

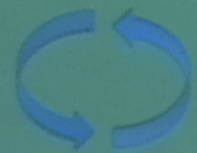
Title: Quantum Time-Like Curves: From Thought Experiment to Real Experiment

Date: Jun 26, 2012 11:10 AM

URL: <http://pirsa.org/12060053>

Abstract: Thought experiments involving quantum mechanics in the presence of closed time-like curves (CTCs) seem to have little to do with reality. However, even particles that traverse the CTC passively and without interactions can lead to highly non-trivial effects, such as the maximal violation of the uncertainty principle. Moreover, these effects may carry over to curved space-times without CTCs, presenting novel opportunities for testing non-standard physics in the relativistic regime.

Q: What happens when we modify quantum mechanics to allow for possible violations of causality?



+ QM = ?

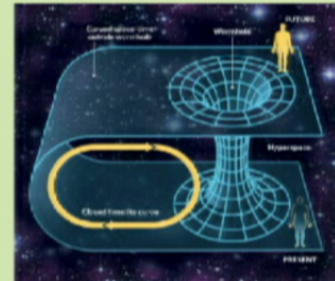
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Why?

-QM assumes definite causality. This assumption may be a barrier to quantum gravity.

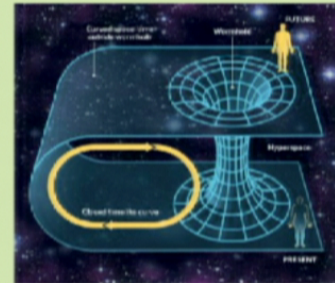
-GR predicts closed time-like curves. The paradoxes of these CTCs can be resolved by QM, leading to possible insights into a deeper theory.



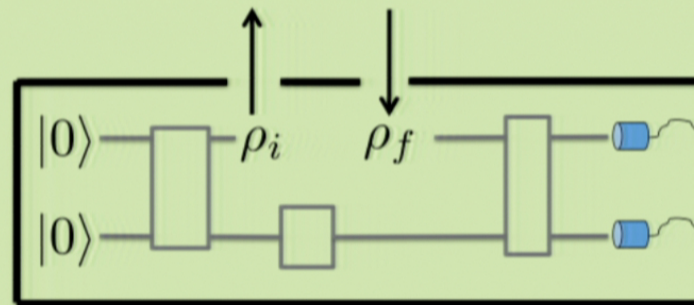
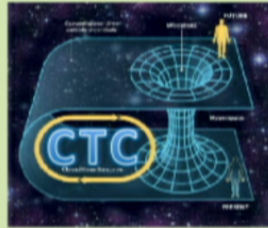
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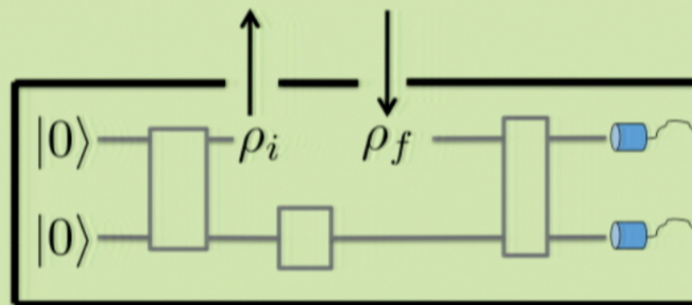
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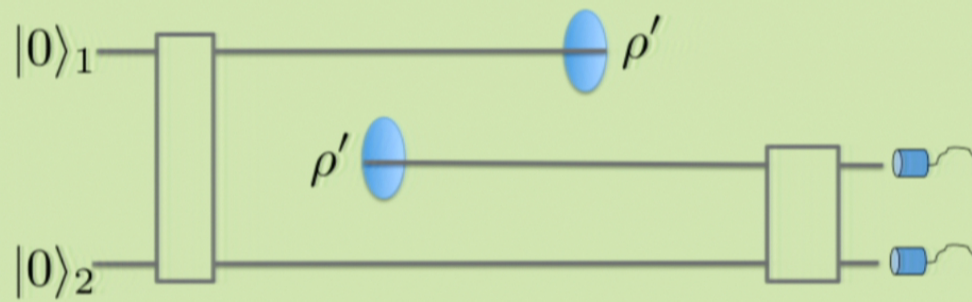
A quantum gravity thought experiment.



