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Quantum reference frames and the covariance of quantum physics

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Abstract:

This Thesis addresses two foundational aspects related to the absence of a classical spacetime at the interface of quantum theory and general relativity: the generalisation of the notion of reference frames and the introduction of indefinite causal structures.

This Thesis develops an operational formalism for quantum reference frames, i.e., reference frames "attached" to quantum systems, which can be in a quantum superposition or entangled with other physical systems. States, measurements, and dynamical evolution are described in different quantum reference frames in purely relational terms, and a generalised notion of covariance of physical laws is introduced. An application of the formalism to the operational definition of spin in a special-relativistic context is provided. In addition, the process matrix formalism to describe situations with indefinite causal structures is generalised to infinite dimensional systems, and it is shown under which conditions the causal structure can dynamically transform, e.g., change from definite to indefinite.