THERMOCOHERENT EFFECT:

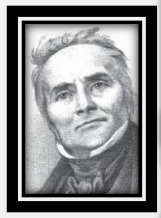
GENERALIZATION OF ONSAGER'S RECIPROCITY RELATIONS FOR HEAT AND QUANTUM CORRELATIONS

Onur Pusuluk & Özgür E. Müstecaplıoğlu
onur.pusuluk@gmail.com

QTD 2022 — KOÇ UNIVERSITY

1 MOTIVATION


T.J. Seebeck (1822)


J.C.A. Peltier (1834)

- Role of the initial q-properties of the environment in heat conduction?
- Relations between heat & q-coherence and q-correlations?
- Coherent Peltier & Seebeck effects?

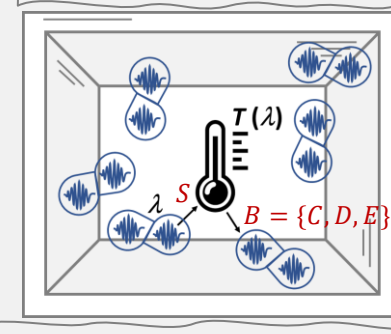
@ PRR 3, 023235 (2021)


Lord Rayleigh (1891)


Lars Onsager (1931)

2 Q – RAYLEIGH PROBLEM

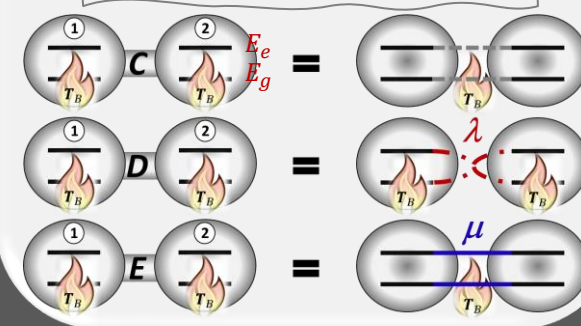
$\rho_S(0) = q_g\,|g\rangle\langle g| + q_e\,|e\rangle\langle e|$



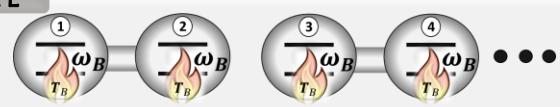
$\rho_C = p_g\,|gg\rangle\langle gg| + p_e\,|ee\rangle\langle ee|$

$\rho_D = \rho_{C_1} \otimes \rho_{C_2} + \lambda\,(|ge\rangle\langle eg| + H.c.)$

$\rho_E = \rho_C + \mu\,(|gg\rangle\langle ee| + H.c.)$



3 DYNAMICS TO STEADY STATE



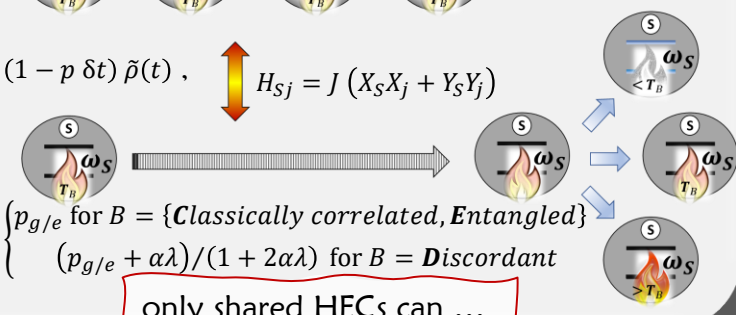
Assumptions :

- $\rho(t) = \rho_S(t) \otimes \rho_B$,
- $\tilde{\rho}(t+\delta t) = p\,\delta t\,U(\tau)\,\tilde{\rho}(t)\,U^{\dagger}(\tau) + (1-p\,\delta t)\,\tilde{\rho}(t)$,
- arbitrary collision times !