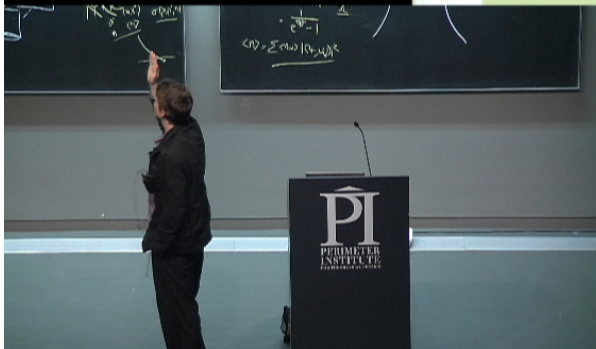
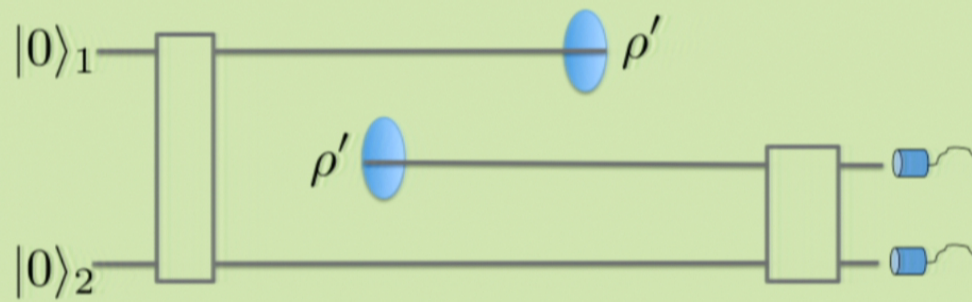
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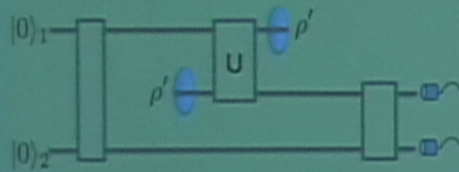
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A quantum gravity thought experiment.



Nonlinear consequences



$$\rho' = \text{Tr}_{\neq 1} \{ \hat{U} (\rho_{\text{in}} \otimes \rho') \hat{U}^\dagger \}$$

*T. A. Brun, J. Harrington, and M. M. Wilde, Phys. Rev. Lett. **102**, 210402 (2009).

**D. Ahn et al., e-print arXiv:1008.0221v2 [quant-ph] (2010).

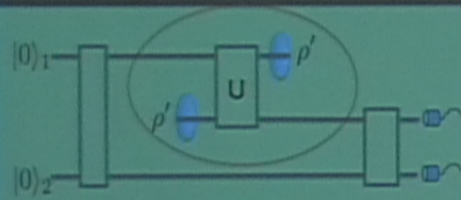
***D. Bacon, Phys. Rev. A, **70**, 032309 (2004).

-Perfect state Discrimination*

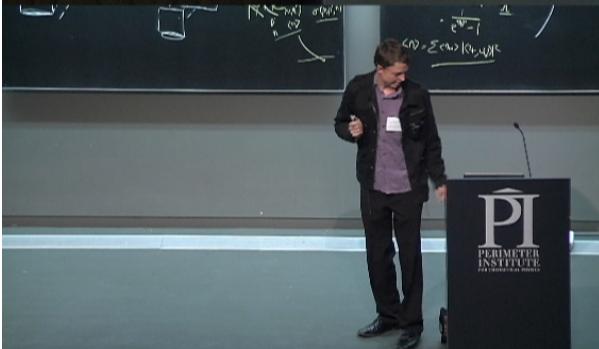
-Cloning of unknown states**

-Efficiently solve NP-complete problems.***

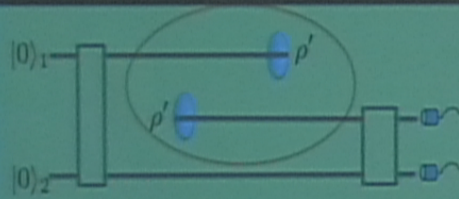
Our result:



