Title: Do black holes create polyamory

Date: Aug 17, 2015 05:00 PM

URL: http://pirsa.org/15080063

Abstract: Of course not, but if one believes that information cannot be destroyed in a theory of quantum gravity, then we run into apparent contradictions with quantum theory when we consider evaporating black holes. Namely that the no-cloning theorem or the principle of entanglement monogamy is violated. Here, we show that neither violation need hold, since, in arguing that black holes lead to cloning or non-monogamy, one needs to assume a tensor product structure between two points in space-time that could instead be viewed as causally connected. In the latter case, one is violating the semi-classical causal structure of space, which is a strictly weaker implication than cloning or non-monogamy. We show that the lack of monogamy that can emerge in evaporating space times is one that is allowed in quantum mechanics, and is very naturally related to a lack of monogamy of correlations of outputs of measurements performed at subsequent instances of time of a single system. A particular example of this is the Horowitz-Maldacena proposal, and we argue that it needn't lead to cloning or violations of entanglement monogamy. In the case of the AMPS firewall experiment we find that the entanglement structure is modified, and one must have entanglement between the infalling Hawking partners and early time outgoing Hawking radiation which surprisingly tame violation of entanglement monogamy. http://arxiv.org/abs/1506.07133

Do Black Holes Create Polyamory?

1506.07133 Grudka et al

1401.1523 (JHEP) An alternative Amps experiment w/ B. Unruh

0902.2361 (ask for v2) Fundamental information Destruction w/ B. Reznik

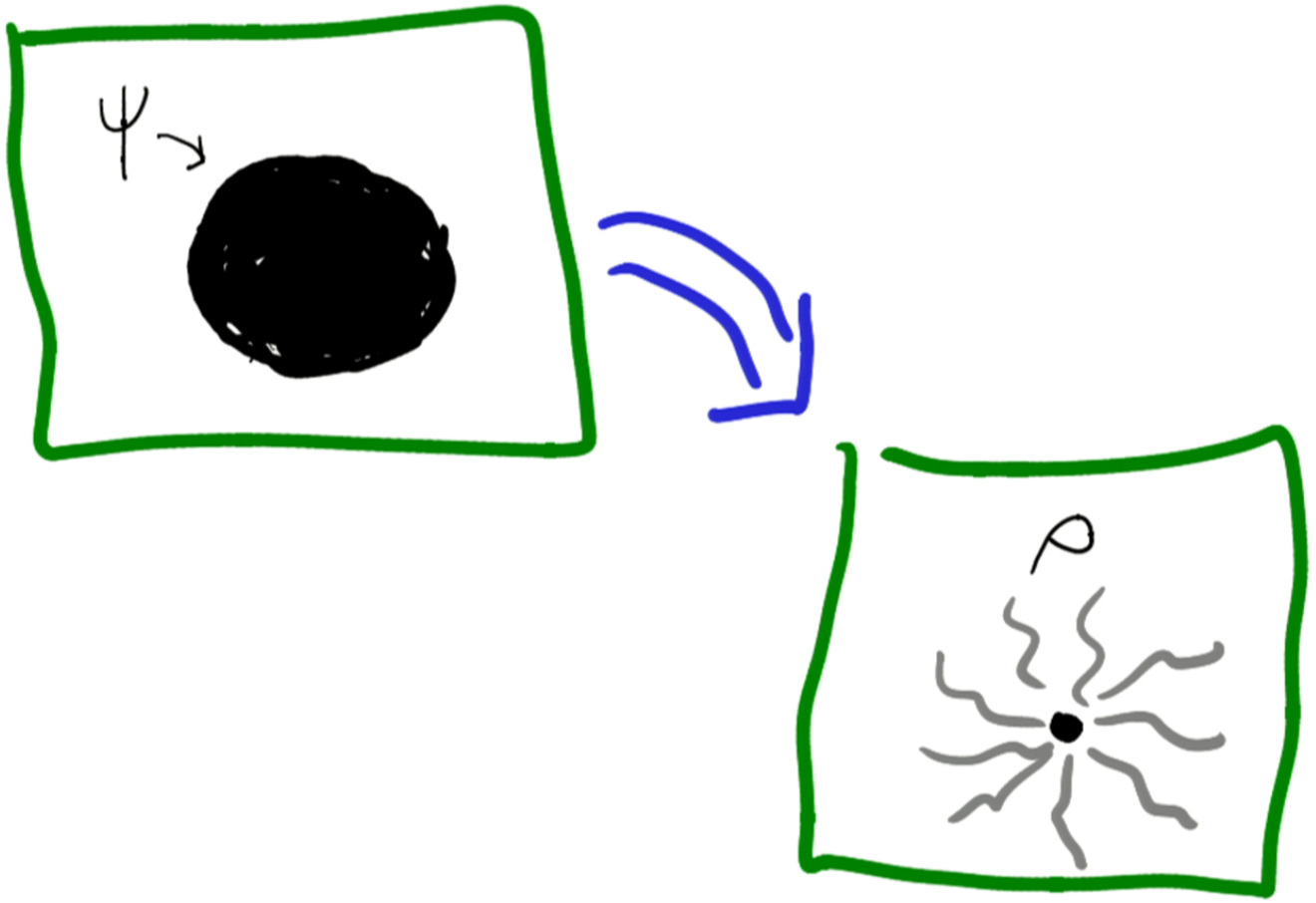
J. Oppenheim (University College London)