$H_{Sj} = J\,(X_S X_j + Y_S Y_j)$

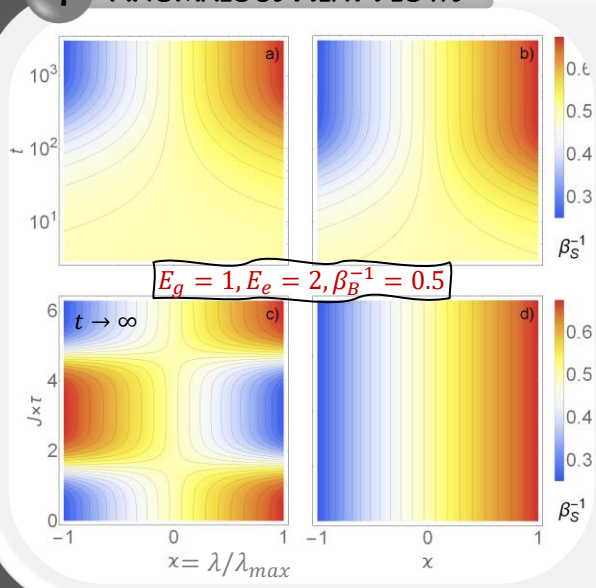
Solution of the master equation :

$\rho_S^{\infty} = \Gamma_g\,|g\rangle\langle g| + \Gamma_e\,|e\rangle\langle e|$ with $\Gamma_{g/e} = \begin{cases} p_{g/e} \text{ for } B = \{\textit{Classically correlated}, \textit{Entangled}\} \\ (p_{g/e} + \alpha\lambda)/(1+2\alpha\lambda) \text{ for } B = \textit{Discordant} \end{cases}$

