Finite and infinite quantum systems
QUANTUM

Investigation of the recent developments that changed the status of quantum mechanics (a new"quantum revolution") and made the development of Quantum Technologies a European flagship:

- quantum simulations and many-body physics,
- entanglement in applied quantum technologies,
- quantum thermodynamic machines,
- mesoscopic quantum dynamics of open systems, ...

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Quantum Thermodynamics

Fundamental questions at the interface between quantum theory and thermodynamics, vital for the development of quantum thermo-machines:

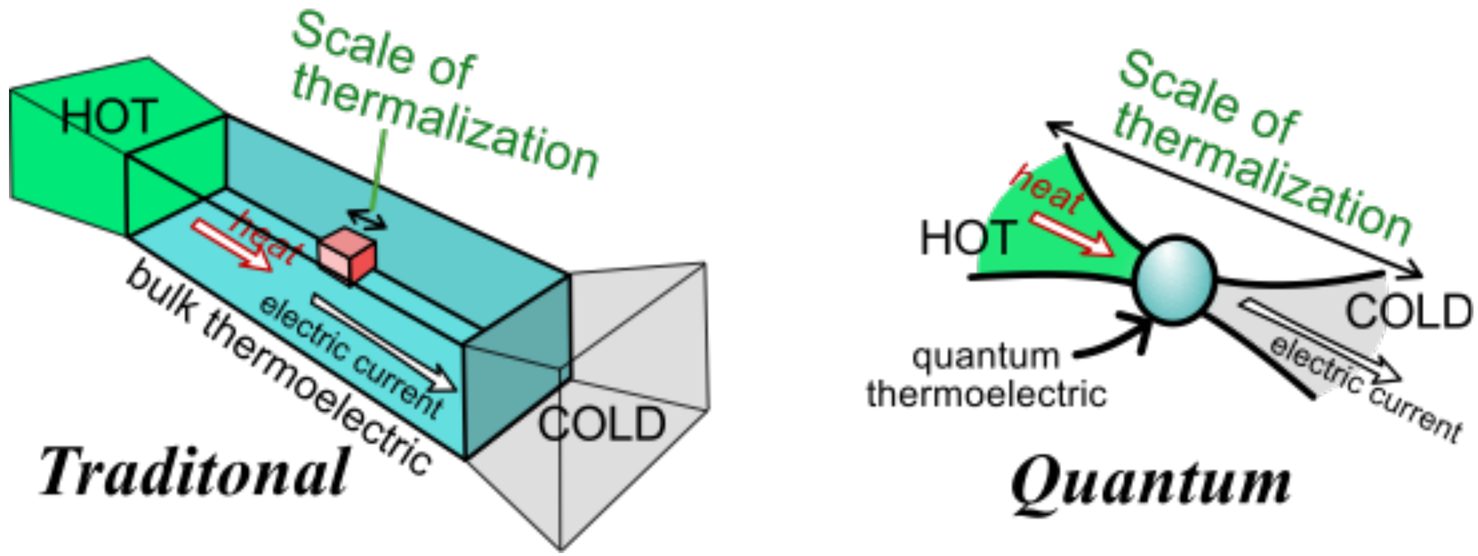
- Definition of heat and work in quantum mechanics

- Role of coherence, entanglement, quantum measurements and fluctuations in quantum machines

- Efficiency and power of small, nanoscale thermal machines

- Minimum temperature achievable in small quantum refrigerators

Traditional versus quantum thermoelectrics



Relaxation length (tens of nanometers at room T) of the order of the mean free path; Inelastic scattering (phonons) thermalizes the electrons

Structures smaller than the relaxation length (many microns at low T). Quantum interference effects, Boltzmann transport theory cannot be applied

[see G.B., G.Casati, K.Saito, R.S.Whitney, Phys. Rep. **694**, 1 (2017)]

Quantum aspects relevant for nanoscale applications

Mildred Dresselhaus et al. (Adv. Materials, 2007):
"a newly emerging field of low-dimensional thermoelectricity, enabled by material nanoscience and nanotechnology ... Thermoelectric phenomena are expected to play an increasingly important role in meeting the energy challenge for the future ..."

