Department of Physics
Faculty of Science

Stella Seah

BEST GRADUATE RESEARCHER AWARD

Stella with her supervisor, Professor Valerio Scarani

Achievements

For her PhD research, Stella Seah focused on quantum thermodynamics and developed models of quantum thermal machines. Specifically, she was invited to contribute to a collective book Thermodynamics in the Quantum Regime by Springer on quantum rotor engines. More recently, she gave a contributed talk on a project on an autonomous Maxwell Demon engine in Finland at the international Quantum Thermodynamics Conference. Stella has a strong track record at conference and has presented talks at other conferences including the Institute of Physics Singapore Meeting in each of the past three years, as well as international conferences in Jeju and Tokyo in 2017 and 2018 respectively.

Stella receiving her award from Professor Lu Yixin, Vice Dean (Graduate Studies and Safety)

Videos

Scan the QR codes to watch Stella in CQT's three-part video series on 'The definition of quantum theory', particularly in parts 2 and 3.

The definition of quantum theory - Part I

The definition of quantum theory - Part II

The definition of quantum theory - Part III

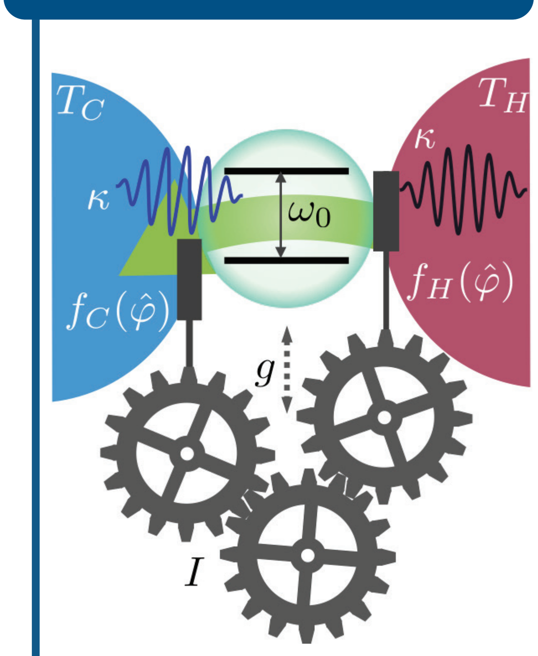
Autonomous Quantum Thermal Machines

STELLA SEAH, SUPERVISOR: PROF. VALERIO SCARANI

Quantum thermal machines: quantum systems that exploit thermal resources in order to attain desired functionalities (e.g. cooling in refrigerators, work production in engines, entanglement generation)

Research focus: to study autonomous quantum thermal machines that are self-contained and do not assume additional (hidden) resources beyond those described by the set-ups

