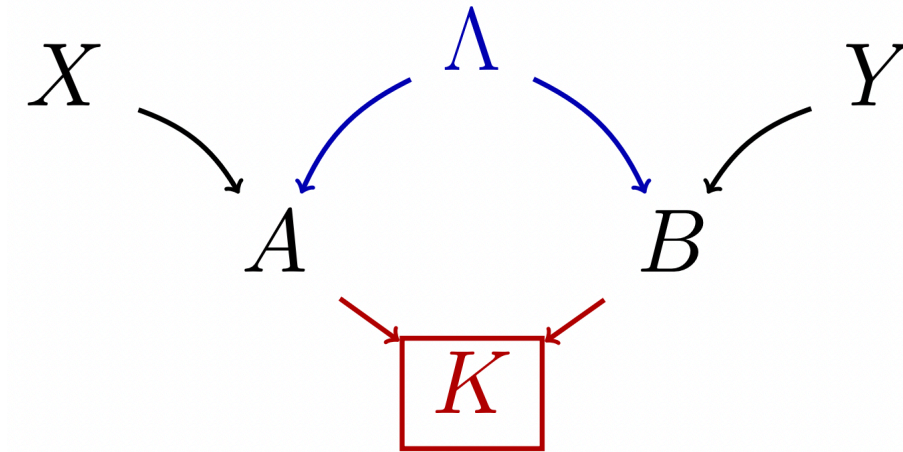


# NONLOCALITY WITH CAUSAL-DIAGRAM-CERTIFIED POSTSELECTION

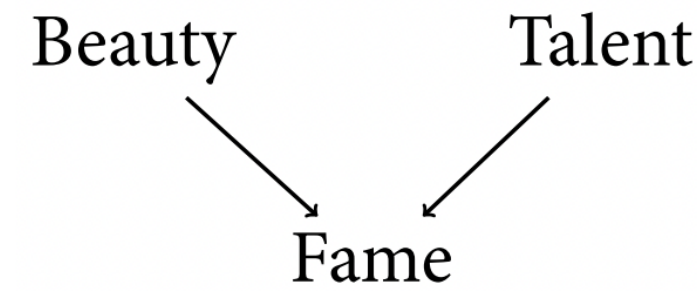
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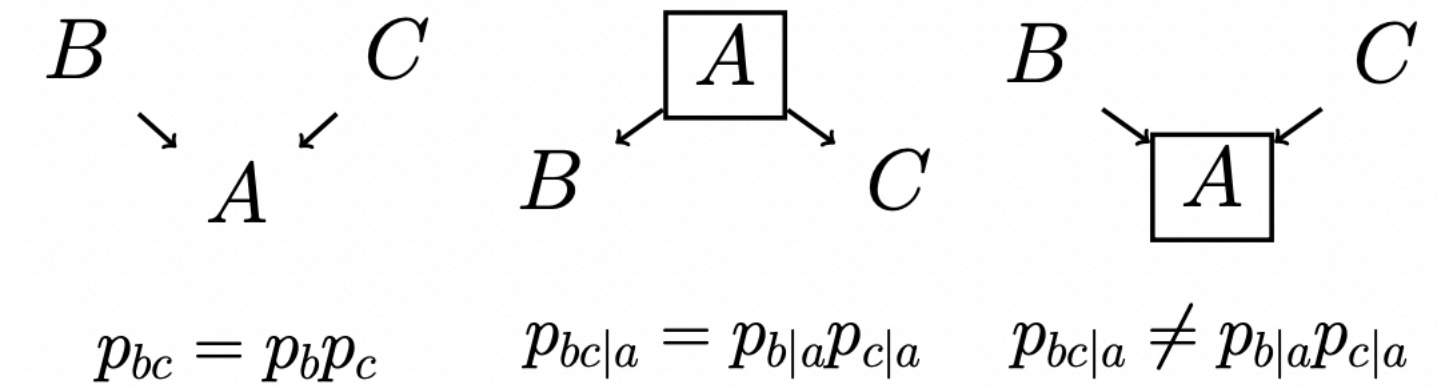
**Problem:** Postselecting statistics in Bell experiments can create correlations that mimic nonlocality via the SELECTION BIAS.



**Selection bias (Berkson's paradox):** Two independent quantities can become dependent if one conditions on an effect of both. Example: The independent traits of "talent" and "attractiveness" are anti-correlated in the subpopulation of celebrities.



