General Relativity and Quantum Cosmology

Causal categories: relativistically interacting processes

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A symmetric monoidal category naturally arises as the mathematical structure that organizes physical systems, processes, and composition thereof, both sequentially and in parallel. This structure admits a purely graphical calculus. This paper is concerned with the encoding of a fixed causal structure within a symmetric monoidal category: causal dependencies will correspond to topological connectedness in the graphical language. We show that correlations, either classical or quantum, force terminality of the tensor unit. We also show that well-definedness of the concept of a global state forces the monoidal product to be only partially defined, which in turn results in a relativistic covariance theorem. Except for these assumptions, at no stage do we assume anything more than purely compositional symmetric-monoidal categorical structure. We cast these two structural results in terms of a mathematical entity, which we call a `causal category'. We provide methods of constructing causal categories, and we study the consequences of these methods for the general framework of categorical quantum mechanics.

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