Limits of Absoluteness of Observed Events in Timelike Scenario: A no-go Theorem

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SN Bose National Centre For Basic Science

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Two Sets of Rules in Quantum Mechanics

Rules that dictate what the experimental statistics would be

All the times before measurements

★ Systems are described by a wavefunction, and all the properties of the system are deemed hidden in the wavefunction.

★ The state evolves according to the Schrodinger equations.

When Measured

?

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- ★ Systems are described by a wavefunction, and all the properties of the system are deemed hidden in the wavefunction.
- ★ The state evolves according to the Schrodinger equations.

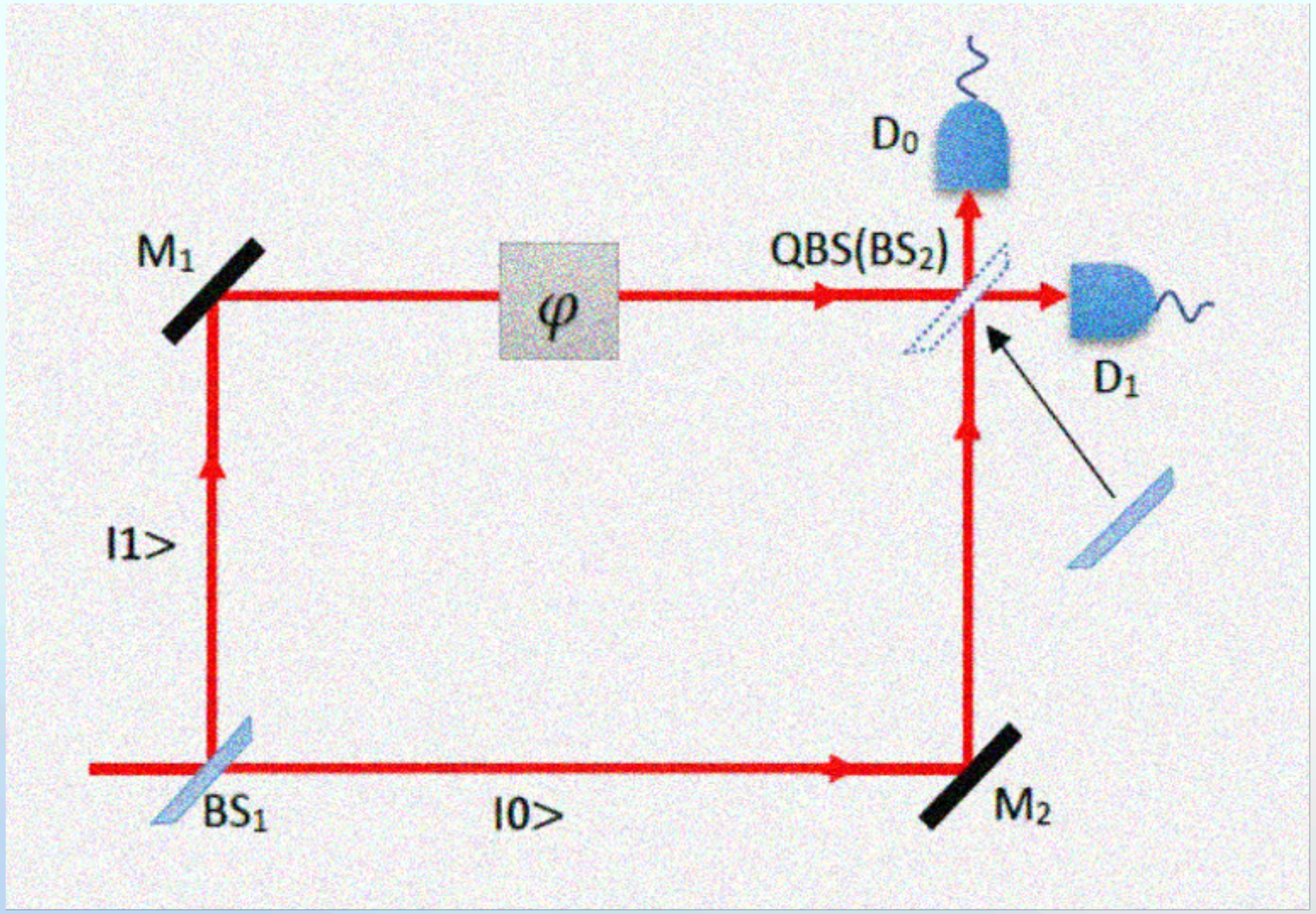
When measured/observed

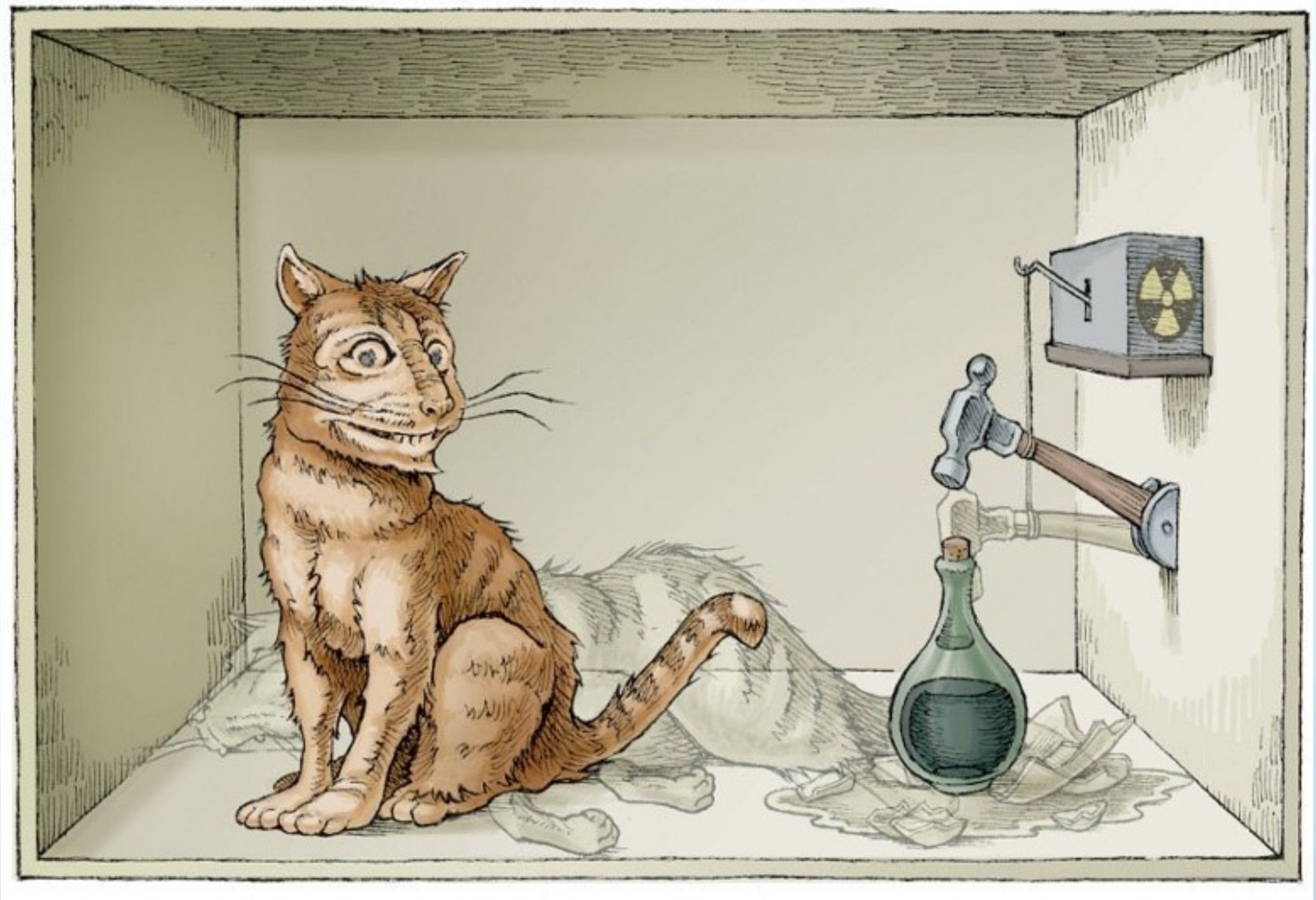
- ★ The wavefunction collapses to a particular eigenstate of the measured observable.
- ★ According to Born's rule, the absolute square of Ψ describes the probability of getting the system in state Ψ.

The Quantum Measurement Problem!

Quantum Bizarreness

From Interference in MZI to Schrödinger's Cat





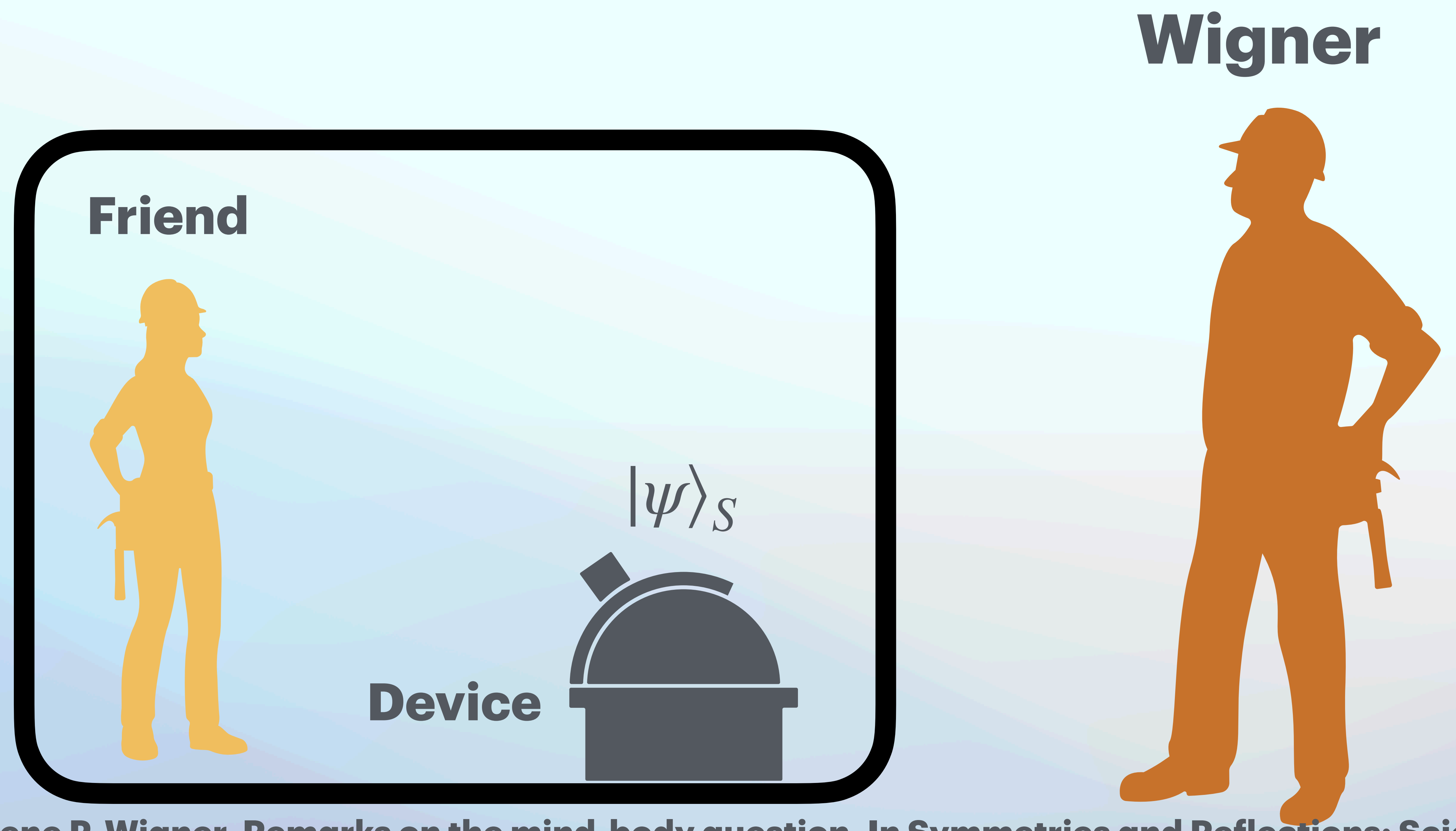
The Quantum Measurement Problem!

Observation Matters? Wigner’s Friend paradox:

Observations not only disturb what has to be measured, they produce it….**We** compel [the electron] to assume a definite position…. **We ourselves** produce the results of measurements.” -Pascual Jordan

$$|\psi\rangle_S = \frac{|\uparrow\rangle_S + |\downarrow\rangle_S}{\sqrt{2}}$$

$$\mathcal{T} : \begin{cases} |\uparrow\rangle_S \rightarrow |\uparrow\rangle_S \otimes |\uparrow\rangle_D \otimes |\uparrow\rangle_F \equiv |\uparrow\rangle_L \\ |\downarrow\rangle_S \rightarrow |\downarrow\rangle_S \otimes |\downarrow\rangle_D \otimes |\downarrow\rangle_F \equiv |\downarrow\rangle_L \end{cases}$$



$$|\psi\rangle_W = \frac{|\uparrow\rangle_L + |\downarrow\rangle_L}{\sqrt{2}}$$

$$\bar{\rho}_F = |\uparrow\rangle_S\langle\uparrow|_S$$

$$\bar{\rho}_W = Tr_{rest}[|\psi\rangle_W\langle\psi|_W] = \frac{1}{2}(|\uparrow\rangle_S\langle\uparrow|_S + \downarrow\rangle_S\langle\downarrow|_S)$$

Eugene P. Wigner. Remarks on the mind-body question. In Symmetries and Reflections: Scientific Essays, pages 171–184. Indiana University Press, 1967. Originally published in: I. J. Good (Ed.), The Scientist Speculates, 1961

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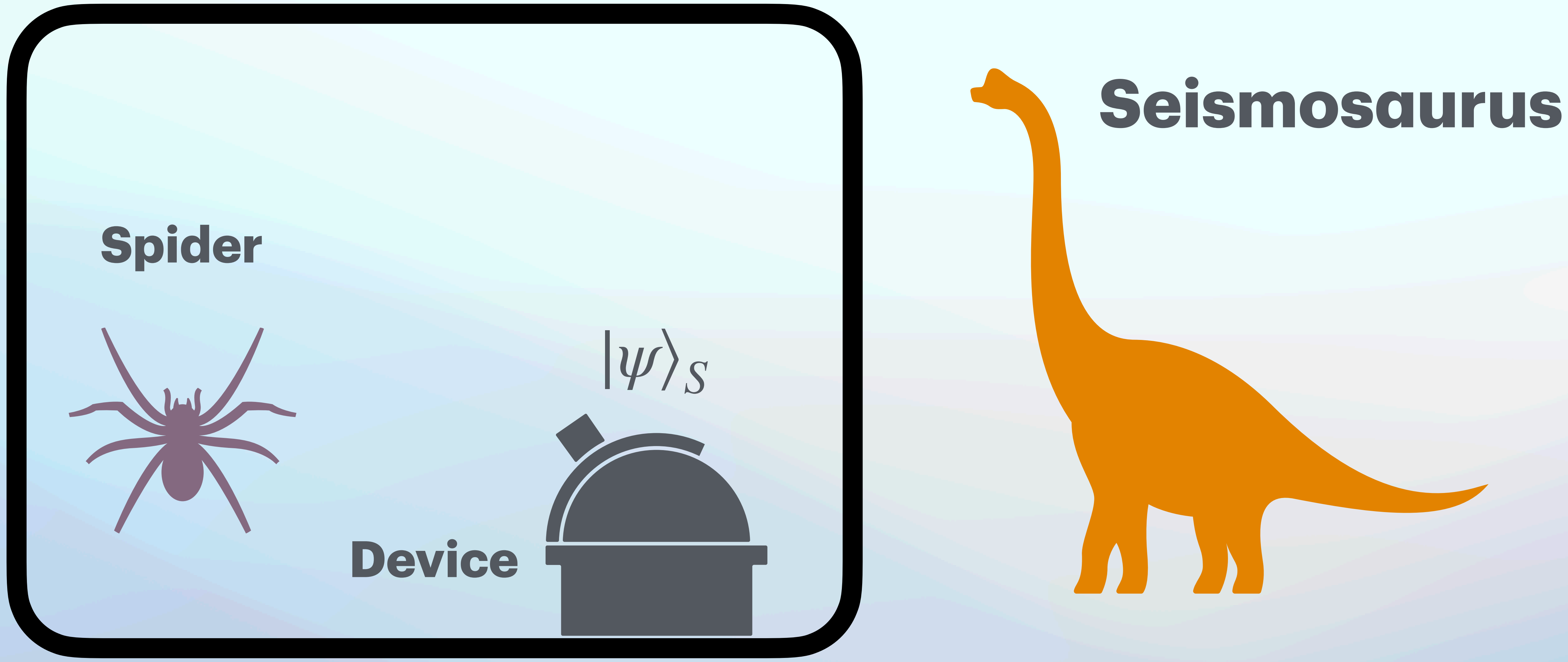