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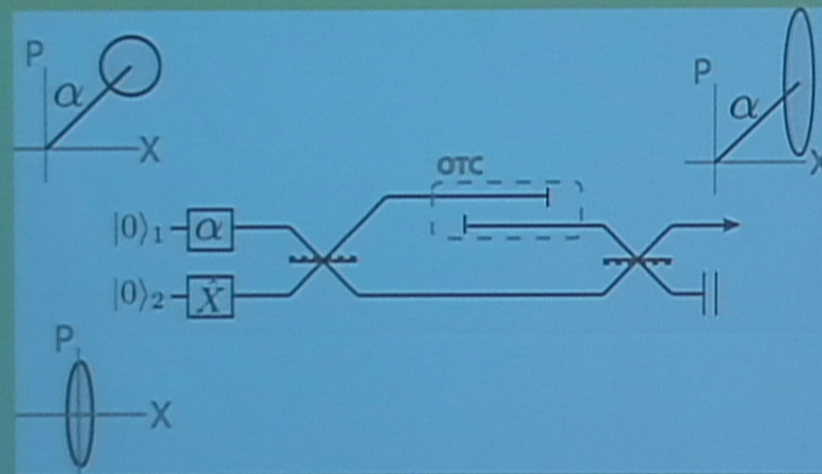
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-Perfect state
Discrimination

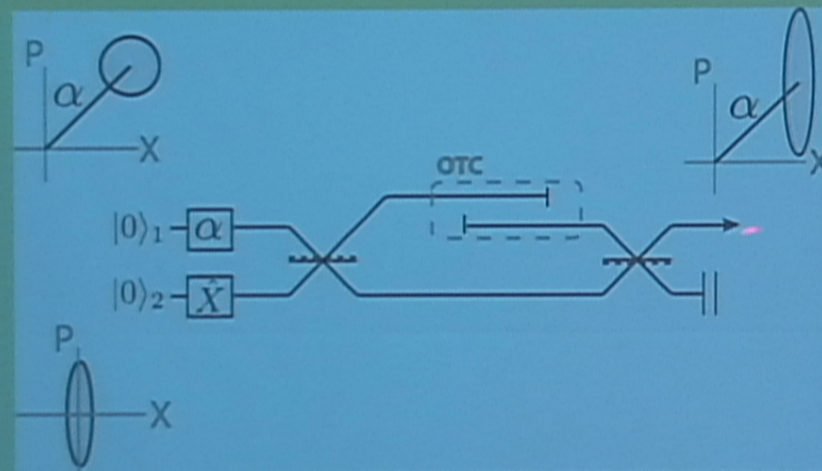
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Technical Details 1