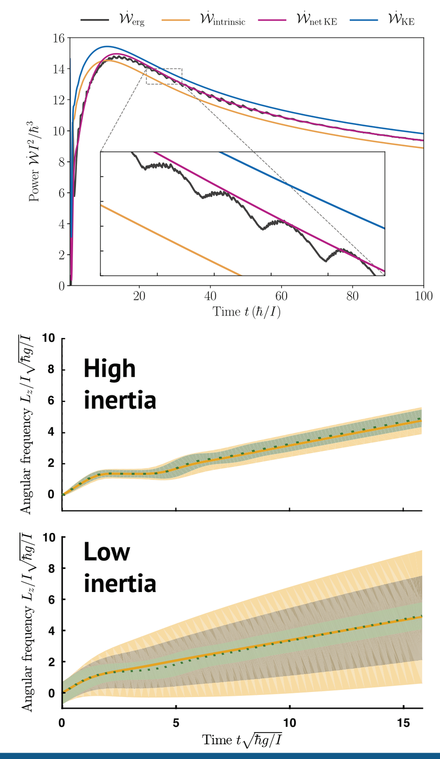
Rotor Engines



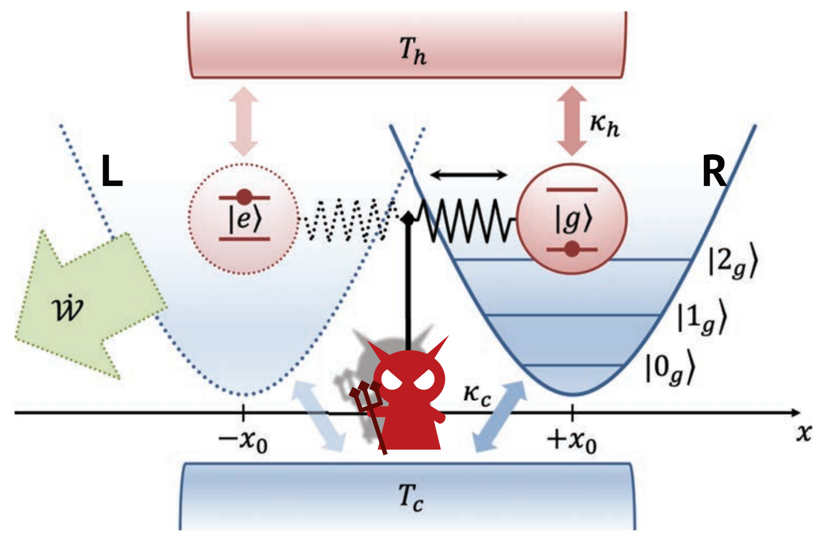
Set-up: working medium → **qubit** and work repository → **rotor**

Motivations:
- To study/isolate quantum effects in a heat engine by exploiting the **directed motion** of rotors and comparing it with a classical rotor
- To explore the various definitions of work: (1) **ergotropy** derived on axiomatic grounds for quantum states), (2) **classical** work (force x displacement) and (3) **kinetic energy** due to **NET motion**

Key results:
- Quantum engine noisier due to vacuum fluctuations and measurement-backaction as a result of the angle-dependent couplings to baths, i.e. an indirect position measurement of rotor each time a photon is excited/absorbed from the bath
- Net KE ~ Ergotropy & Total KE = Classical work + Backaction heating

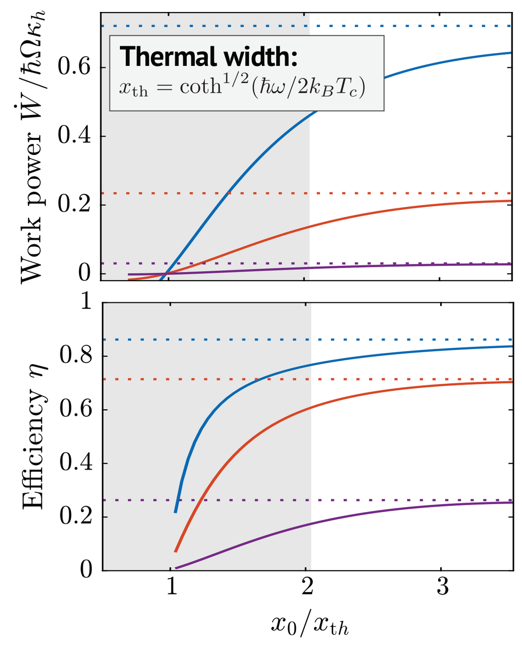


Maxwell Lesser Demon



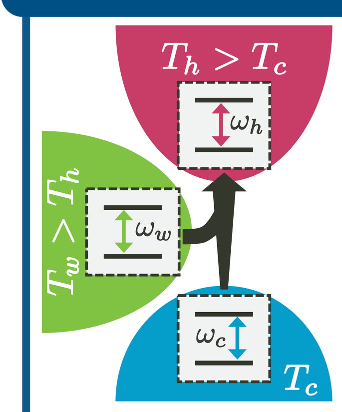
Motivations: To investigate the role of measurements in quantum thermodynamics and the associated energy cost due to erasure, non-ideal measurements etc.