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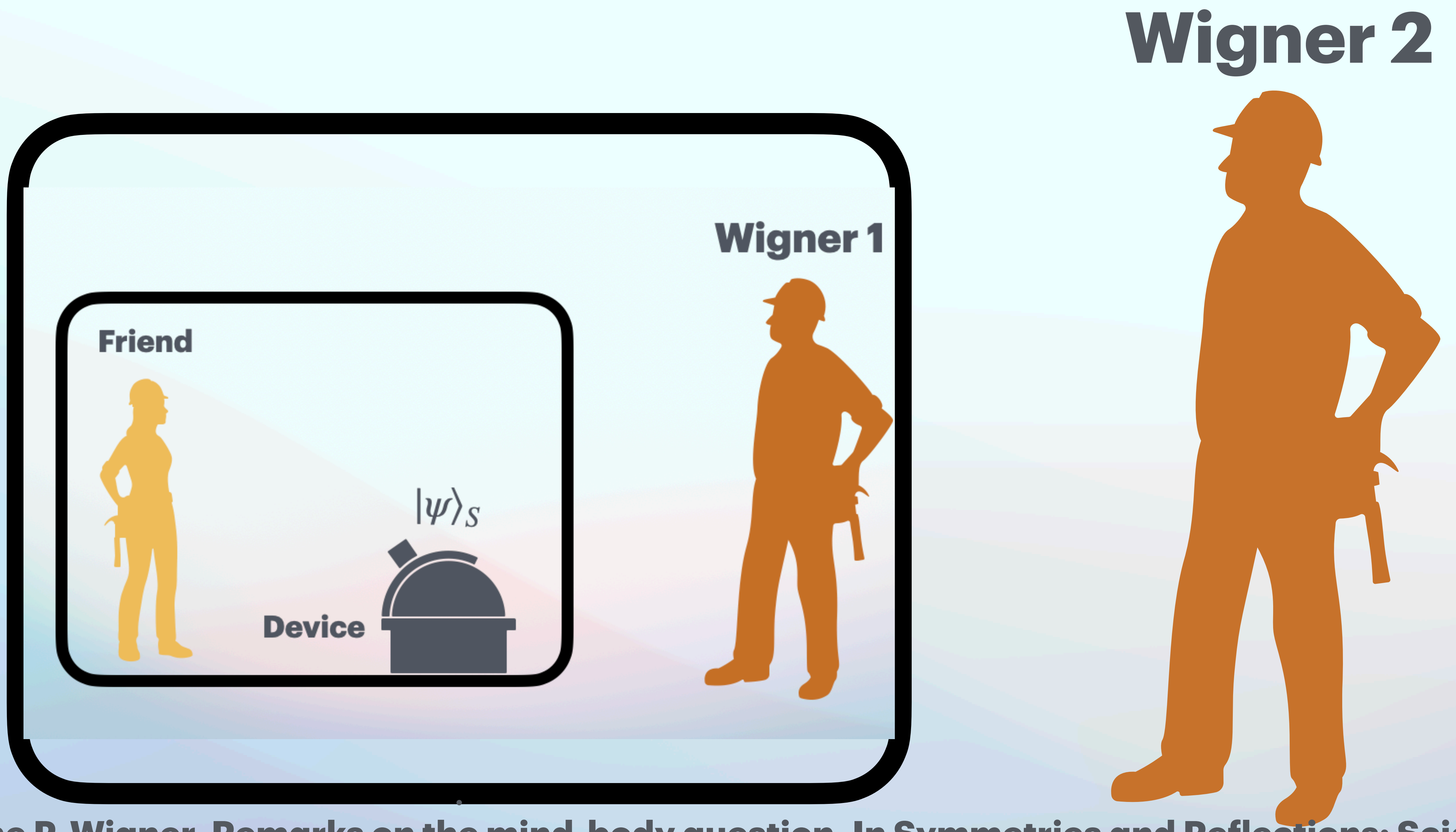

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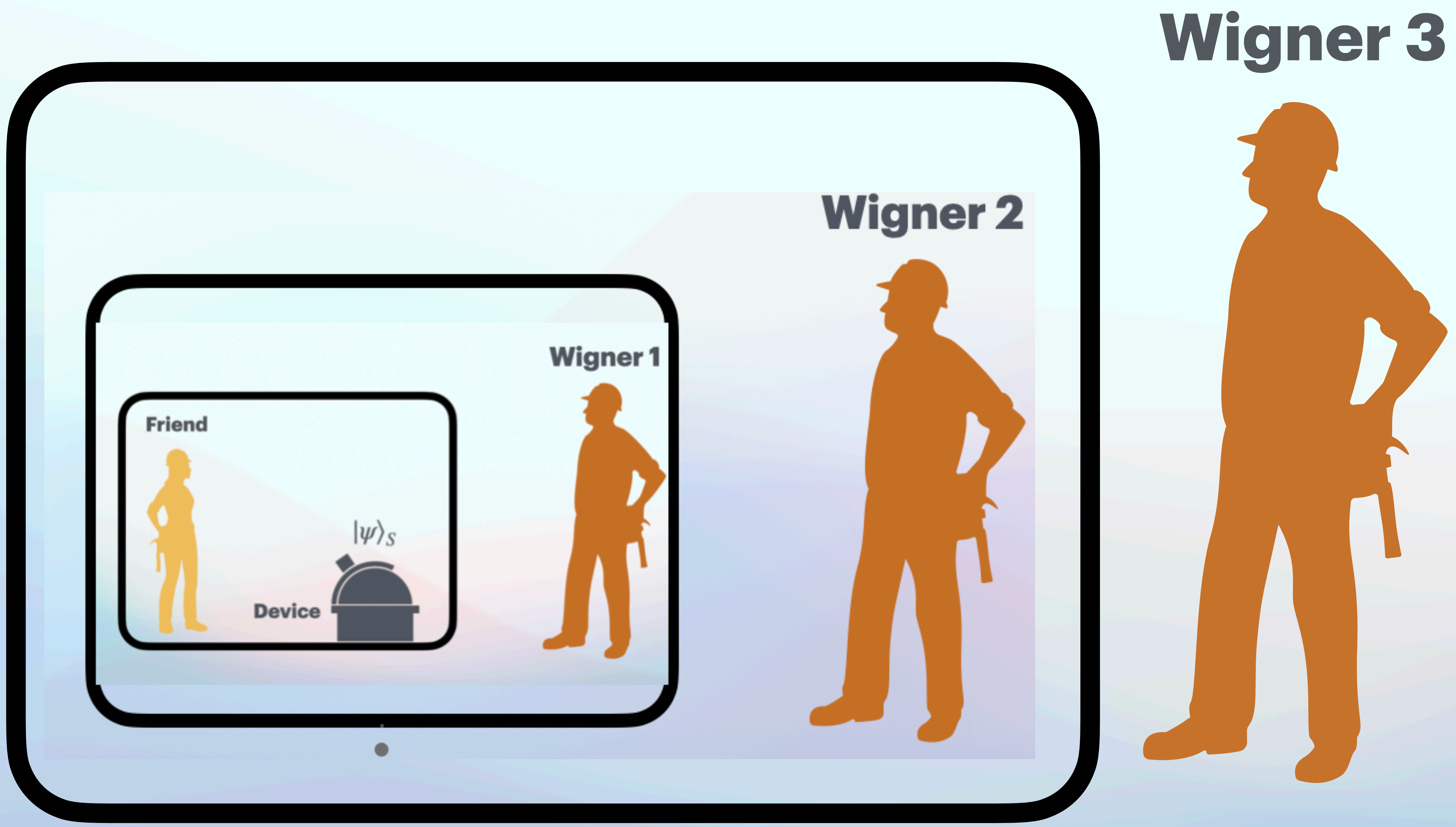

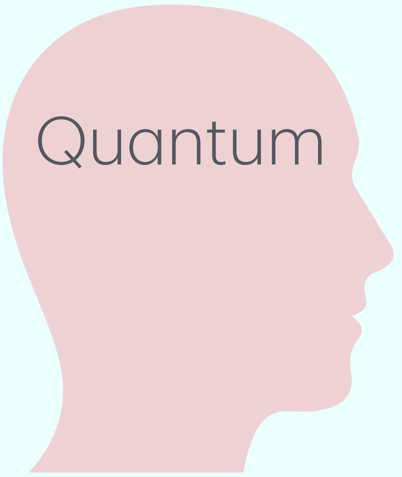

I am still consistent with your worldview

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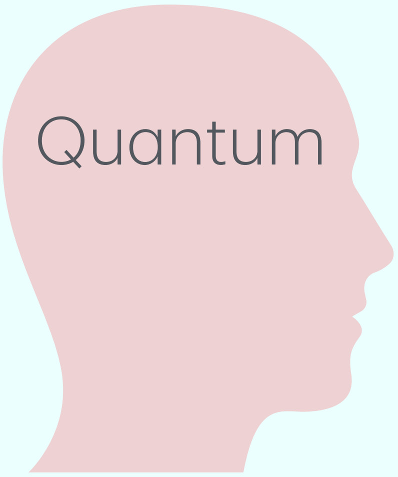
Unperformed experiments have no result!



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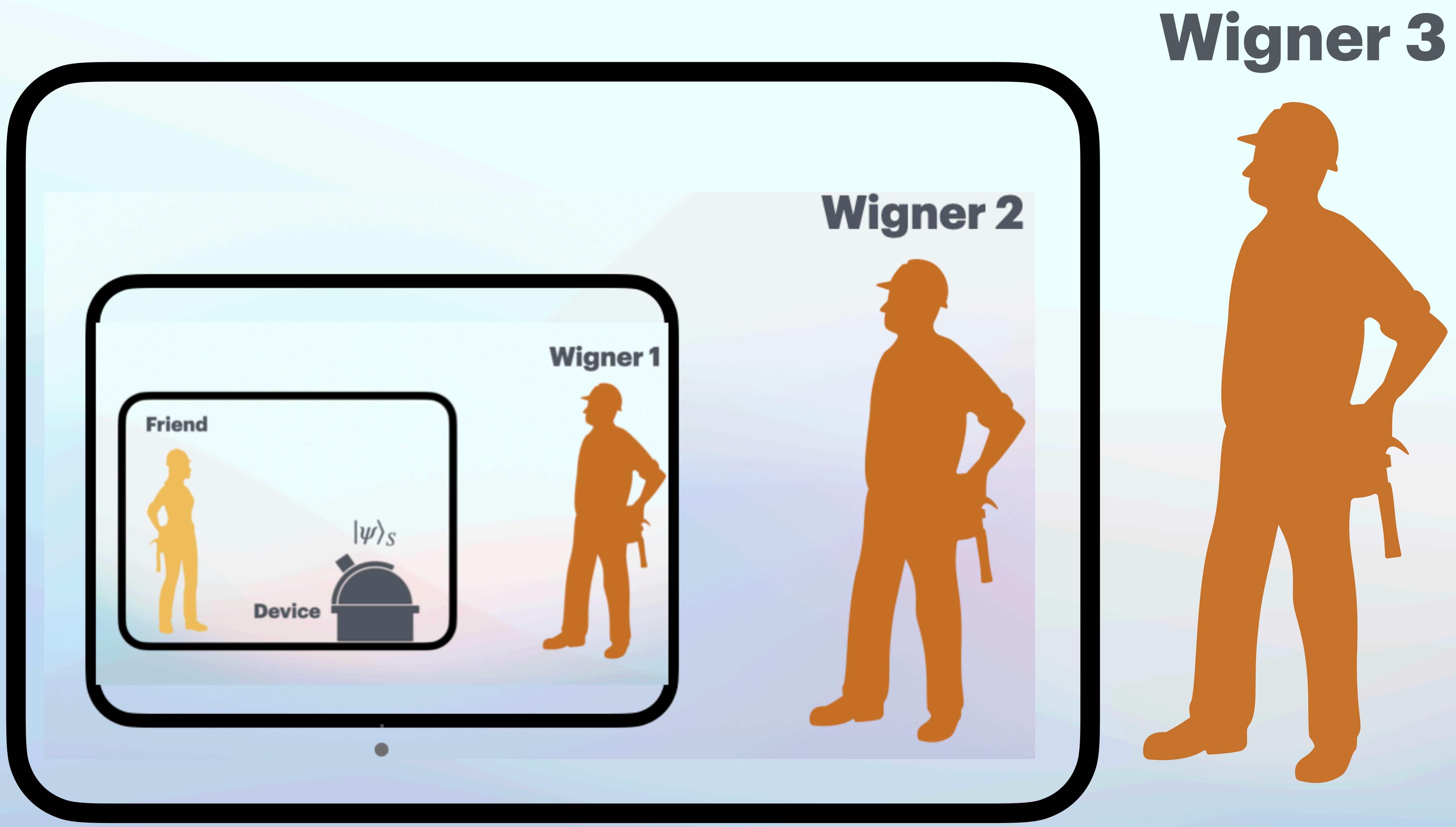

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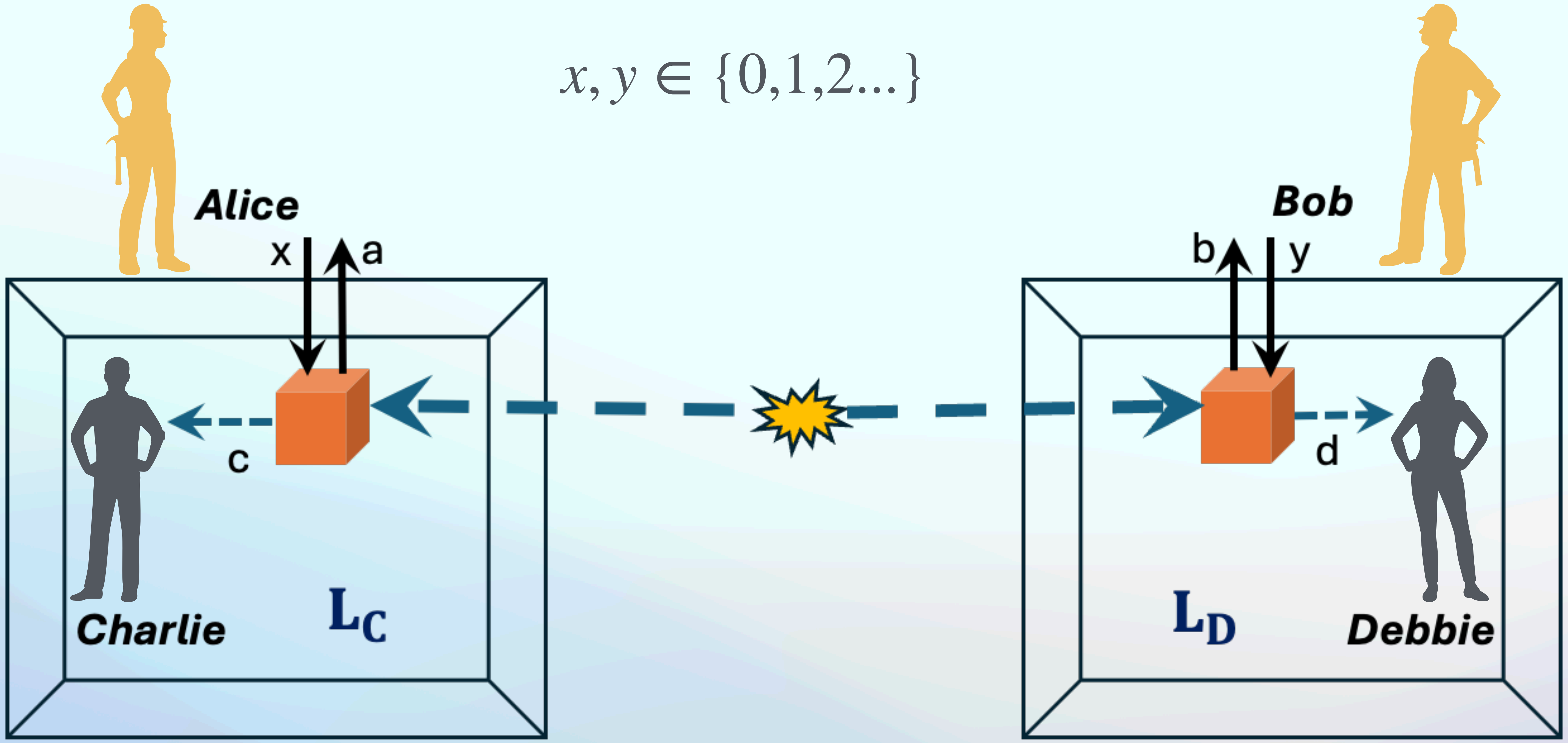
Local Friendliness Paradox

