

Title: Extended Wigner's Friend Inequalities are Nonclassical Causal Compatibility Inequalities

Speakers:

Collection: Perimeter Institute Graduate Studentsâ€™ Conference 2023

Date: September 15, 2023 - 1:25 PM

URL: <https://pirsa.org/23090058>

Extended Wigner's Friend Inequalities are Nonclassical Causal Compatibility Inequalities

Marina Maciel Ansanelli

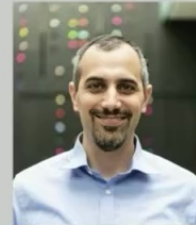
Yilè Yīng



Andrea Di Biagio



Elie Wolfe



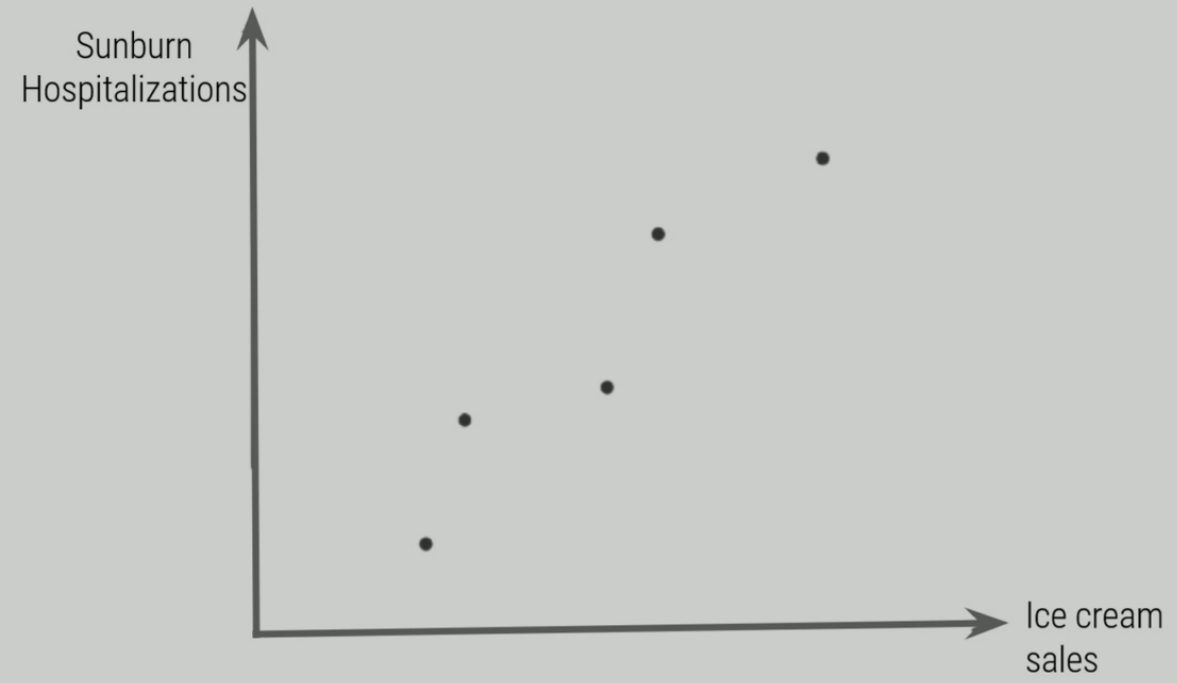
Eric Cavalcanti

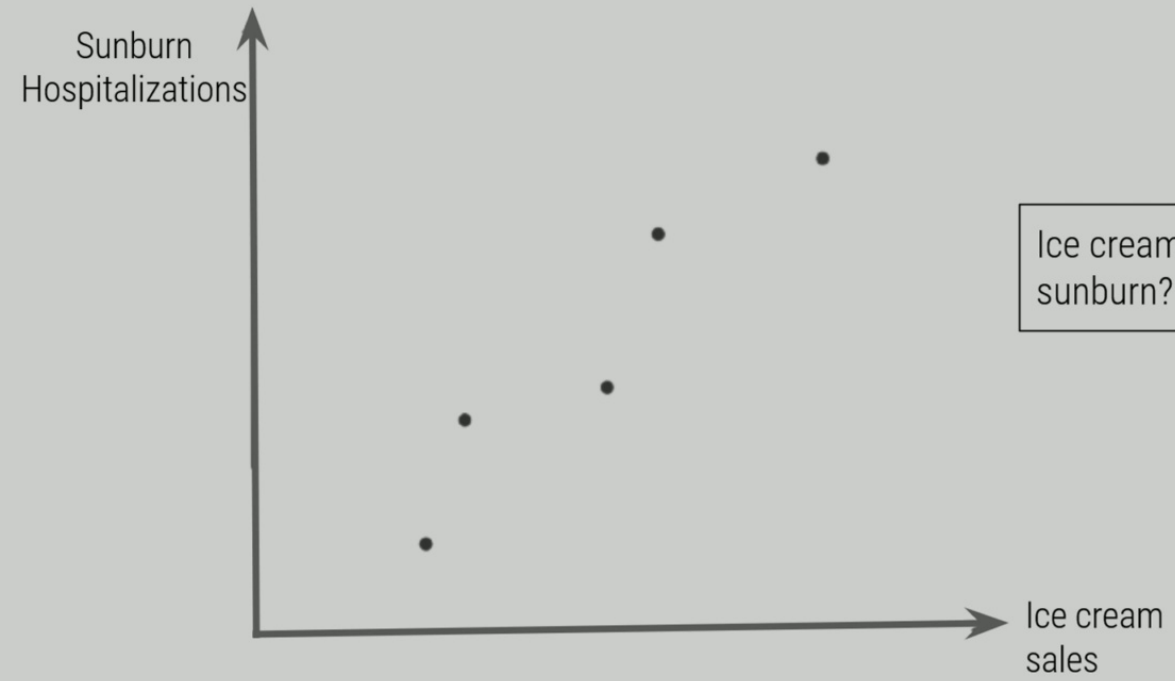


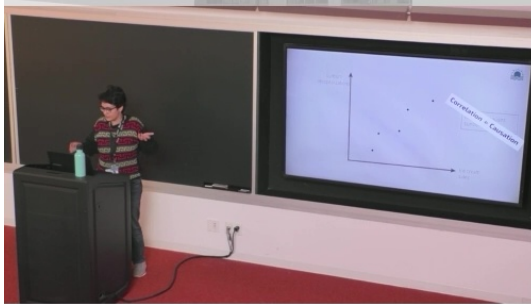
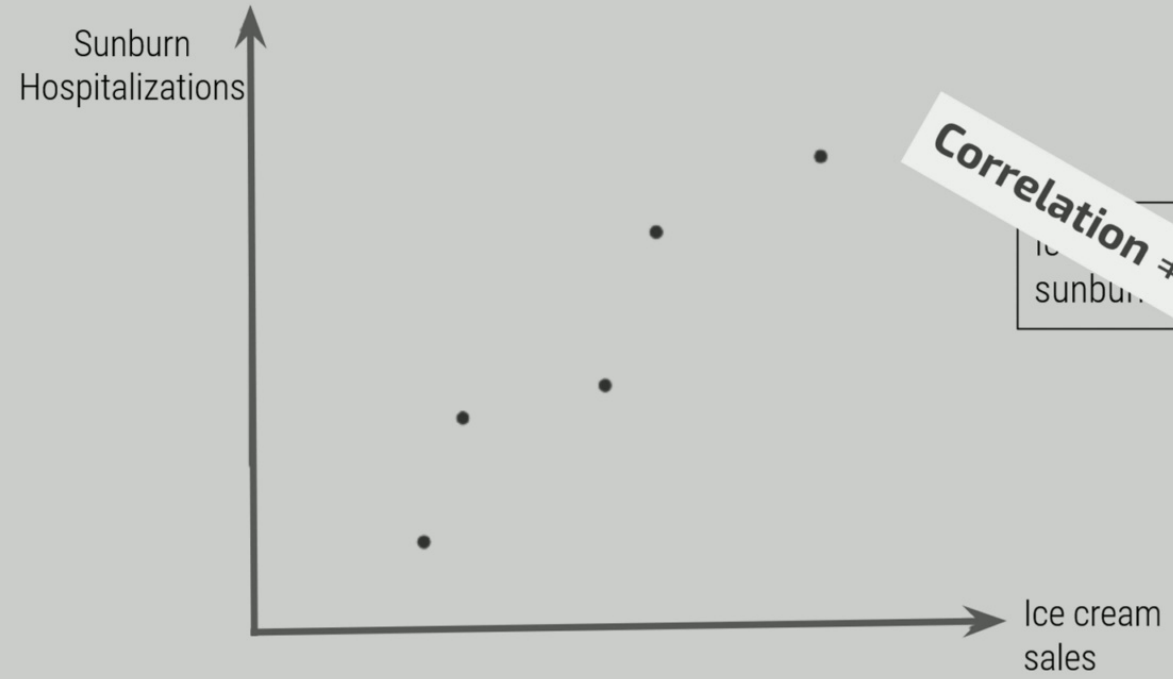
01