To infer relations of conditional independence from a causal diagram one uses the **d-separation rules**: Generally, any path connecting two variables of the diagram can lead to a statistical dependence.



**Which assumptions or conditions do we need such that the postselection cannot create fake correlations?**

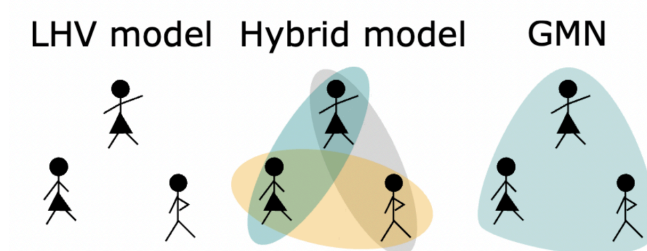
The postselected statistics  $p_{ab|xyk}$  fulfil the Bell inequality if (I)  $p_{\lambda|xyk} = p_{\lambda|k}$  and (II)  $p_{ab|xy\lambda k} = p_{a|x\lambda k} p_{b|y\lambda k}$

## The fair-sampling assumption with causal diagrams [1]

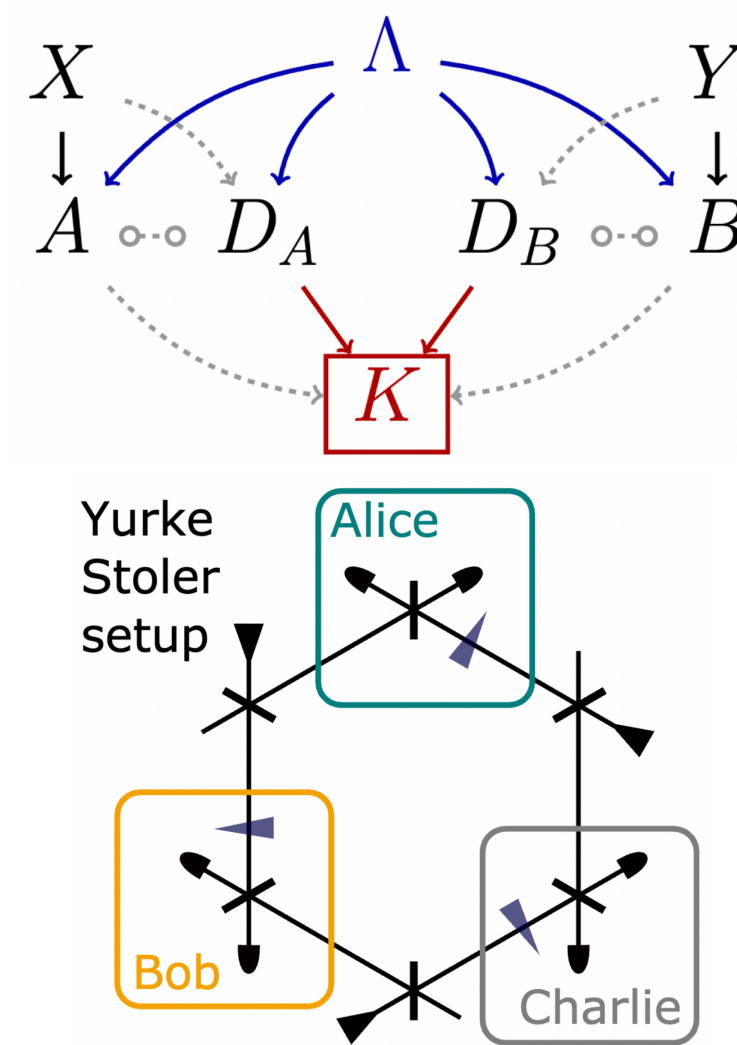
known as "postselected statistics is a fair sample of ideal statistics" or "postselection is not influenced by detector settings"

What is the **minimal extension** of the original bipartite causal diagram that allows for a collective postselection?

The assumption can also be applied to a multipartite Bell scenario, in particular, in an experiment to verify **genuine multipartite nonlocality (GMN)**.



As special cases it includes postselection due to non-perfect detection and losses or experiments where the particles are distributed randomly among the parties (**Yurke-Stoler setup**).