$x = 0 \implies a = c \quad x = 1,2,3.... \implies a$

$y = 0 \implies b = d \quad x = 1,2.3... \implies b$

$x, y \in \{0,1,2...\}$



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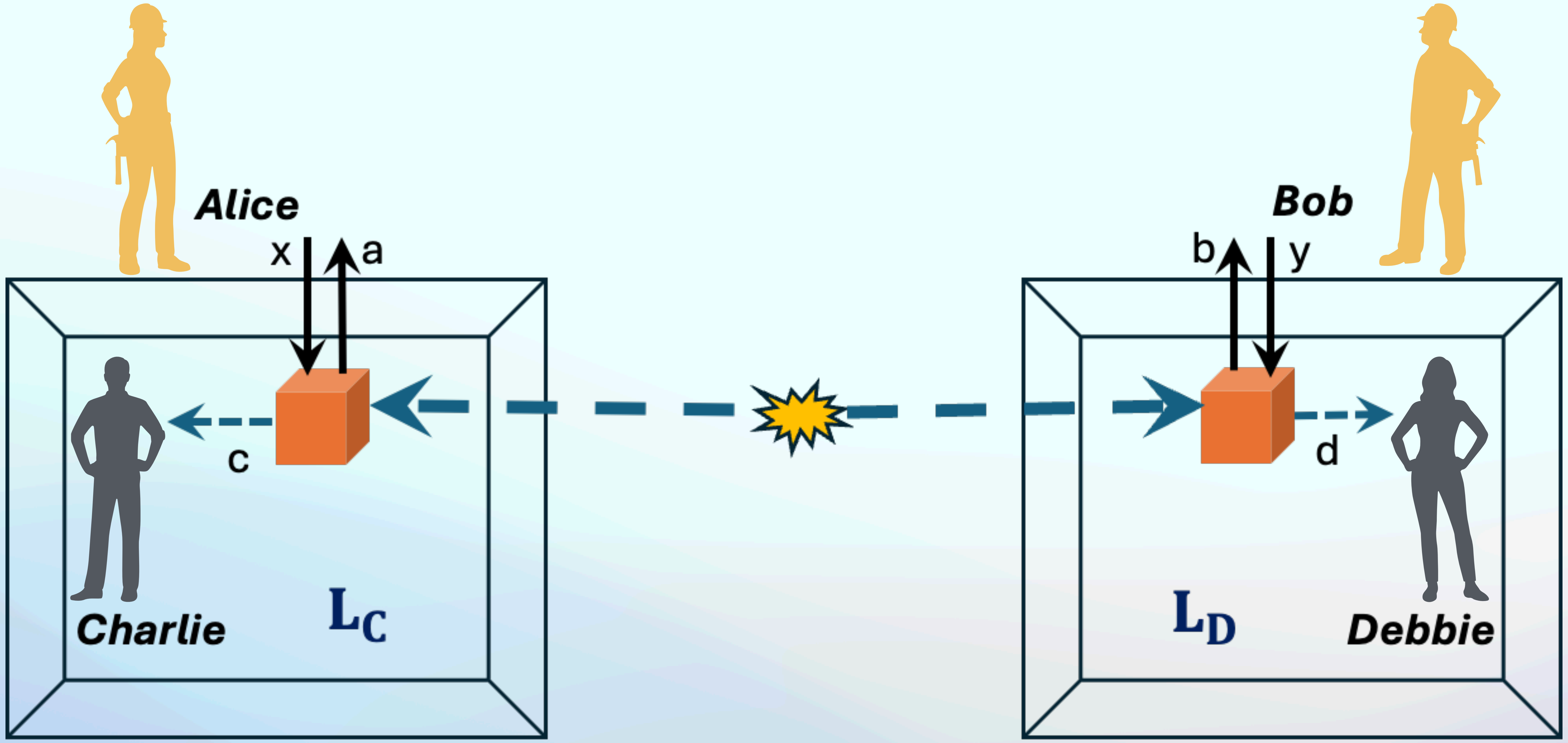

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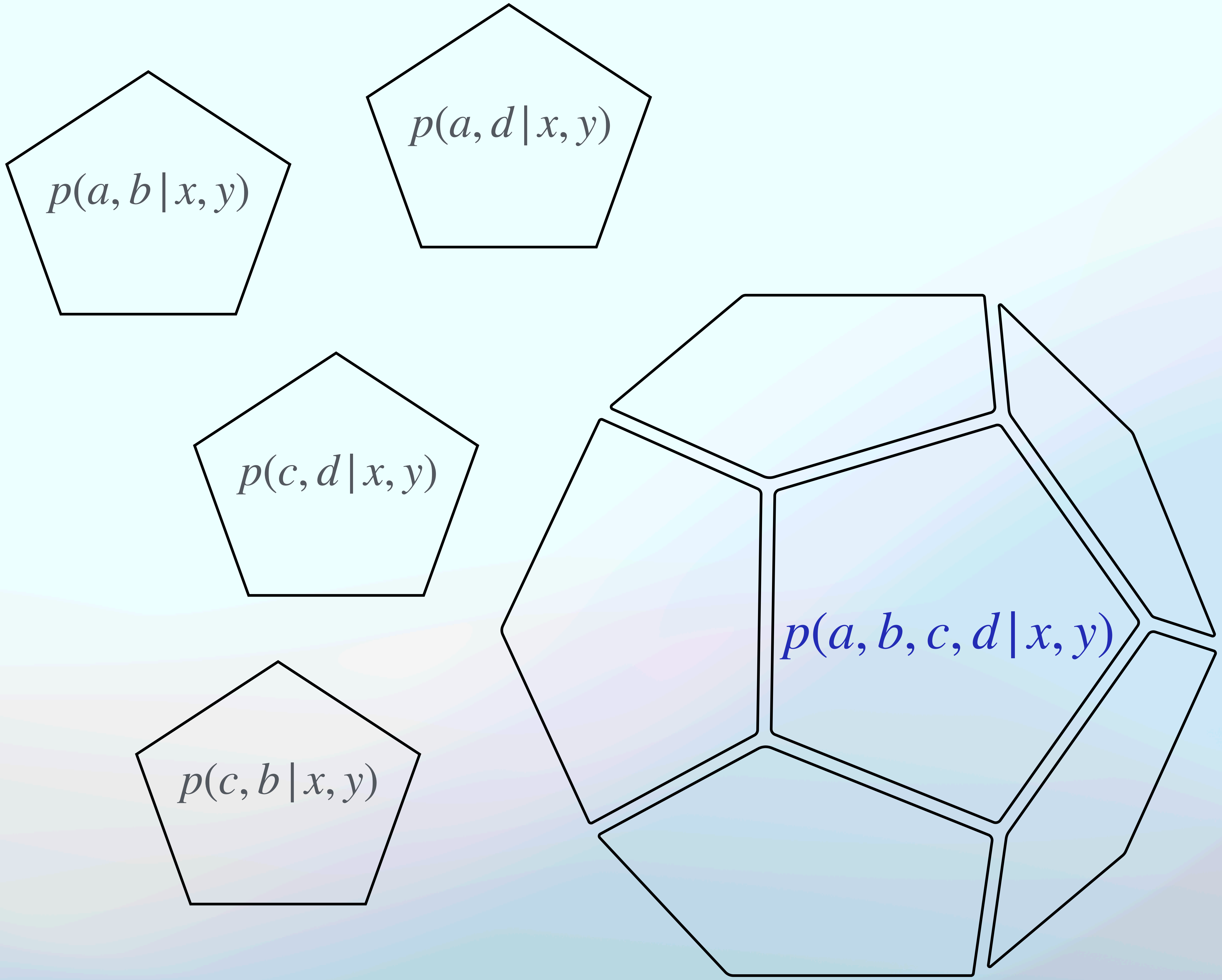

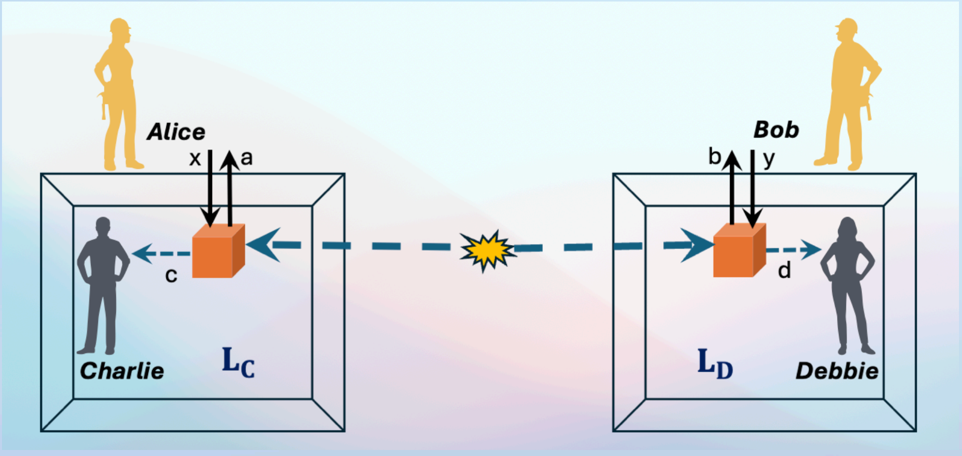

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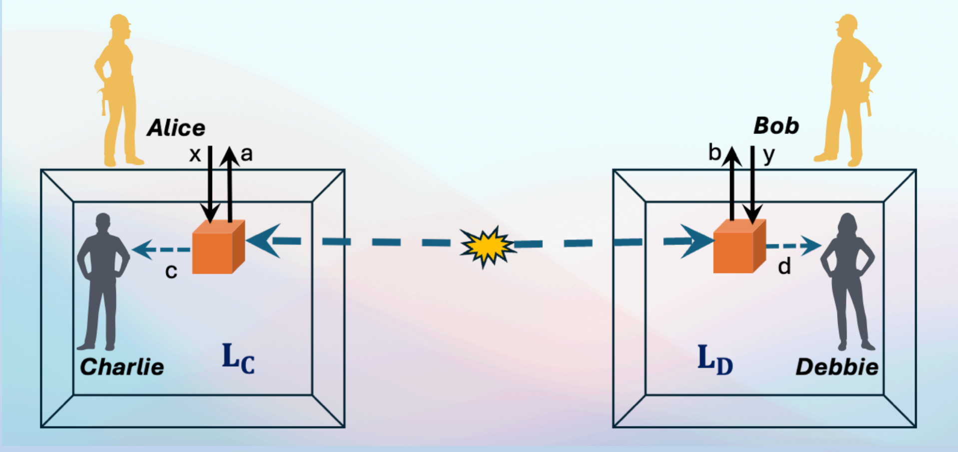
$$p(c, d \mid x, y) = p(c, d) \quad \forall c, d, x, y$$ No-Superdeterminism

$$\left.\begin{aligned} p(a \mid c, d, x, y) &= p(a \mid c, d, x) \quad \forall c, d, x, y, a \\ p(b \mid c, d, x, y) &= p(a \mid c, d, y) \quad \forall c, d, x, y, b \end{aligned}\right\}$$ Locality



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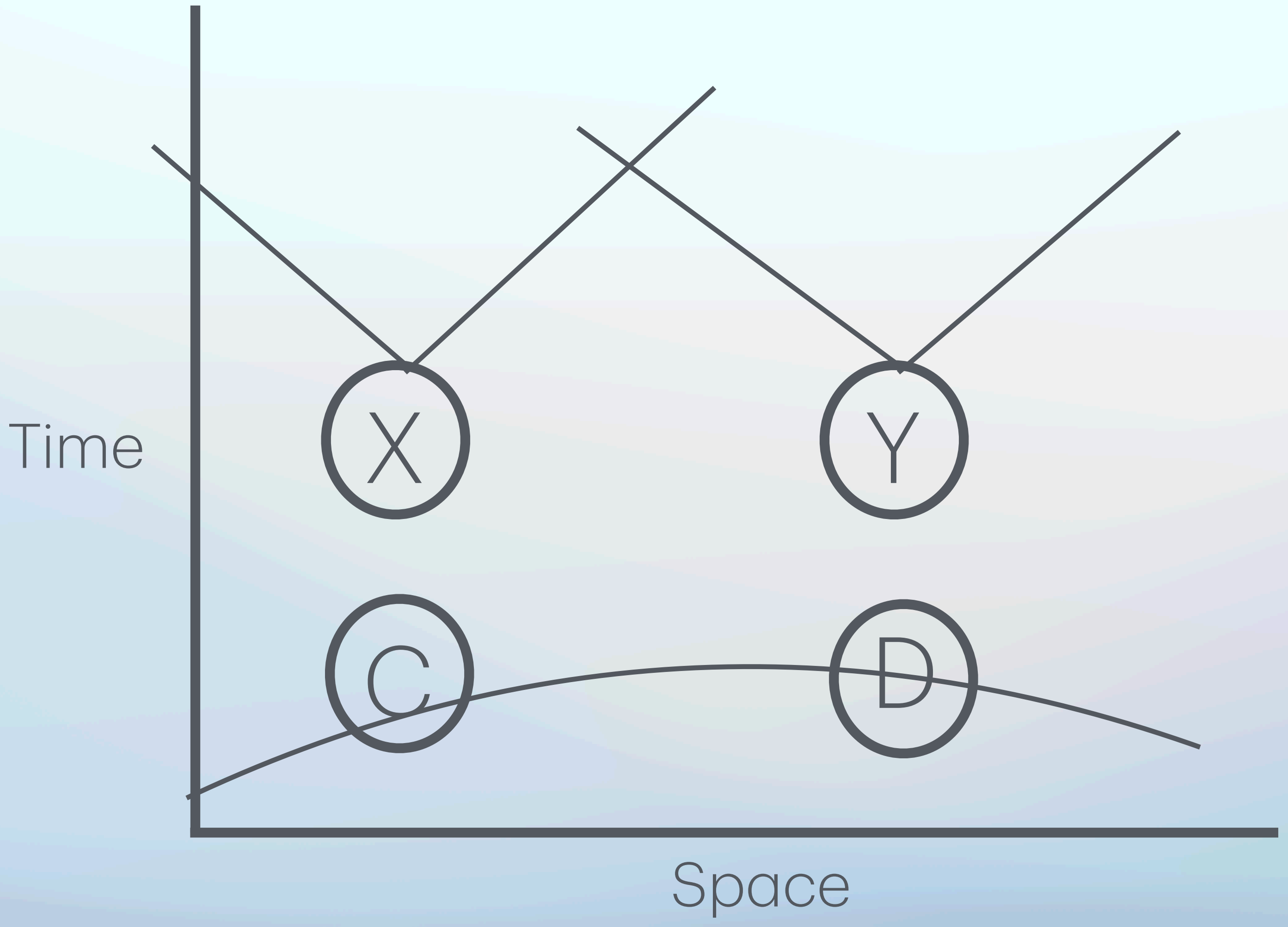