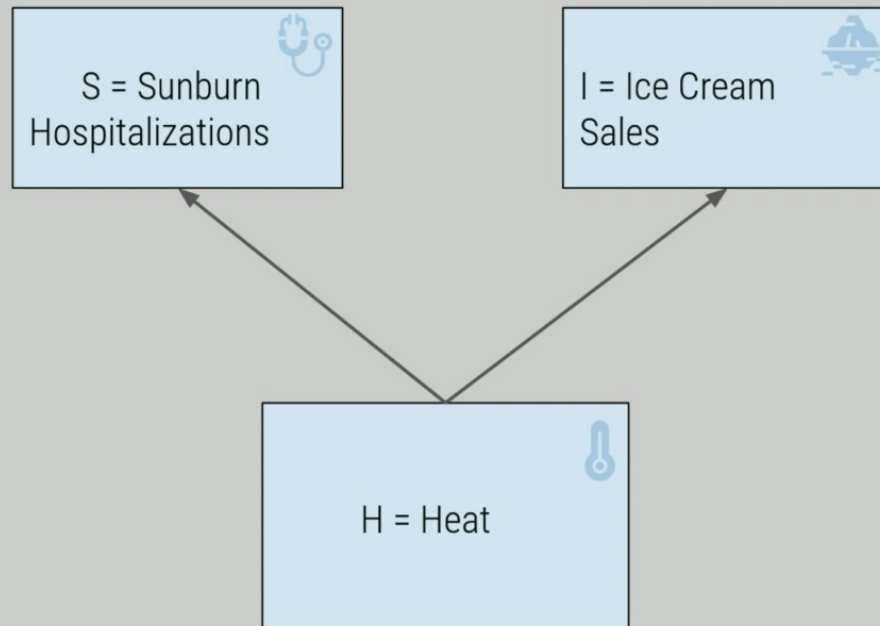
Causal Inference



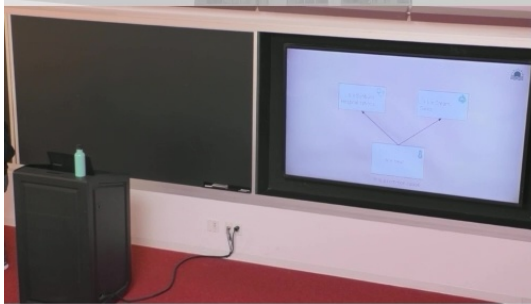


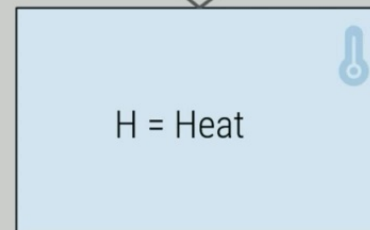
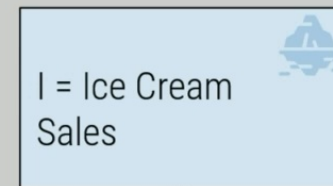
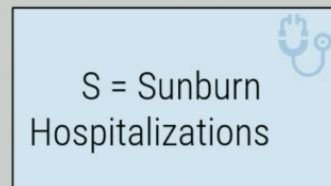






H is a common cause





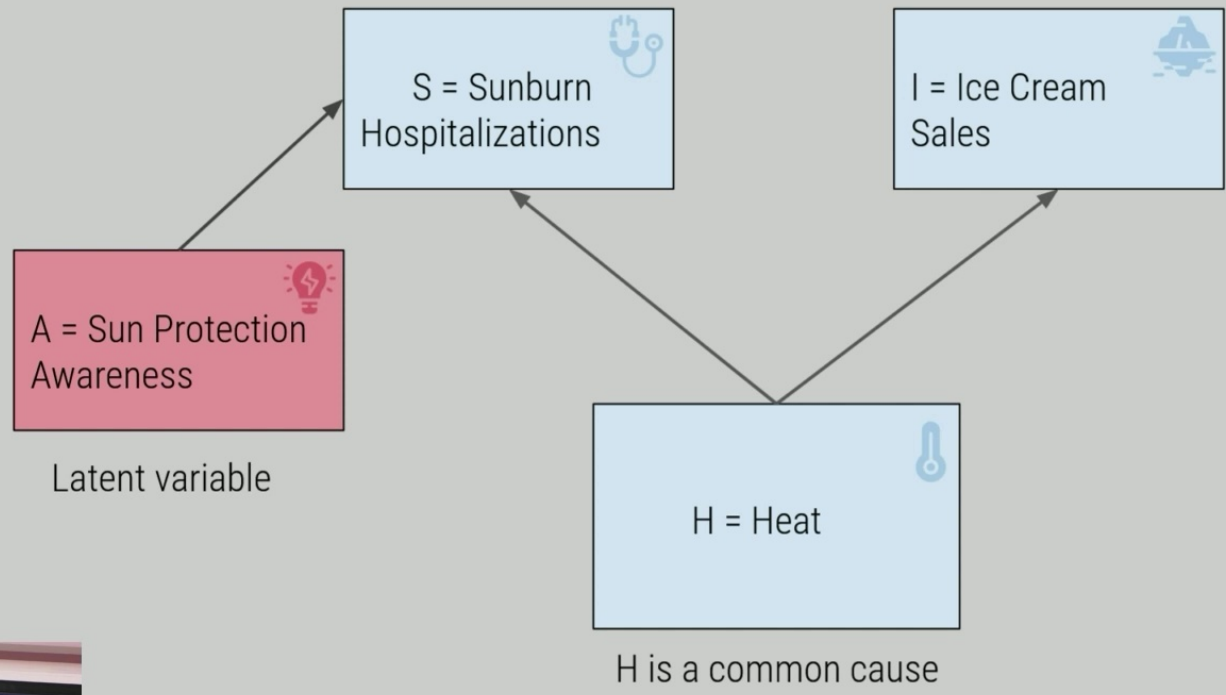
When we can measure H:

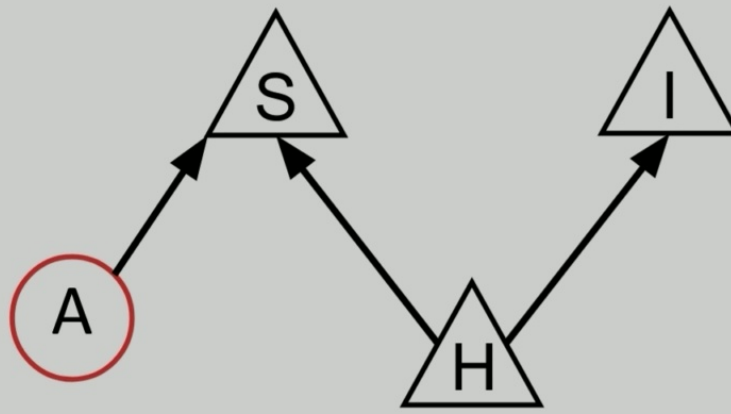
$$P(IS|H) = P(I|H)P(S|H)$$

Restriction on the probability distributions that are compatible with this causal structure

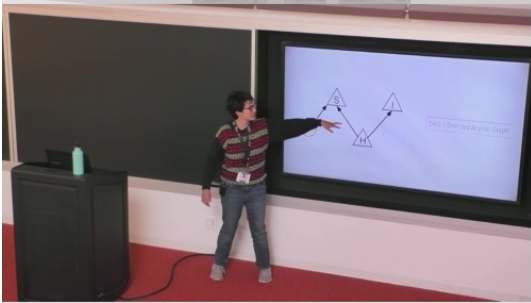
H is a common cause







DAG = Directed Acyclic Graph



Applications to Classical Data Analysis



JOURNAL ARTICLE

Examining the Causal Mediating Role of Subclinical Cardiovascular Disease on the Effect of Subclinical Cardiovascular Disease on Cognitive Impairment via Separable Effects

Ryan M Andrews, PhD, MHS, Ilya Shpitser, PhD, Vanessa Didelez, PhD (Dr. rer. nat.), Paulo H M Chaves, MD, PhD, Oscar L Lopez, MD, Michelle C Carlson, PhD

The Journals of Gerontology: Series A, Volume 78, Issue 7, July 2023, Pages 1172–1178, <https://doi.org/10.1093/gerona/glad077>

Published: 04 March 2023 [Article history](#)

Article | [Open Access](#) | Published: 11 August 2020

Improving the accuracy of medical diagnosis with causal machine learning

Jonathan G. Richens, Ciarán M. Lee & Saurabh Johri

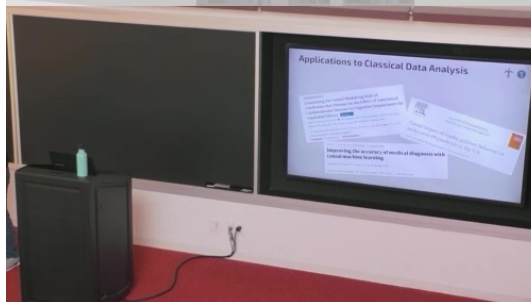
Nature Communications 11, Article number: 3923 (2020) | [Cite this article](#)



Journal of Econometrics
Volume 220, Issue 1, January 2021, Pages 23–62

Causal impact of masks, policies, behavior on early covid-19 pandemic in the U.S.

