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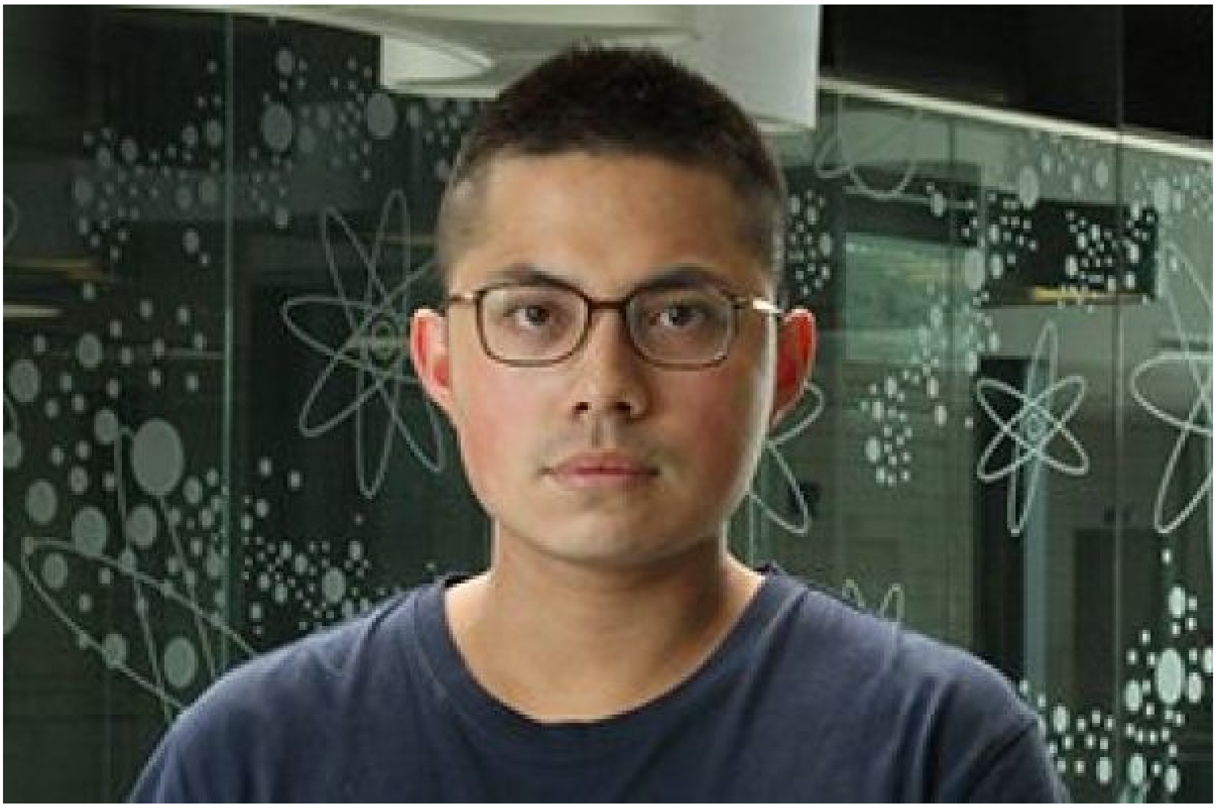

PhD THESIS DEFENSE: Resource Theories of Quantum Dynamics

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As one of our most successful theories, quantum theory has greatly strengthened our understanding of nature and significantly advanced technologies. pecifically, quantum effects provide advantages in a broad range of information processing tasks. The exploration of the interplay of quantum phenomena and information theory is the interdisciplinary field dubbed quantum information theory. Since its inception, quantum information theory has revolutionised our understanding of quantum phenomena and shown that various quantum properties act as resources for performing useful tasks, such as computation, information transmission, energy extraction, cryptography, metrology, and information storage. These findings set the stage for the theoretical approaches termed quantum resource theories, which allow in a mathematically rigorous fashion to describe a wide range of quantum phenomena. Quantum information theory identifies several intriguing quantum properties, and quantum resource theories provide the means to construct the ?rulers' to measure these properties operationally. However, despite their great success in describing ?static' quantum phenomena, it was unknown whether resource theories would be as powerful in their descriptions of physical systems that ?evolve in time', namely, when we consider ?dynamical' quantum properties. Recent results have allowed us to extend quantum resource theories to the dynamical regime, which has already revealed novel links between quantum communication, quantum memory, and quantum thermodynamics. This thesis aims at substantially developing this newly-established, interdisciplinary research direction that is called dynamical resource theories.

The main contributions of the thesis are divided into three parts. The first part focuses on improving our understanding of dynamical resource theories' general structures. Adopting the resource-theoretical approaches, we formulate `the ability of quantum dynamics to preserve a physical property' as a dynamical resource. The resulting framework is called resource preservability theories. We systematically study their theoretical structures and further explore their applications to communication and thermodynamics. In the second part, we upgrade our discussion from a single quantum dynamics to a collection of local quantum dynamics. In this regime, an important question is whether the given local dynamics can be realised simultaneously; namely, as the marginals of a single, global dynamics. To systematically address this question, we introduce the channel marginal problems (CMPs), which are dynamical generalisations of the well-known state marginal problems.

Using the resource-theoretical approach, we analyze CMPs' general solutions via semi-definite programming, which helps us derive a witness form and operational interpretations of CMPs. Finally, in the last part, we consider a specific question that is behind the structures of dynamical resource theories and channel marginal problems: We ask whether globally distributed quantum entanglement can survive locally performed thermalisation when shared randomness is the only allowed resource to assist the process. Such a dynamics, whenever it exists, is called entanglement preserving local thermalisation. We show that such dynamics exist for every nonzero local temperatures and non-degenerate finite-energy local Hamiltonians.

In summary, in this thesis we contribute to the field of dynamical resource theories by introducing general frameworks to describe quantum resource preservation and compatibility of local quantum dynamics. Our general results have implications across quantum physics, quantum communication, thermodynamics of quantum systems, and causal structures

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