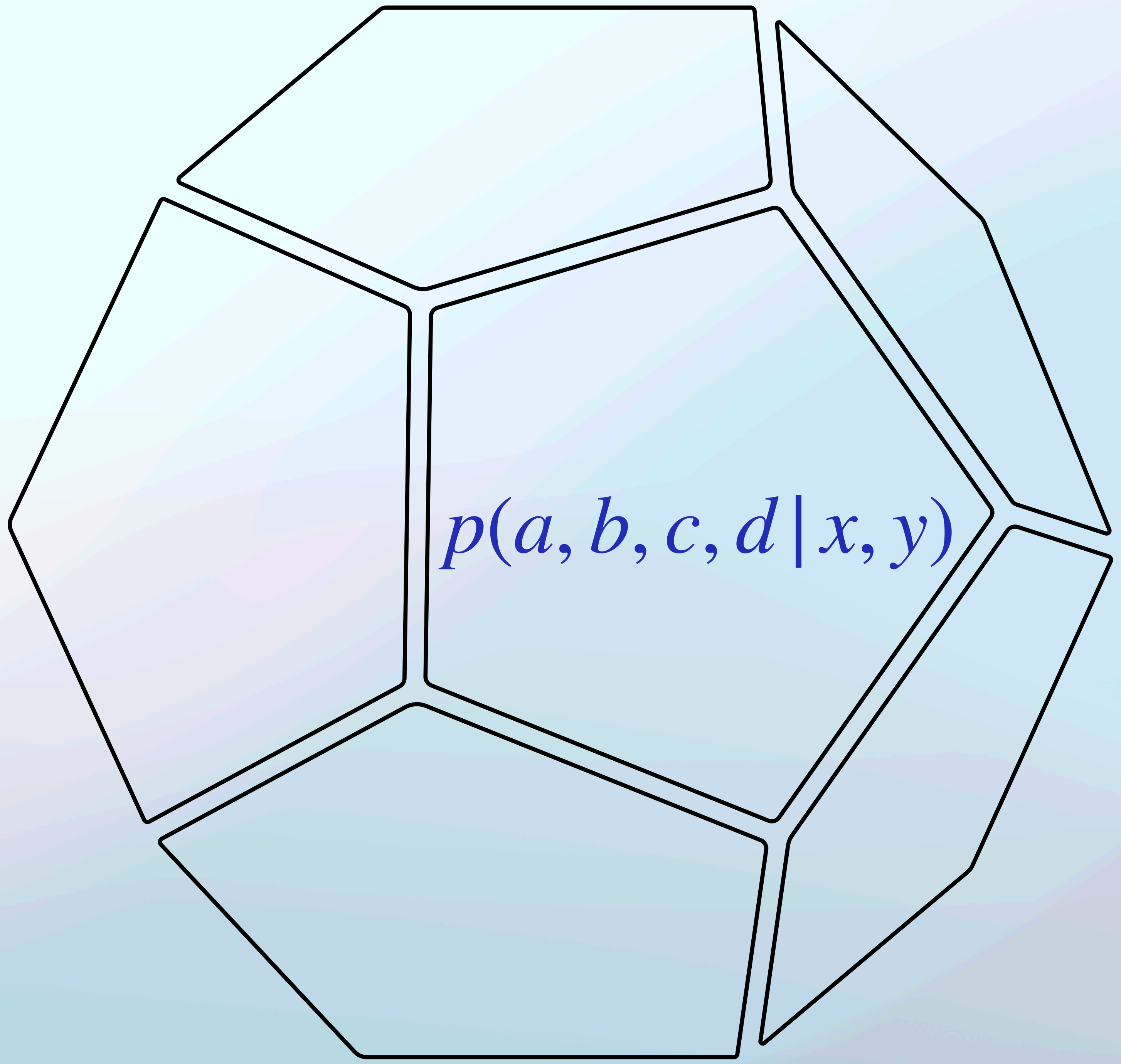

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Assumption 1 (Absoluteness of Observed Events (AOE). An observed event is an absolute single event, not relative to anything or anyone:

Assumption 2 (Local Agency). No-signalling outside the future light cone, which would be verified by a hypothetical agent with access to all the relevant variables, still holds even if it cannot be verified by a single agent.

$$p(c, d \mid x, y) = p(c, d) \quad \forall c, d, x, y$$

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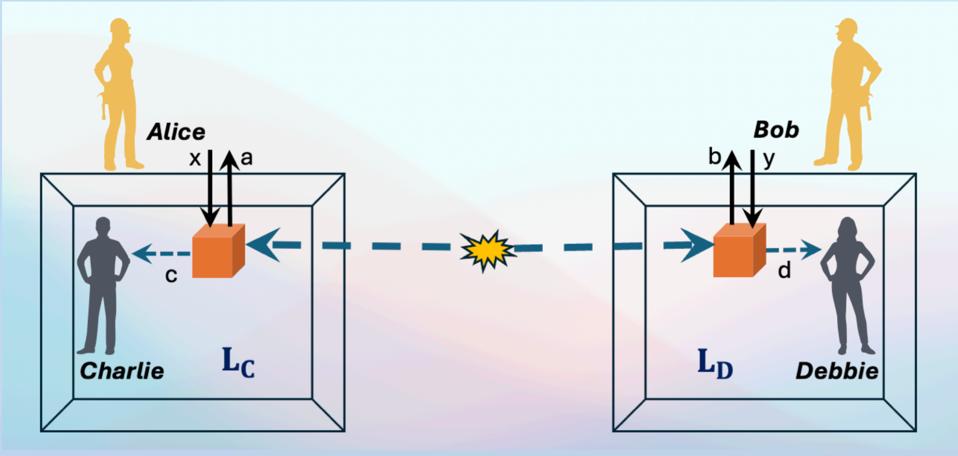

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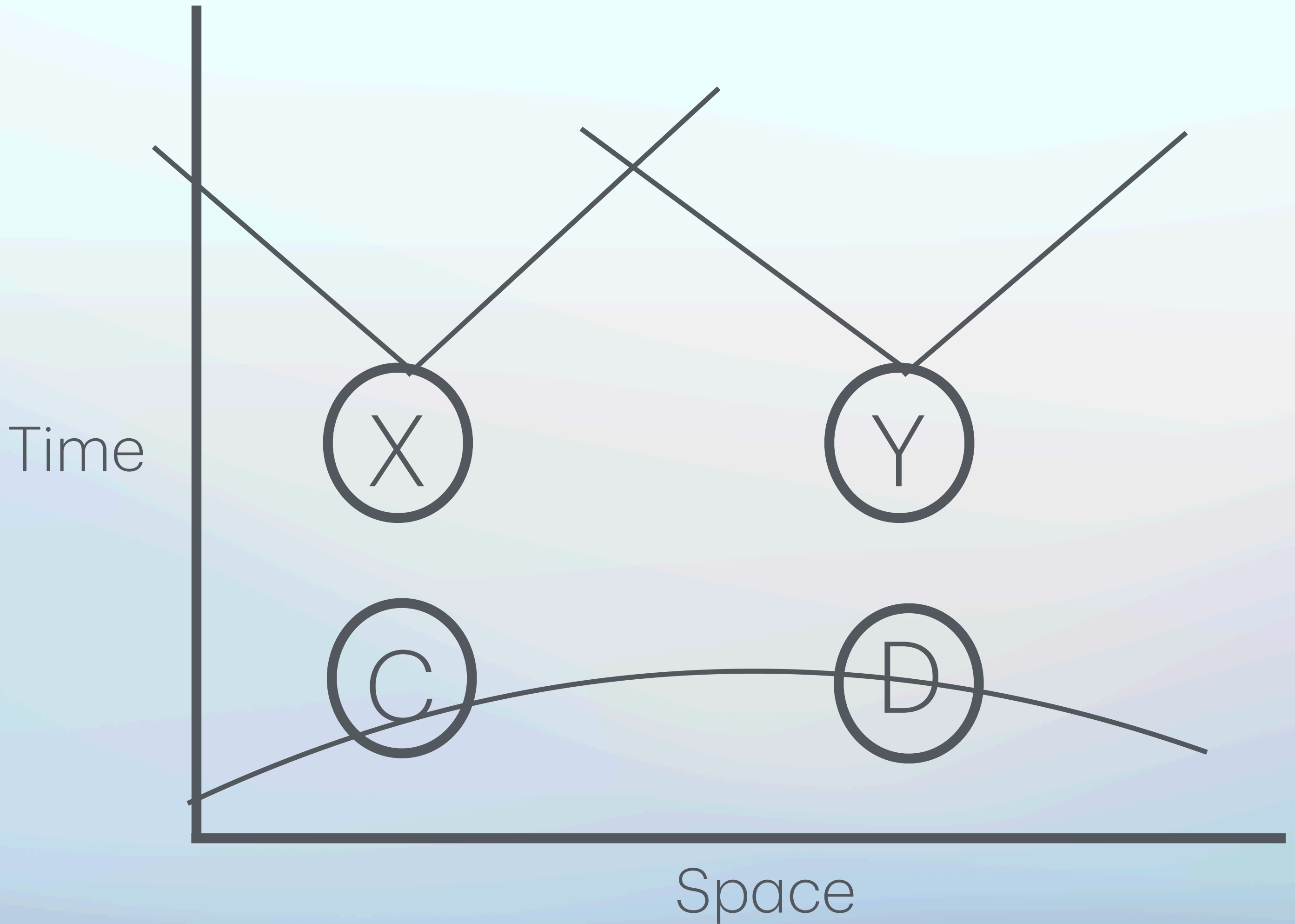

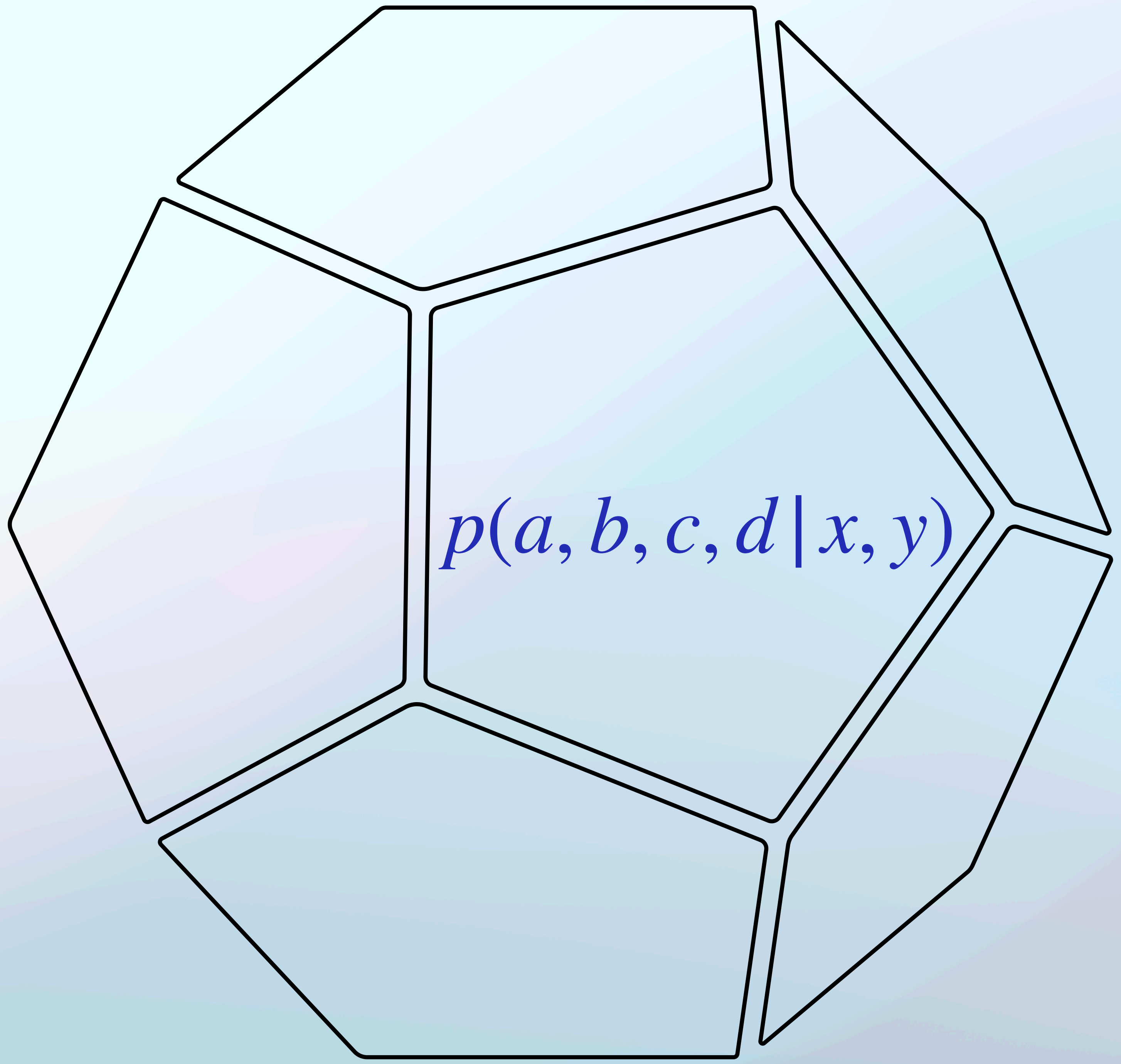

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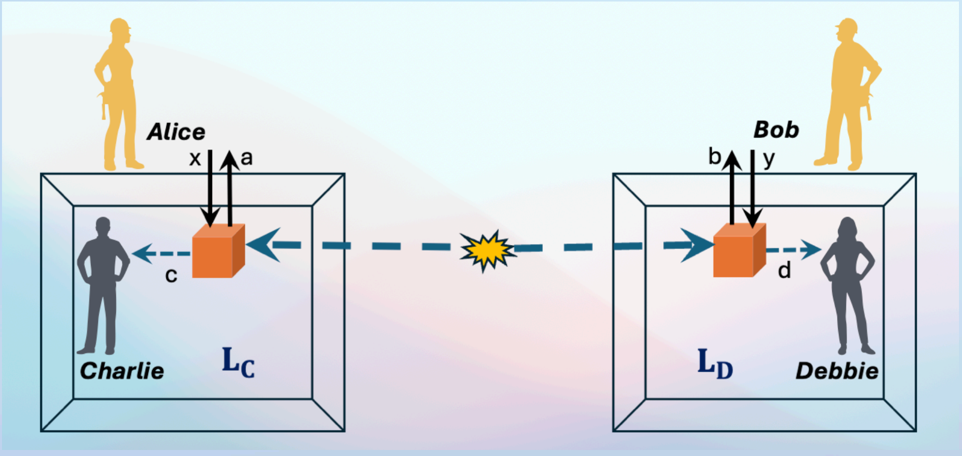
Locality

$$\mathscr{L} \leq c \qquad\qquad \mathscr{L}_Q \geq c$$



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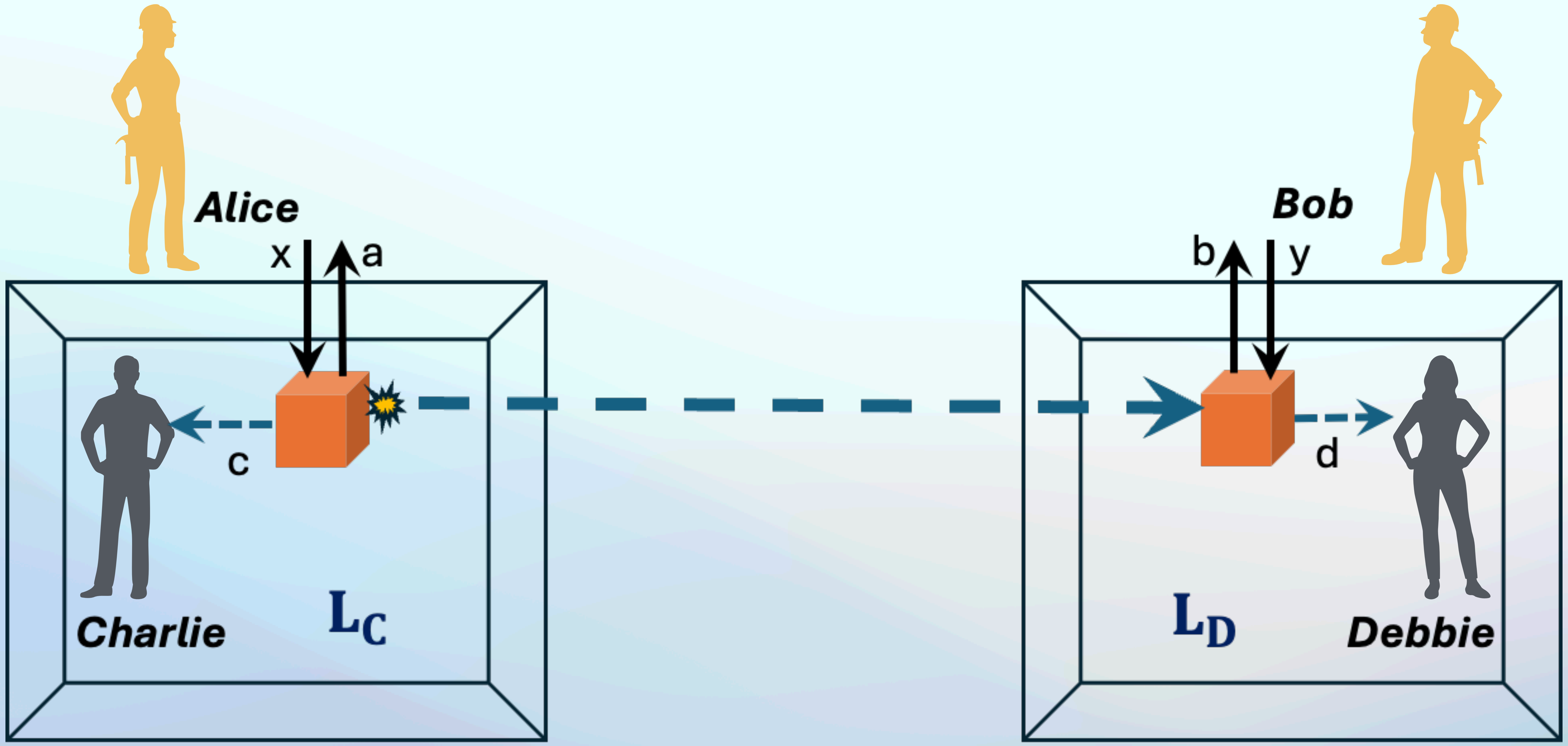

