

Do Black Holes Create Polyamory?

1506.07133 Grudka et al

1401.1523
(JHEP)

An alternative Amps experiment
w/ B. Unruh

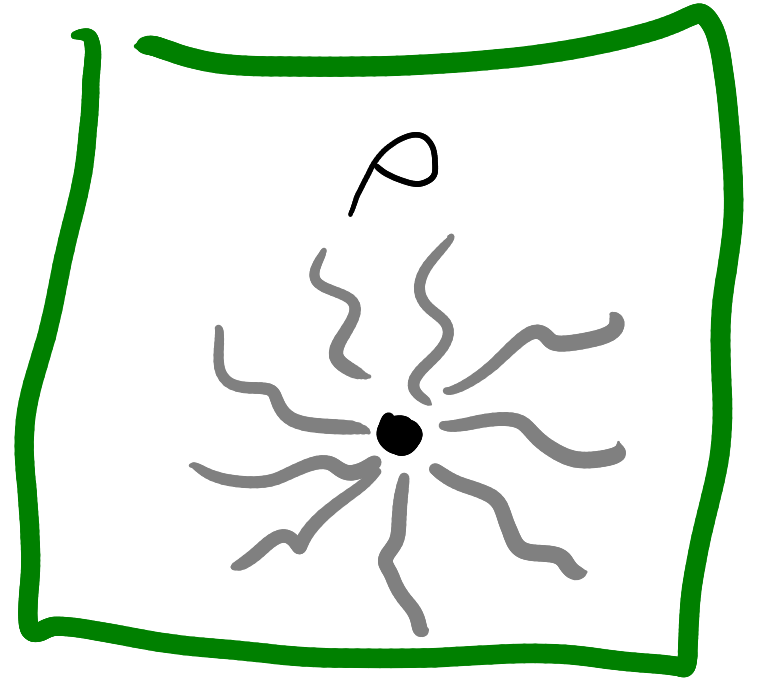
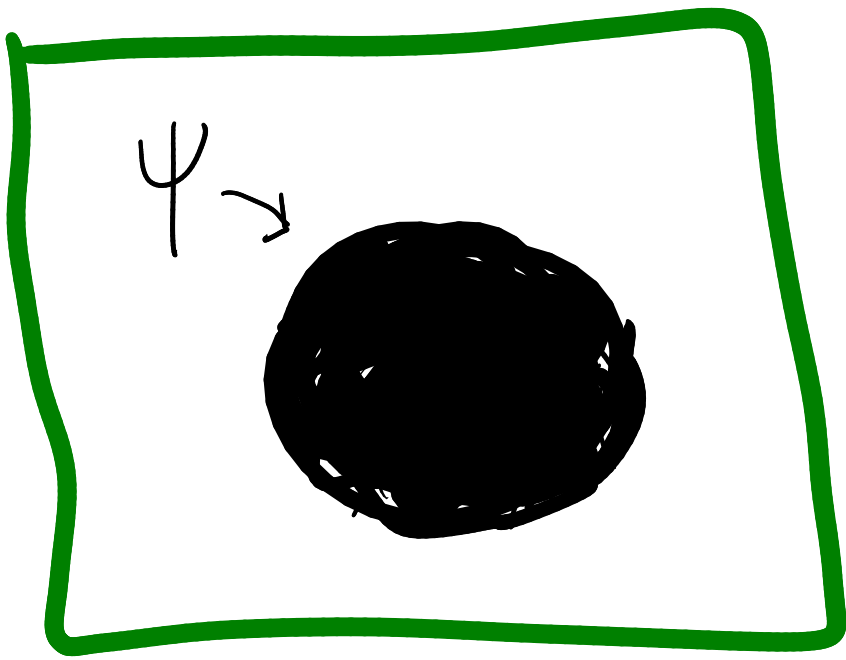
0902.2361
(ask for v2)

Fundamental information
Destruction w/ B. Reznik

J. Oppenheim (University College London)

Of Course Not!

- Black hole information problem v2
- Monogamy
- Black holes destroy information or create polyamory
- But we can choose it to be Polyamory "in time"



Black hole info loss v1.0

Quantum Information meets Quantum Gravity

• no cloning!

$$\langle \text{no cloning!} \rangle \quad |\psi\rangle|0\rangle \rightarrow |\psi\rangle|\psi\rangle$$