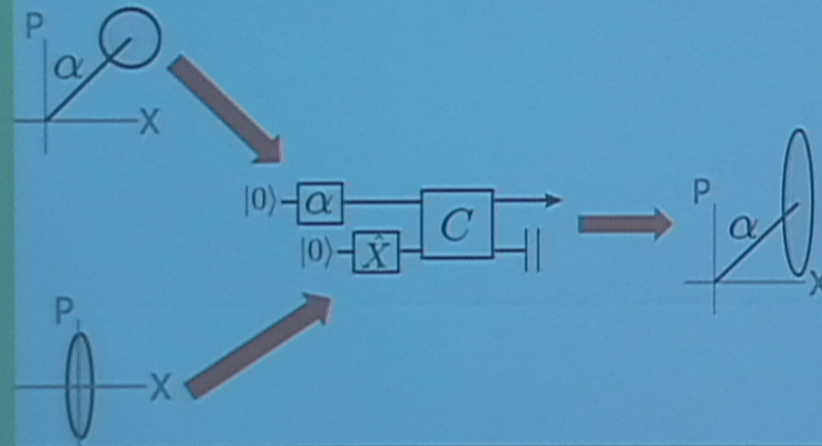


Technical Details 1

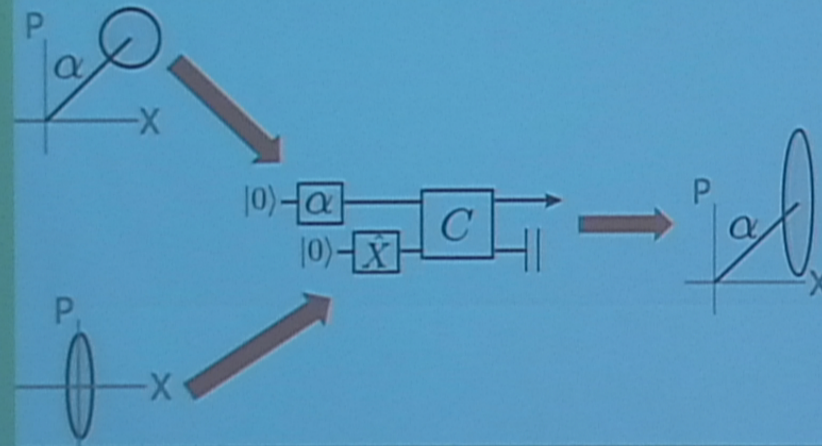


$$\langle n \rangle = \sum_{m=0}^{\infty} m |c_m|^2$$

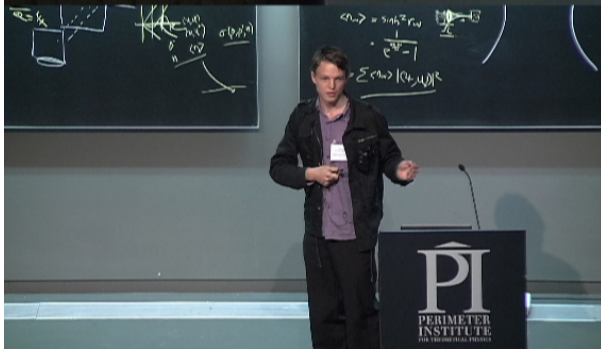
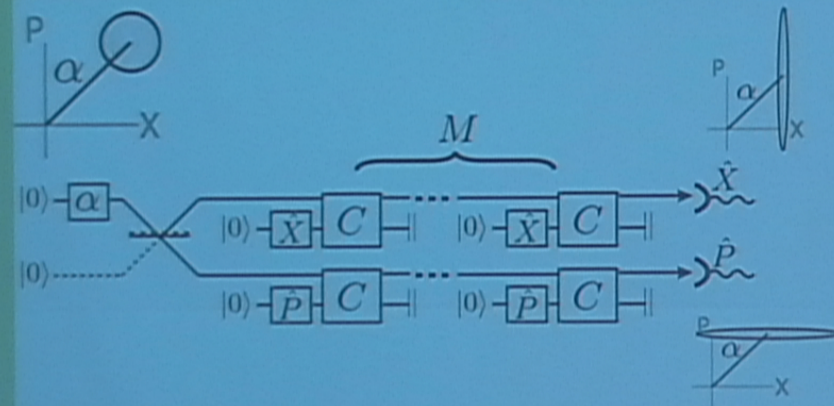
Technical Details 1b



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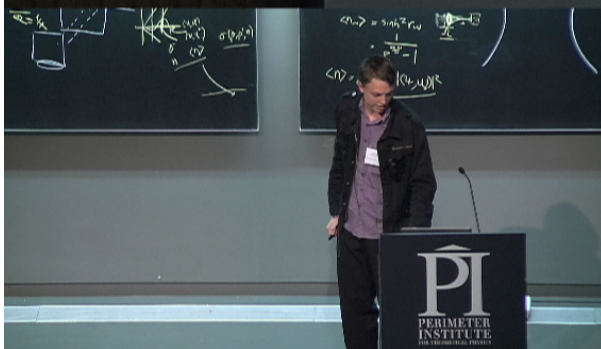