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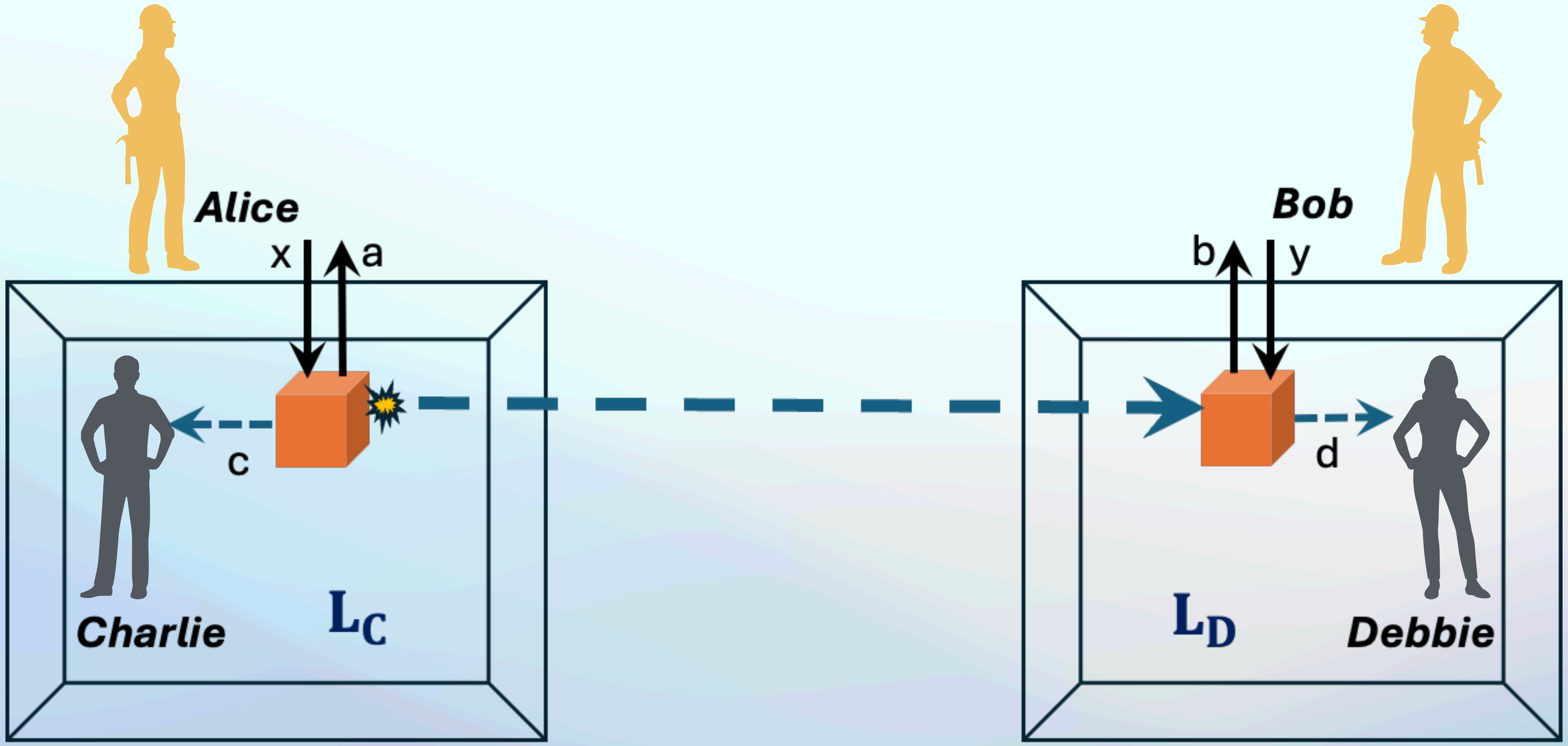
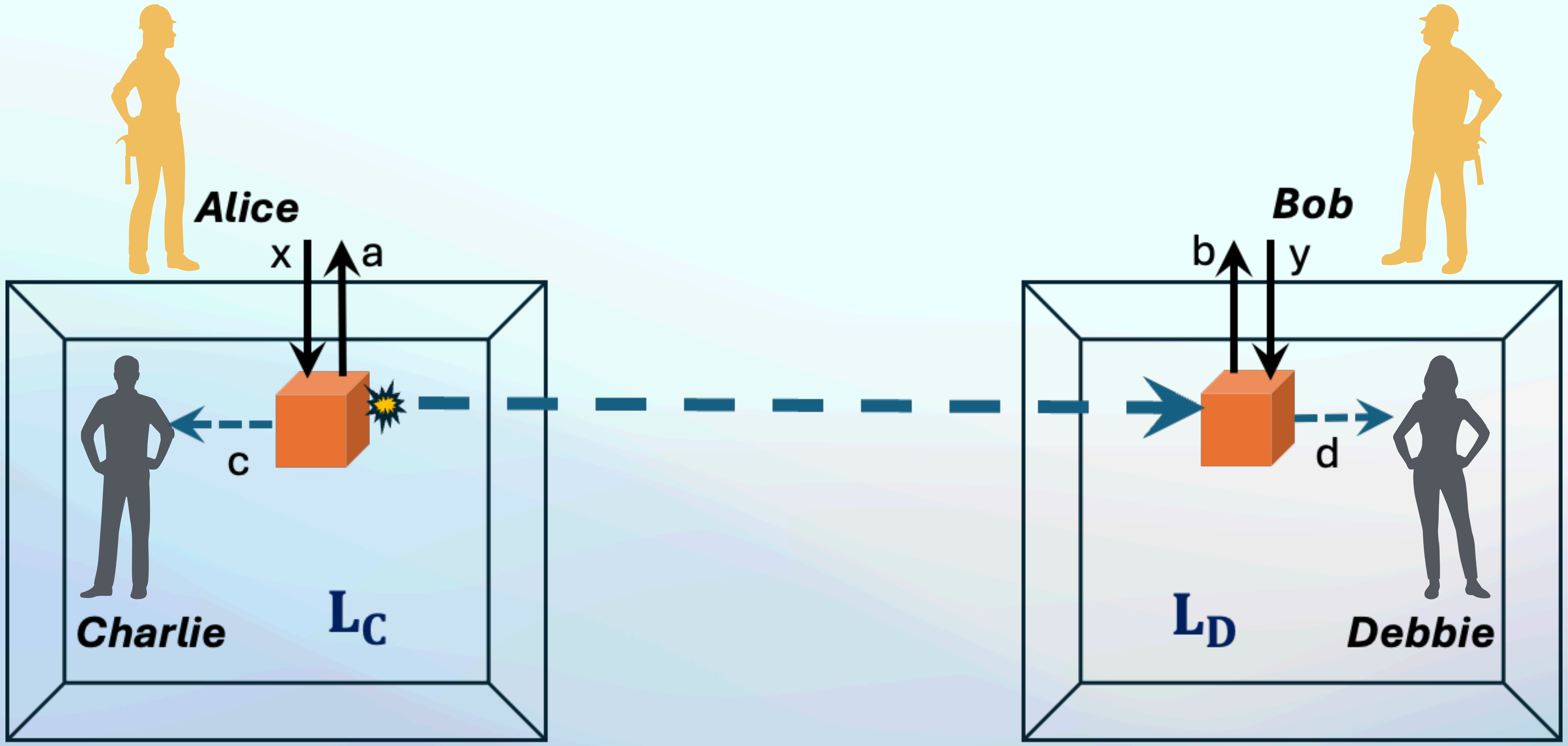
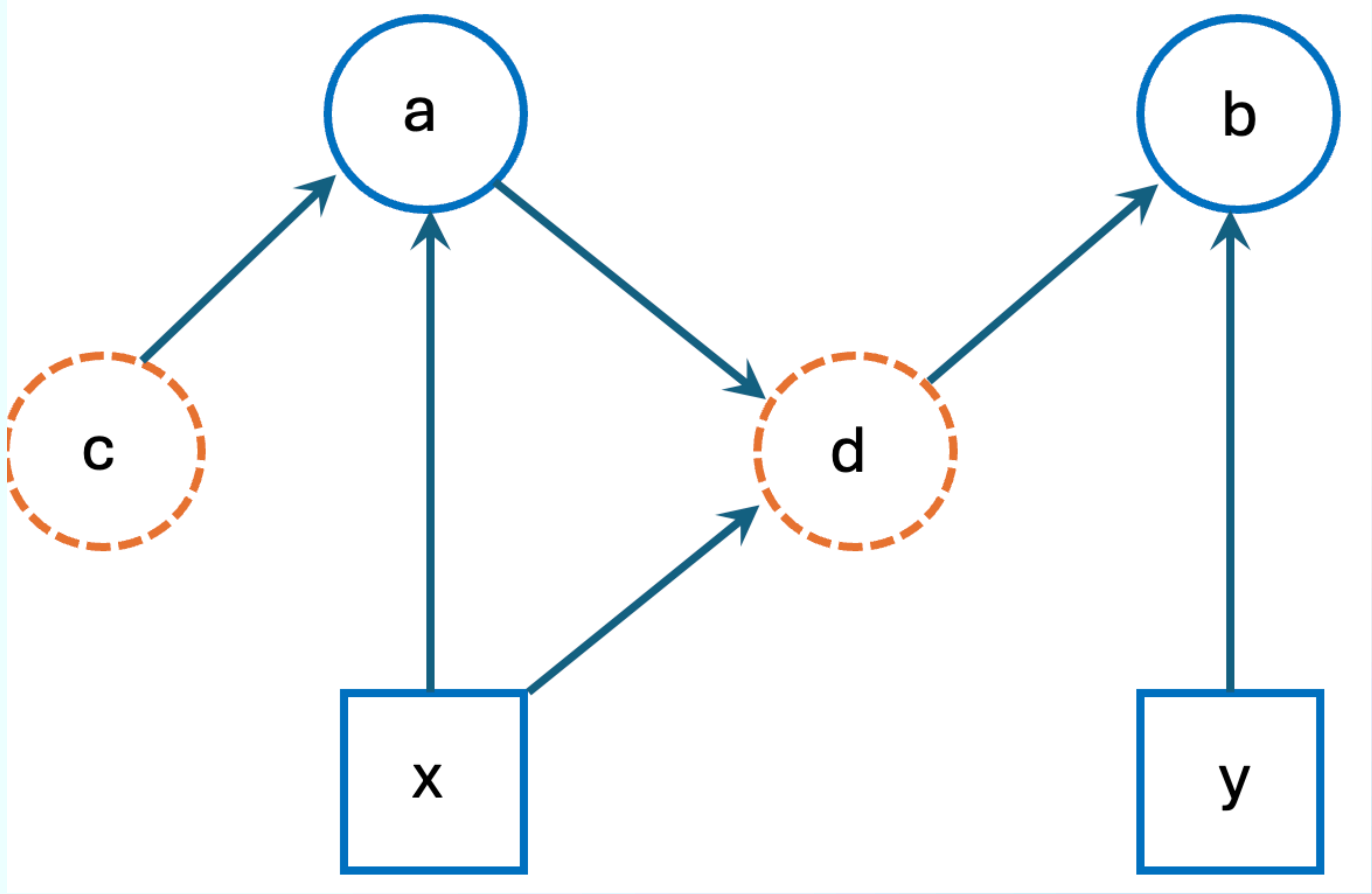


1. Truely-observed events
2. Pseudo events

Causal-Friendliness Scenario





Causal Influence Diagram

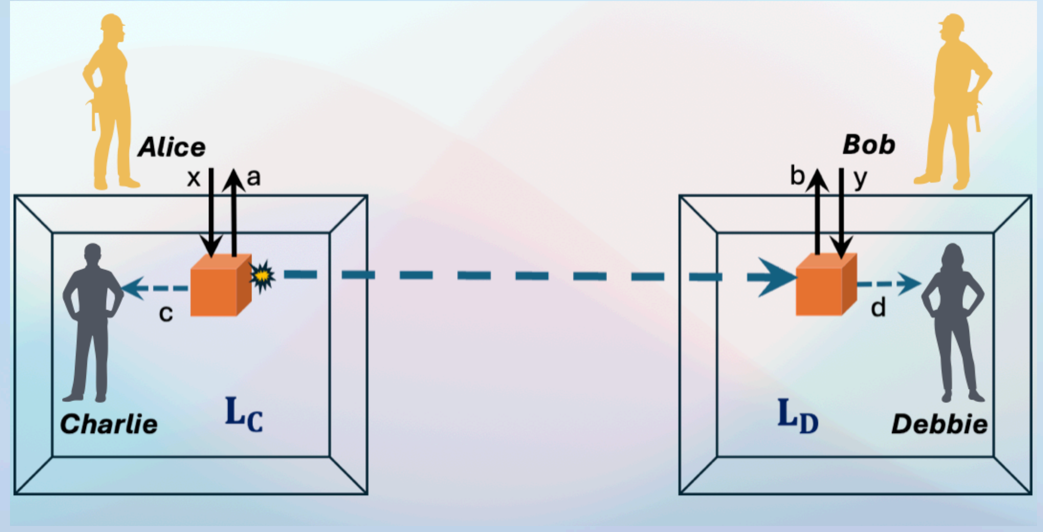
1. Truely-observed events
2. Pseudo events

Causal-Friendliness no-go theorem

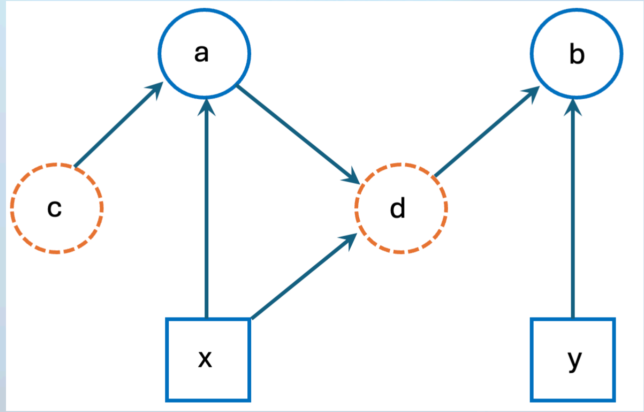
Assumption 1

Absoluteness of Observed Events (AOE): All observed events at a particular point on the space-time region characterised by measurement outcomes a,b,c,d have definite values, irrespective of any event that occurred at any other point in the space-time. This means the joint probability p(c,a,d,b|x,y) exists and the observed probability p(a,b|x,y) can be recovered from it via marginalisation as,

$$p(a,b\,|\,x,y) = \sum_{c,d} p(c,a,d,b\,|\,x,y) \quad \forall x,y,a,b\,.$$



CF Scenario



Causal Influence Diagram

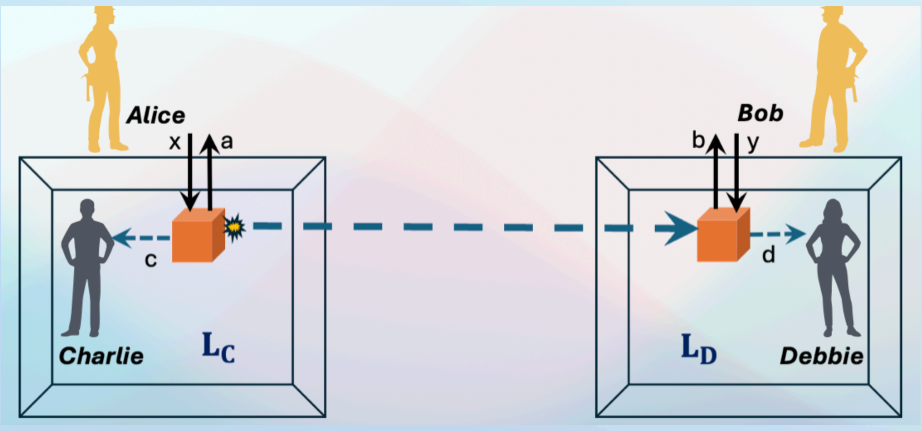
Causal-Friendliness no-go theorem

Definition.

Operational Time Symmetry: A prepare-measure experiment with preparation $\mathbb{P}$ and measurement $\mathbb{M}$ has operational time symmetry if there exists a time-reversed experiment, with preparation $\mathbb{P}'$ and measurement $\mathbb{M}'$, in which $\mathbb{P}' \equiv \mathbb{M}$ and $\mathbb{M}' \equiv \mathbb{P}$ such that $p_{\leftarrow}(f, e \,|\, v, u) = p_{\rightarrow}(e, f \,|\, u, v) \; \forall u, v, x, y$.

