Information causality in multipartite scenarios

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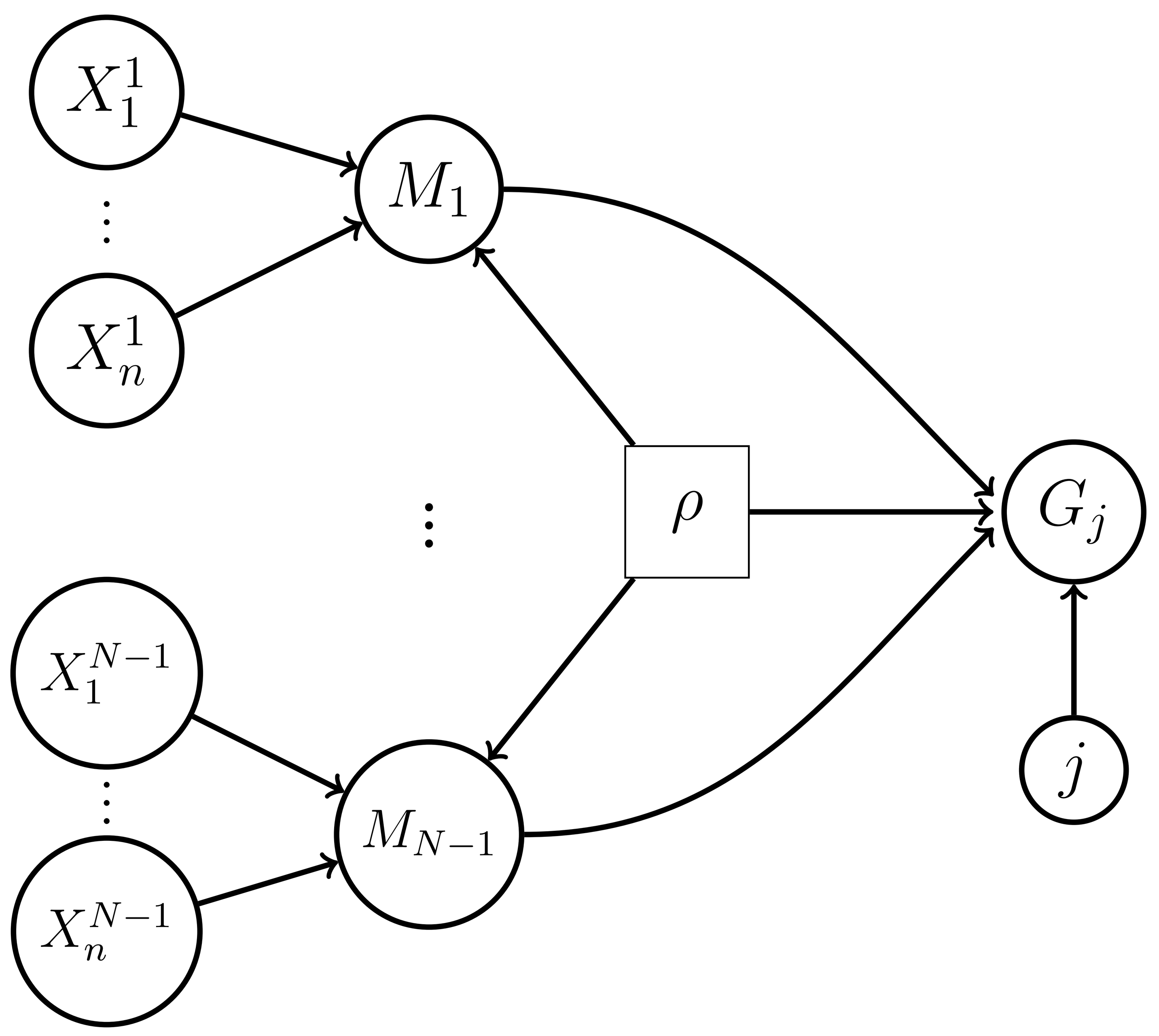
Introduction

- The quantum theory non-locality has been attracted much attention in recent decades, mainly due to its applicability as a resource in information processing;
- The non-locality of the quantum theory is limited, although the reasons remain far from being clear;
- The principle of information causality (IC) bounds the information gain in a communication task [1];
- Previous works indicate a necessity of a genuinely multipartite formulation for any proposal of quantum theory informational principle [2];
- In our work we provide an intrinsically multipartite generalization a multipartite approach that is always respected by the quantum theory [3];
- We described several classes of multipartite post-quantum correlations, which are forbidden by our new informational criterion.

Model

Multipartite communication task:



Multipartite IC:

$$\sum_k^{N-1}\sum_i^{n} I(X_i^k : X_i^1,\dots,X_i^{k-1},X_i^{k+1},\dots,X_i^{N-1},G_i) \leq \sum_k^{N-1} C_k + \sum_i^{n} I(X_{i+1}^k,\dots,X_n^k : X_i^k). \quad (1)$$

Multiple copies:

- Correlations:

$$p\left(\bigoplus_{k=1}^{N} a_k = \bigoplus_{k=1}^{N-1} x_k x_N\right) = \frac{1}{2}(1+E_{x_N}). \quad (2)$$

- Success probability:

$$p\left(G_j = \bigoplus_{k=0}^{N-2} X_j^k\right) = \frac{1}{2}(1+E_I^{K-r}E_{II}^r), \quad (3)$$

