bring it into physics

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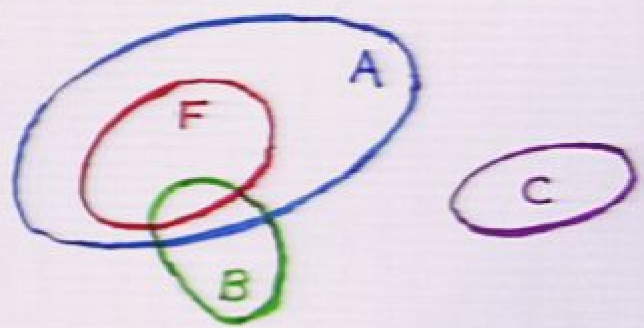

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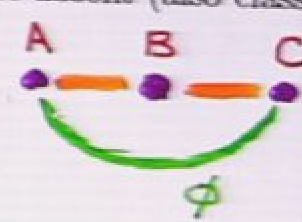

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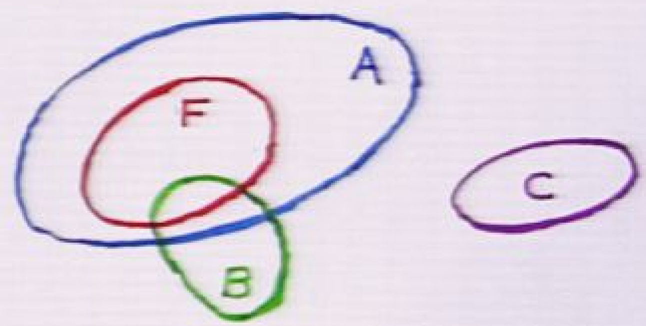

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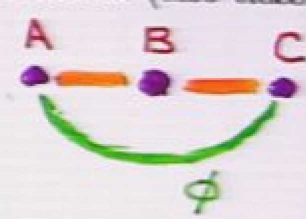

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Let us retain preclusion unchanged

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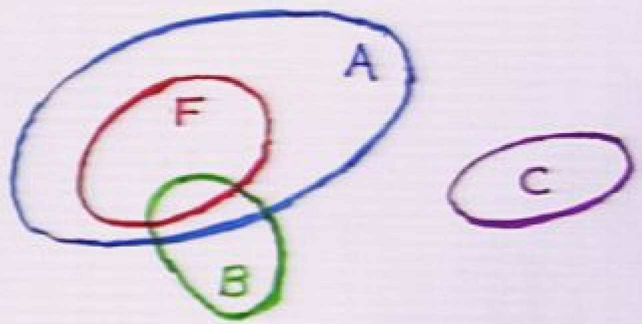

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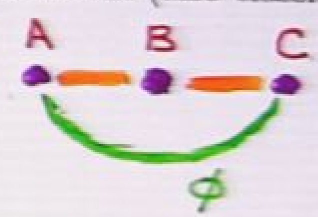

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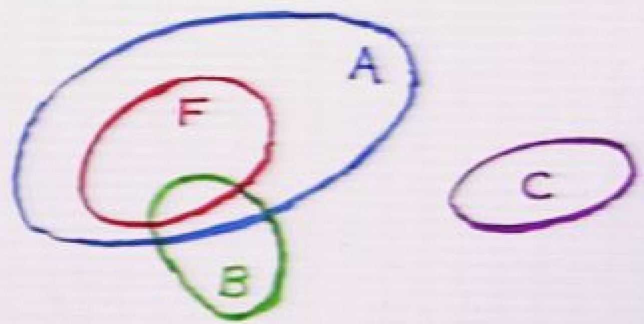

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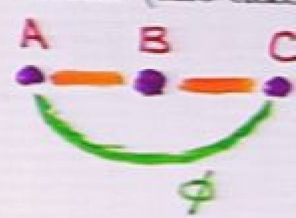

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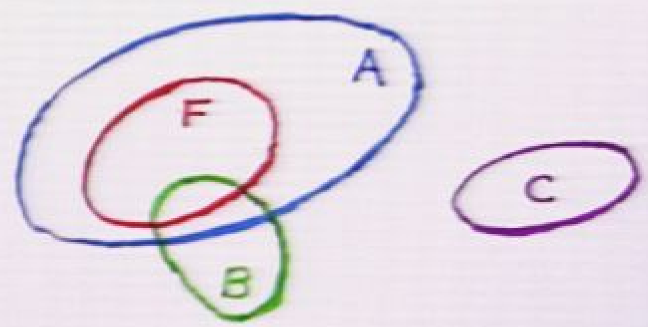