Of Course Not!

- Black hole information problem v1 (Hawking)
- Black hole information problem v2
  Black holes destroy information, create polyamorous entanglement, or have firewalls

But we can choose v1 or v2

Polyamory "in time"
eg "black hole fine state"
Horowitz-Maldecana (2003)
Lloyd Preskill (2013)



Black hole info loss v1.0

Quantum Information meets Quantum Gravity

- no cloning!

- entanglement is monogamous

$$|\psi^-\rangle_{AB} = \frac{1}{\sqrt{2}}\left[|\uparrow\downarrow\rangle - |\downarrow\uparrow\rangle\right]_{AB}$$

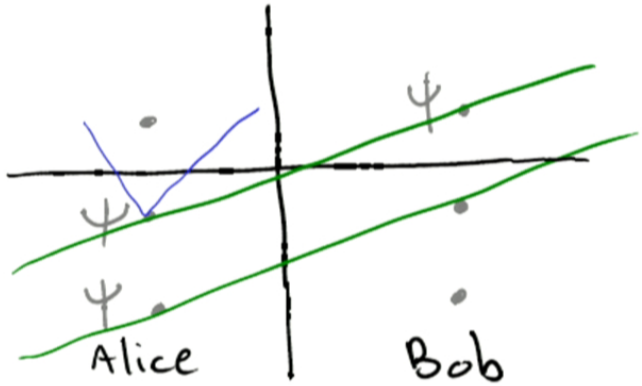
correlated pure

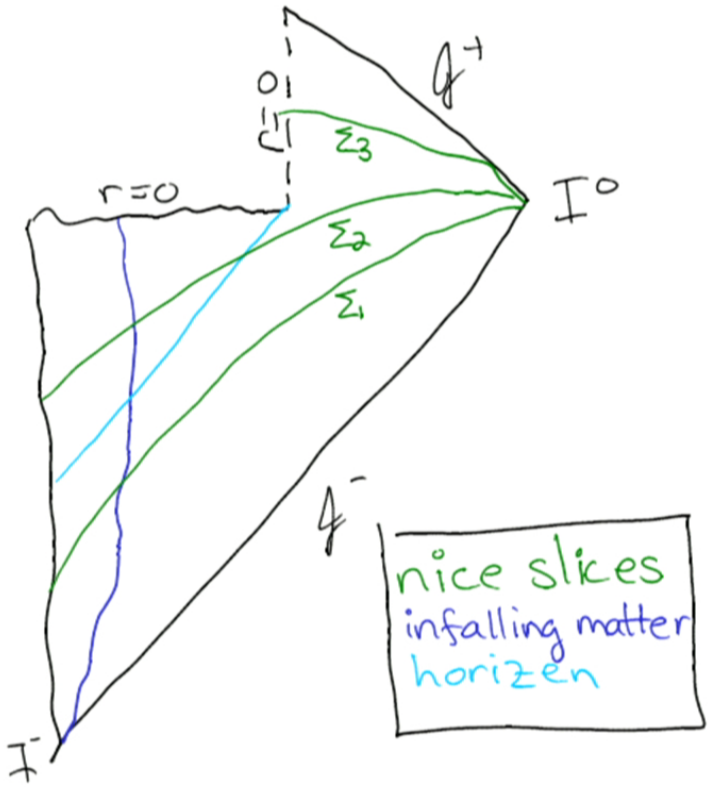
$$|\psi\rangle_{ABE} = |\psi^-\rangle_{AB}|0\rangle_E$$

$$\sigma_{classical} = \frac{1}{2}|\uparrow\uparrow\rangle\langle\uparrow\uparrow|_{AB} + \frac{1}{2}|\downarrow\downarrow\rangle\langle\downarrow\downarrow|_{AB}$$

$$\sigma_{ABE} = \frac{1}{2}|\uparrow\uparrow\uparrow\rangle\langle\uparrow\uparrow\uparrow|_{ABE} + \frac{1}{2}|\downarrow\downarrow\downarrow\rangle\langle\downarrow\downarrow\downarrow|_{ABE}$$