- Multiple copies multipartite IC:

$$E_I^2 + E_{II}^2 \leq 1. \quad (4)$$

Results

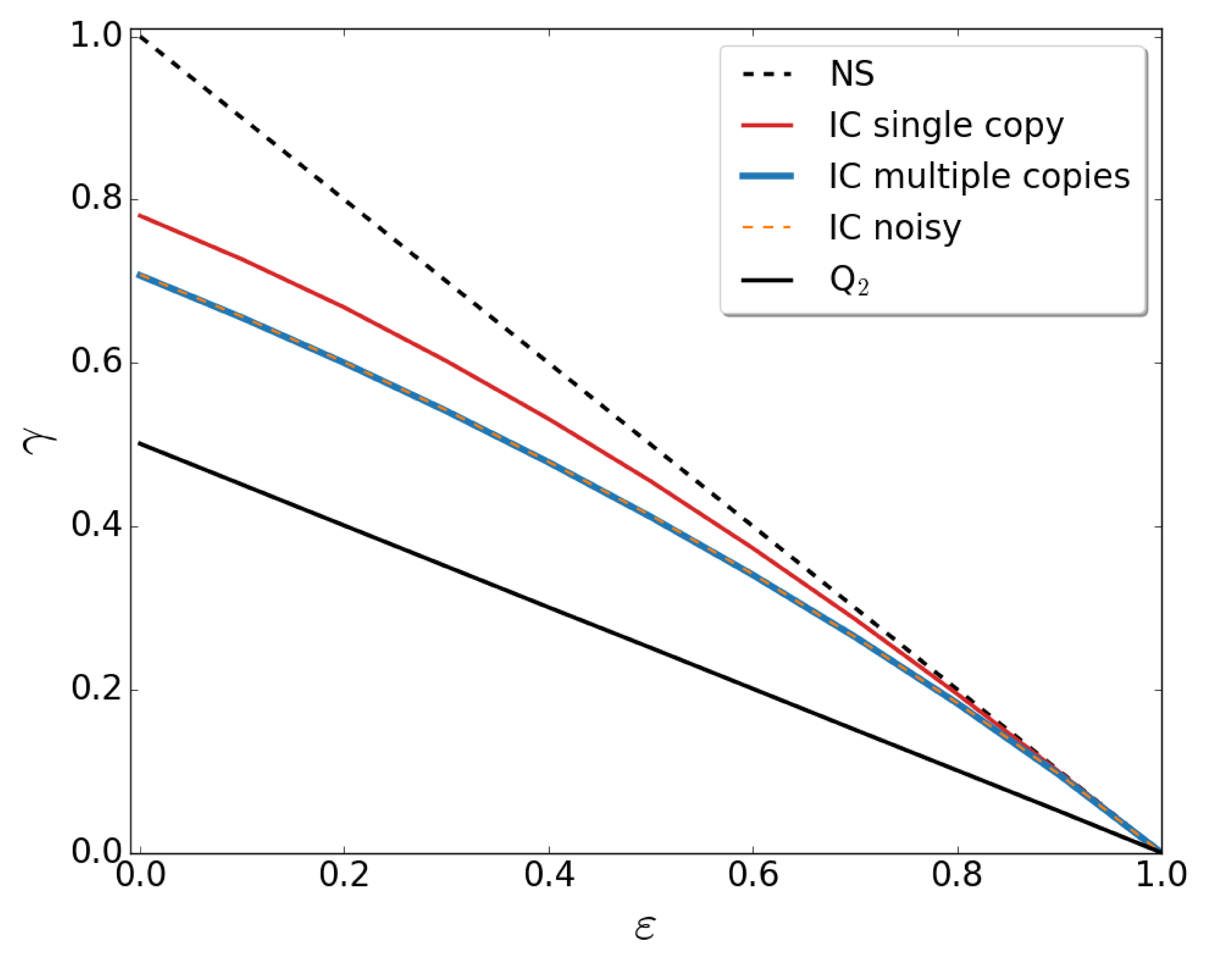
Multipartite IC violation:

- Multipartite correlation:

$$p(a_1,a_2,\cdots,a_N|x_1,x_2,\cdots,x_N) = \begin{cases} 1/2^{N-1} & \text{if } \bigoplus_{k=1}^{N} a_k = \bigoplus_{k=1}^{N-1} x_k x_N; \\ 0 & \text{else.} \end{cases} \quad (5)$$

- Tripartite correlation:

$$p(a,b,c|x,y,z) = \gamma\frac{1}{4}\delta_{a\oplus b\oplus c = xz\oplus yz} + \epsilon\delta_{a,0},\delta_{b,0}\delta_{c,0} + (1-\gamma-\epsilon)\frac{1}{8} \quad (6)$$



- Extremal correlations:

Inequality	Extremal boxes
(IC (4))	35, 37, 38, 40, 41, 42, 43, 44, 45
(Uffink [4])	21, 22, 30, 34, 36, 39, 41, 44, 46

Conclusion

- New multipartite communication task in which the previous IC formulation does not detect non-local advantage;
- New informational criterion for IC, which is true for the whole set of quantum correlations, for any number of parts;
- We also prove an stronger version for (1) where the parties can share multiple copies of the correlation (5);

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Bibliography

1. M. Pawłowski et al., Nature **461**, 1101–1104 (2009).
2. T. H. Yang et al., New Journal of Physics **14**, 013061 (2012).
3. L. Pollyceno et al., Phys. Rev. A **107**, 042203 (2023).
4. J. Uffink, Phys. Rev. Lett. **88**, 230406 (23 May 2002).