Technical Details 2

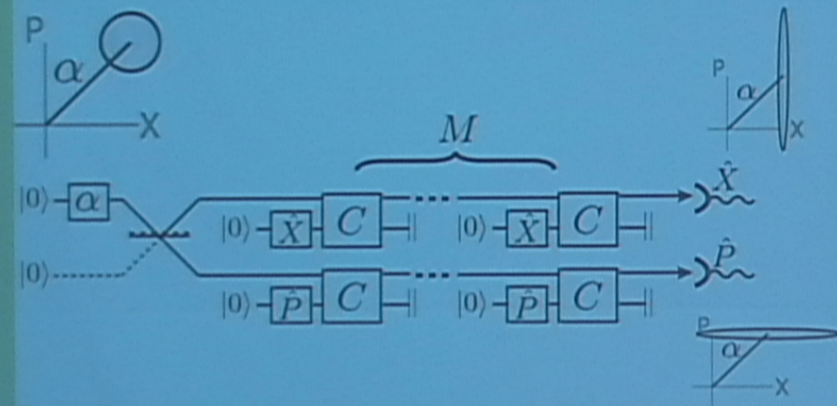


**Conclusion: interaction-free (open)
CTCs can be used to violate the
Heisenberg uncertainty principle.**

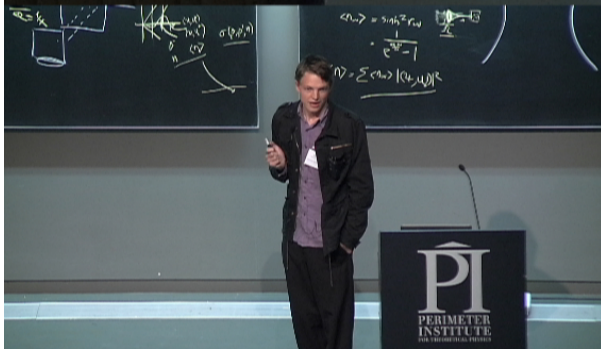
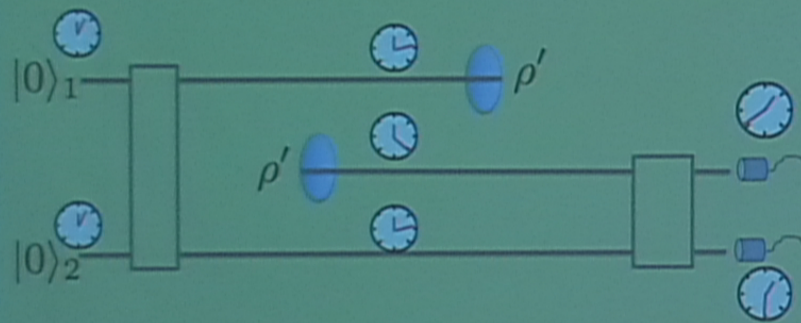
But what does this mean?



Technical Details 2

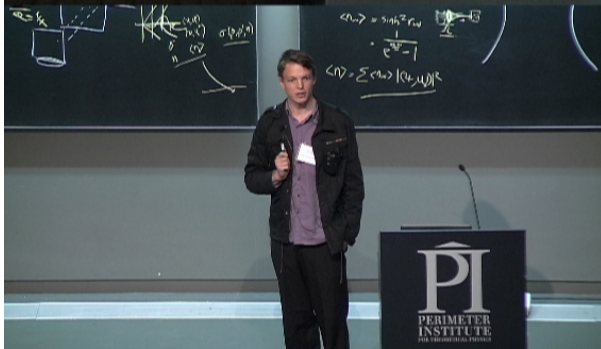
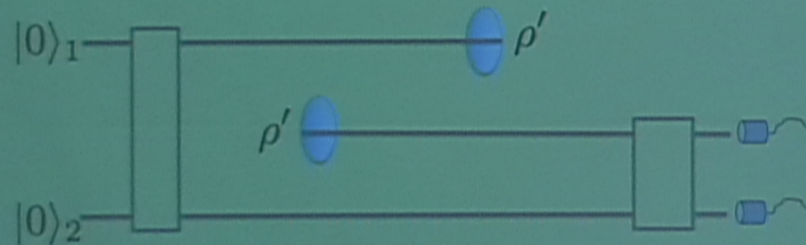


What causes the non-linearity?