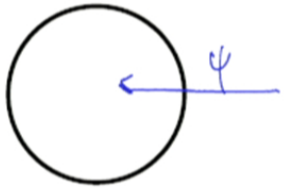
Either information is destroyed in which case, the evolution is non-unitary, or information comes out, in which case it is "cloned", and the evolution must be non-unitary.



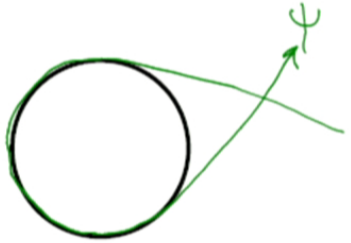


Black hole complementarity

One way out is to reject the idea that there exists a simultanious description of the inside and outside of the black hole.



infalling observer



outside observer

there is only a contradiction if the outside observer can collect the outgoing radiation to recover ψ and then jump into the black hole to get ψ

Black hole information problem v2

AMPS: Almheiri, Marolf, Polchinski, Sully

or modification due to J.O., Unruh (2014)

evading Harlow-Hayden obstruction

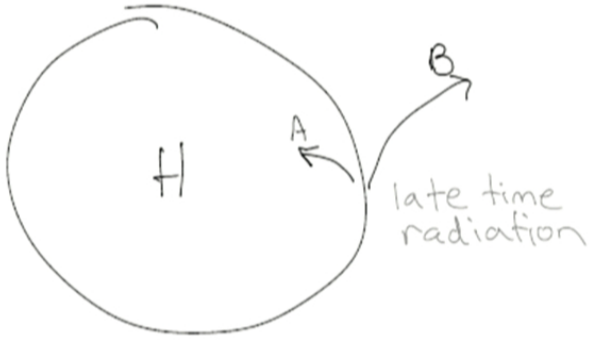
1) $|\Psi\rangle_H \otimes |0\rangle_R$

2) Ψ_{RH}

3) After the page time. each subsequent emitted photon B is entangled with R

BR entaingled (unitarity)

but BA entangled (Hawking pair-creation)