• entanglement is monogamous

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

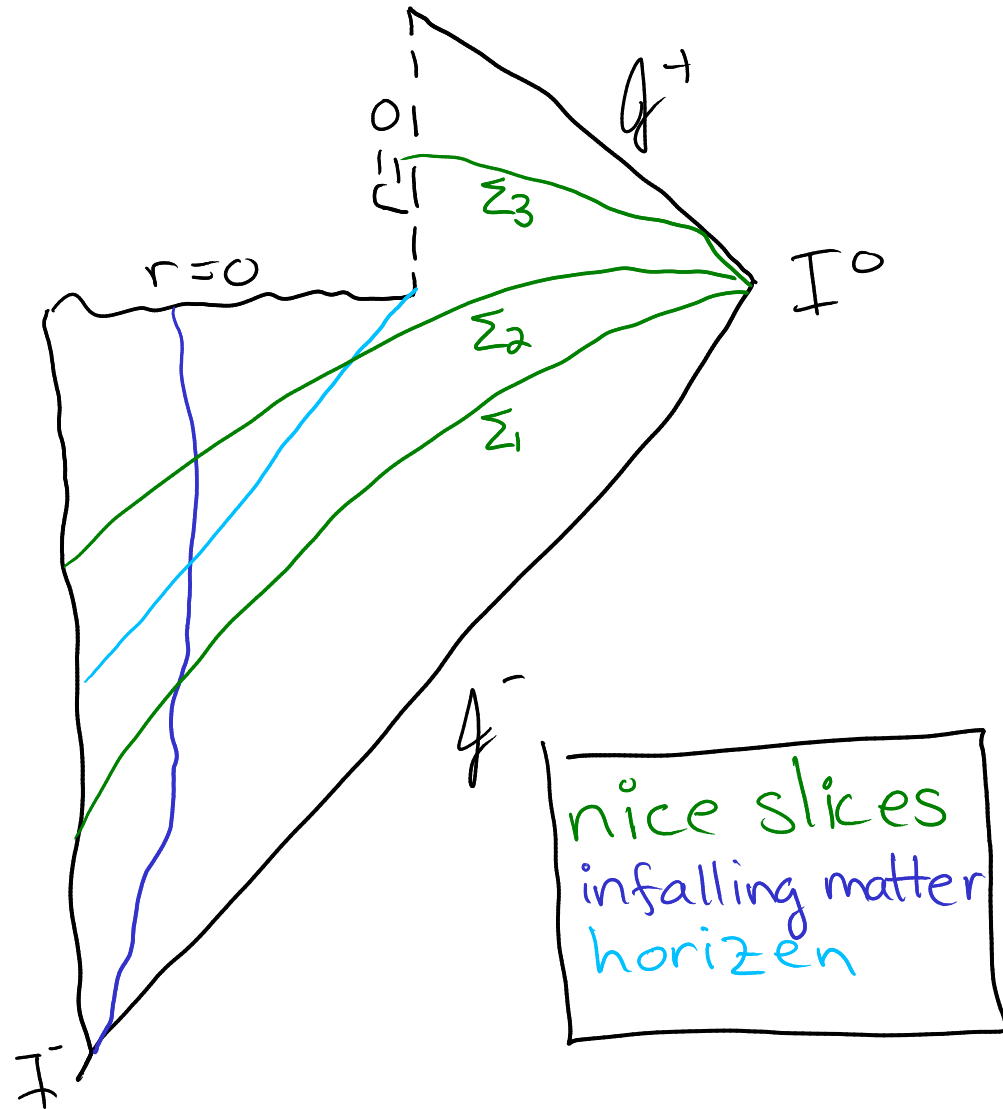
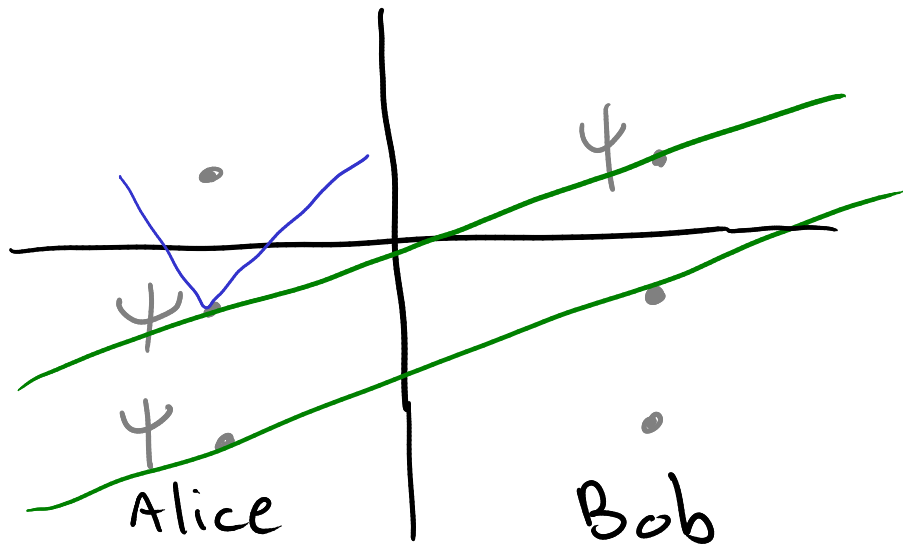
correlated
pure

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

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

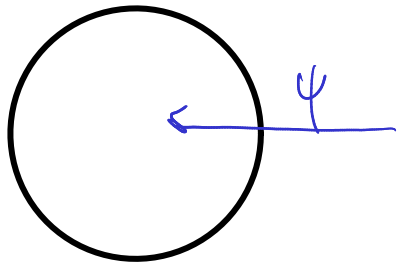
$$\sigma_{ABE} = \frac{1}{2} |\uparrow\uparrow\uparrow\rangle \langle\uparrow\uparrow\uparrow|_{ABE} + \frac{1}{2} |\downarrow\downarrow\downarrow\rangle \langle\downarrow\downarrow\downarrow|_{ABE}$$

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.

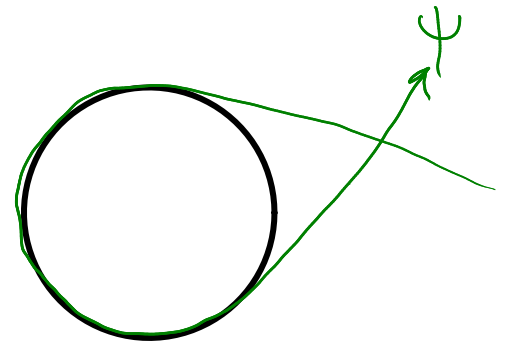


Black hole complementarity

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



infalling observer

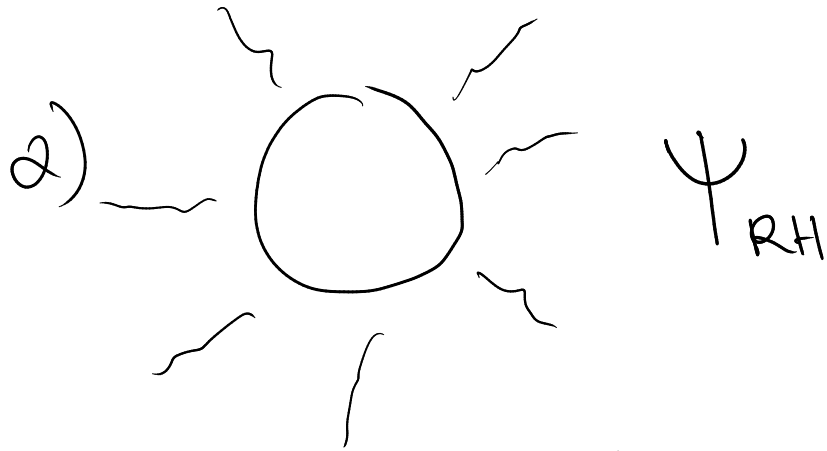
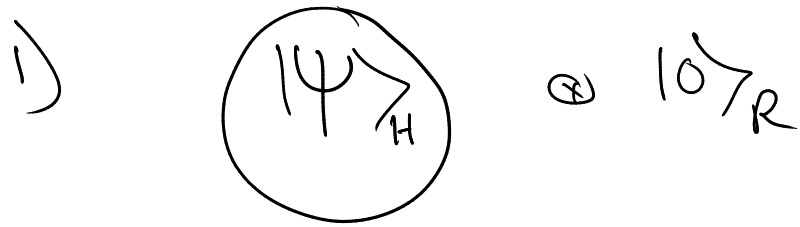


