Kay Brandner
UKRI Future Leaders Fellow

University of Nottingham
School of Physics and Astronomy
University Park
Nottingham, NG7 2RD

**Thermodynamics of Permutation-Invariant Quantum Many-Body Systems:
A Group-Theoretical Framework**

Abstract. Quantum systems of indistinguishable particles are commonly described using the formalism of second quantization, which relies on the assumption that any admissible quantum state must be either symmetric or anti-symmetric under particle permutations. Coherence-induced many-body effects such as super-radiance, however, can arise even in systems whose constituents are not fundamentally indistinguishable as long as all relevant dynamical observables are permutation-invariant. Such systems are not confined to symmetric or anti-symmetric states and therefore require a different theoretical approach. Focusing on non-interacting systems, here we combine tools from representation theory and thermodynamically consistent master equations to develop such a framework. We characterize the structure and properties of the steady states emerging in permutation-invariant ensembles of arbitrary multi-level systems that are collectively coupled to a thermal environment. As an application of our general theory, we further explore how these states can in principle be used to enhance the performance of quantum thermal machines. Our group-theoretical framework makes it possible to analyze various limiting cases that would not be accessible otherwise. In addition, it allows us to show that the properties of multi-level ensembles differ qualitatively from those of spin ensembles, which have been investigated earlier using the standard *Clebsch-Gordan* theory. Our results pave the way for systematic investigations of collective effects arising from permutation-invariance in quantum thermodynamics.

Reference: B. Yadin, B. Morris, KB; arXiv:2206.12639 (2022)