Thermodynamics of Quantum Measurement: Making tunneling particles and vacuum fluctuations work

Andrew N. Jordan

Chapman University, 1 University Dr., Orange 92866, USA

Measuring an operator that does not commute with the system's Hamiltonian generally leads to exchange of energy between the system and the measuring device. I will describe how this disordered form of energy can be harvested to fuel engines and refrigerators. Recent advances will be described concerning the continuous measurement of the presence of a tunneling particle in its classically forbidden region [1]. I will show how the measurement leads to enhanced tunneling and how the energy the measurement process gives can be harnessed to make a thermoelectric engine and refrigerator [2]. This basic physics can be transferred to the many-body context, where a measurmement-based engine is fueled via many-body entanglement together with local measurements and feedback operations. This engine admits a universal thermodynamic characterization in terms of how the quantum vacuum bends under increasing interaction strength [3].

This work is supported by the John Templeton Foundation, grant number 63209.

[1] Alok Nath Singh, Bibek Bhandari, Rafael Sánchez, Andrew N. Jordan, Capturing an Electron in the Virtual State, arXiv:2503.10064

[2] Rafael Sánchez, Alok Nath Singh, Andrew N. Jordan, Bibek Bhandari, Making the Virtual Real: Measurement-Powered Tunneling Engines, Phys. Rev. B 113, 125414 (2026)

[3] Robert Czupryniak, Bibek Bhandari, Paolo Andrea Erdman, Andrew N Jordan, Universal Characterization of Quantum Vacuum Measurement Engines, arXiv:2602.03706