Causal influence versus signalling for interacting quantum channels

AlessandroTosini, [1]
Kathleen Barsse,[12] Paolo Perinotti,[1] and Leonardo Vaglini[1]
[1] *QUIT group, Physics Dept., Pavia University, and INFN Sezione di Pavia, via Bassi 6, 27100 Pavia, Italy*
[2] *Université Paris-Saclay, ENS Paris-Saclay, 91190, Gif-sur-Yvette, France*

alessandro.tosini@unipv.it

Abstract based on Ref. [1]

A causal relation between quantum agents, say Alice and Bob, is necessarily mediated by an interaction. Modelling the last one as a reversible quantum channel, an intervention of Alice can have causal influence on Bob's system, modifying correlations between Alice and Bob's systems. *Causal influence* between quantum systems necessarily allows for *signalling*. However, a largely unexplored side of quantum information processing is the scaling between the strength of correlations and the amount of signalling activated by a quanutm interaction.

Here we prove a *mismatch* between causal influence and signalling via direct computation of the two quantities for the Cnot gate. We show that, for the quantum Cnot, signalling is strictly smaller than causal influence, thus indicating that the "extra" causal effect beyond signalling has to be sought in the leverage that it enables on correlations.

Finally we show a *continuity theorem* for causal effects of unitary channels: a channel has small causal influence iff it allows for small signalling.

References

[1] A Kathleen Brasse, Paolo Perinotti, Alessandro Tosini, Leonardo Vaglini, arXiv:2309.07771