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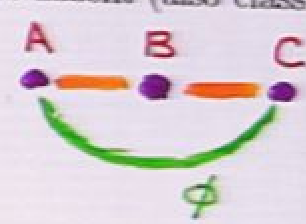

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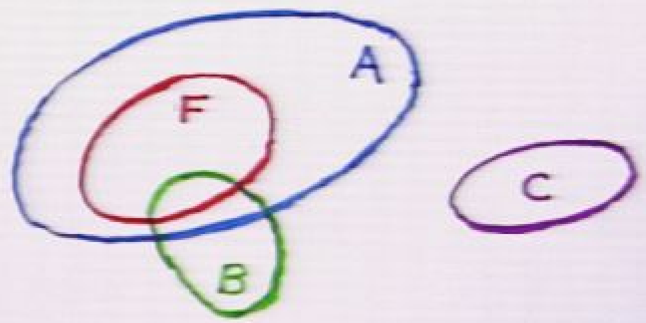

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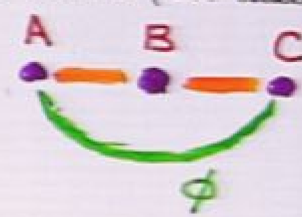

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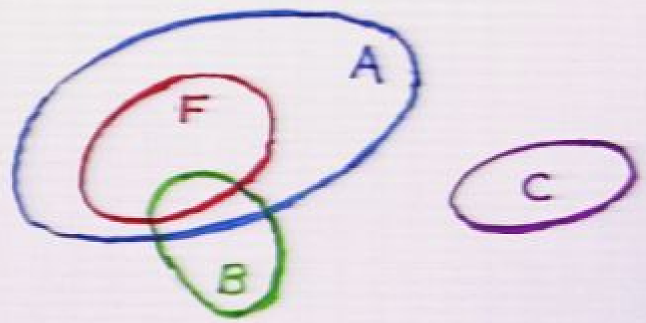

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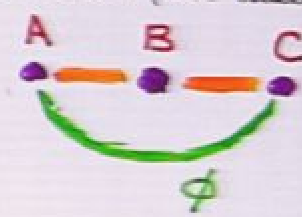

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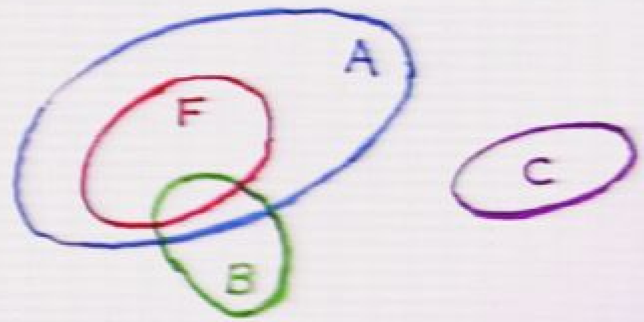

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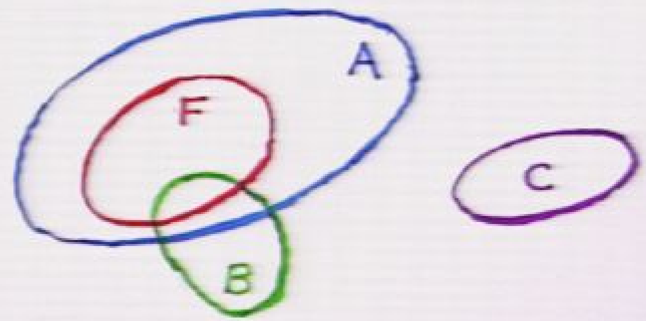