outside observer

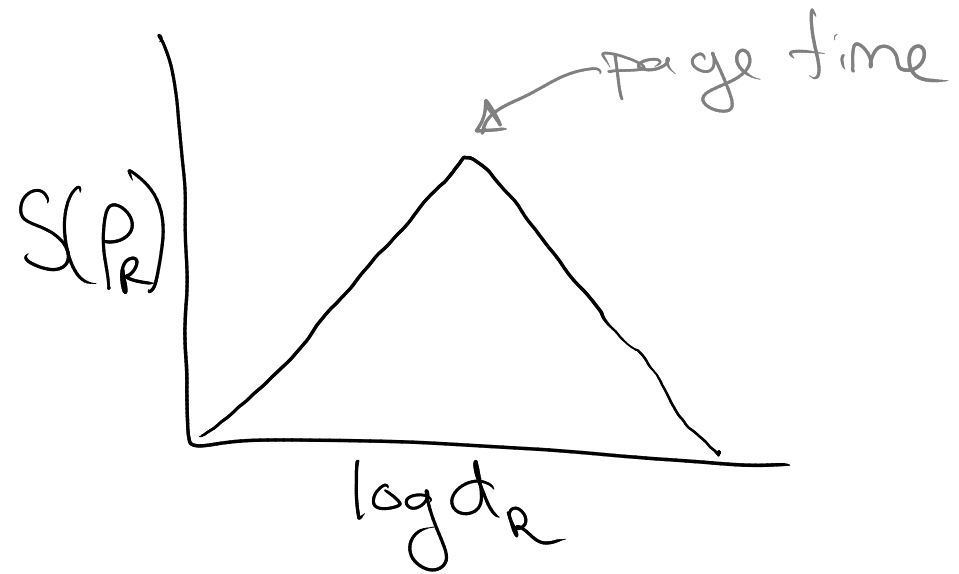
there is only a contradiction if the outside observer can collect the outgoing radiation to recover ψ and then jump into the black hole to get ψ

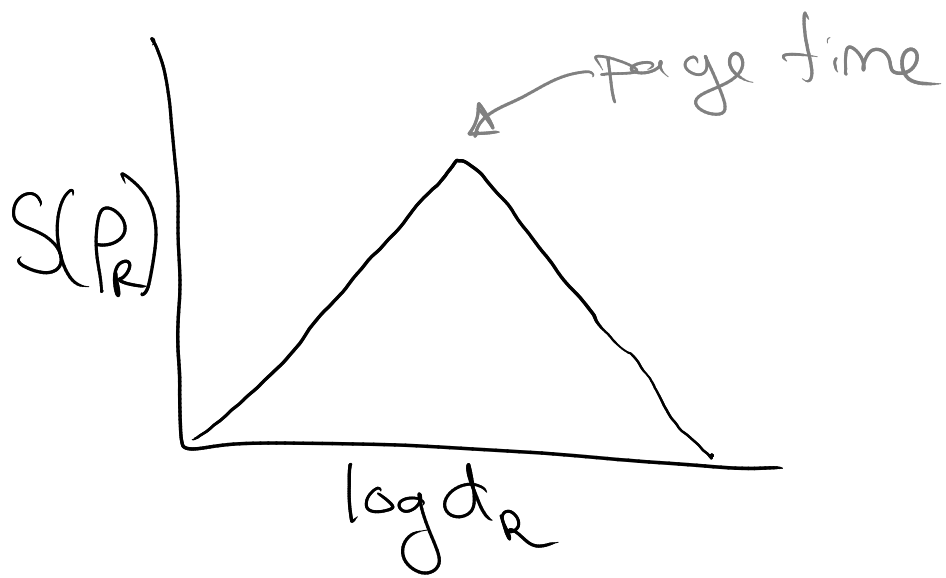
Black hole information problem v2

AMPS: Almheiri, Marolf, Polchinski, Sully
or modification due to J.O., Unruh (2014)



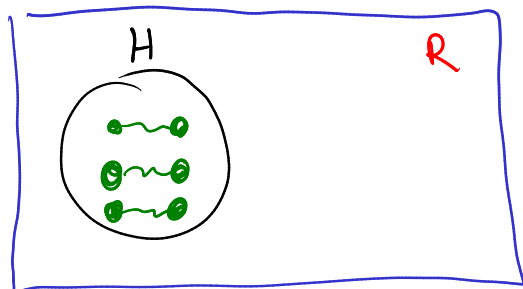
3) After the page time, each subsequent emitted photon B is entangled with R



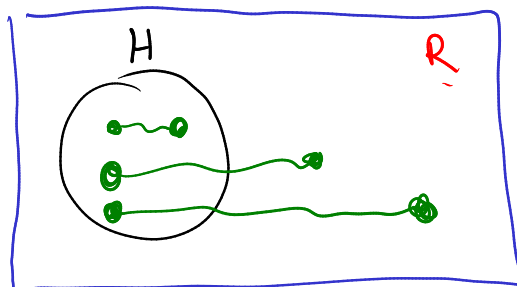


After which each late time photon is entangled with an early time one.