Small scale (quantum) thermoelectricity could be relevant for cooling directly on chip, by purely electronic means. Nanoscale heat management is crucial to reduce the energy cost in many applications of microelectronics.

Summary (keywords)

Optimizing the performances of nanoscale quantum thermal engines

Heat management in nanodevices

Quantum information protocols in the ultra-strong coupling regime

In circuit quantum electrodynamics the ultra-strong coupling regime can be achieved, with the frequency of Rabi oscillations of the order of the cavity frequency

New research direction on
strongly correlated light-matter states

CAVITY QED

A single mode of the field (cavity mode) rather than an infinite number of modes is considered

The quantization volume (of the cavity) is fixed and the limit of infinite volume is not taken at the end of the computation

Non-adiabaticity: the interaction is switched on abruptly and we focus on transient phenomena (finite-time QED)

Ultra-strong coupling

QUANTUM-MI publications (2017-18)

P.A. Erdman, F. Mazza, R. Bosisio, G. Benenti, R. Fazio and F. Taddei, Thermoelectric properties of an interacting quantum dot based heat engine, PRB 95, 245432 (2017).

U. Bissbort, C. Teo, C. Guo, G. Casati, G. Benenti and D. Poletti, Minimal motor for powering particle motion from spin imbalance, PRE 95, 062143 (2017).

G. Benenti, G. Casati, K. Saito, and R. Whitney, Fundamental aspects of steady-state conversion of heat to work at the nanoscale, Phys. Rep. 694, 1 (2017).

F. Hoeb, F. Angaroni, J. Zoller, T. Calarco, G. Strini, S. Montangero and G. Benenti, Amplification of the parametric dynamical Casimir effect via optimal control, PRA 96, 033851 (2017).

S. Chen, D. Donadio, G. Benenti and G. Casati, Efficient thermal diode with ballistic spacer, PRE 97, 030101(R) (2018).

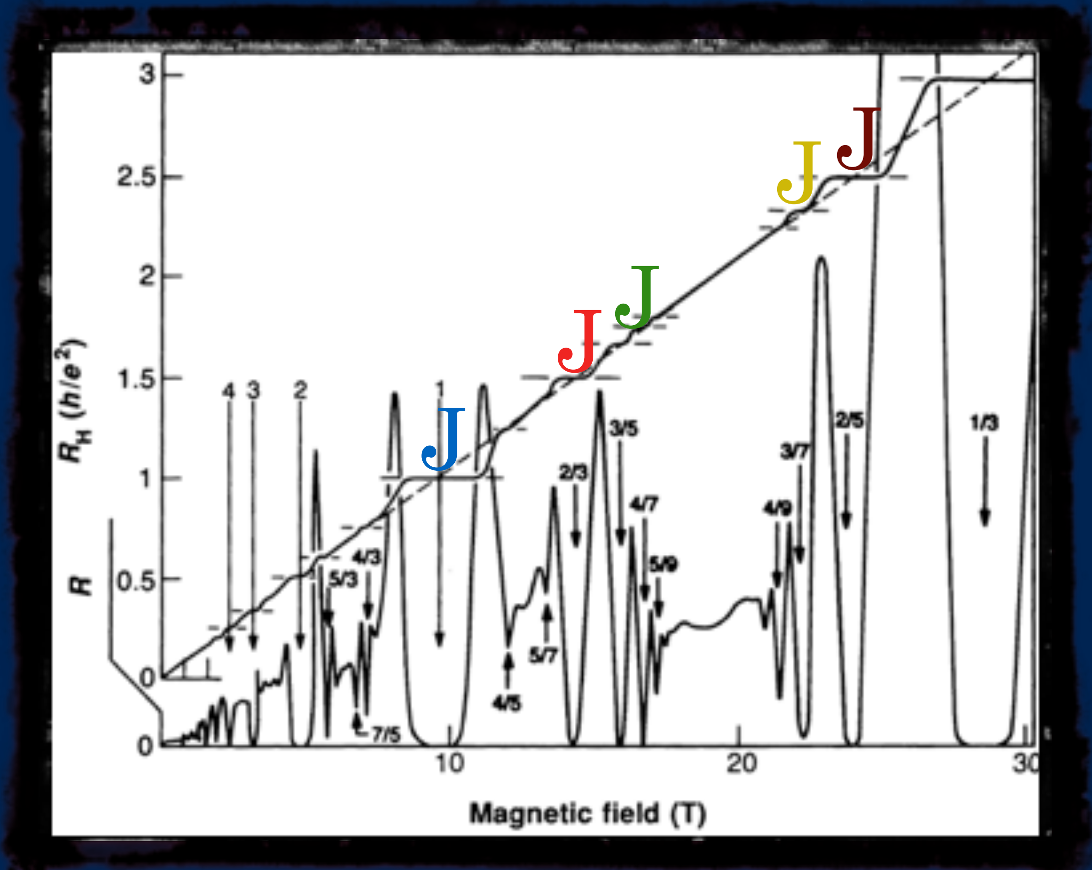
V. Balachandran, G. Benenti, E. Pereira. G. Casati and D. Poletti, Perfect diode in quantum spin chains, PRL 120, 200603 (2018).