Victor Chernozhukov, Hiroyuki Kasahara, Paul Schrimpf



02

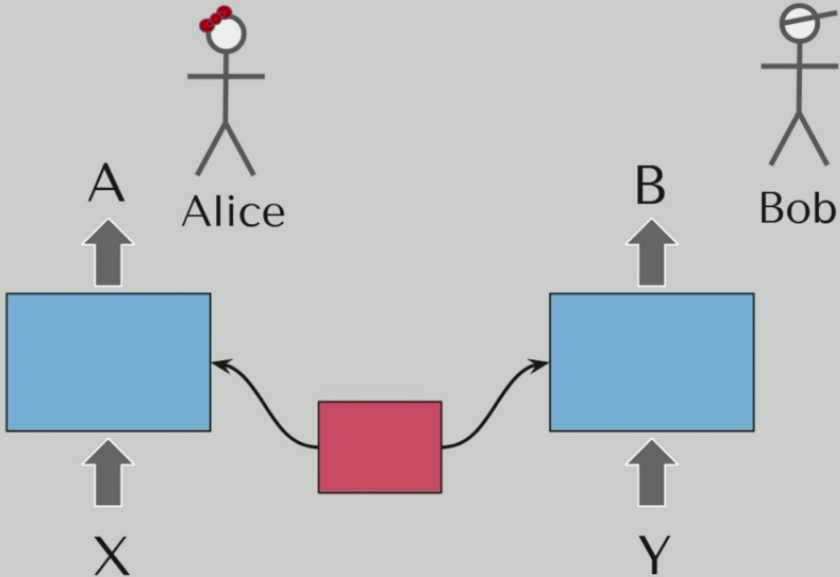
Bell No-Go Theorem



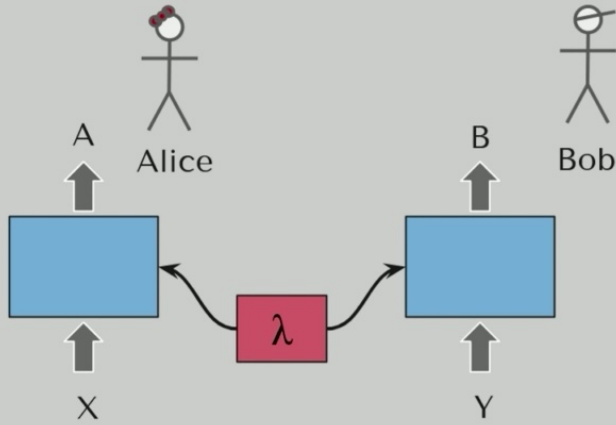
Bell-CHSH Scenario

Measurement Outcomes →

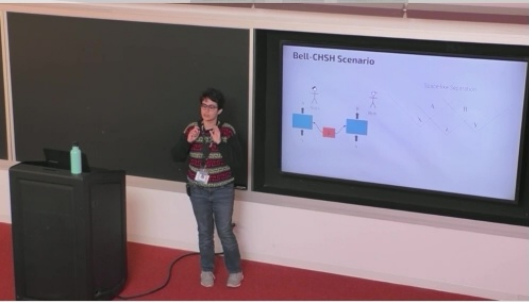
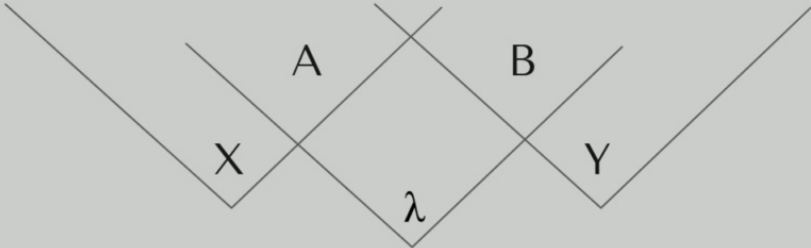
Measurement Choices →



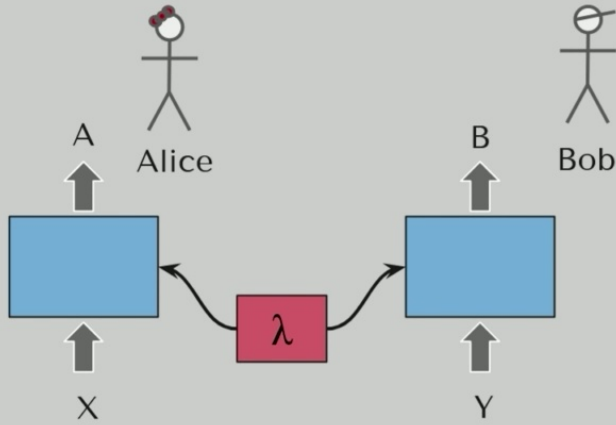
Bell-CHSH Scenario



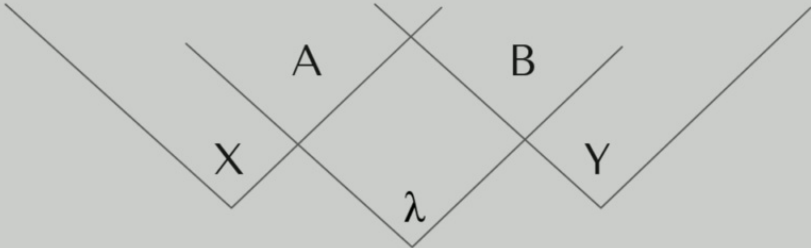
Space-like Separation



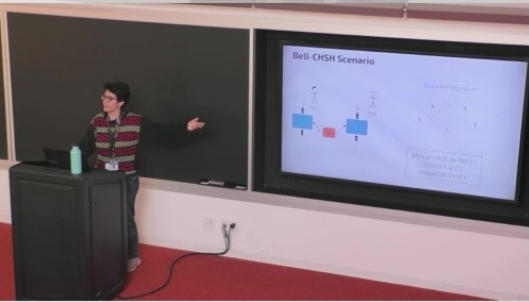
Bell-CHSH Scenario



Space-like Separation



Alice and Bob are free to choose X and Y independently of λ

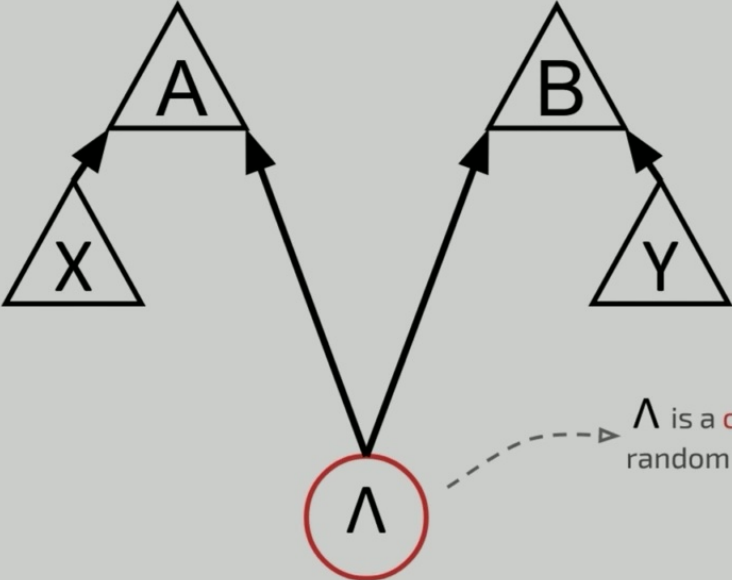


Causal Modelling the Bell Scenario

C. J. Wood and R. W. Spekkens: New Journal of Physics, 17, 08 2012.

Measurement outcomes →

Measurement choices →



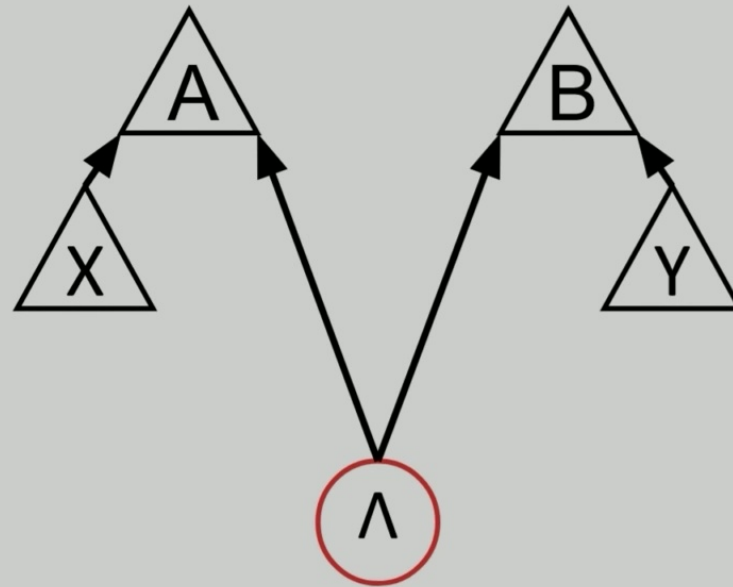
Bell DAG

Λ is a **classical** random variable

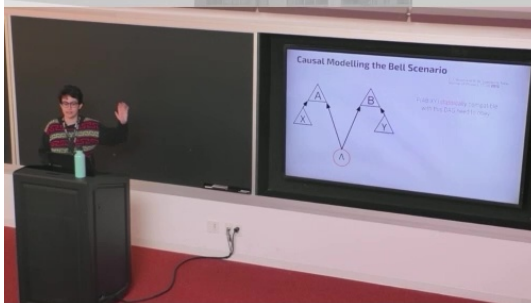


Causal Modelling the Bell Scenario

C. J. Wood and R. W. Spekkens: New Journal of Physics, 17, 08 2012.

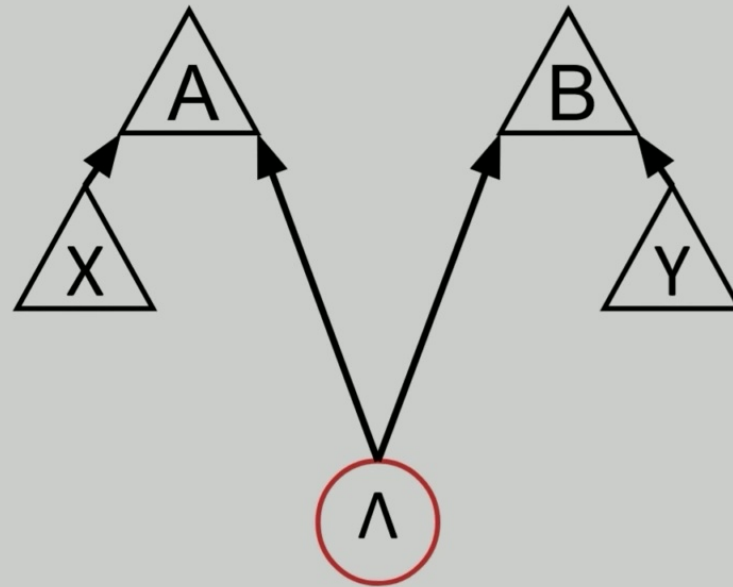


$P(AB|XY)$ classically compatible with this DAG need to obey:



Causal Modelling the Bell Scenario

C. J. Wood and R. W. Spekkens: New Journal of Physics, 17, 08 2012.



$P(AB|XY)$ classically compatible with this DAG need to obey:

$$P(A|XY) = P(A|X)$$

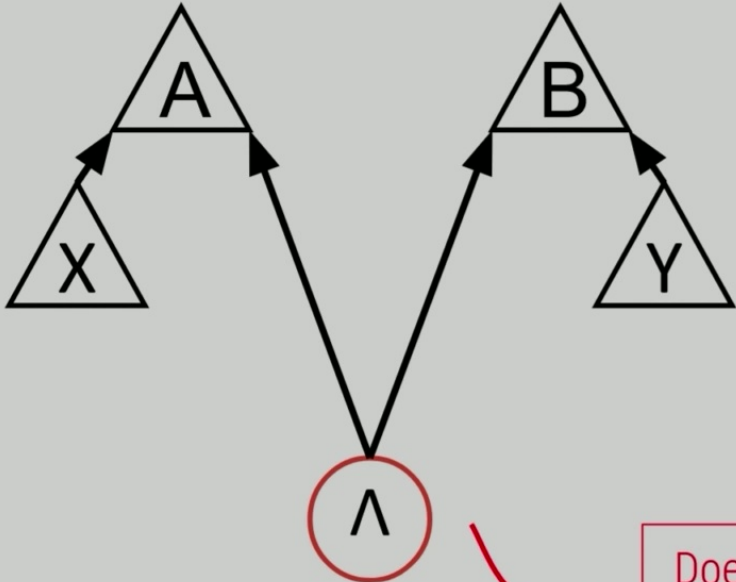
$$P(B|XY) = P(B|Y)$$

+ Bell inequalities



Causal Modelling the Bell Scenario

C. J. Wood and R. W. Spekkens: New Journal of Physics, 17, 08 2012.



$P(AB|XY)$ classically compatible with this DAG need to obey:

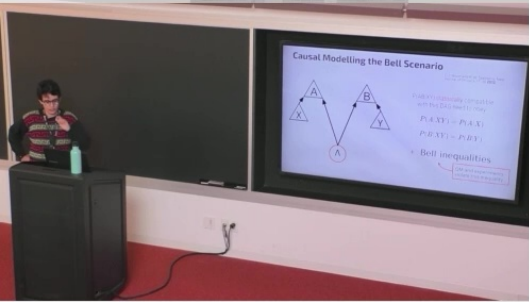
$$P(A|XY) = P(A|X)$$

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+ Bell inequalities

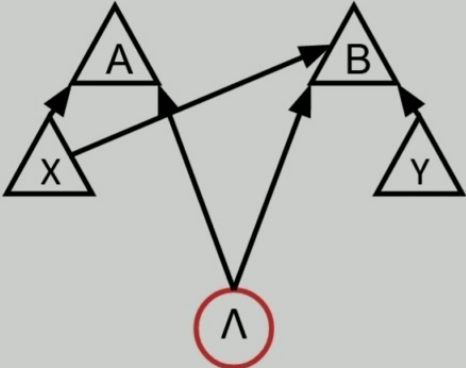
Does not explain the quantum predictions

QM and experiments violate this inequality

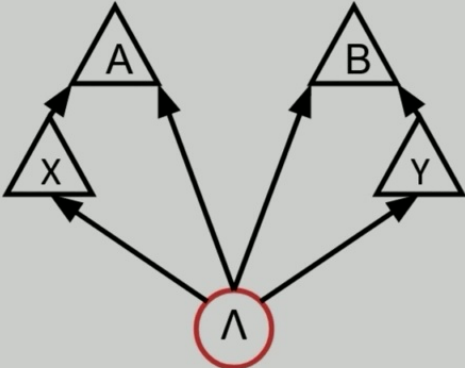


Problems with Classical Causal Explanations

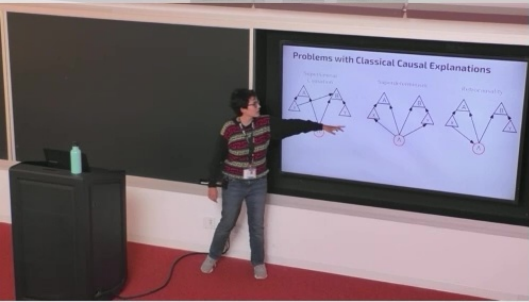
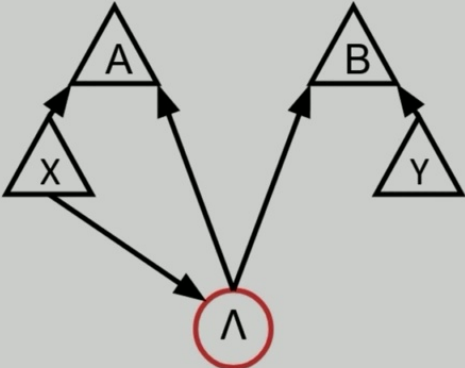
Superluminal Causation



Superdeterminism

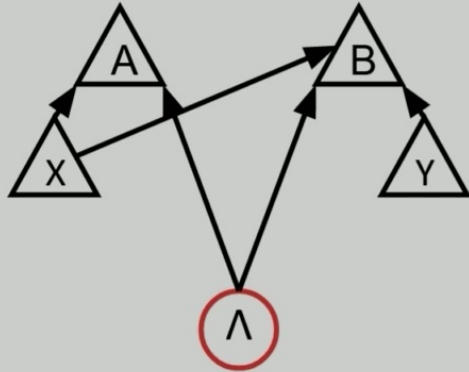


Retrocausality

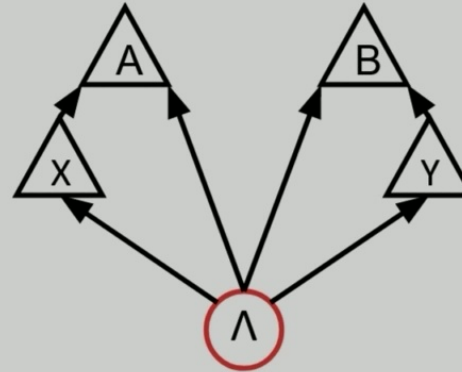


Problems with Classical Causal Explanations

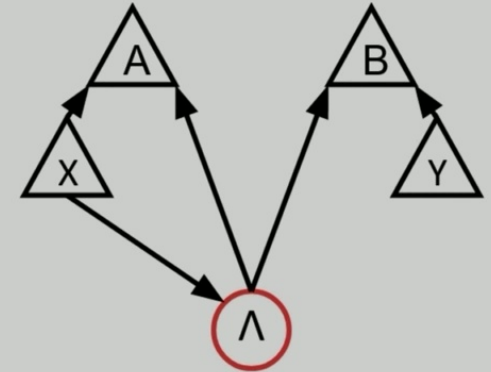
Superluminal Causation



Superdeterminism



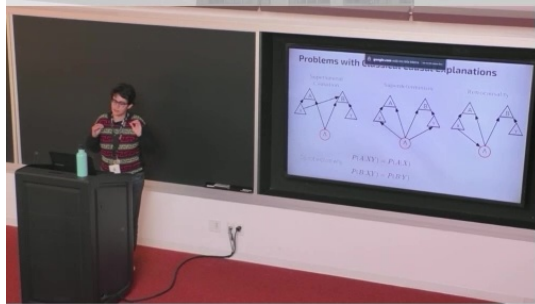
Retrocausality



Do not explain why

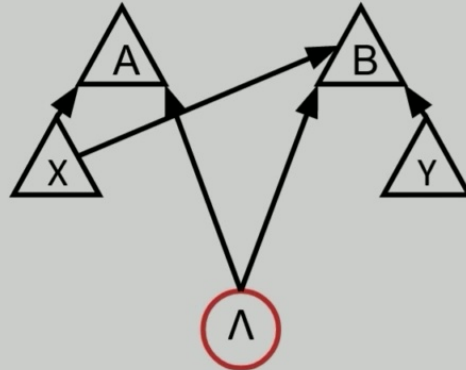
$$P(A|XY) = P(A|X)$$

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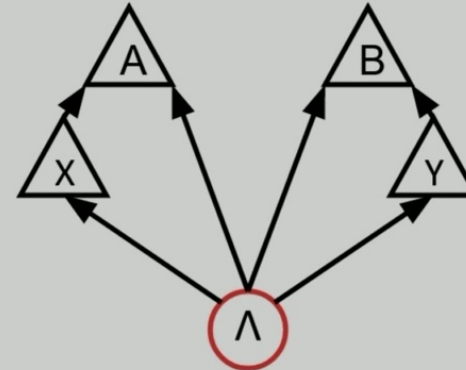