①

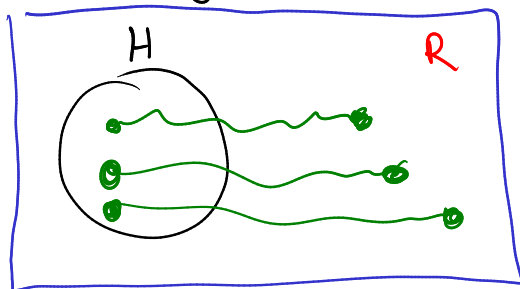


②

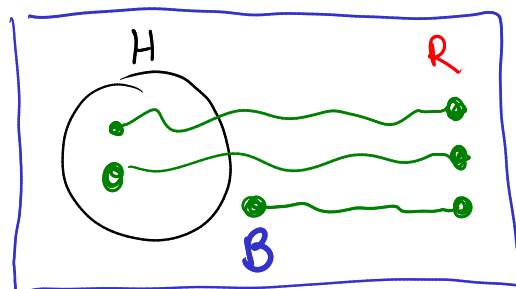


Page Time

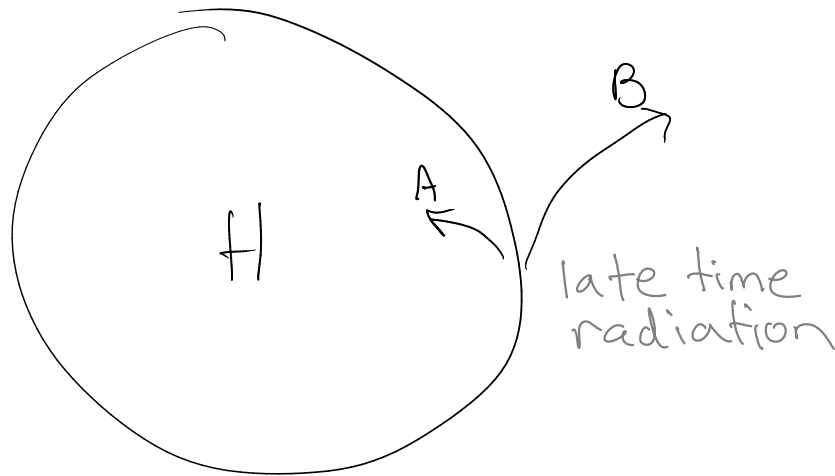
③



④



BR entangled (unitarity)
but BA entangled (Hawking pair-creation)