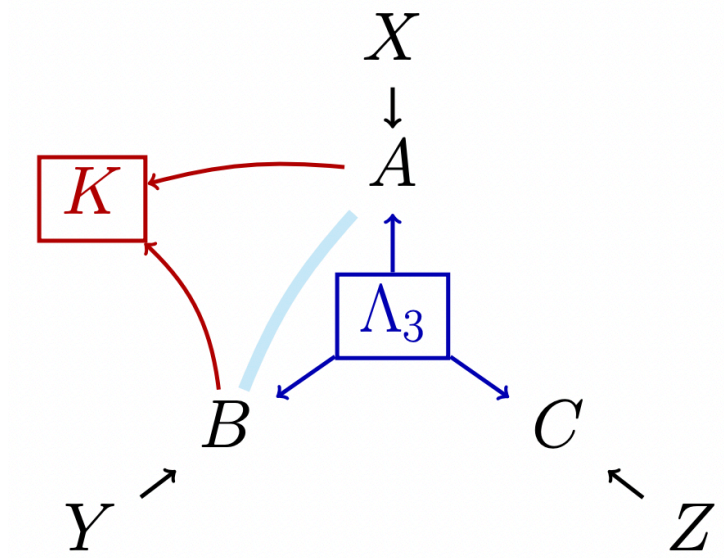


## Collective postselection for GMN [2]

If we do not want to assume fair sampling, how can any collective postselection be valid for the demonstration of GMN? One can show that:

In the three-partite Bell scenario, a postselection that can be equivalently **decided by any two parties** is valid for verification of genuine three-partite nonlocality.

In an n-partite scenario one must be able to exclude half of the parties.



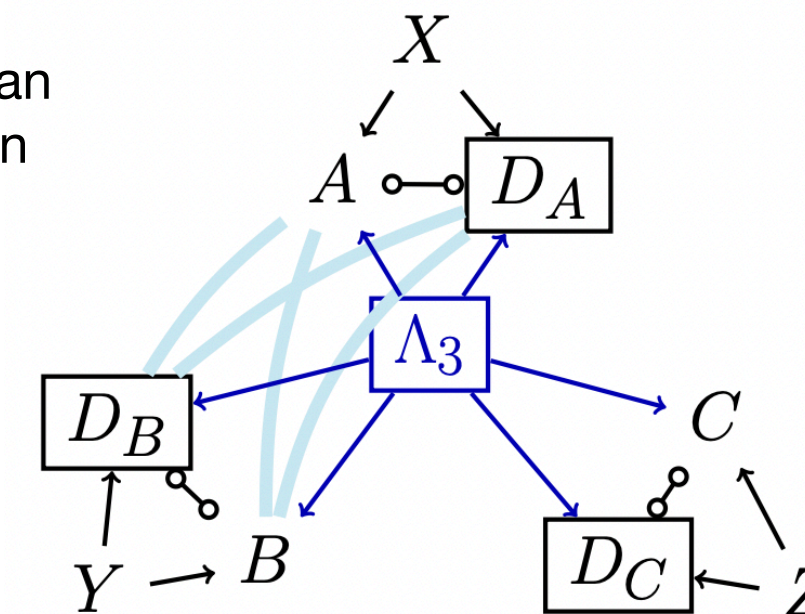
## Coincidence postselection for GMN [3]

In the special case of a coincidence postselection, one can show that, in any n-partite Bell scenario, the postselection is valid if it can be decided when excluding one party.

For realistic scenarios with losses, we cannot use causal diagrams anymore, but we can derive

**threshold detection efficiencies  $\eta_c^*$ .**

Bell inequality	$\eta_c^*$	$\eta_{det}^*$ in YS setup
CHSH inequality	0.83	0.91
Mermin inequality	0.75	0.9
Svetlichny inequality	0.967	0.989



## References:

- [1] V. Gebhart and A. Smerzi, Extending the fair sampling assumption using causal diagrams, arXiv:2207.09348 (2022).
- [2] V. Gebhart, L. Pezzè and A. Smerzi, Genuine Multipartite Nonlocality with Causal-Diagram Postselection, *Phys. Rev. Lett.* **127**, 140401 (2021).
- [3] V. Gebhart and A. Smerzi, Coincidence postselection for genuine multipartite nonlocality: Causal diagrams and threshold efficiencies, arXiv:2207.13579 (2022).