Problems with Classical Causal Explanations

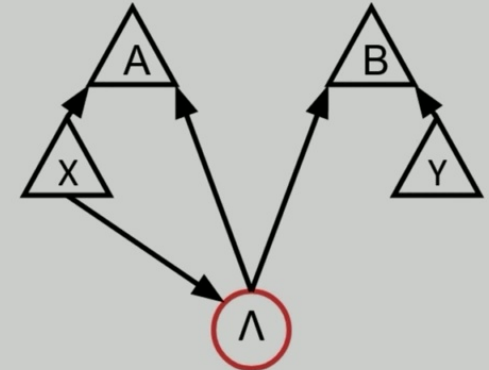
Superluminal Causation



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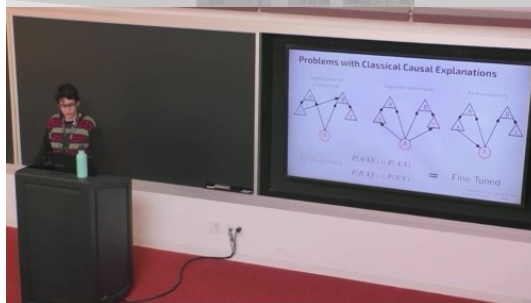
$$P(A|XY) = P(A|X)$$

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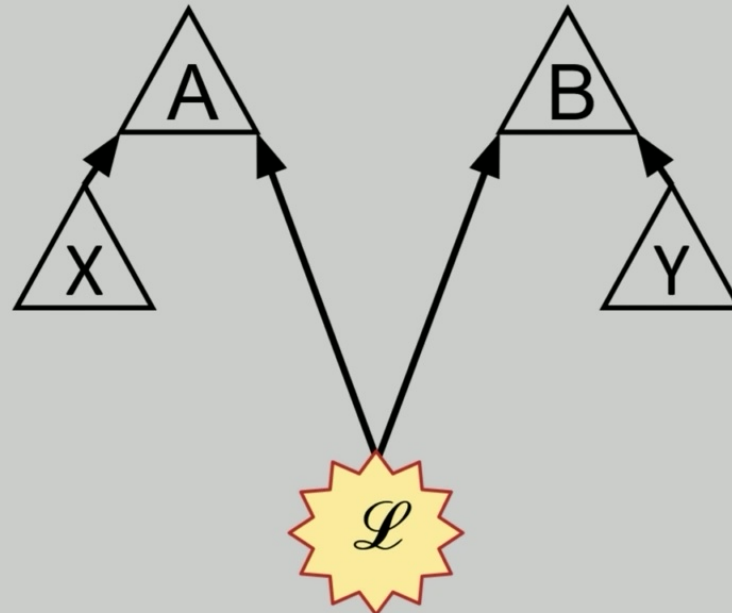


Fine Tuned

C. J. Wood and R. W. Spekkens: New Journal of Physics, 17, 08 2012.



Solution: Quantum/GPT Causal Modelling



Keep the causal structure intact, but change the way causality works.

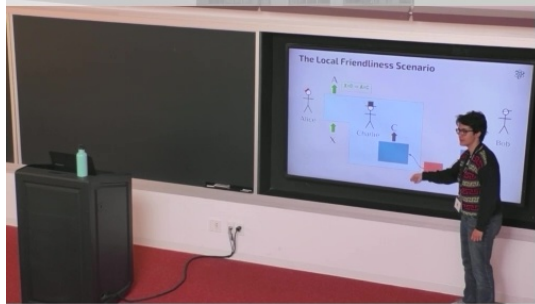
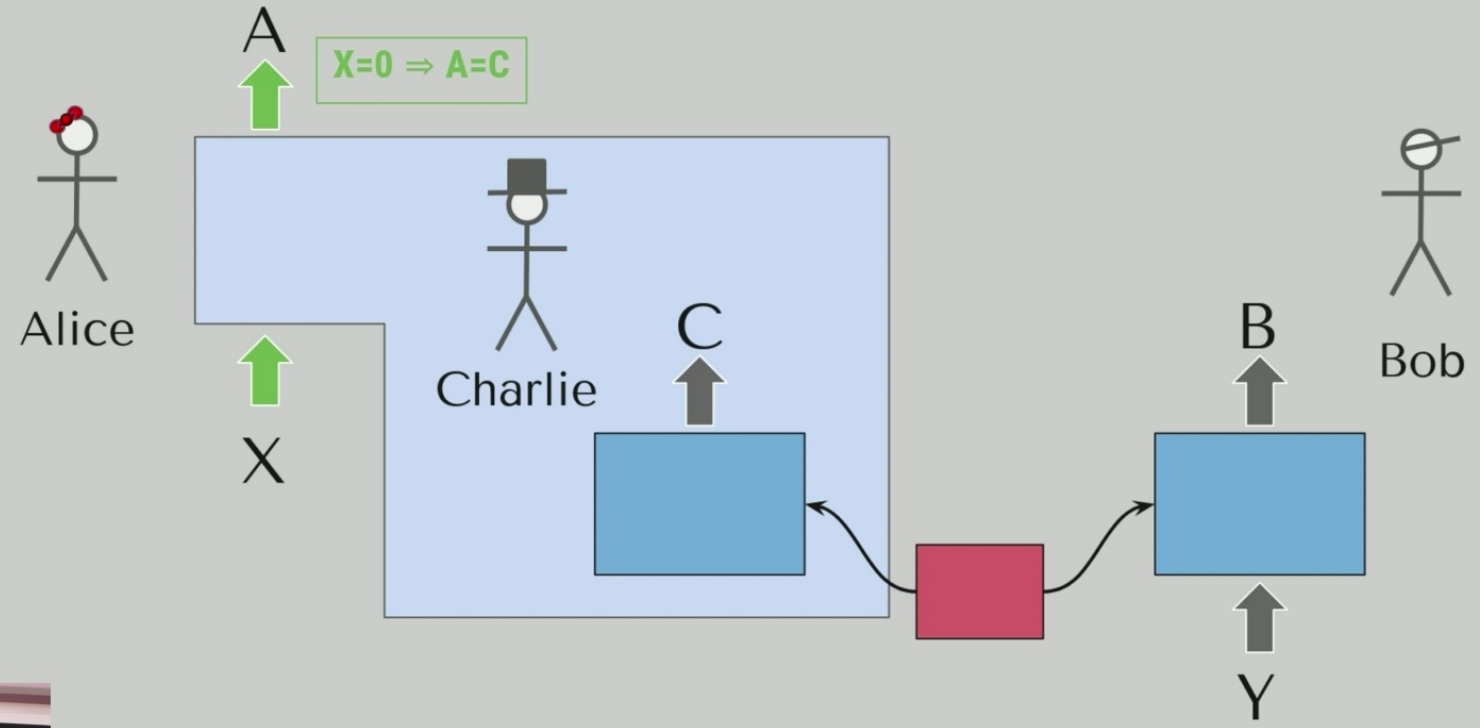