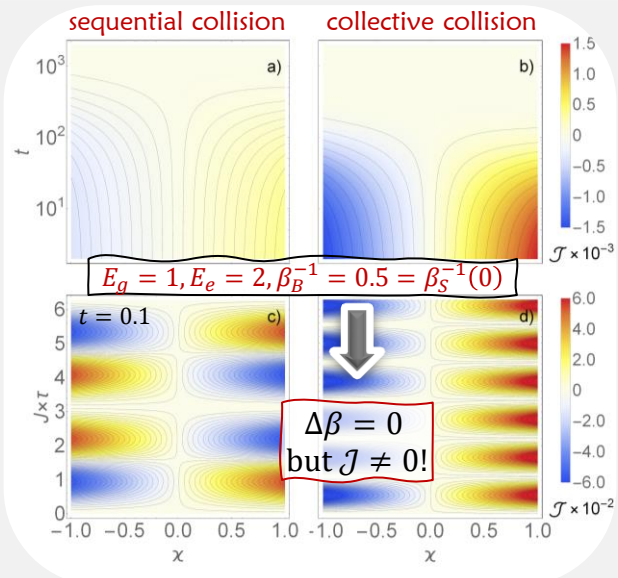


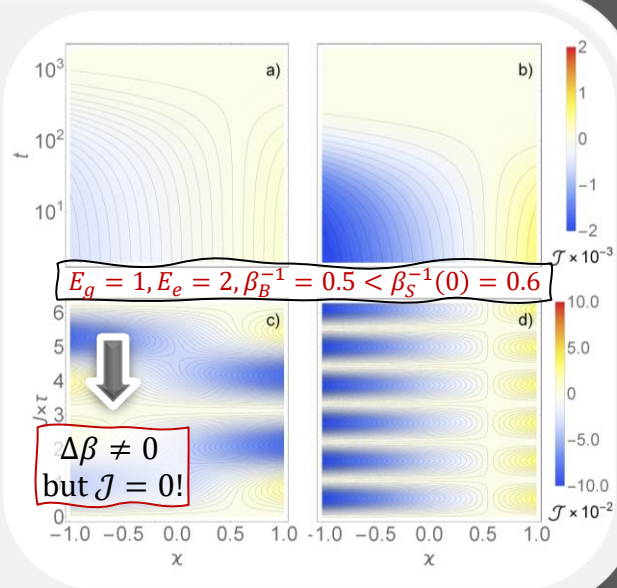
only shared HECs can …

4 ANOMALOUS HEAT FLOWS

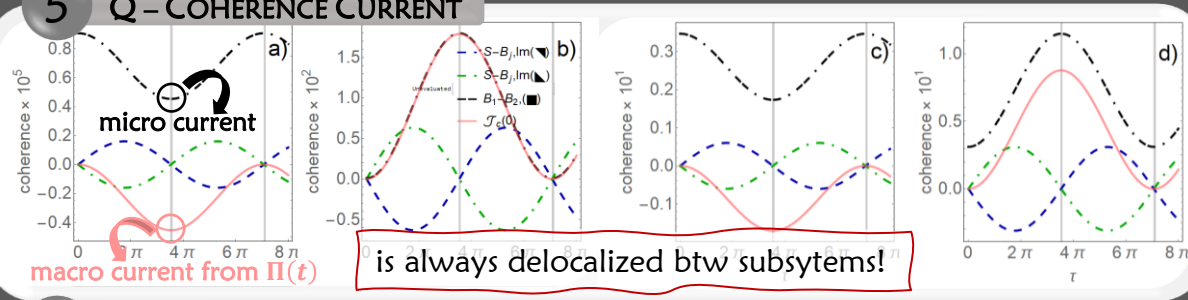


sequential collision — collective collision





5 Q – COHERENCE CURRENT



is always delocalized btw subsytems!

6 Q – THERMOCOHERENT RELATIONS

Transient regime (single bath) :

$$\Pi(t) = -\,\mathrm{tr}[\mathcal{D}(\rho_S)\,\ln(\rho_S)] + \mathrm{tr}[\mathcal{D}(\rho_S)\,\ln(\rho_S^{\infty})] = \mathcal{J}(t)\big(\beta_S(t) - \beta_S(\infty)\big) \geq 0$$

$$\approx \gamma(t)\{\Delta\beta\,\mathcal{J}_h(t) - \beta_S(\infty)\,\Delta C\,\mathcal{J}_c(t)\}$$

➢ $\mathcal{J}_h(t) \equiv \gamma(t)\big(\tilde{L}_{hh}\,\Delta\beta - \tilde{L}_{hc}\,\beta_S(0)\,\Delta C\big)$ & $-\mathcal{J}_c(t) \equiv \gamma(t)\big(\tilde{L}_{ch}\,\Delta\beta - \tilde{L}_{cc}\,\beta_S(0)\,\Delta C\big)$

Steady state (double bath) :

$$\Pi(\infty) = \dot{S}\left[\rho_{S|BB'}^{\infty}\right] + \mathrm{tr}\left[\mathcal{D}\left(\rho_{S|BB'}^{\infty}\right)\ln\left(\rho_{S|B}^{\infty}\right)\right] + \mathrm{tr}\left[\mathcal{D}'\left(\rho_{S|BB'}^{\infty}\right)\ln\left(\rho_{S|B'}^{\infty}\right)\right]$$

$$= -\mathcal{J}_h\,\beta_{S|B}^{\infty} - \mathcal{J}_{h'}\,\beta_{S|B'}^{\infty} \approx \Delta\beta\,\mathcal{J}_h(t) - \left(\beta_{S|B'}^{\infty}C' - \beta_{S|B}^{\infty}C\right)\mathcal{J}_c$$

➢ $\mathcal{J}_h \equiv L_{hh}\,\Delta\beta - L_{hc}\beta_{S|BB'}^{\infty}\Delta C$ & $-\mathcal{J}_c \equiv L_{ch}\,\Delta\beta - L_{cc}\beta_{S|BB'}^{\infty}\Delta C$

where $L_{jk} = \tilde{L}_{jk}/2 = (E_e - E_g)^2\,\eta(J,\tau)/8\alpha$.

7 Q – TECH APLICATIONS

Thermocoherent Peltier effect

- ❑ Local heating/cooling by q–coherence injection.
- ❑ Heat transfer in nanoscale using well-focused coherent lasers.
- ❑ Temperature manipulation within a single molecule, e.g., PCR?

Thermocoherent Seebeck effect

- ❑ Q–coherence production by a thermal gradient.
- ❑ Q–technologies based on phononics, e.g., thermal diodes & transistors.

Optimization of thermocoherent coefficients

- ❑ «Thermocoherent» devices.
- ❑ «Dicoherent» materials that preserve the q-coherence in a reservoir.

Improved control over chemical reactions

- ❑ Onsager's monomolecular triangle reaction & q-superpositions of molecular configurations!