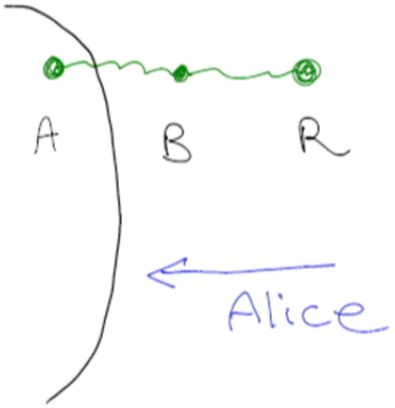


R

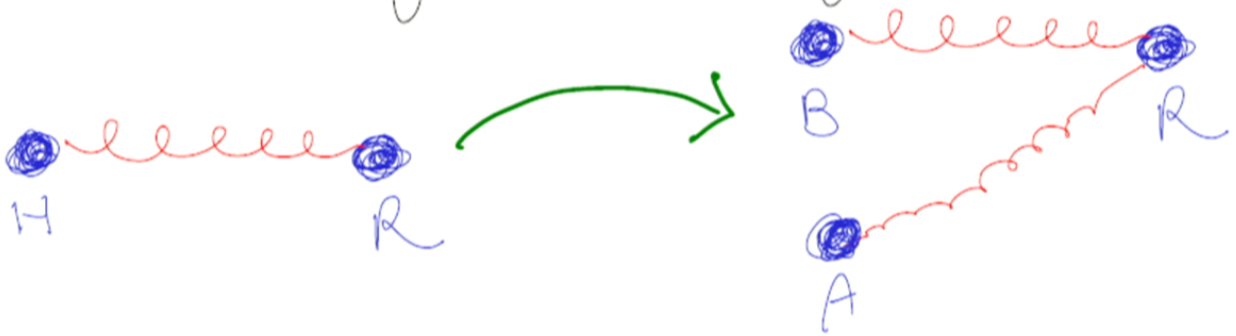
early radiation

Ψ_{BR} max. entangled

Ψ_{BA} max. entangled



Cloning → Polyamory



→ tachyons

complementarity can't save us

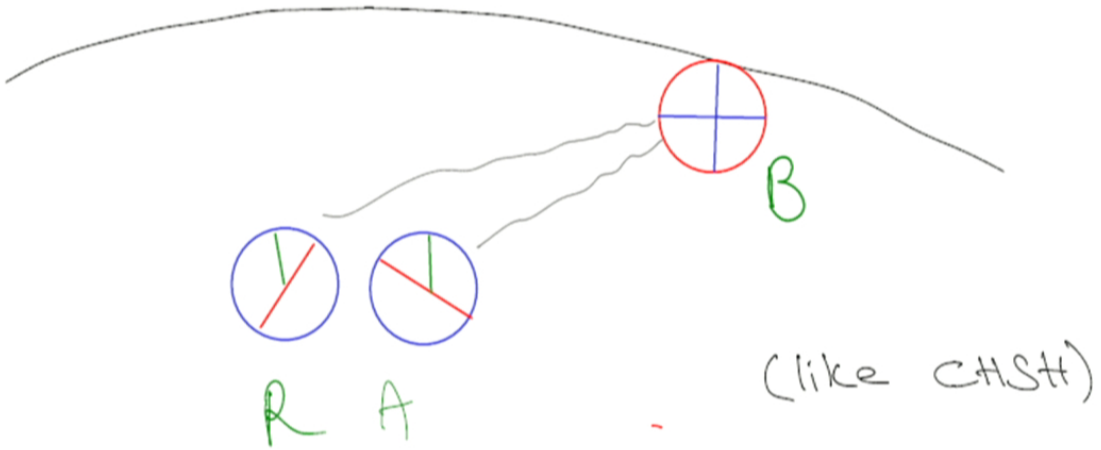
1) Non-monogamy implies info. destruction

a) Non-monogamy implies superluminal signals

b) Super luminal signals implies C.T.C.'s

c) CTC's imply info. destruction

a)



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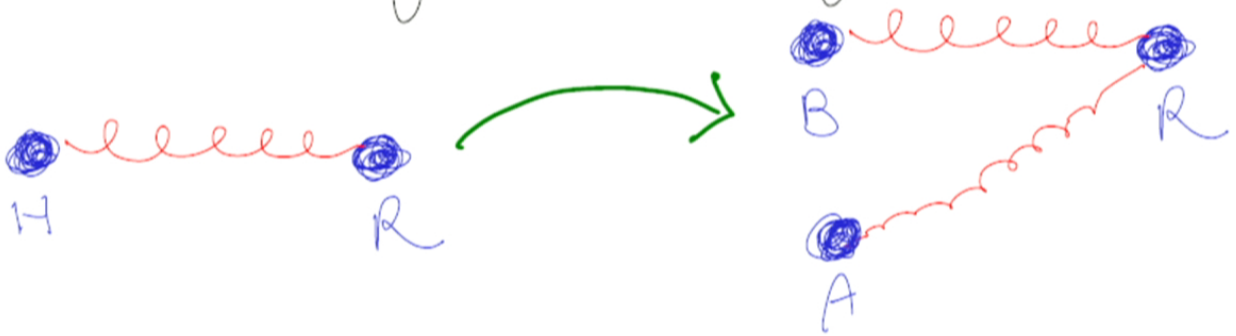

