ATELIER SUR LES FONDEMENTS DE LA MÉCANIQUE QUANTIQUE À LA LUMIÈRE DE L'INFORMATION QUANTIQUE III
6–9 DÉCEMBRE 2011

WORKSHOP ON QUANTUM FOUNDATIONS IN THE LIGHT OF QUANTUM INFORMATION III
DECEMBER 6–9, 2011

A contextual extension of Spekkens' toy model

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Quantum systems show contextuality. More precisely, it is impossible to reproduce the quantum-mechanical predictions using a non-contextual realist model, i.e., a model where the outcome of one measurement is independent of the choice of compatible measurements performed in the measurement context. There has been several attempts to quantify the amount of contextuality for specific quantum systems, for example, in the number of rays needed in a KS proof, or the number of terms in certain inequalities, or in the violation, noise sensitivity, and other measures. This paper is about another approach : to use a simple contextual model that reproduces the quantum-mechanical contextual behaviour, but not necessarily all quantum predictions. The amount of contextuality can then be quantified in terms of additional resources needed as compared with a similar model without contextuality. In this case the contextual model needs to keep track of the context used, so the appropriate measure would be memory. Another way to view this is as a memory requirement to be able to reproduce quantum contextuality in a realist model. The model we will use can be viewed as an extension of Spekkens' toy model [Phys. Rev. A 75, 032110 (2007)], and the relation is studied in some detail. To reproduce the quantum predictions for the Peres-Mermin square, the memory requirement is more than one bit in addition to the memory used for the individual outcomes in the corresponding noncontextual model.

(preprint `arXiv:1111.3561`)

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