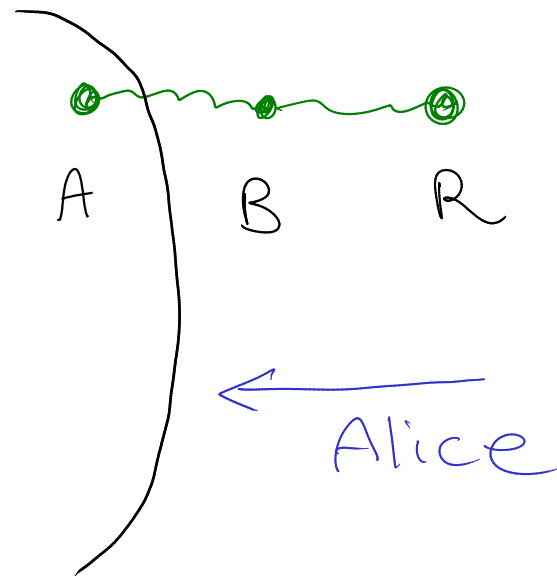
R
early
radiation

Ψ_{BR}

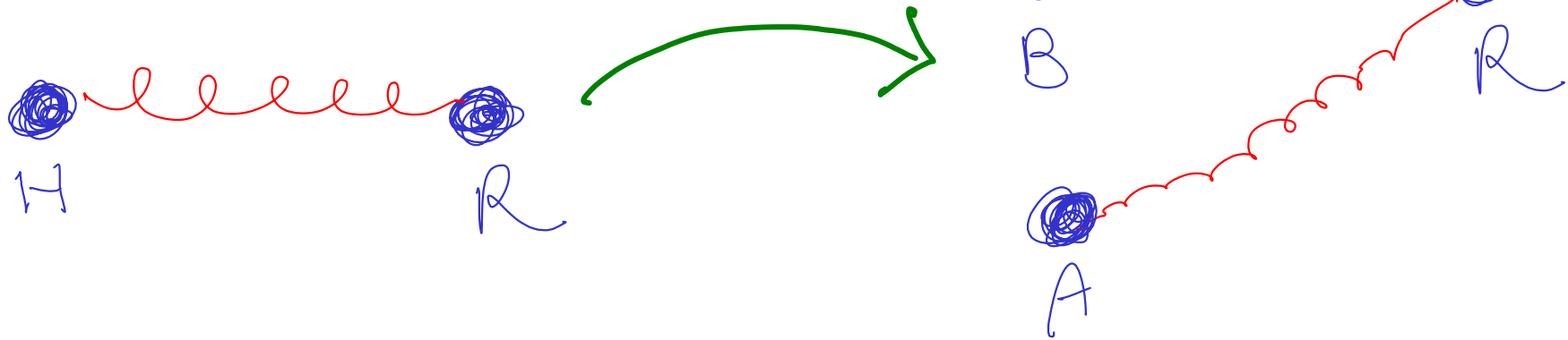
max. entangled

Ψ_{BA}

max. entangled



Cloning → Polyamory



→ tachyons

complementarity can't save us

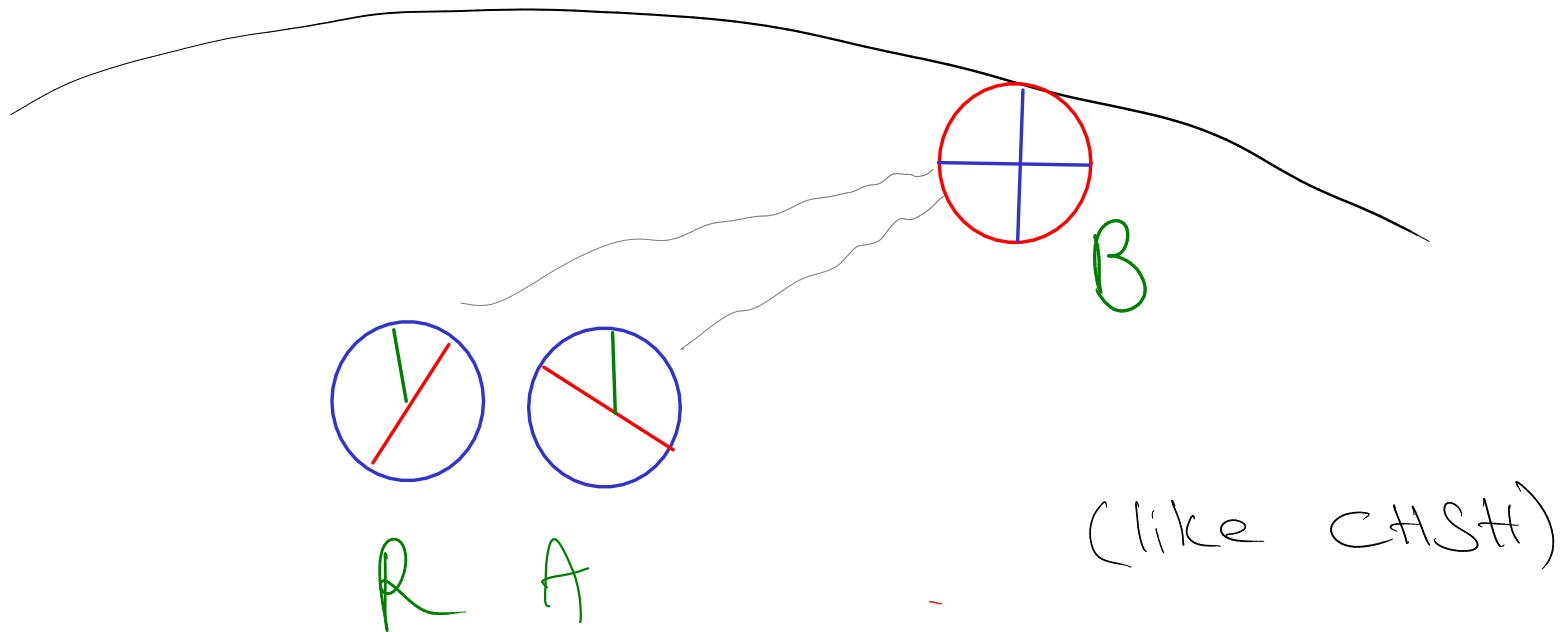
1) Non-monogamy implies info. destruction

a) Non-monogamy implies superluminal signals

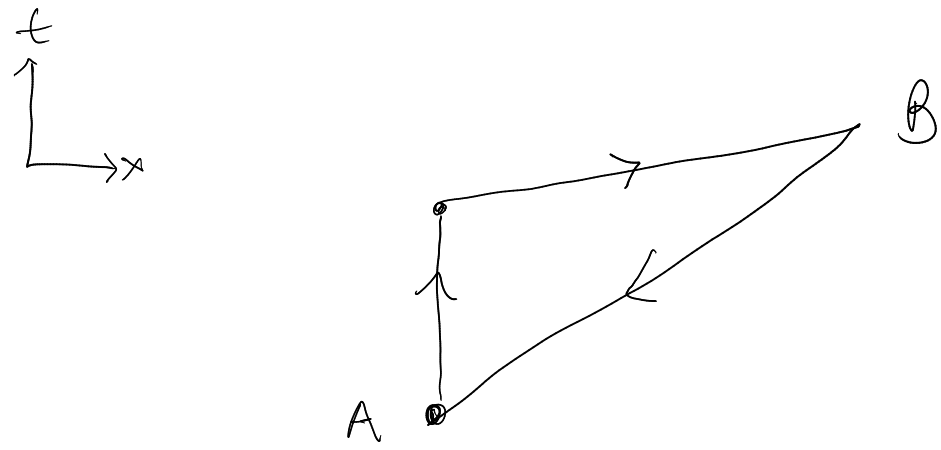
b) super luminal signals implies CTC's

c) CTC's imply info. destruction

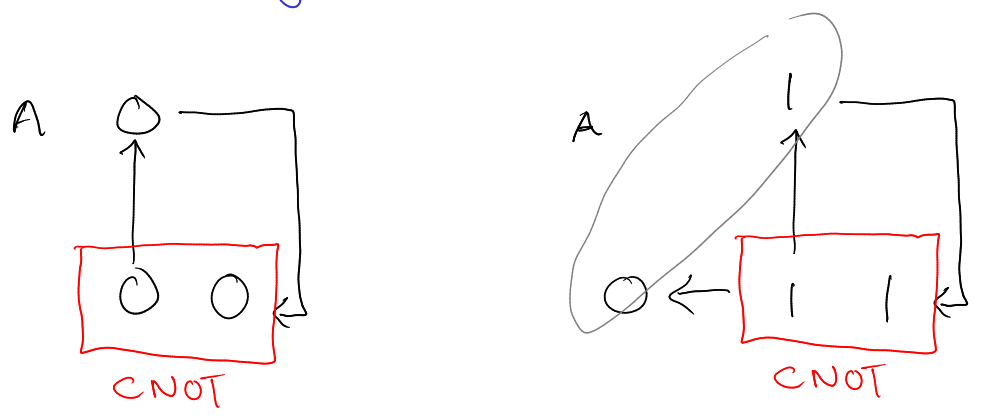
a)