Set-up:
- working medium → **qubit** and pointer → **HO**
- **hot bath** couples to qubit and randomly adds **excitation**, **cold bath** couples to HO and **resets** it to its equilibrium position
- demon **reads off** pointer position to obtain associated qubit state L→$|e\rangle$ and R→$|g\rangle$ and performs **feedback** to **extract work** when pointer is on the left, i.e. when qubit is most likely excited



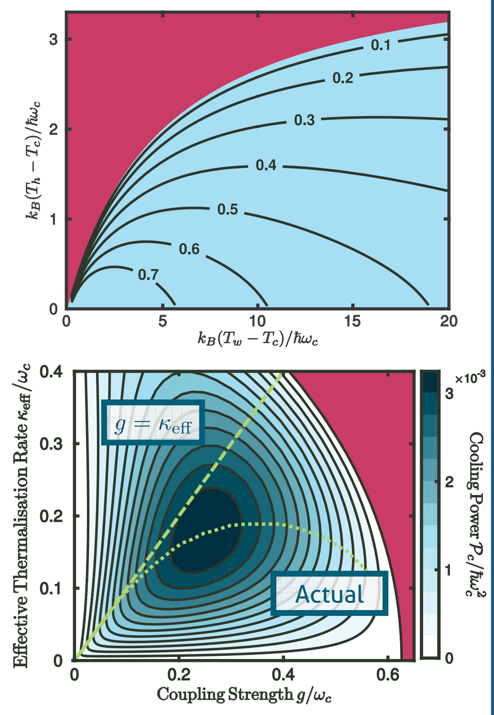
Key results:
- Optimum performance at vanishing overlap between L/R pointer steady states → occurs at slow measurement rates when noise induced by measurements is minimal
- NO work-efficiency tradeoff & engine operates beyond Otto window into the gray region where occupation numbers $n_c > n_h$

Absorption Refrigerators at Strong Coupling



Set-up of a Quantum Absorption Refrigerator (QAR):
- Unlike conventional refrigerators, heat flow from **cold to hot** is driven by **heat absorption** from a **work bath** instead of direct work input
- Occurs due to **resonant exchange of energies: work qubit** supplies energy together with the **cold qubit** to excite the **hot qubit**

Motivations: To investigate the performance of QAR beyond weak internal coupling using an effective master equation valid across arbitrary interaction strengths



Key results:
- weak int. → vanishing cooling due to weak transfer of energies between qubits
- strong int. → uncontrolled heating through global coupling between bath and qubits, i.e. individual qubits can feel the effects of all the baths through the other qubits
- Optimum when int. strength in the order of the effective bath decoherence rate
- Shrinking cooling window due to strong int. captured with a valid coarse-grained master equation

Publications

Peer-reviewed articles

- ✓ S. Seah, S. Nimmrichter, V. Scarani, Nonequilibrium Dynamics with Finite-Time Repeated Interactions, *Phys Rev E* **99**, 042103 (2019).
- ✓ S. Seah, S. Nimmrichter, V. Scarani, Refrigeration beyond weak internal coupling, *Phys. Rev. E* **98**, 012131 (2018).
- ✓ S. Seah, S. Nimmrichter, V. Scarani, Work production of quantum rotor engines, *New J. Phys.* **20**, 043045 (2018).
- ✓ A. Roulet, S. Nimmrichter, J. M. Arrazola, S. Seah, V. Scarani, Autonomous rotor heat engine, *Phys. Rev. E* **95**, 062131 (2017).
- ✓ S. Seah, E. W. C. Lim, Density segregation of dry and wet granular mixtures in gas fluidized beds, *AIChE J.* **61**, 4069 (2015).

Book chapter

- ✓ S. Seah, S. Nimmrichter, A. Roulet, V. Scarani, Quantum Rotor Engines, Thermodynamics in the Quantum Regime- Recent Progress and Outlook, *Springer* 227-245 (2019).

Unpublished manuscripts

- ✓ A. Shu, Y. Cai, S. Seah, S. Nimmrichter, V. Scarani, Almost thermal operations: inhomogeneous reservoirs (2019). *arXiv:1904.08736*
- ✓ S. Seah, S. Nimmrichter, D. Grimmer, J. P. Santos, A. Shu, V. Scarani, G. T. Landi, Collisional quantum thermometry (2019). *arXiv:1904.12551*
- ✓ S. Seah, S. Nimmrichter, V. Scarani, Maxwell's Lesser Demon (2019). *arXiv:1908.10102*