Assumption 2

Axiological Time Symmetry (ATS): If we invert the order of the scenario (i.e., have Debbie and Bob acting before Charlie and Alice), this inversion preserves the structure of these joint probabilities, i.e., $p_{\leftarrow}(d, b, c, a \,|\, y, x) = p_{\rightarrow}(c, a, d, b \,|\, x, y) \; \forall x, y, a, b, c, d$



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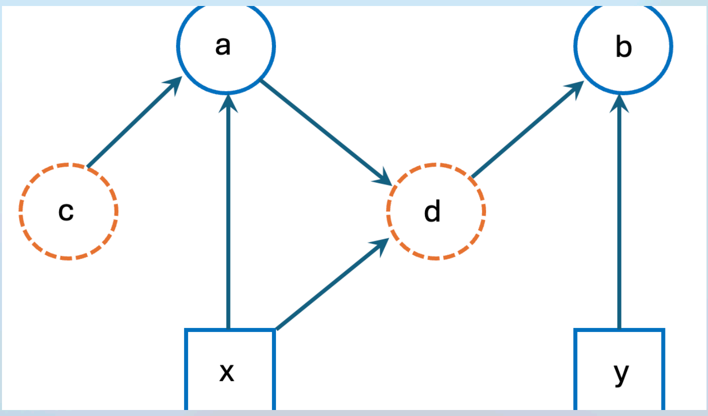


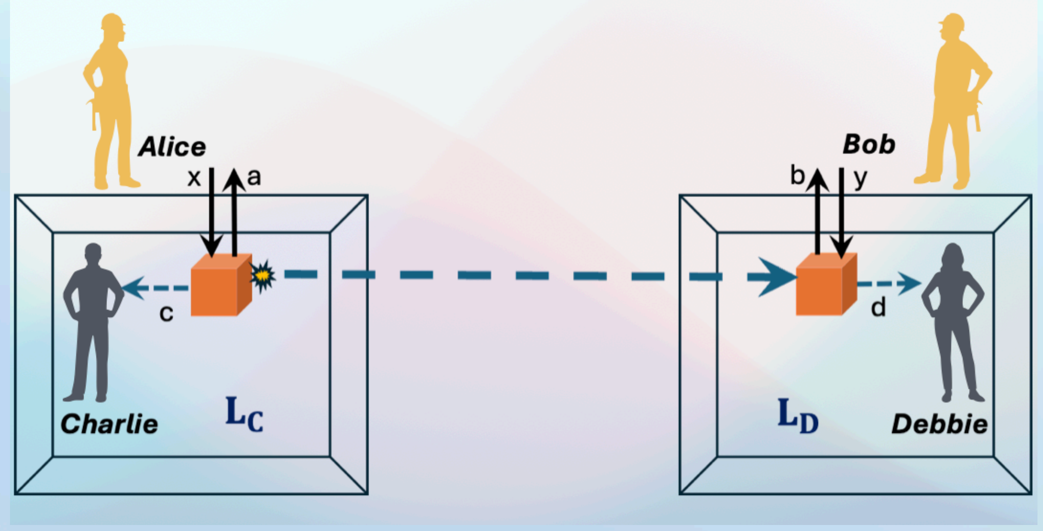
Causal Diagram

Huw Price, Does time-symmetry imply retrocausality? How the quantum world says "Maybe"? Studies in History and Philosophy of Science Part B: Studies in History and Philosophy of Modern Physics,Volume 43, Issue 2, May 2012.

Causal-Friendliness no-go theorem

Assumption 3

No Retrocausality (NRC): Any future measurement choice $x(y)$ cannot influence the past outcomes corresponding to the Pseudo Events $c(d)$, and any observed event a in the past cannot be influenced by the future Pseudo Event d.



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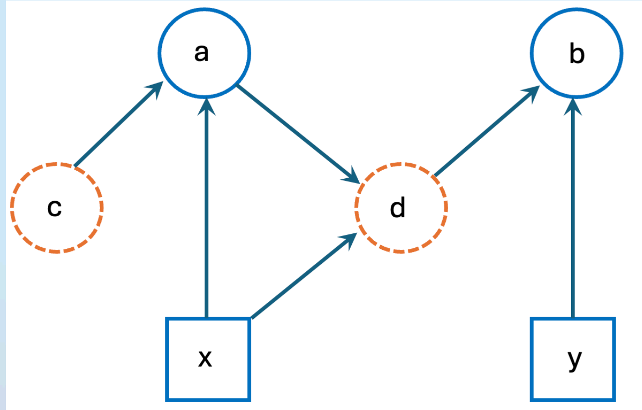

Causal Influence Diagram

Matthew S. Leifer and Matthew F. Pusey. Is a time-symmetric interpretation of quantum theory possible without retrocausality? Proc. Roy. Soc. A, 473(2202):20160607,, 2017.

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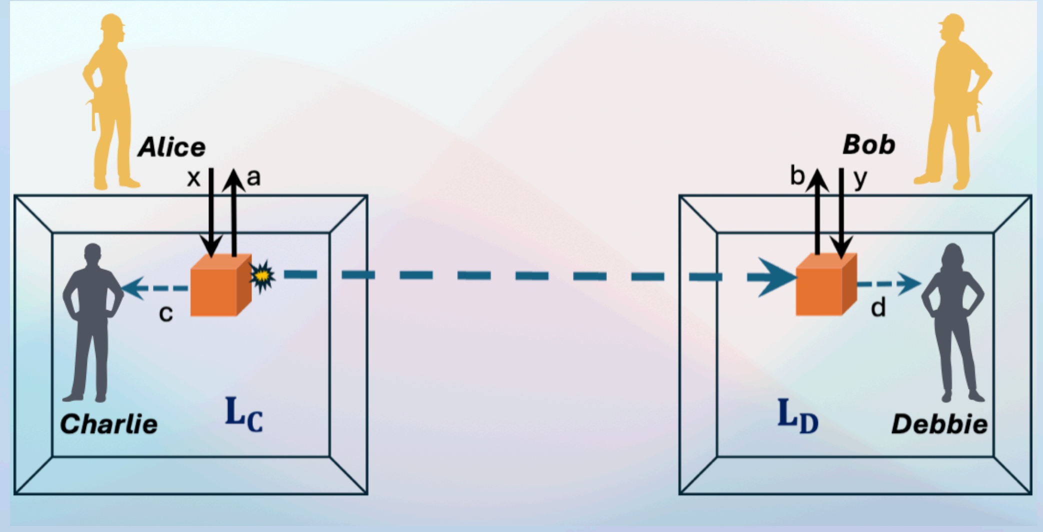
Assumption 4

Screening via Pseudo Events (SPE):} Every Truly-Observed Event is screened off from all the non-input variables in its causal past by appropriate pseudo-events.



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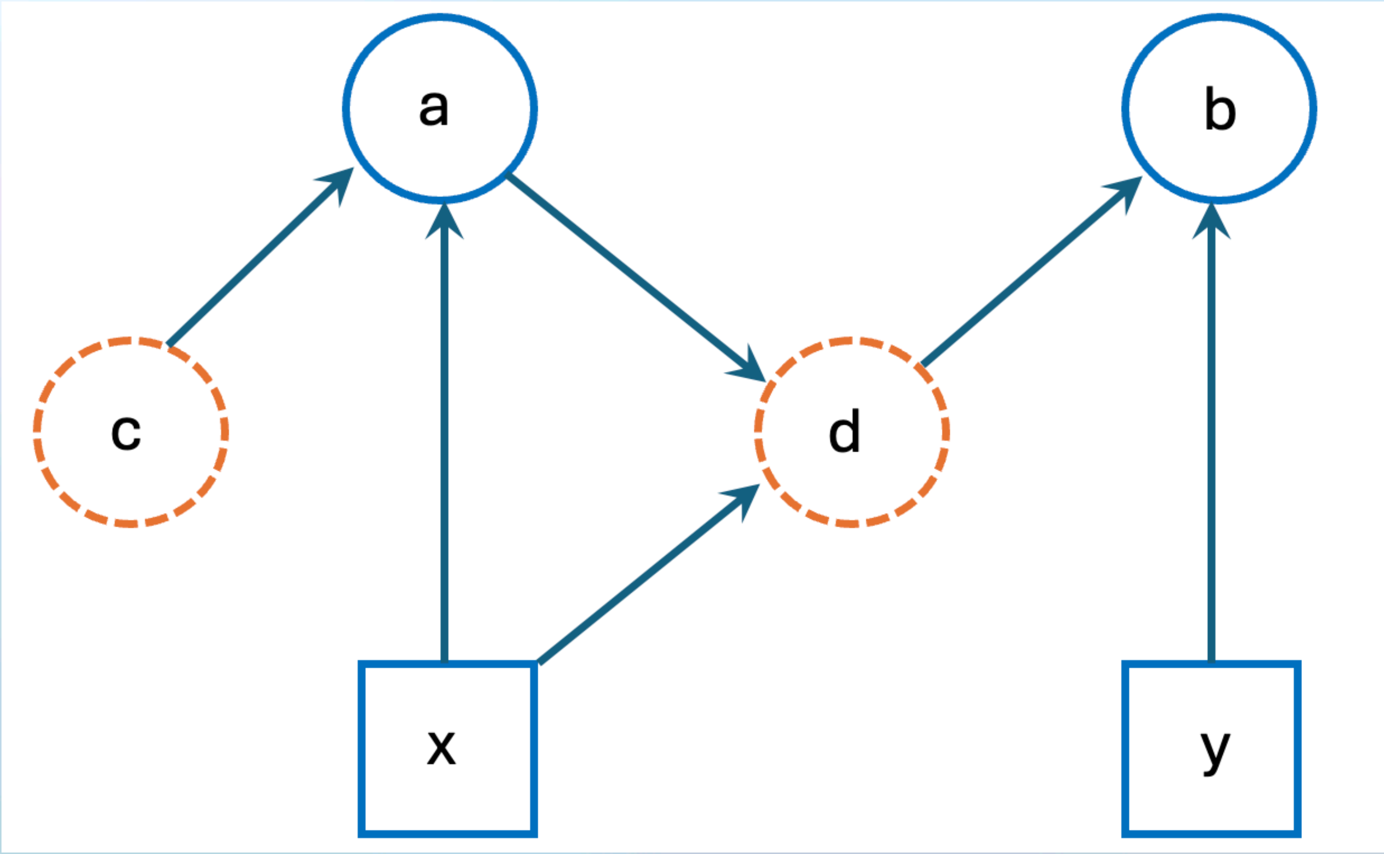


Causal Influence Diagram

Causal-Friendliness no-go theorem

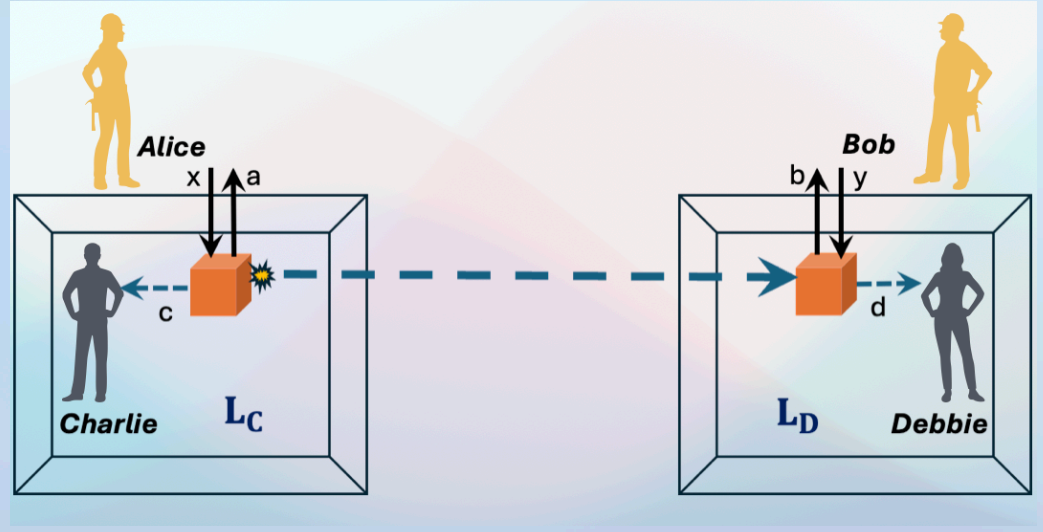
Theorem:

Consider the CF scenario in which Charlie and Alice act before Debbie and Bob. Let $a, b, c, d \in \{\pm 1\}$ denote the outcomes of Alice, Bob, Charlie, and Debbie, respectively, and let $x, y \in \{0,1\}$ denote the measurement settings of Alice and Bob.

Given the Assumptions AOE, ATS, NRC, SPE are satisfied, the observed correlations satisfy the inequality

$$S = \left| \langle A_0 B_0 \rangle + \langle A_0 B_1 \rangle + \langle A_1 B_0 \rangle - \langle A_1 B_1 \rangle \right| \leq 2 \text{, where } \langle A_x B_y \rangle = \sum_{a,b=\pm 1} ab\, p(a, b \,|\, x, y) \text{ are the}$$

joint expectation values for the measurements, conditioned on the inputs (x, y).



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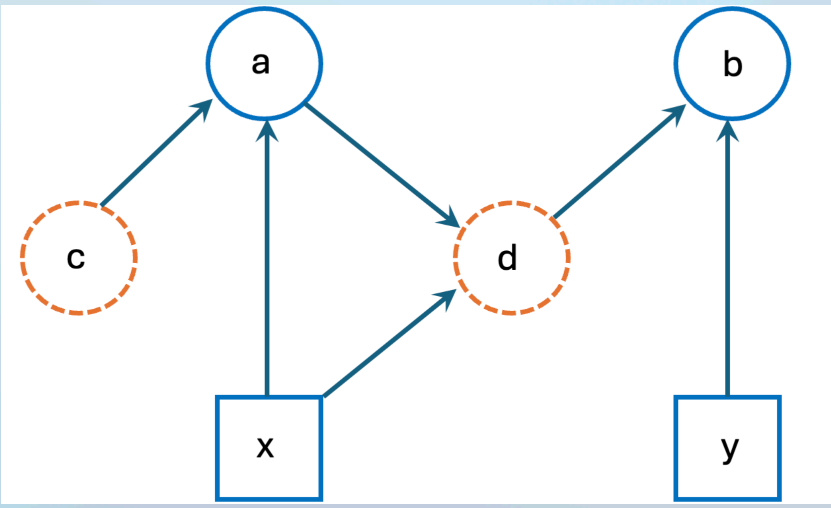
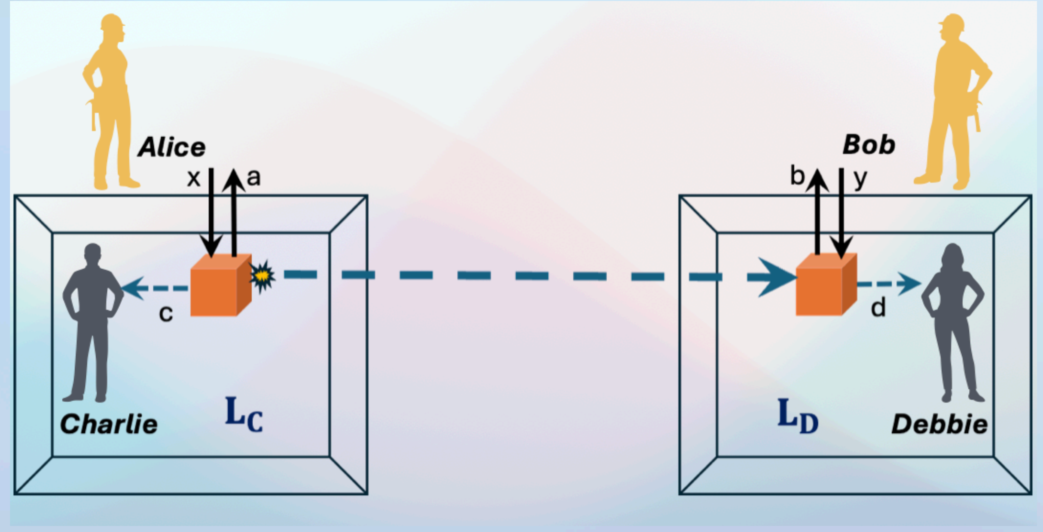


Causal Influence Diagram

Causal-Friendliness no-go theorem

Lemma 1:

If **AOE, ATS and NRC** hold, then Charlie and Debbie's joint outcome statistics are independent of Alice and Bob's choice of measurements x and y, i.e., $p(c,d|x,y) = p(c,d)$.