b) Tolman telephone to your past



c) Cnot your past controlled on your future



$$\Phi_{RA} = \frac{1}{\sqrt{2}} [|00\rangle + |11\rangle]$$

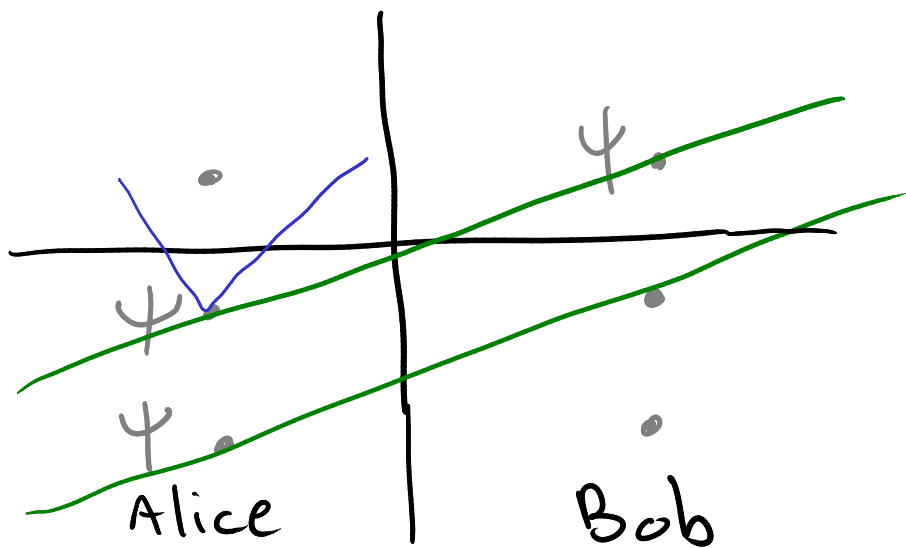
$$\rightarrow \frac{1}{2} \left[\begin{matrix} |0\rangle \\ R \end{matrix} \langle 0| + \begin{matrix} |1\rangle \\ R \end{matrix} \langle 1| \right] \otimes \begin{matrix} |0\rangle \\ A \end{matrix} \langle 0|$$

pure go to mixed

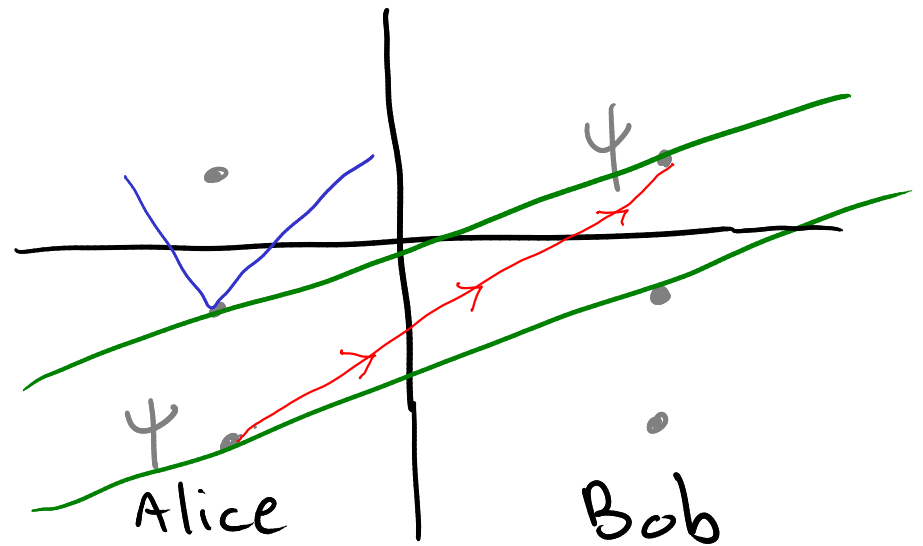
Unitarity \rightarrow polyamory \rightarrow non-unitarity
acausality

But is it polyamory?

polyamory in space vs polyamory in time



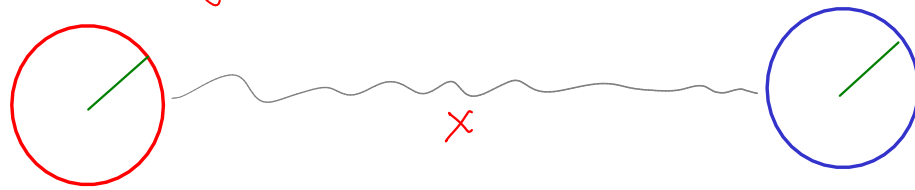
$\Psi \otimes \Psi$
tensor product



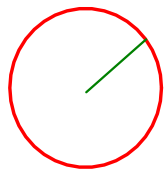
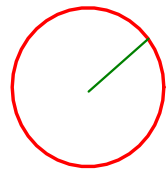
$\Psi(t_0) \rightarrow \Psi(t_1)$
temporal product

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

measuring A prepares state on B



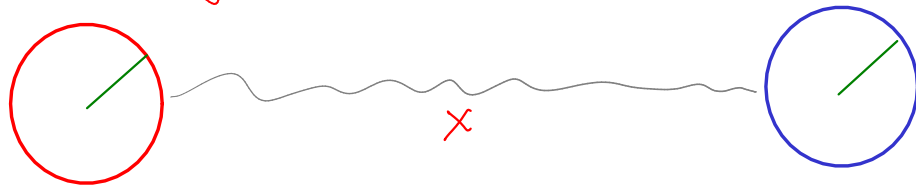
Entanglement in time $\rho(t_0) = \frac{1}{2}$



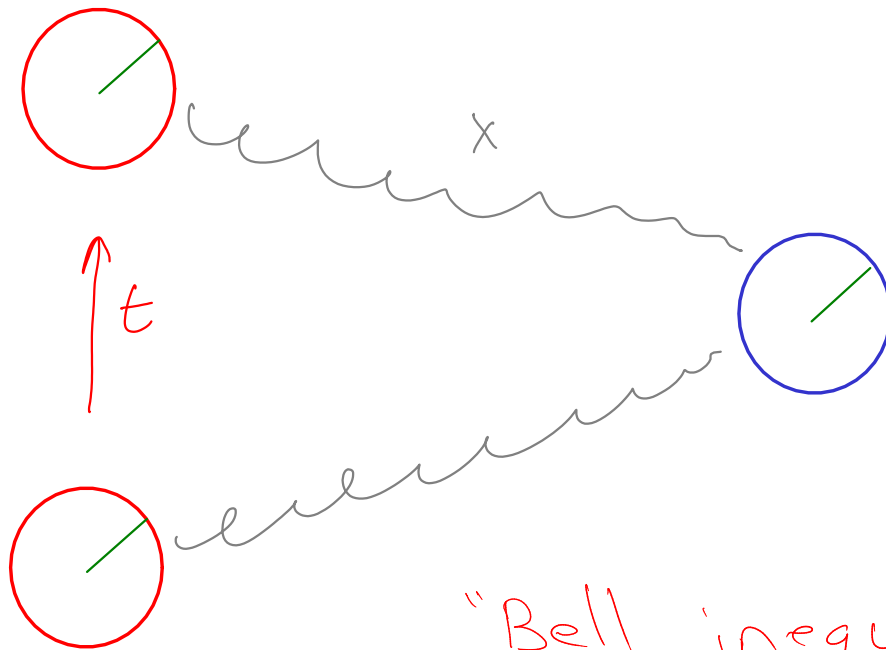
"Bell inequality in time"