03

Local Friendliness No-Go Theorem

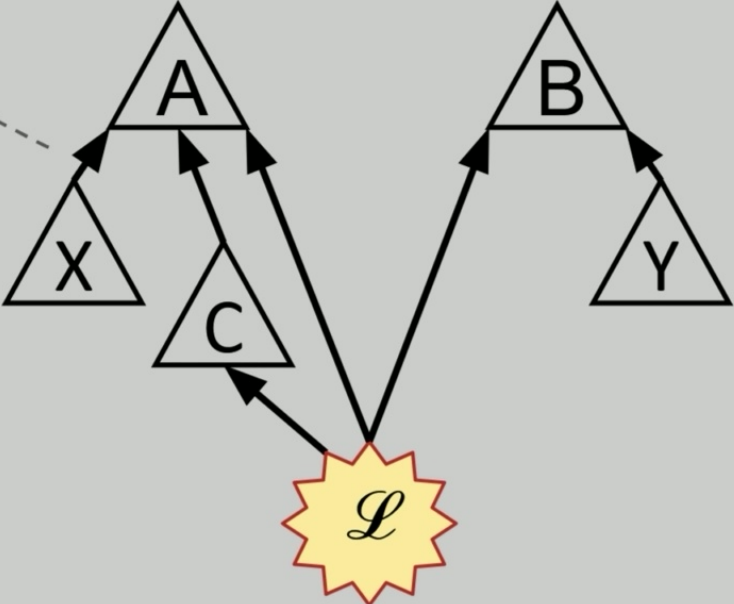


The Local Friendliness Scenario

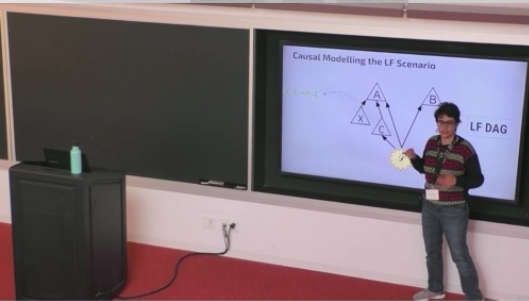


Causal Modelling the LF Scenario

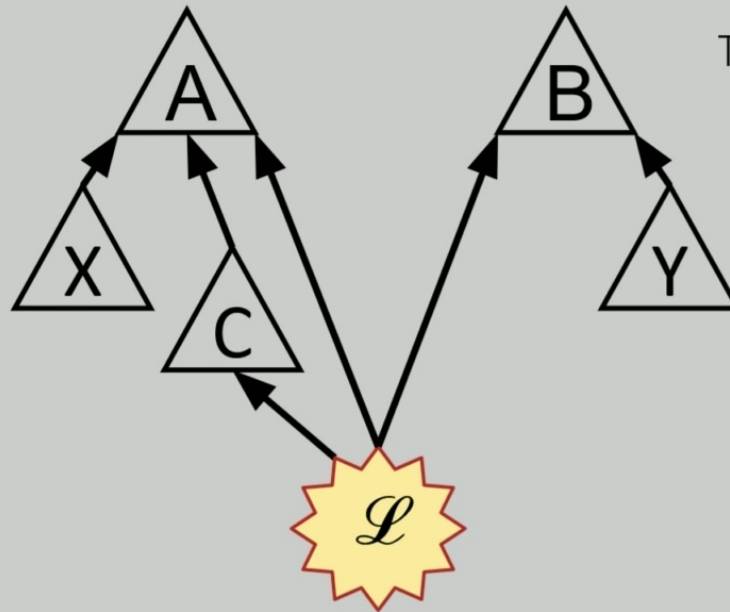
$X=0 \Rightarrow A=C$



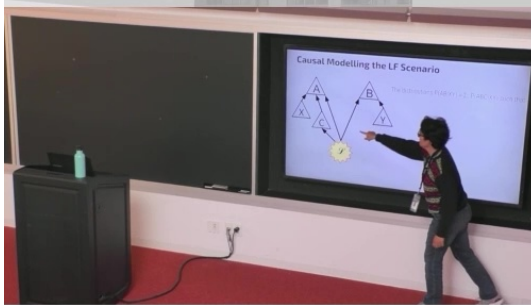
LF DAG



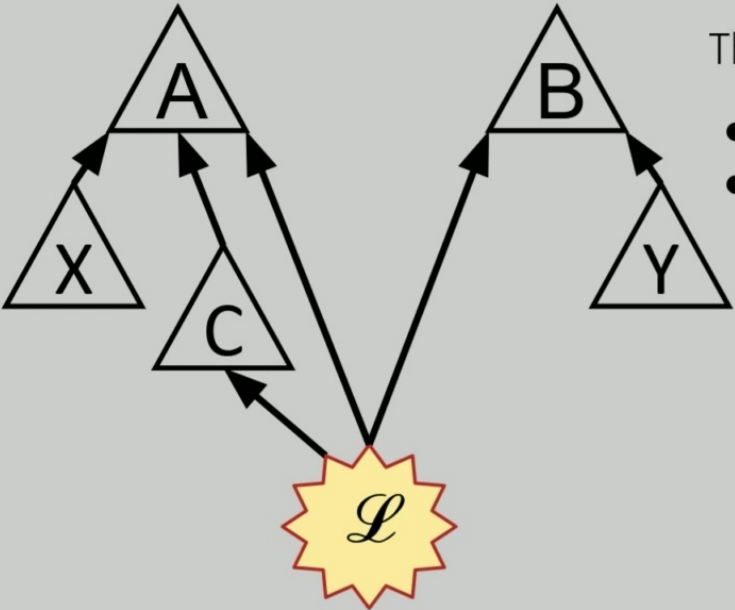
Causal Modelling the LF Scenario



The distributions $P(AB|XY) = \sum_c P(ABC|XY)$ such that



Causal Modelling the LF Scenario



The distributions $P(AB|XY) = \sum_c P(ABC|XY)$ such that

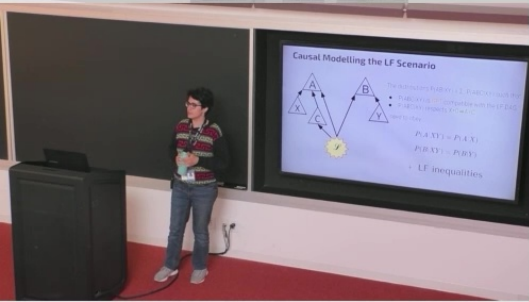
- $P(ABC|XY)$ is GPT compatible with the LF DAG
- $P(ABC|XY)$ respects $X=0 \Rightarrow A=C$

need to obey:

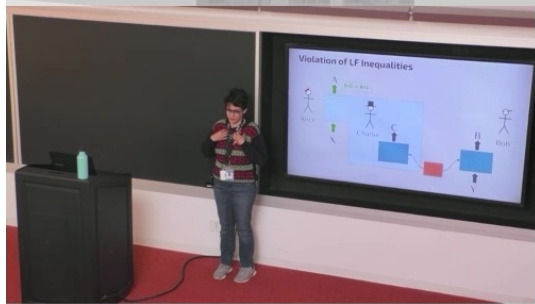
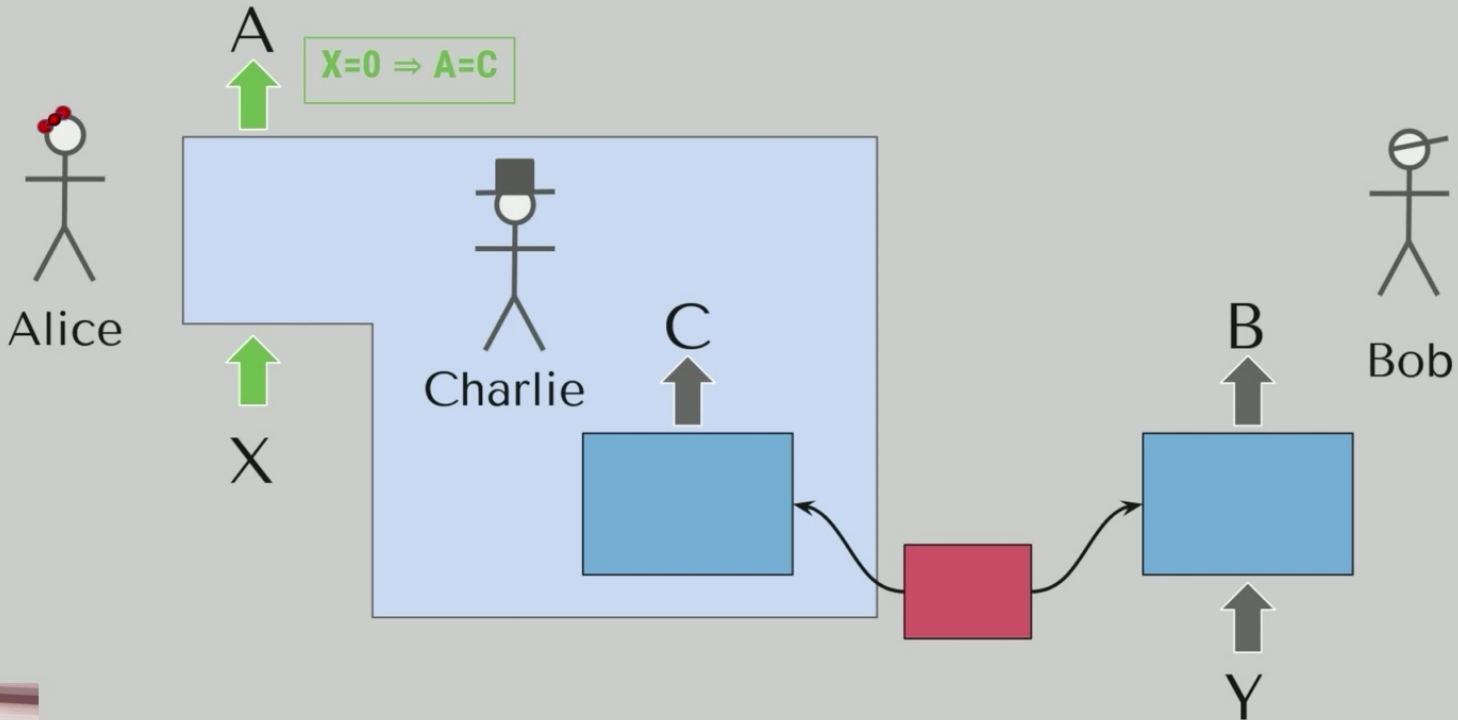
$$P(A|XY) = P(A|X)$$