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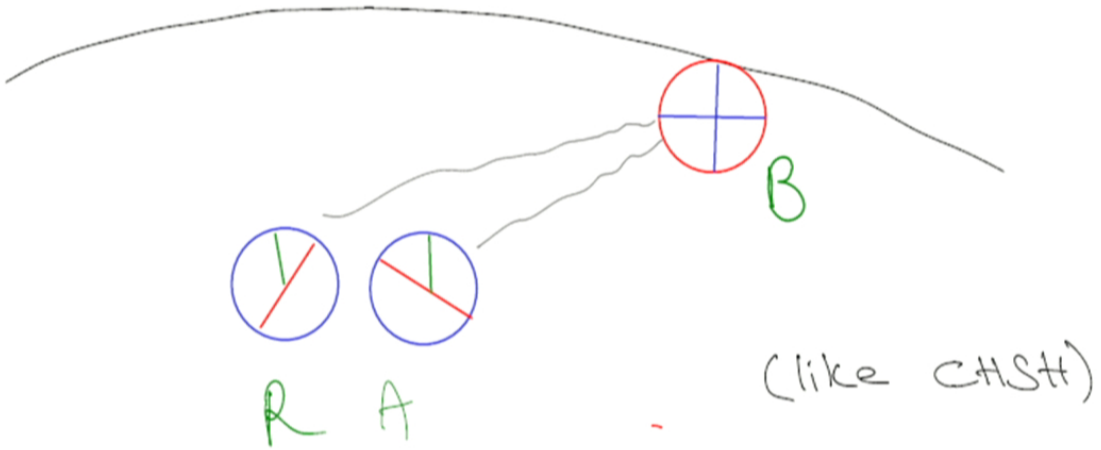
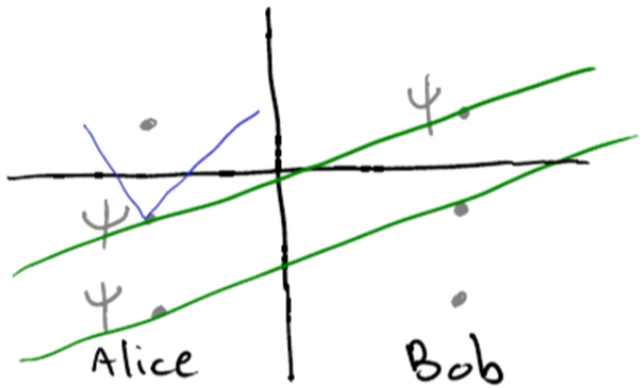
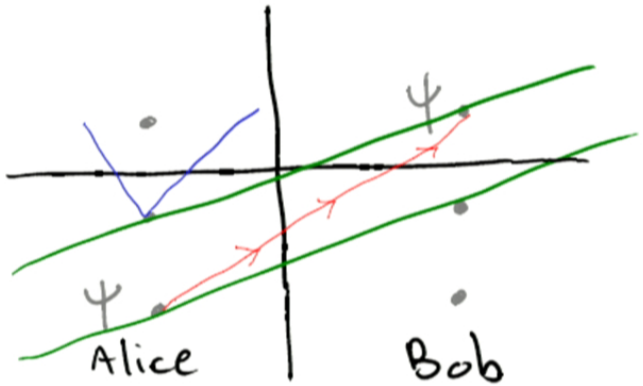


Unitarity → polyamory → non-unitarity
acausality

But is it polyamory?

polyamory in space vs polyamory in time





$\Psi \otimes \Psi$

tensor product

$\Psi(t_0) \to \Psi(t_1)$

temporal product

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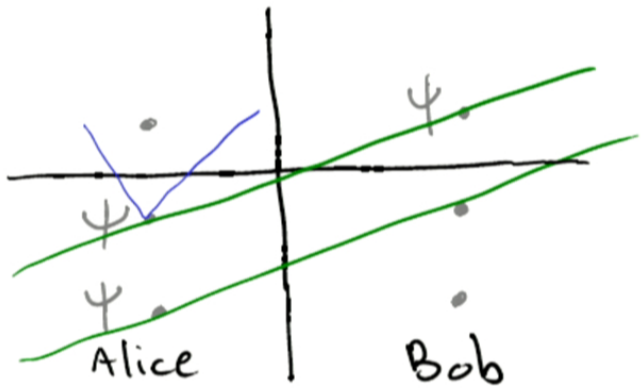
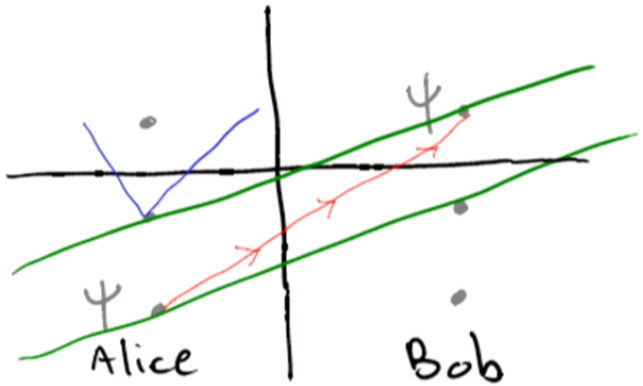