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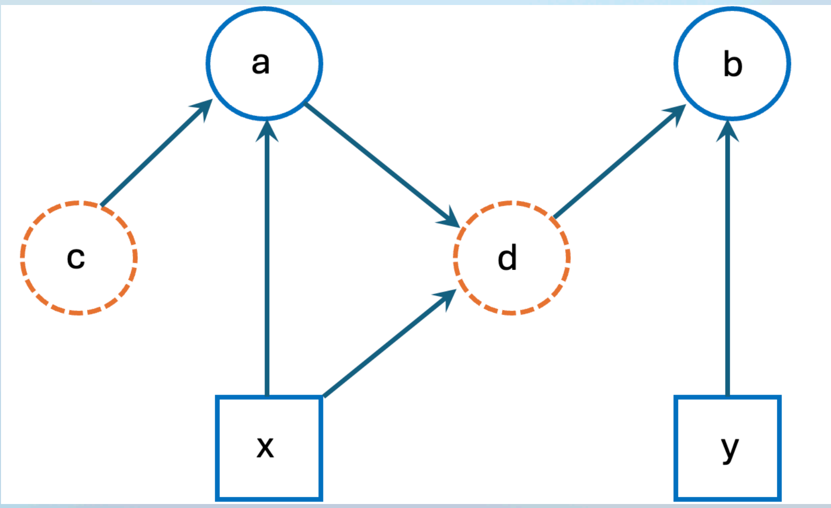

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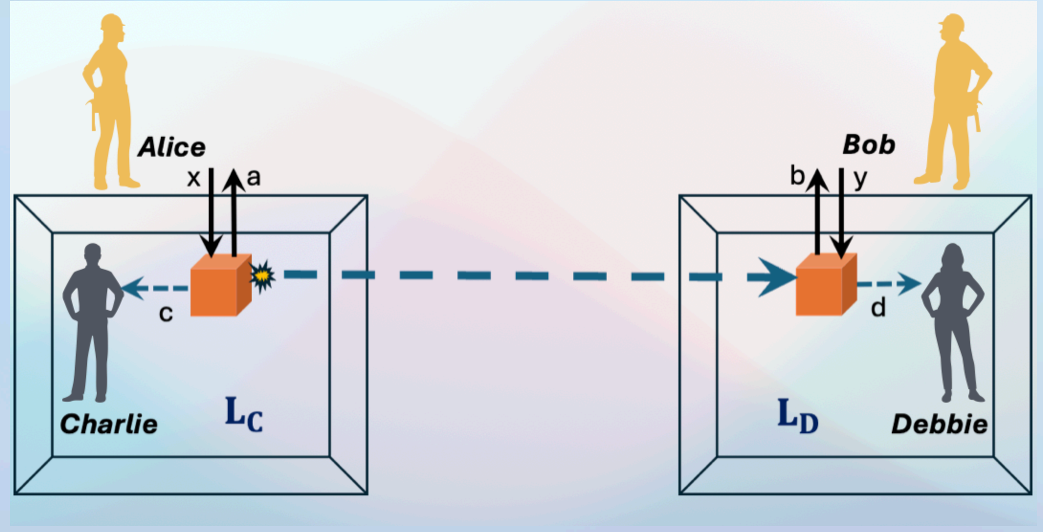
Lemma 2:

Alice(Bob) cannot depend on Bob's(Alice's) choice of measurement beyond c, d: If **AOE, ATS and NRC** hold, then Alice's(Bob's) outcome $a(b)$ is effectively screened off by the Pseudo Events in its causal past; that is, it cannot depend on Bob's (Alice's) choice of measurement, and hence,

$p(a \mid c, d, x, y) = p(a \mid c, x, d)$ and $p(b \mid y, c, x, d) = p(b \mid y, c, d)$



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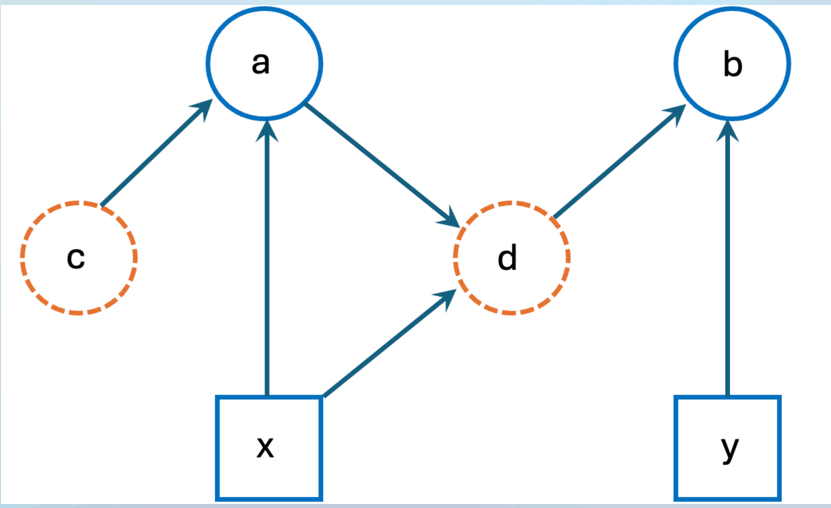

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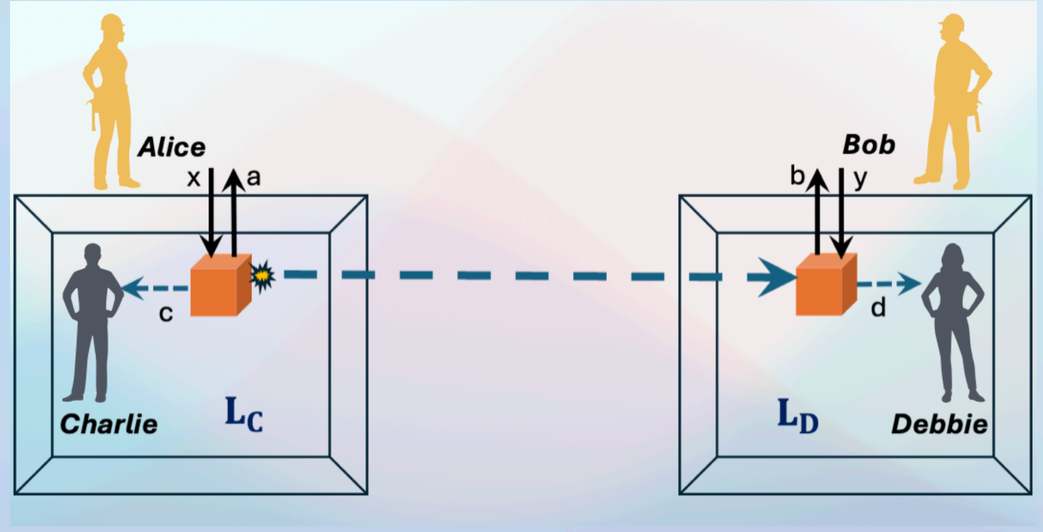
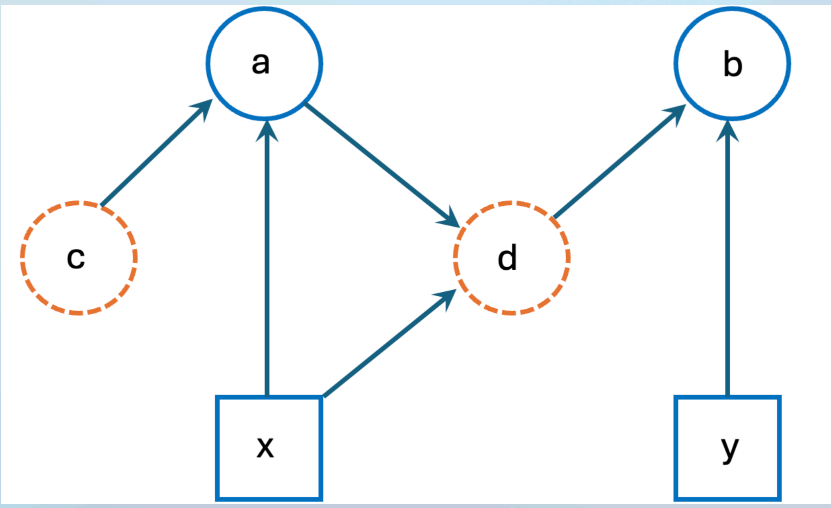


CF Scenario

Lemma 1 + Lemma 2+ SPE $\Longrightarrow$ inequality



Causal Influence Diagram

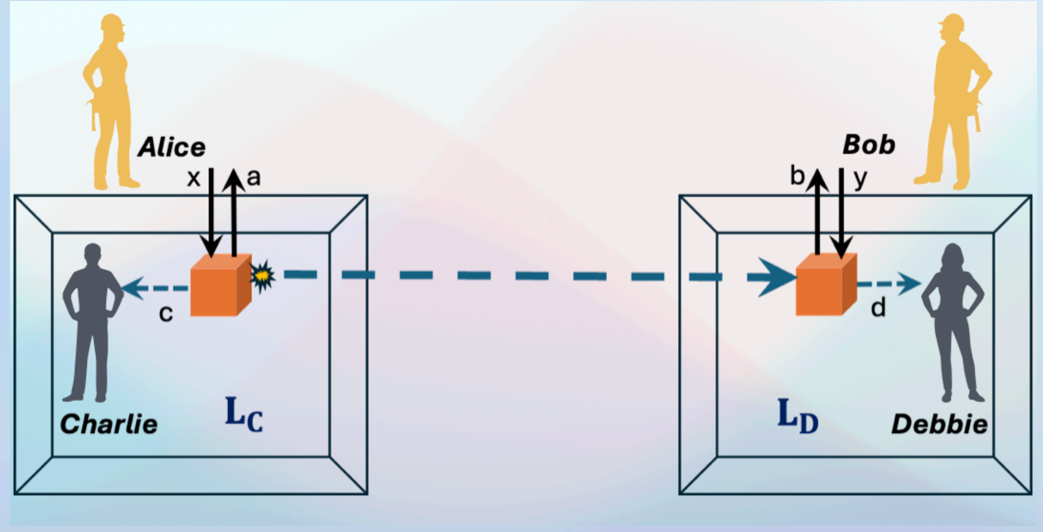
Causal-Friendliness no-go theorem

Lemma 1:

If **AOE, ATS and NRC** hold, then Charlie and Debbie's joint outcome statistics are independent of Alice and Bob's choice of measurements x and y, i.e., $p(c,d|x,y) = p(c,d)$.

Lemma 2:

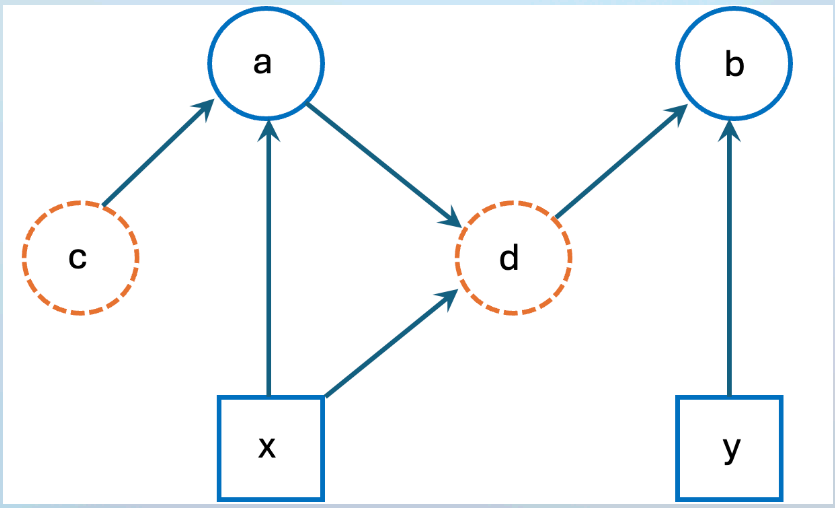
Alice(Bob) cannot depend on Bob's(Alice's) choice of measurement beyond c, d: If **AOE, ATS and NRC** hold, then Alice's(Bob's) outcome $a(b)$ is effectively screened off by the Pseudo Events in its causal past; that is, it cannot depend on Bob's (Alice's) choice of measurement, and hence, $p(a|c,d,x,y) = p(a|c,x,d)$ and $p(b \mid y,c,x,d) = p(b \mid y,c,d)$



CF Scenario

Lemma 1 + Lemma 2+ SPE $\Longrightarrow$ inequality

$$S_Q = 2\sqrt{2}$$



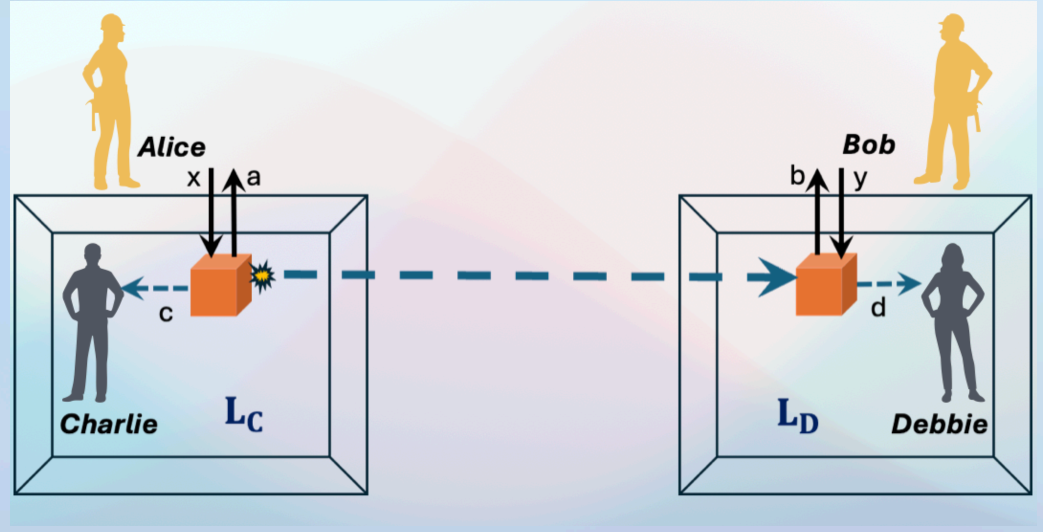
Causal Influence Diagram

Causal-Friendliness no-go theorem

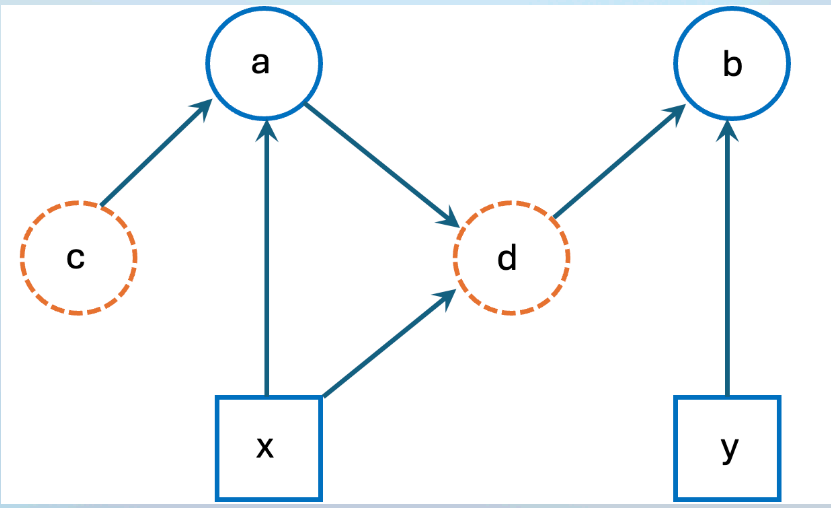
Can we weaken AOE?

Existence of marginals (EOM): For all settings (x, y) there exist well-defined operational marginals $p(c, d \mid x, y)$ and conditional response functions $p(a \mid x, c)$ and $p(b \mid y, c, d)$ describing how the outcomes of Truly-Observed Events a and b depend on Pseudo Events and the choice of measurement settings.