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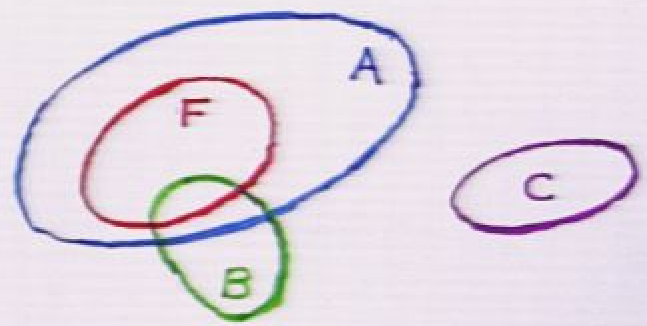

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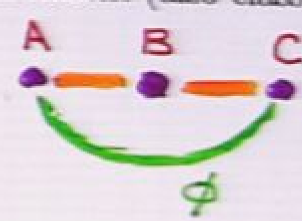

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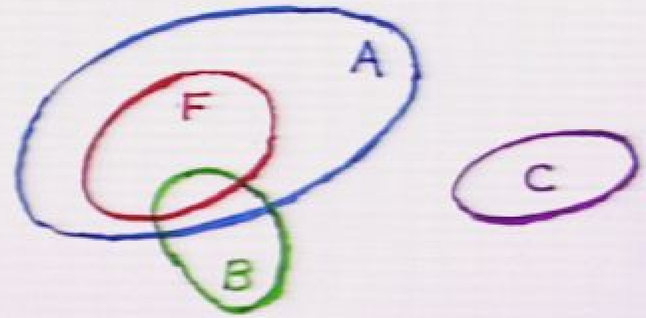

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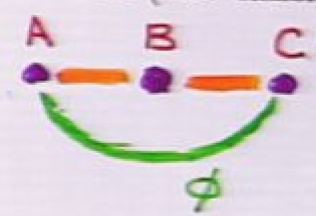

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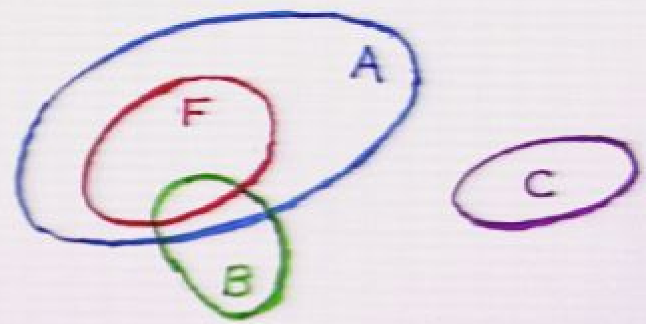

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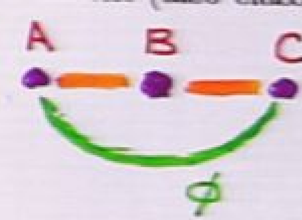

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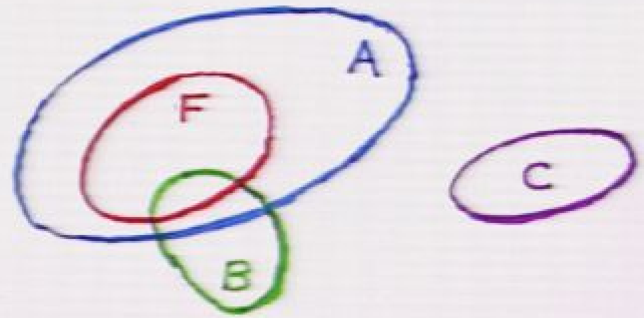

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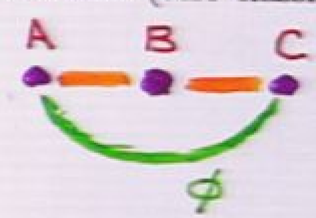

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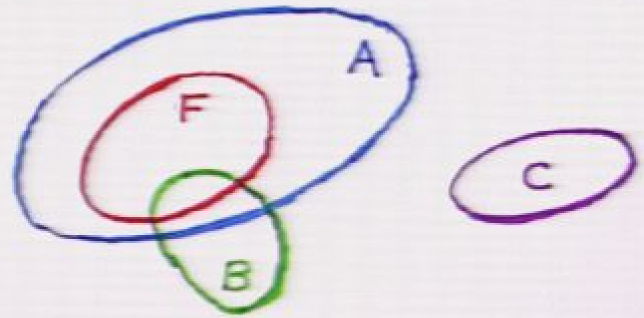