$\Psi \otimes \Psi$

tensor product

$\Psi(t_0) \to \Psi(t_1)$

temporal product

Entanglement in space $|\Psi\rangle_{AB} = \frac{1}{\sqrt{2}}\left[|\uparrow\downarrow\rangle - |\downarrow\uparrow\rangle\right]_{AB}$

measuring A prepares state on B

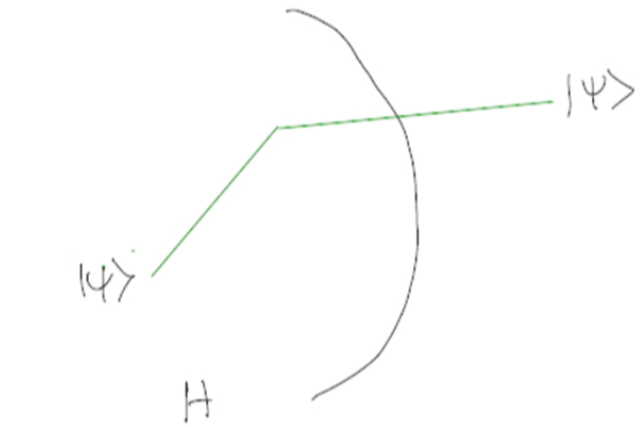
Entanglement in time $\rho(t_0) = \frac{\mathbb{1}}{2}$

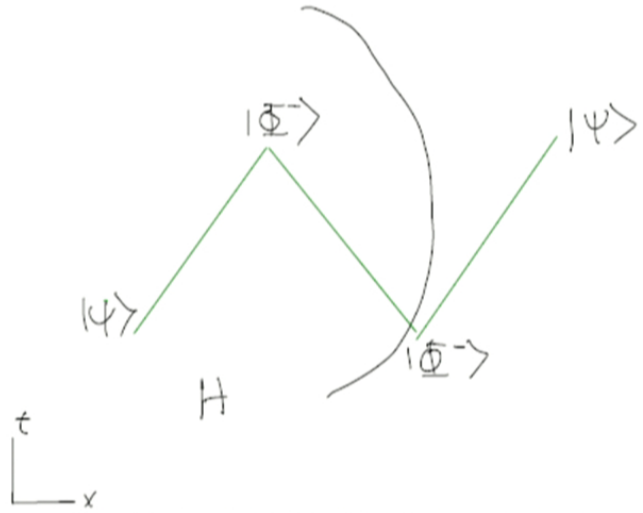
"Bell inequality in time"