R. Luo, G. Benenti, G. Casati and J. Wang, The best thermoelectric: The role of interactions, arXiv:1710.06646.

F. Angaroni, G. Benenti and G. Strini, Applications of Picard and Magnus expansions to the Rabi model, arXiv:1802.08897.

JACK ON A DEVIL'S STAIRCASE

Luca G Molinari - Physics Dept- Milano

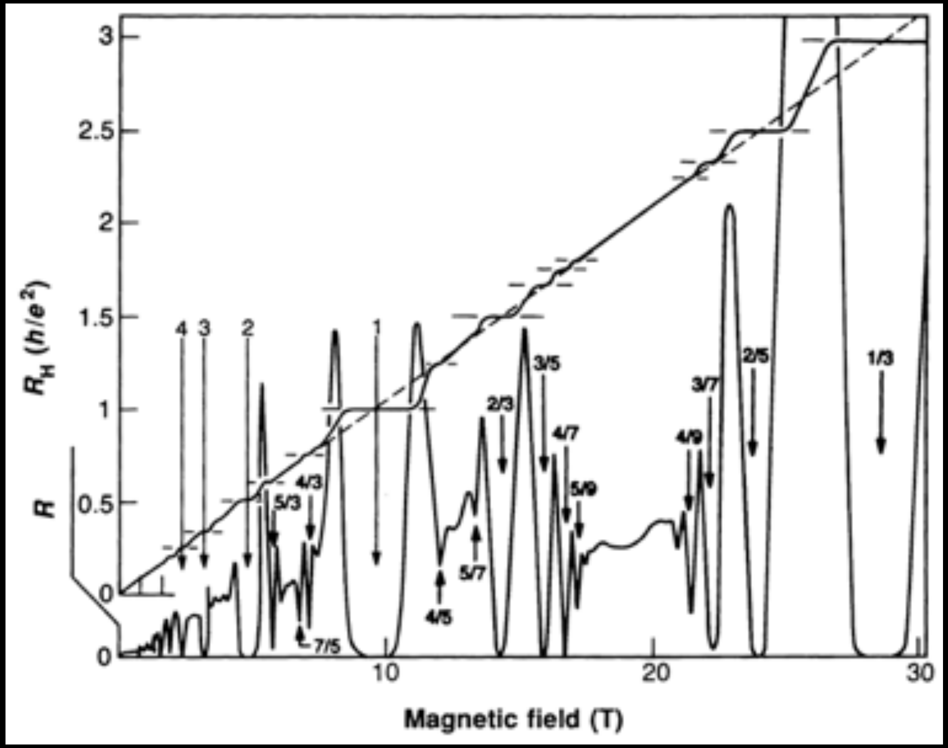


(on the ground states of the FQHE)