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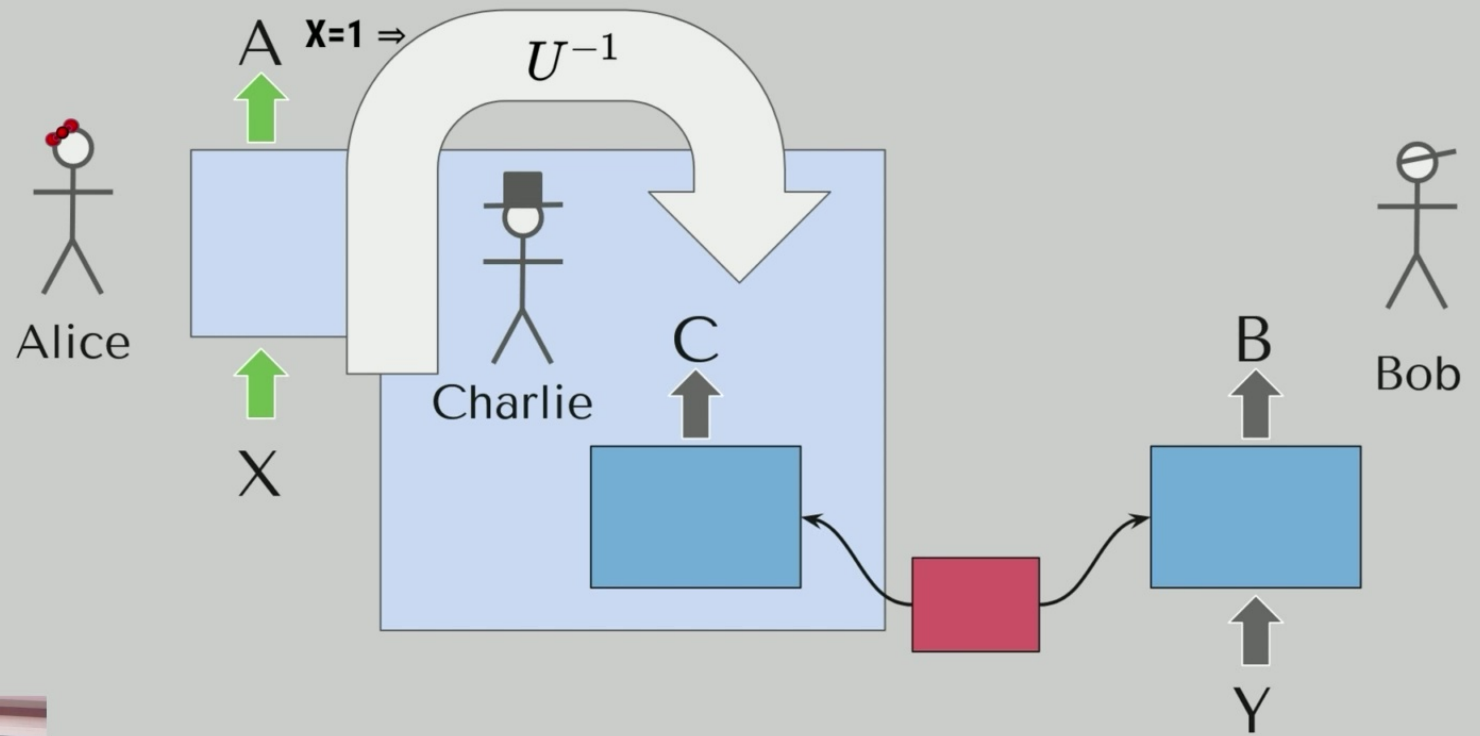
+ LF inequalities



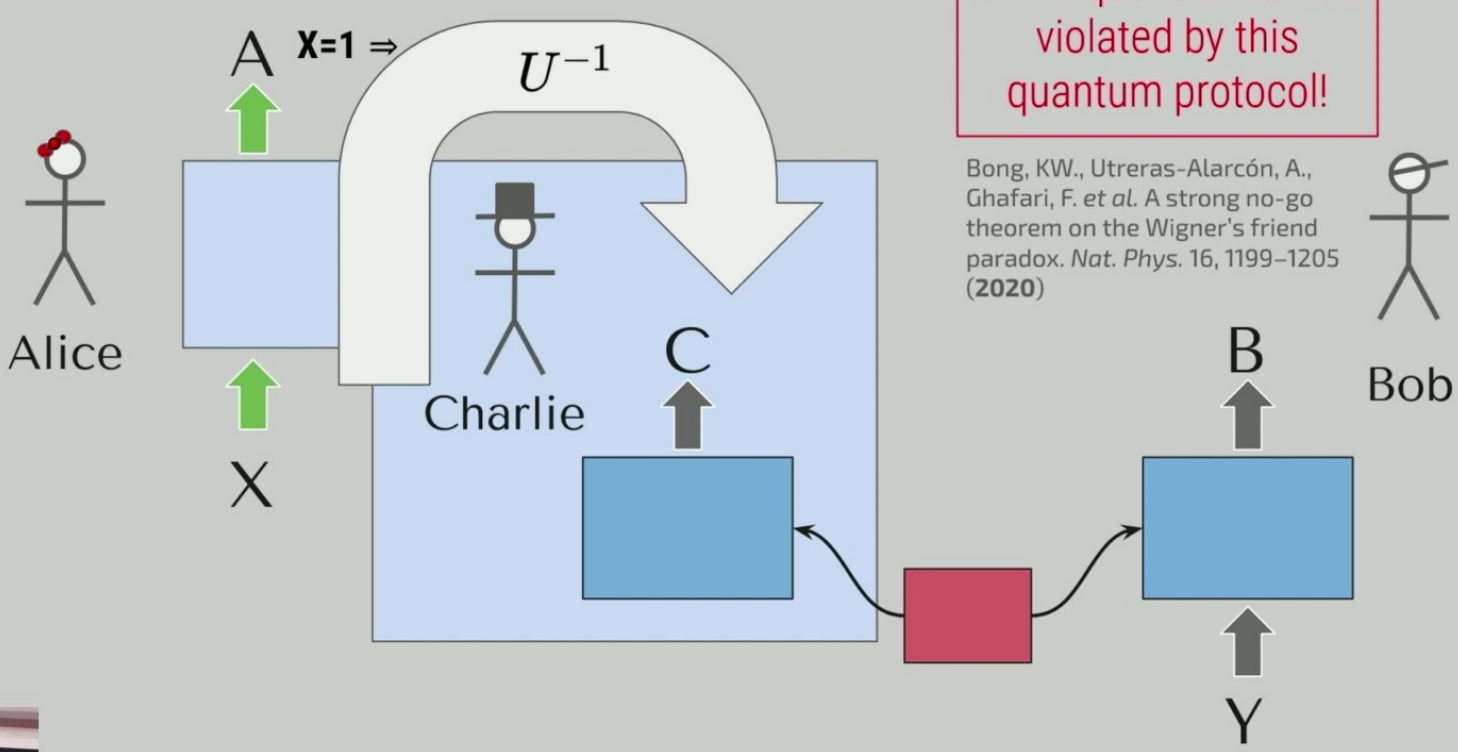
Violation of LF Inequalities



Violation of LF Inequalities

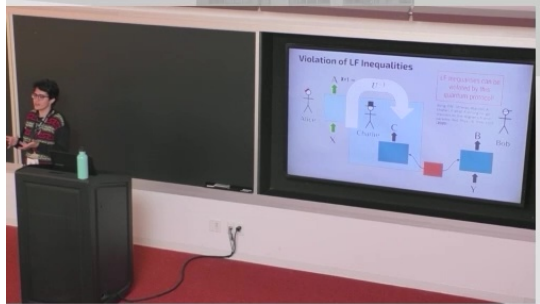


Violation of LF Inequalities

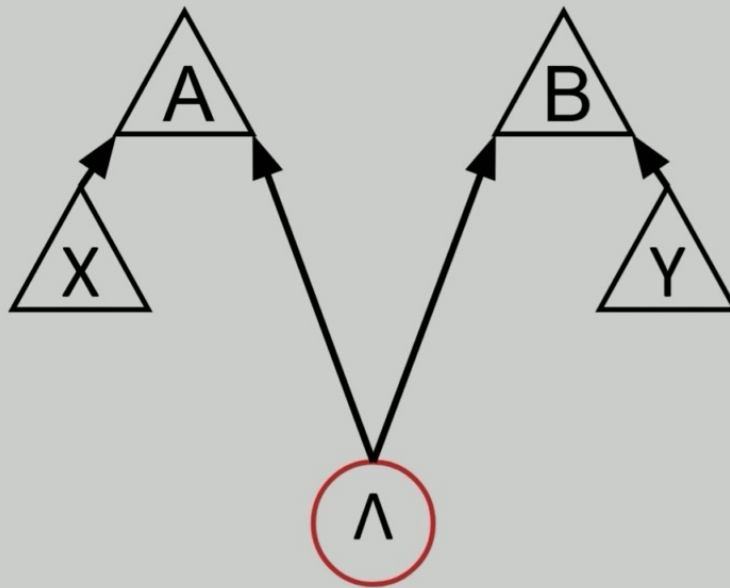


LF Inequalities can be violated by this quantum protocol!

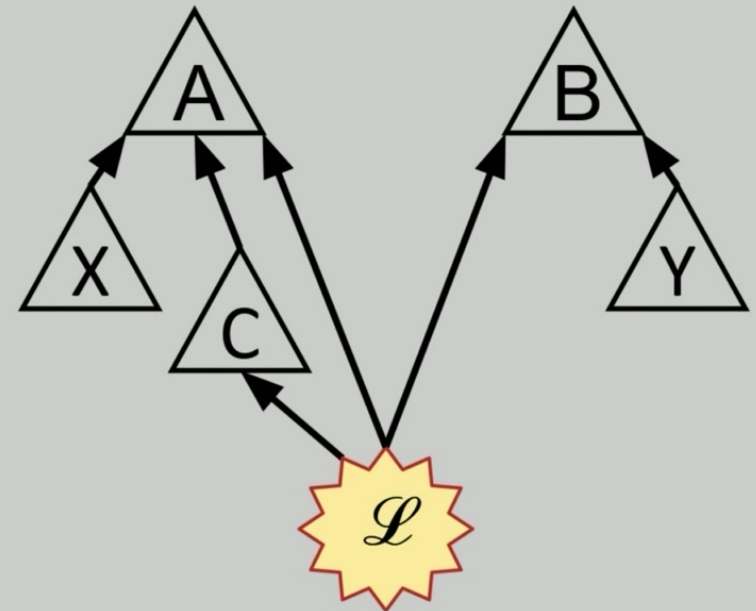
Bong, KW., Utreras-Alarcón, A., Ghafari, F. et al. A strong no-go theorem on the Wigner's friend paradox. *Nat. Phys.* 16, 1199–1205 (2020)