Horowitz-Maldacena

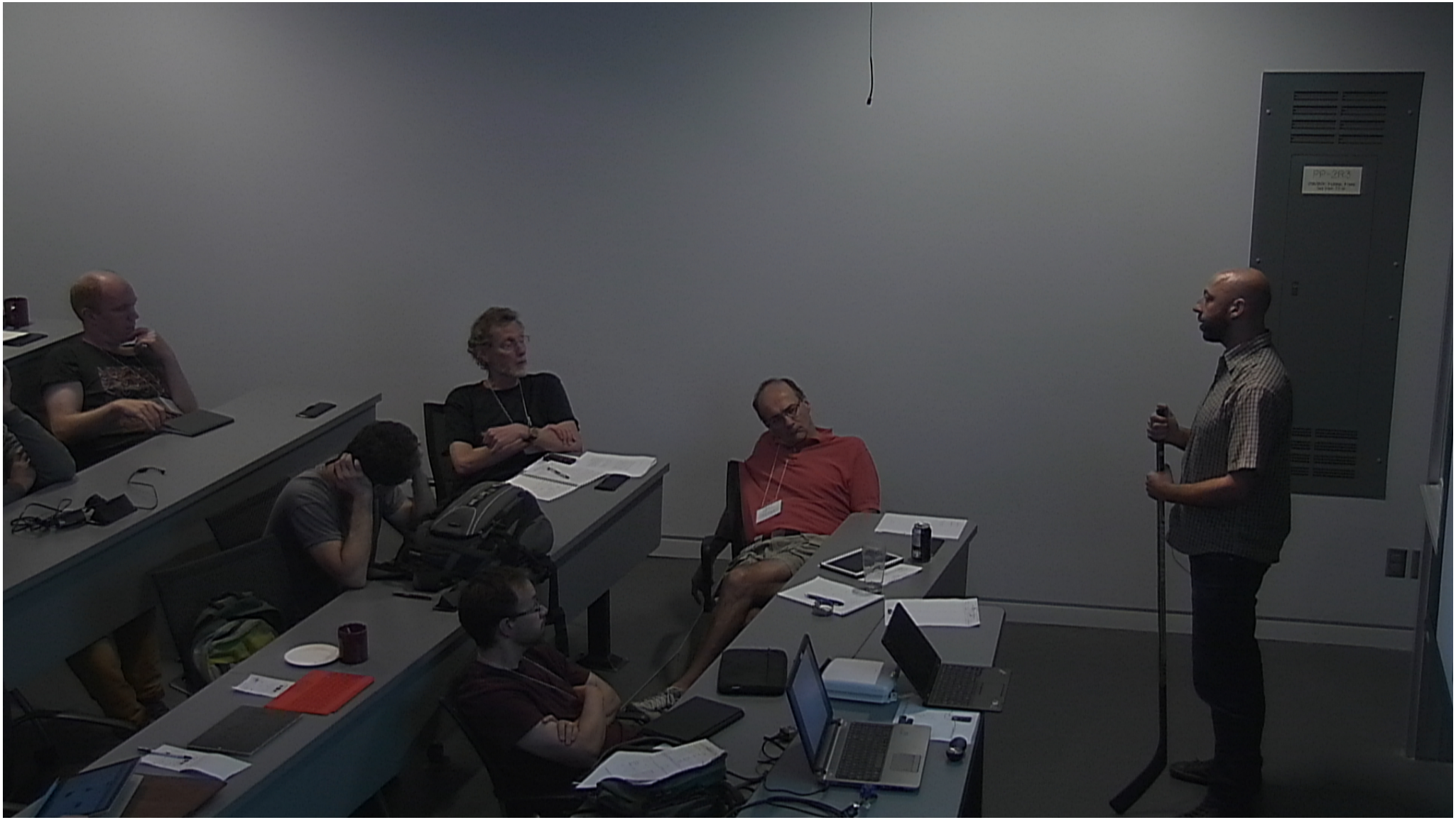
teleportation: $|\Psi\rangle_H \otimes |\Phi^-\rangle_{AB} = \frac{1}{2}|\Phi^-\rangle_{HA}|\Psi\rangle_B + \frac{1}{2}|\Phi^+\rangle Z|\Psi\rangle + \frac{1}{2}|\Psi^+\rangle X Z|\Psi\rangle + \frac{1}{2}|\Psi^-\rangle X|\Psi\rangle$