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

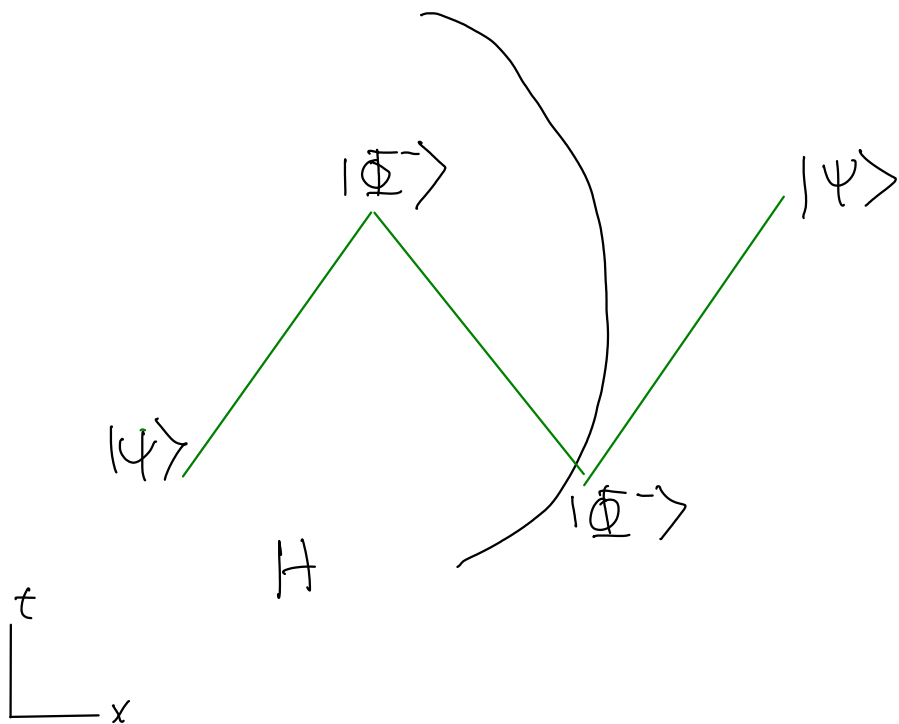
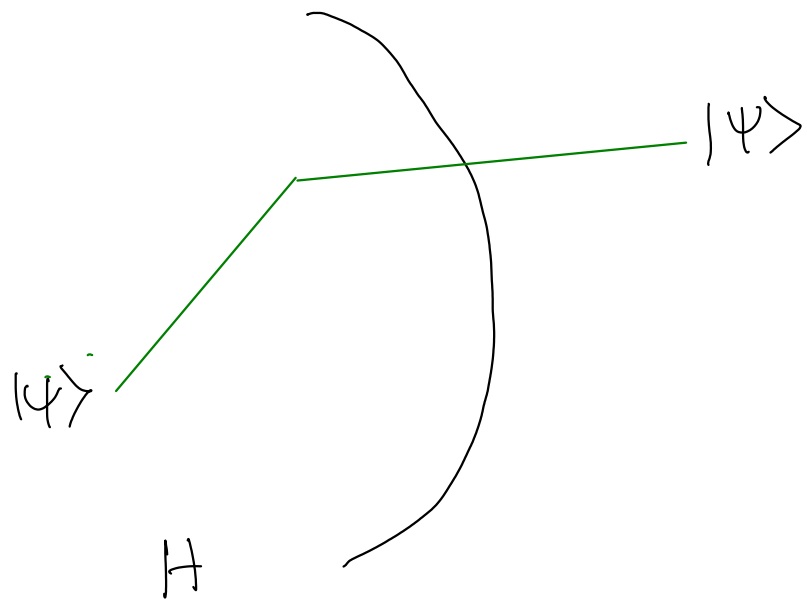
measuring A prepares state on B



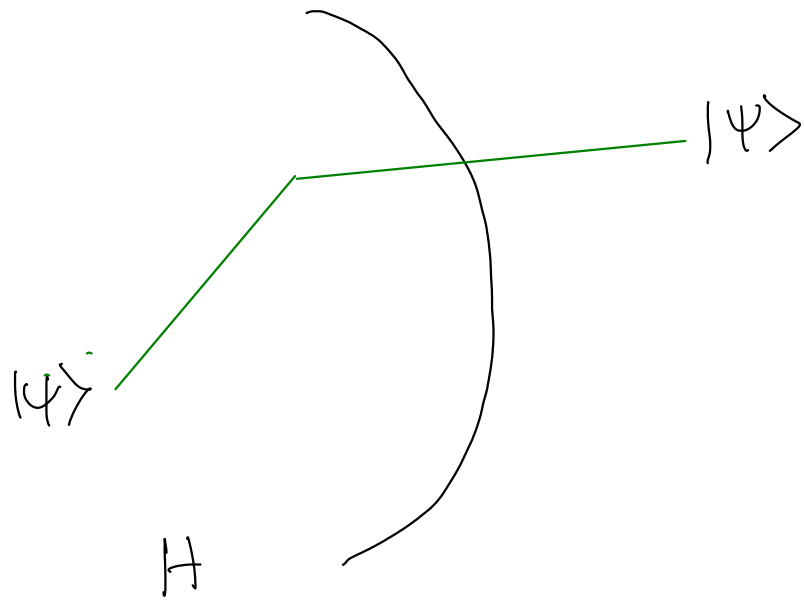
Entanglement in time $\rho(t_0) = \frac{11}{2}$



"Bell inequality in time"