Operational mediation (OM): Pseudo Events c, d acts as the mediator between future and past events such that once c, d are specified, a provides no further information on b beyond that already provided by c, d and y, i.e., $p(b \mid a, c, d, x, y) = p(b \mid c, d, y)$,



CF Scenario



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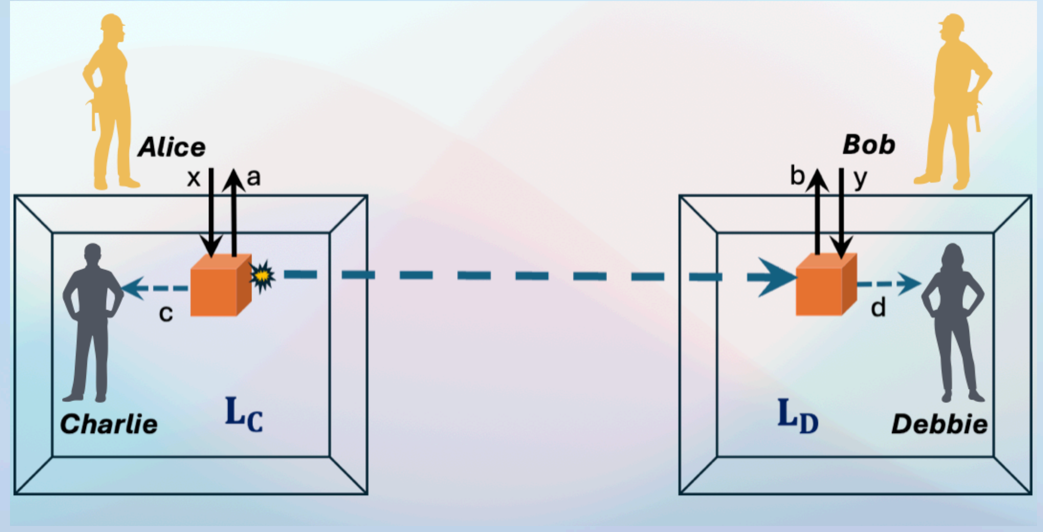
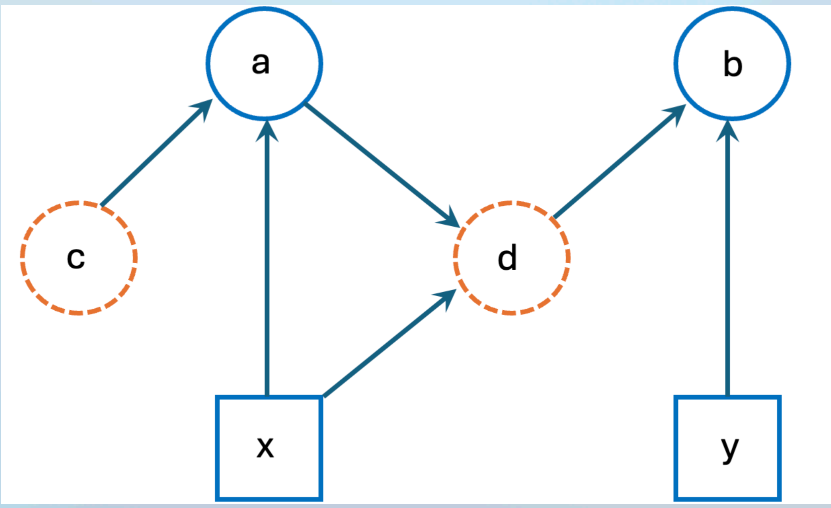
↓

Operational Pseudo Event Mediation (OPEM)



CF Scenario



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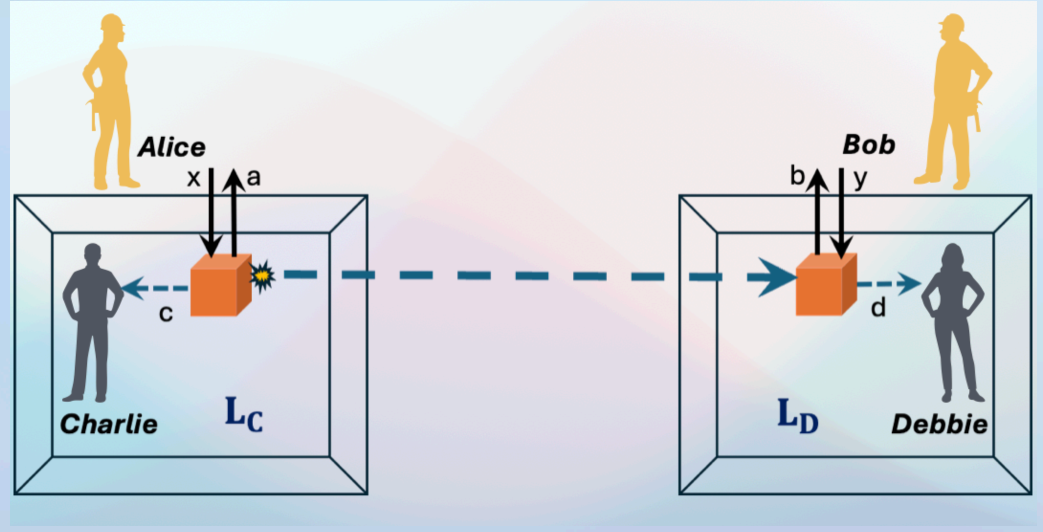
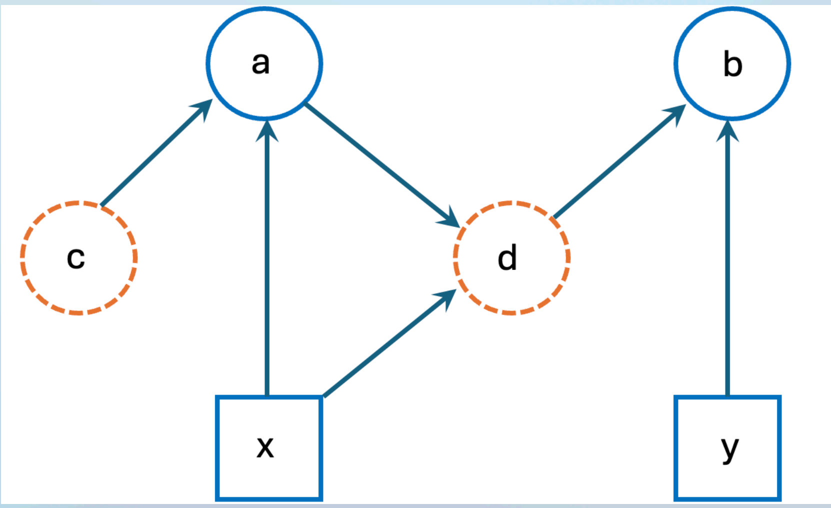
↓

Operational Pseudo Event Mediation (OPEM)

OPEM+ATS+NRC $\implies$ CF inequality



CF Scenario



Causal Influence Diagram

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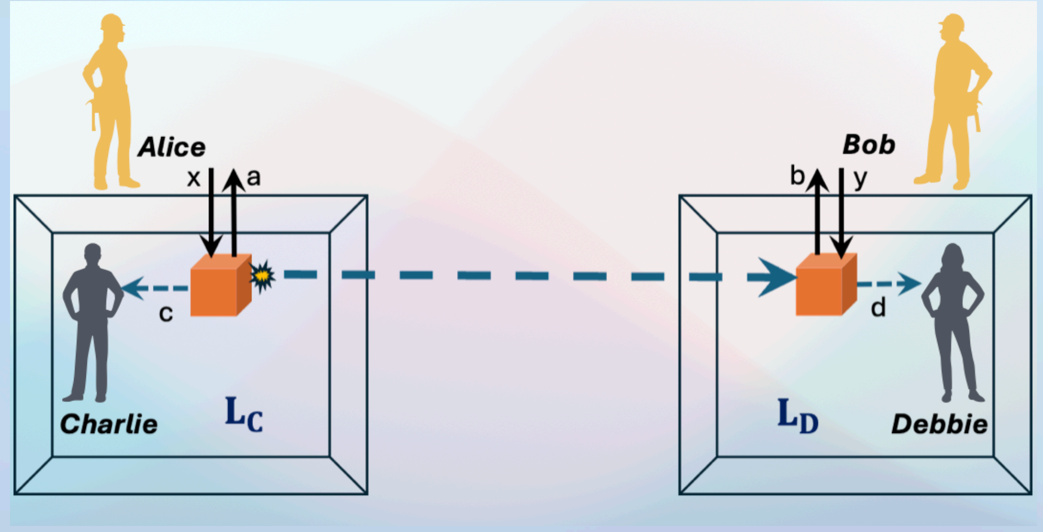
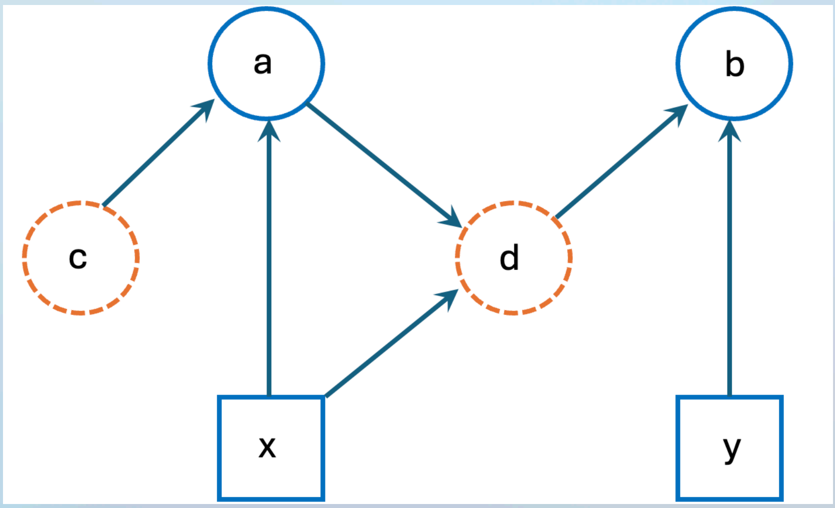


CF Scenario

$$p(a, b|x, y) = \sum_{c,d} p(c, d)\, p(a|x, c)\, p(b\,|\,y, c, d)$$



Causal Influence Diagram

Causal-Friendliness no-go theorem

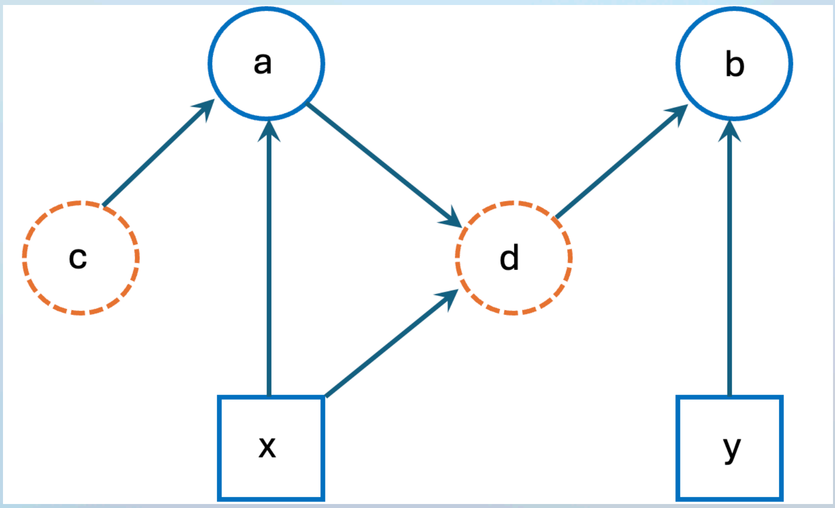
Can we weaken AOE?

Absoluteness of truly-observed events (ATOE): $p(a, b \mid x, y)$ exists.

Absoluteness of pseudo events (APE): $p(c, d \mid x, y) = p(c, d)$ exists.

↓

AOE



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↓

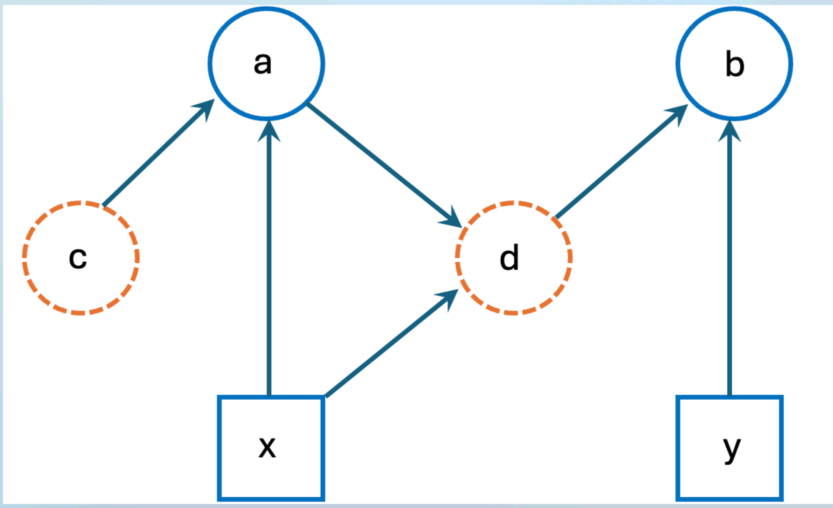
AOE

$$p(c, d \mid x, y) = \begin{cases} 1 & \text{if } (c, d) = (0, 0) \\ & \text{and } (x, y) = (0, 0), \\ 1 & \text{if } (c, d) = (0, 1) \\ & \text{and } (x, y) = (0, 1), \\ 1 & \text{if } (c, d) = (1, 0) \\ & \text{and } (x, y) = (1, 0), \\ 1 & \text{if } (c, d) = (1, 1) \\ & \text{and } (x, y) = (1, 1), \\ 0 & \text{otherwise.} \end{cases}$$

Now if we choose responses such that $A_0^{(0)} = A_1^{(1)} = B_0^{(0,0)} = B_1^{(0,1)} = B_0^{(1,0)} = +1$ and $B_1^{(1,1)} = -1$, then,

$$\langle A_0 B_0 \rangle = \langle A_0 B_1 \rangle = \langle A_1 B_0 \rangle = +1, \langle A_1 B_1 \rangle = -1.$$

→ $S = 4$



Causal Influence Diagram

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↓

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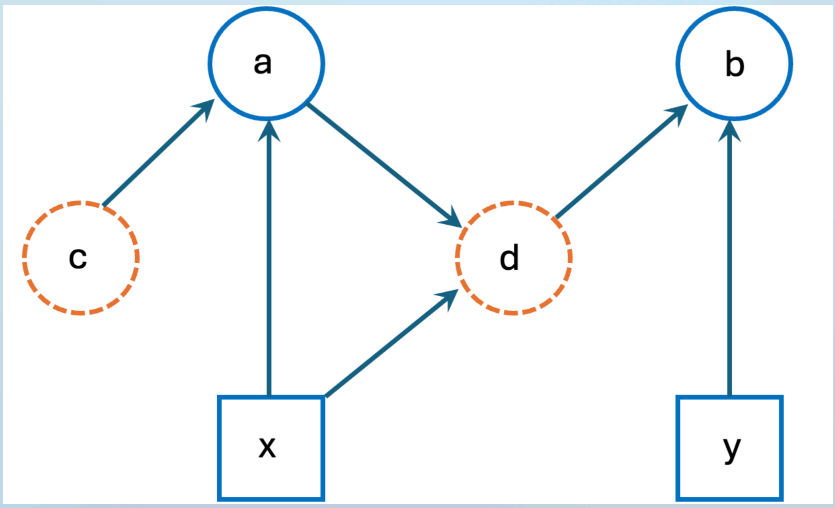
⟶ $S = 4$

EOM+NRC $\Longrightarrow$ ATOE+APE $\equiv$ AOE



Causal Influence Diagram

Summary

- It is proven that observed events are not absolute, even in a time-ordered scenario without requiring any nontrivially correlated system shared between different parties.
- In CF scenario, the AOE assumption can be relaxed further; still, the no-go result works.
- Absoluteness of pseudo-events cannot be compromised.
- Beyond (2-2-2-2) scenario, it is proven that the CF correlations are stronger than any generalised contextual correlation. This is a parallel result of the one that shows LF correlations are stronger than the usual Bell-local correlations.
- In the Time Symmetric sector, Broglie–Bohm (dBB) theory circumvents our no-go results by abandoning the condition of SPE.
- Everett's Many–Worlds interpretation (MWI) explicitly denies the AOE assumption on which our no-go theorem is based.

Based On

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Quantum Physics

[Submitted on 30 Oct 2025]

Limits of Absoluteness of Observed Events in Timelike Scenarios: A No-Go Theorem

Sumit Mukherjee, Jonte R. Hance

Wigner's Friend-type paradoxes challenge the assumption that events are absolute -- that when we measure a system, we obtain a single result, which is not relative to anything or anyone else. These paradoxes highlight the tension between quantum theory and our intuitions about reality being observer-independent. Building on a recent result that developed these paradoxes into a no-go theorem, namely the Local Friendliness Theorem, we introduce the Causal Friendliness Paradox, a time-ordered analogue of it. In this framework, we replace the usual locality assumption with Axiological Time Symmetry (ATS), and show that, when combined with the assumptions of Absoluteness of Observed Events (AOE), No Retrocausality (NRC), and Screening via Pseudo Events (SPE), we obtain a causal inequality. We then show that quantum mechanics violates this inequality and is therefore incompatible with at least one of these assumptions. To probe which assumption might be incompatible, we then examine whether AOE in its entirety is essential for this no-go result. We propose a weaker, operational form of AOE that still leads to inequalities that quantum mechanics violates. This result shows that even under relaxed assumptions, quantum theory resists reconciliation with classical notions of absolute events, reinforcing the foundational significance of Wigner's Friend-type paradoxes in timelike scenarios.

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Thank You

.....Observations aren’t absolute—so think beyond your senses, end the hate, and choose love.