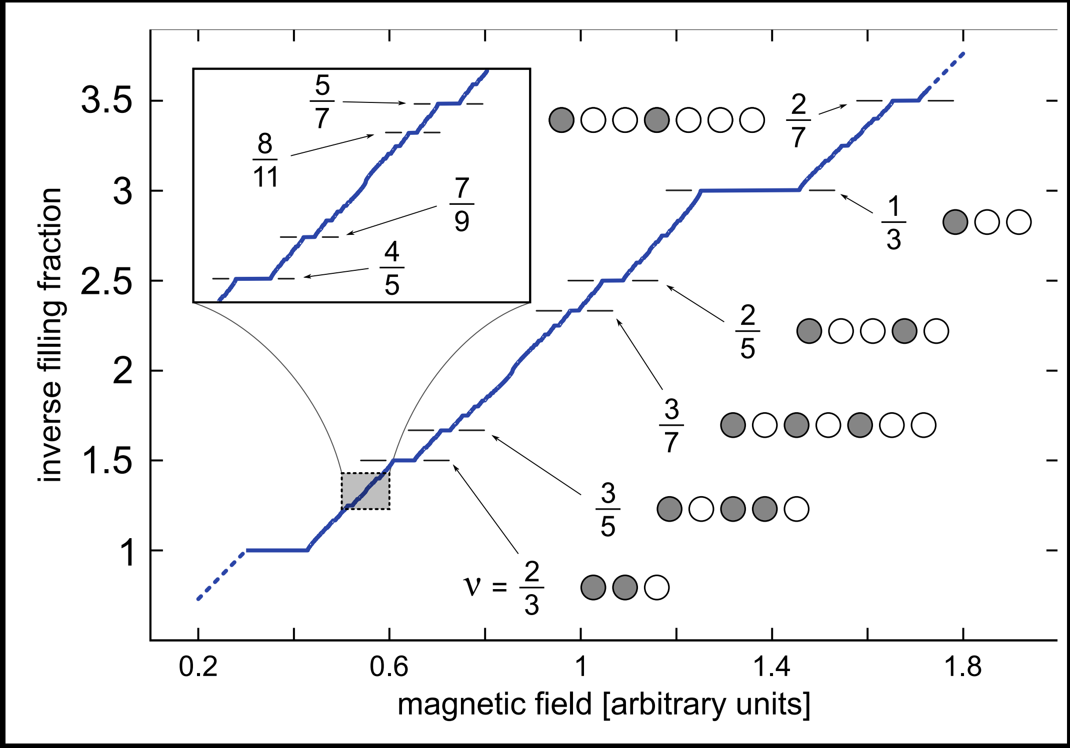
EXACT SOLUTION of Quantum Hall Hamiltonian restricted to the LL level in thin torus limit (Lx << magn. length << Ly, a map to a lattice crystal by Hubbard)

We qualitatively reproduce the experimental diagram of FQHE

FQHE - EXPERIMENT



LATTICE CRYSTAL



Devil's staircase phase diagram of the FQHE in the thin torus limit
PRL 116 (2016) 256803

Unified Fock space representation of FQH states

PRB 95 (2017) 245123 (8pp)

Pietro Rotondo

Luca G Molinari

Andrea Di Gioacchino

Vittorio Erba

We give in Fock space the OPERATOR

thin-torus state → **full "ground state" of FQHE**
(Vandermonde determinant x Jack Polynomial)

ex: $\psi(1/3) = U(1/3)\,|\,100010001000\ldots\,\}$
(Laughlin ansatz, Nobel prize)

The "ground state" $\psi(p/q)$ is actually an eigenstate of the Calogero-Sutherland Hamiltonian

what is JACK doing on a devil's staircase ?