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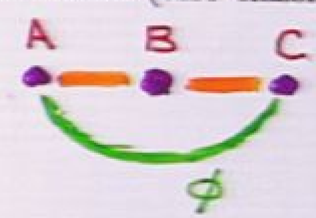

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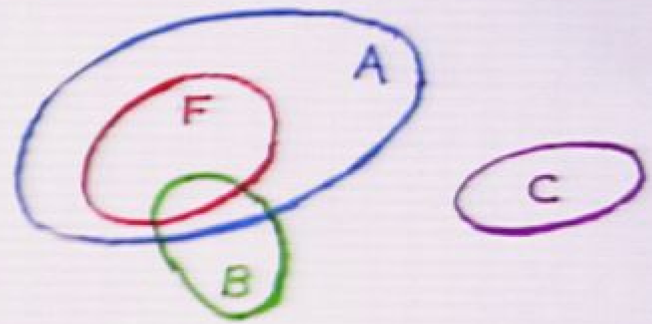

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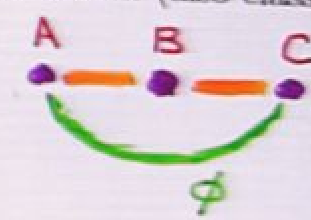

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Preclusive separability and "the Measurement Problem"

Coevents describe microscopic reality directly and anhomomorphic inference resolves the logical paradoxes of qm.

We hope it will light the way to QSG for causets.

Does it solve the measurement problem?

Yes if we can show that $\phi|\mathfrak{A}(instruments)$ must be classical.
(If classical logic governs macro-events then precisely one outcome occurs.)

THEOREM (in the Multiplicative Scheme)

Let ϕ be a PPC and let $\Omega = \Omega' + \Omega''$ be a partition such that

A is precluded iff its intersections with Ω' and Ω'' are both precluded.

Then support(ϕ) lies within either Ω' or Ω''

(the proof is not long)

Therefore either Ω' or Ω'' happens, but not both.

But are macroscopic events preclusively separable in this way?
A sufficient condition: No event in Ω' interferes with any event in Ω''
(a very strong type of "decoherence", closely related to idea of a record**)**
The following weaker condition suffices and I think is plausible.

If a subevent A of Ω' lies within any precluded event B

then it lies within a precluded subevent C of Ω'

The measurement problem "reduces to a calculation"

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> Let ϕ be a PPC and let $\Omega = \Omega' + \Omega''$ be a partition such that
>
> A is precluded iff its intersections with Ω' and Ω'' are both precluded.
>
> Then support(ϕ) lies within either Ω' or Ω''

(the proof is not long)

Therefore either Ω' or Ω'' happens, but not both.

But are macroscopic events preclusively separable in this way?
A sufficient condition: No event in Ω' interferes with any event in Ω''
(a very strong type of "decoherence", closely related to idea of a record)
The following weaker condition suffices and I think is plausible.

> If a subevent A of Ω' lies within any precluded event B
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> then it lies within a precluded subevent C of Ω'

The measurement problem "reduces to a calculation"

Preclusive separability and "the Measurement Problem"

Coevents describe microscopic reality directly and anhomomorphic inference resolves the logical paradoxes of qm.

We hope it will light the way to QSG for causets.

Does it solve the measurement problem?

Yes if we can show that $\phi|\mathfrak{A}(instruments)$ must be classical.
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Open questions and further work

Establish preclusive separability

Probability from Cournot (Kolmogorov etc)

Derivation of collapse rule from precl. sep.
(will be only approximate, but can we ever hope to observe violations?)

Extension to infinite Omega

Application to RC and thence to QSG

Premonitions

"Nirvana"

Product systems

6-analyzer extension of Hardy expt: determinism almost returns!
extend example further to make past sufficiently rich

Is this a hidden variable theory? (Joe Henson)

Relate to intuitionistic logic?

Relate to dialectics, paraconsistent logic (cf tetralemma)

What is $\widehat{\mathfrak{A}}$ for simple quantum systems? (eg Bohm particle in excited eigenstate just sits still! does it also sit still in MSk? Now we can ask this question!)

Express dynamics directly in terms of coevents, bypassing preclusion, measure?

Worries include: "nirvana", product systems, premonitions, ...