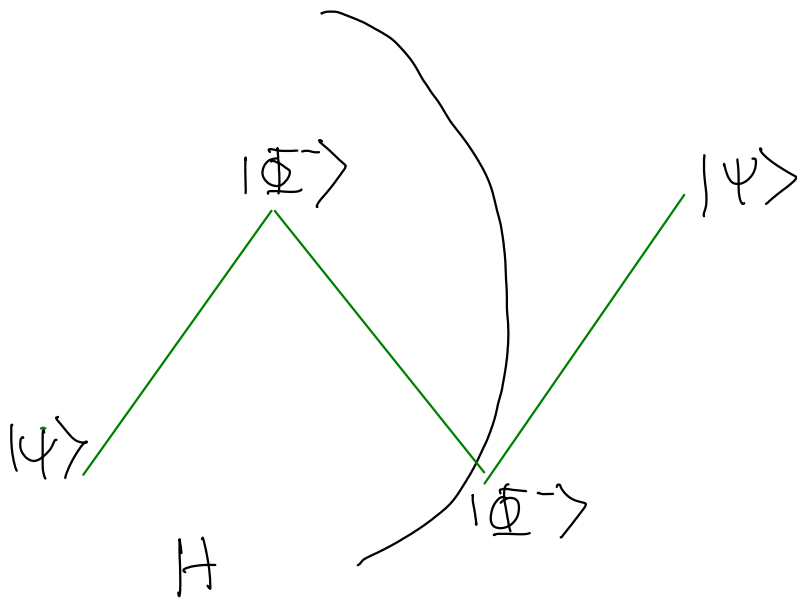
Final State
(Horowitz Maldacena)



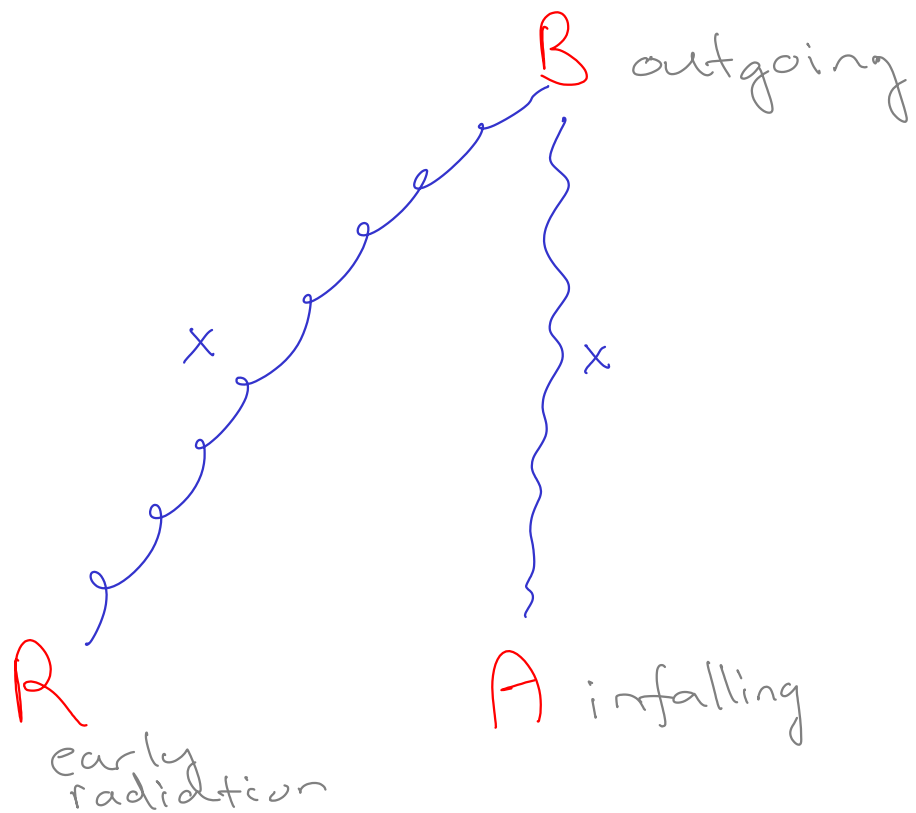
looks like tachyon
in another reference
frame

Final State
(Horowitz Maldacena)

teleportation



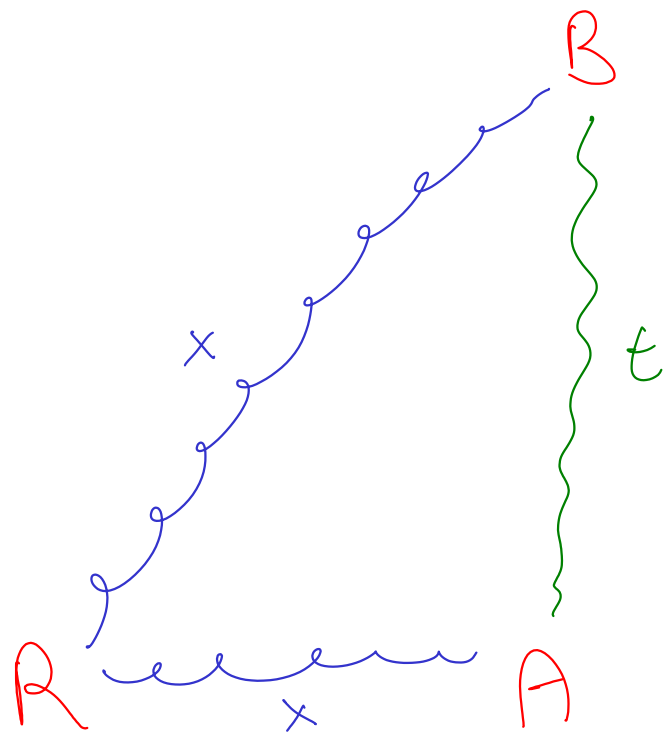
t
x



AMPS

polygamy

vs



Final State

polyamoury

Conclusion

choose one of:

a) information destruction

b) tensor product \rightarrow polyamory \rightarrow causality breakdown

c) temporal product \rightarrow breakdown of semiclassical causal structure

d) perhaps there is something else?

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