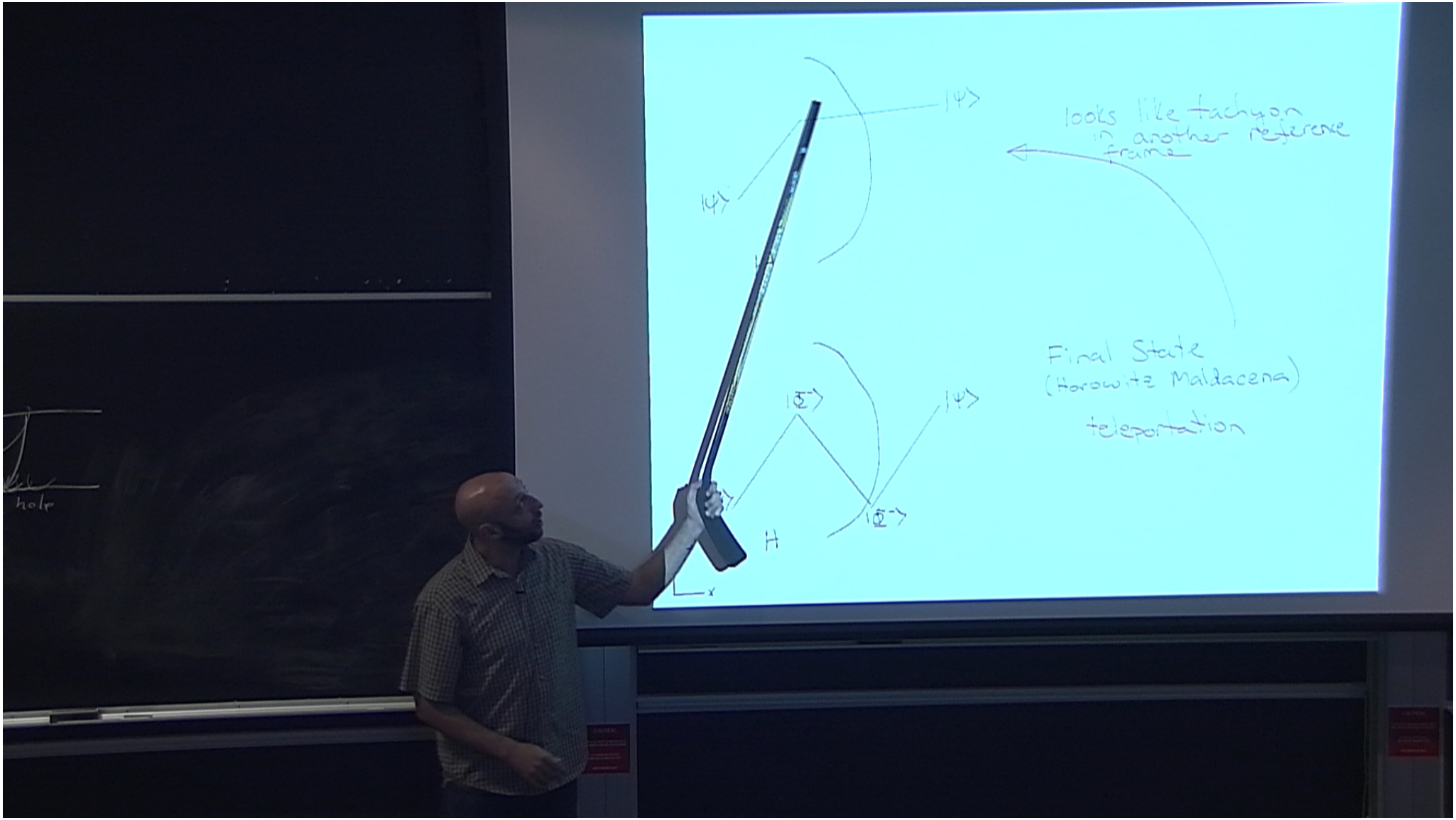
ABL rule

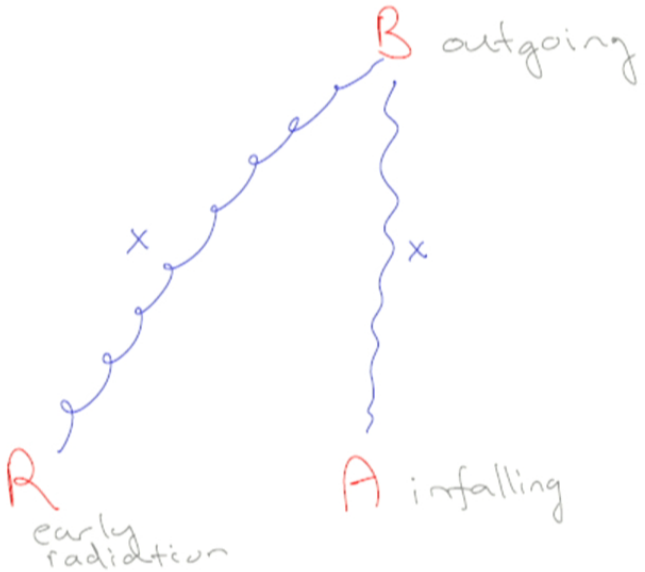


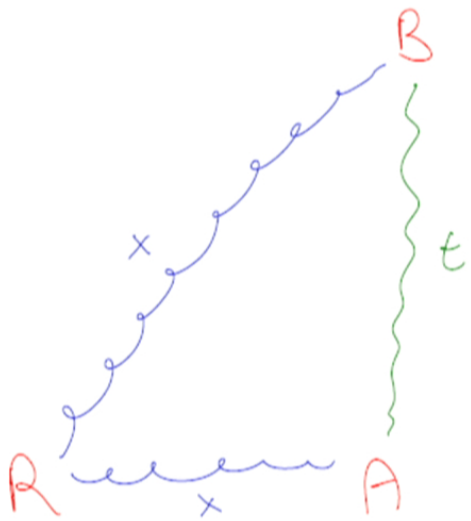


Final State
(Horowitz Maldacena)




looks like tachyon in another reference frame
Final State
(Horowitz Maldacena)
teleportation





AMPS

Final state

polygamy vs polyamoury

Conclusion

choose one of:

a) information destruction

b) tensor product → polyamory → causality breakdown

c) temporal product → breakdown of semiclassical causal structure

d) something else.

2) final state = tachyon (reference frame)

3) fine tuning of interactions