# Causal models for the quantum world

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Science aims to achieve more than merely observing correlations between events: it seeks to explain these correlations in terms of *causal influences*. A rigorous definition of causation and a comprehensive framework of causal models have been developed for the analysis of classical variables [1, 2]. In problems ranging from machine learning to epidemiology, causal models proved themselves an accurate representation of "how a system works" – in particular, they tell us something about how information flows from one event to another. Can we provide a similar account of the relations between a set of quantum variables? I will discuss ways in which classical causal models must be adapted to accommodate quantum variables, highlighting how causation and information processing are different from the classical case.

One major task in the field of causal modeling is causal inference: determining the causal relations between a set of variables, given only *observational* data. For instance, if one observes correlations between two variables, does this show a direct causal influence, or is it due to some hidden common cause? In the classical world, this particular problem is impossible to solve: any pattern of correlations one may observe between two variables is compatible both with a direct causal influence of one on the other, and with a common cause influencing both. For quantum variables, on the other hand, we show that the correlations do encode a signature of the causal structure, allowing one to solve the causal inference problem. We illustrate this with data from a proof-of-concept experiment that corroborates our scheme [3].

## References

[1] J. Pearl, *Causality: reasoning, models and inference.* Cambridge University Press, 2009.

[2] P. Spirtes, C. Glymour and R. Scheines, *Causation, prediction and search.* MIT Press, 2000.

[3] M. Agnew, L. Vermeyden, K. Ried, R. W. Spekkens and K. Resch, *Unified tomography of states and processes*, unpublished.