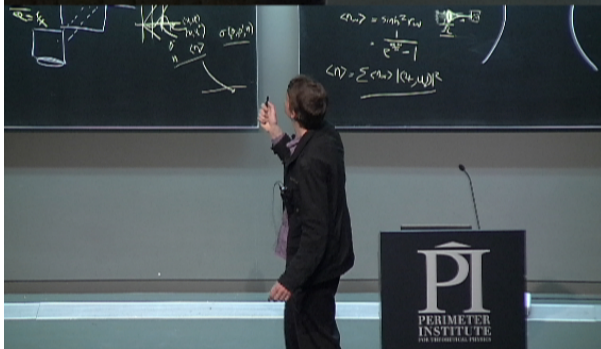
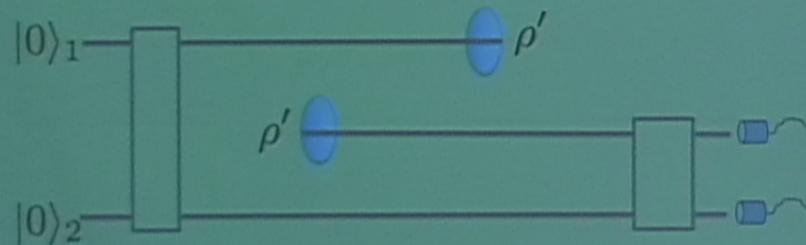
Non-linear predictions for entangled light in a gravitational field.

-Need to generalize the circuit to make quantitative predictions.

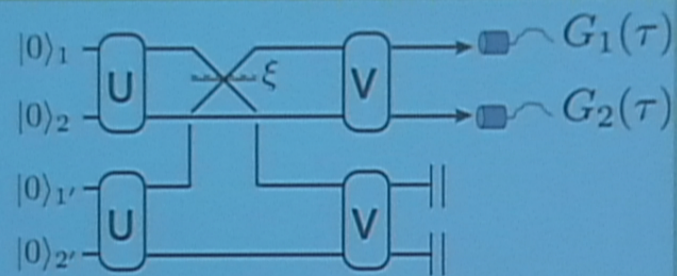


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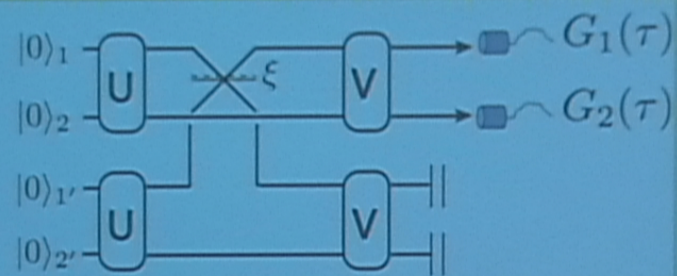


$$\xi \equiv \frac{\int d\tau G_1^*(\tau + \Delta T) G_2(\tau)}{\int d\tau G_1^*(\tau) G_2(\tau)}$$

See also: T. C. Ralph, G. J. Milburn, and T. Downes, Phys. Rev. A, 79, 022121 (2009)



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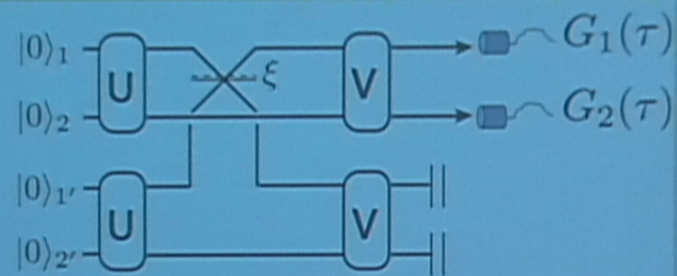


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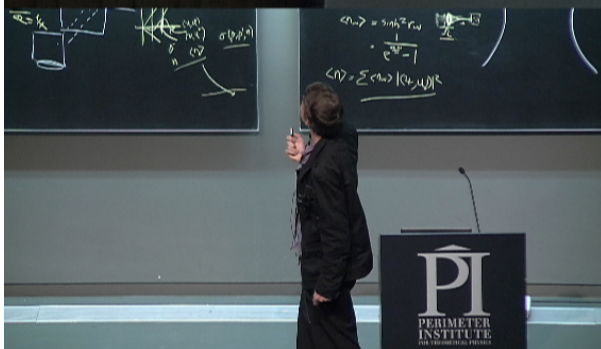


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Conclusions

- Nonlinear behaviour persists in the Deutsch model even when the CTC is empty ("open time-like curve").
- Hence the Deutsch model predicts nonlinear effects for any region of curvature, not just CTCs.
- The Deutsch model can be tested.

See paper: "Open timelike curves violate Heisenberg's uncertainty principle"

arXiv:1206.5485v1