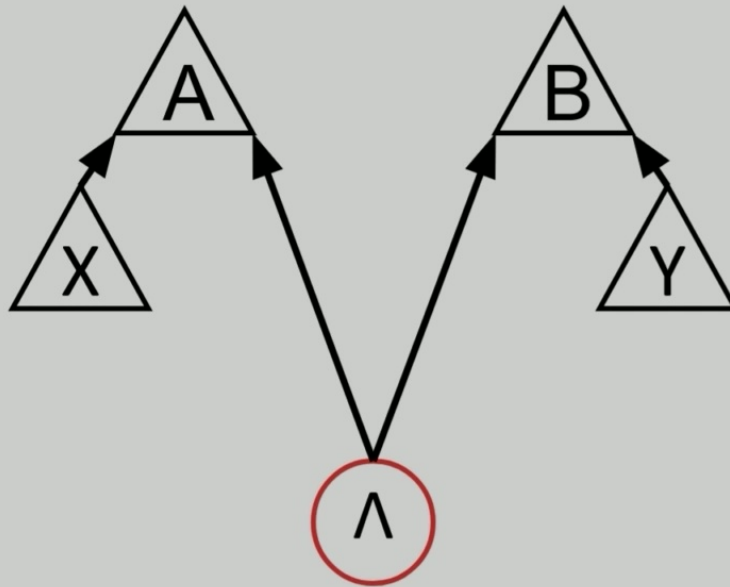
Bell



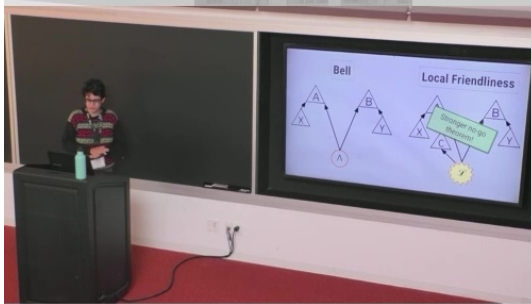
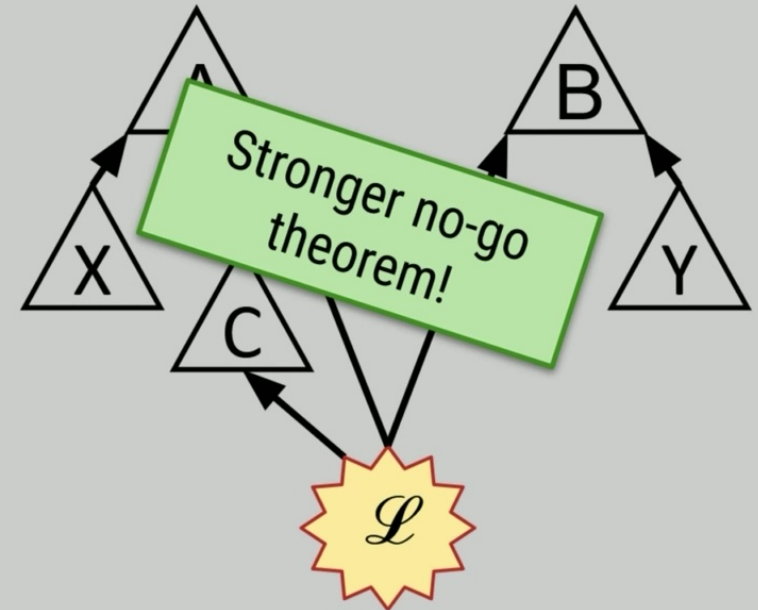
Local Friendliness



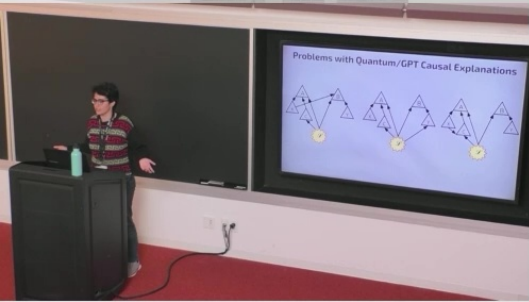
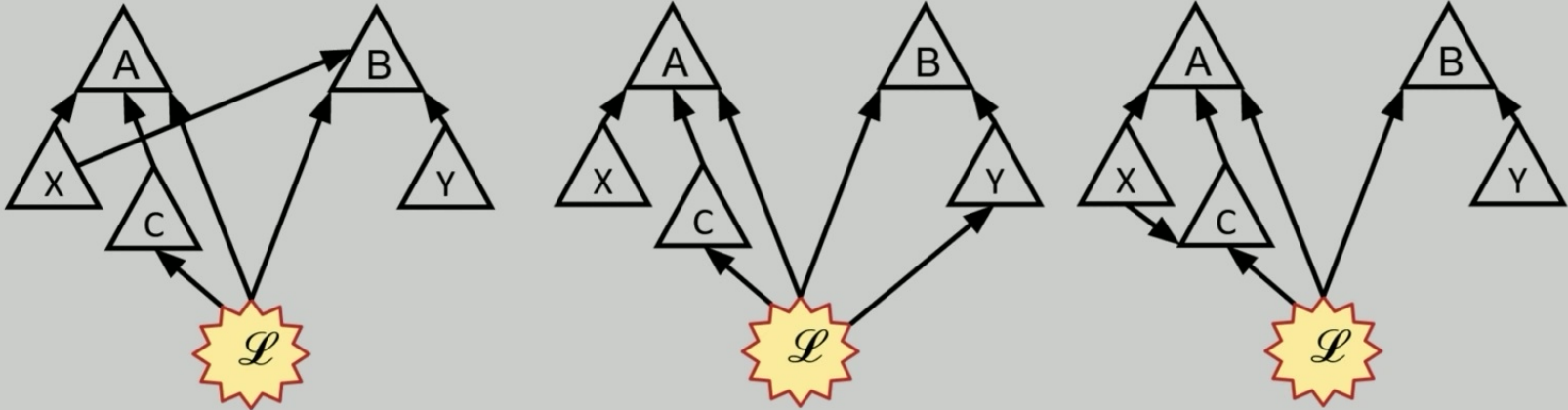
Bell



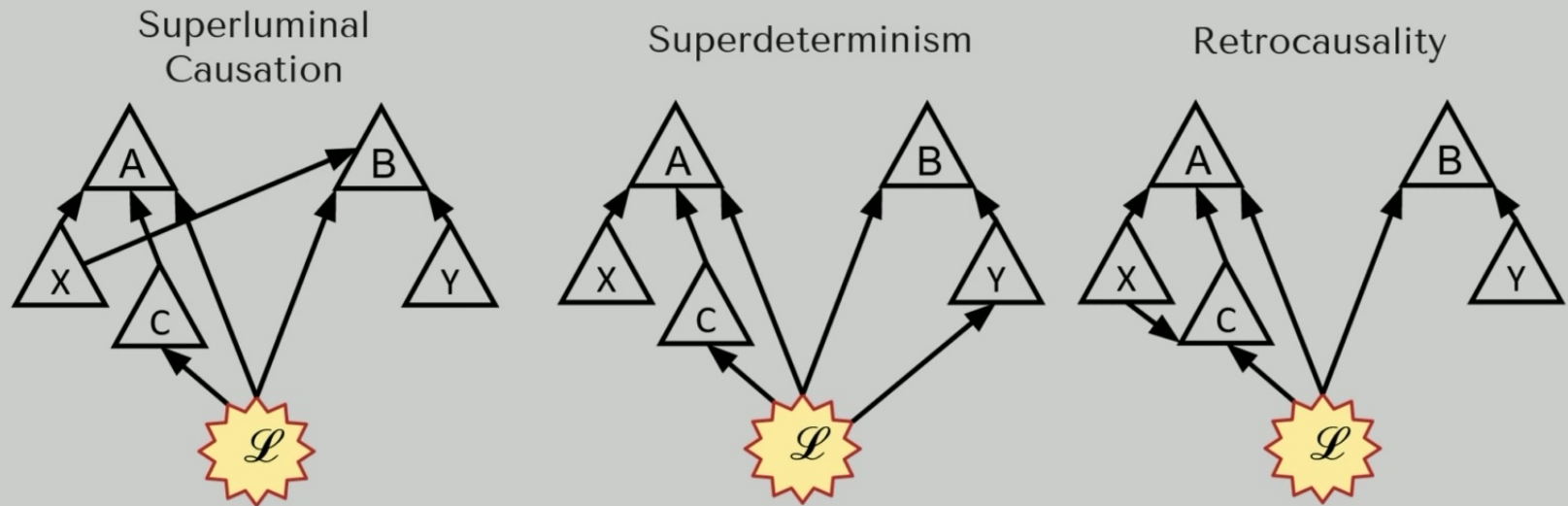
Local Friendliness



Problems with Quantum/GPT Causal Explanations



Problems with Quantum/GPT Causal Explanations



Do not explain why

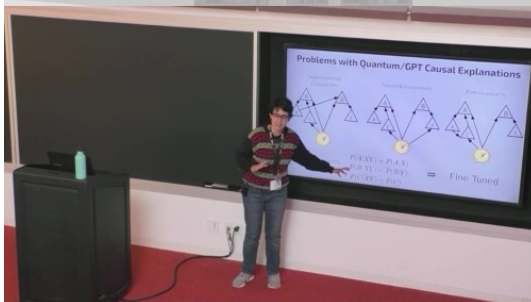
$$P(A|XY) = P(A|X)$$

$$P(B|XY) = P(B|Y)$$

$$P(C|XY) = P(C)$$

⇒

Fine Tuned



The Quantum/GPT Causal Modelling Framework is **not** suited to explain the violation of LF Inequalities.

