quantum measurement cooling

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arXiv: 1806.07814

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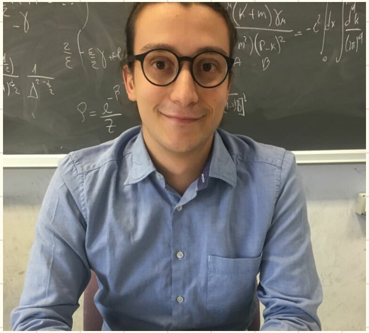

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Q-TIF quantum theory in Florence

qtif.weebly.com

COLLABORATIONS

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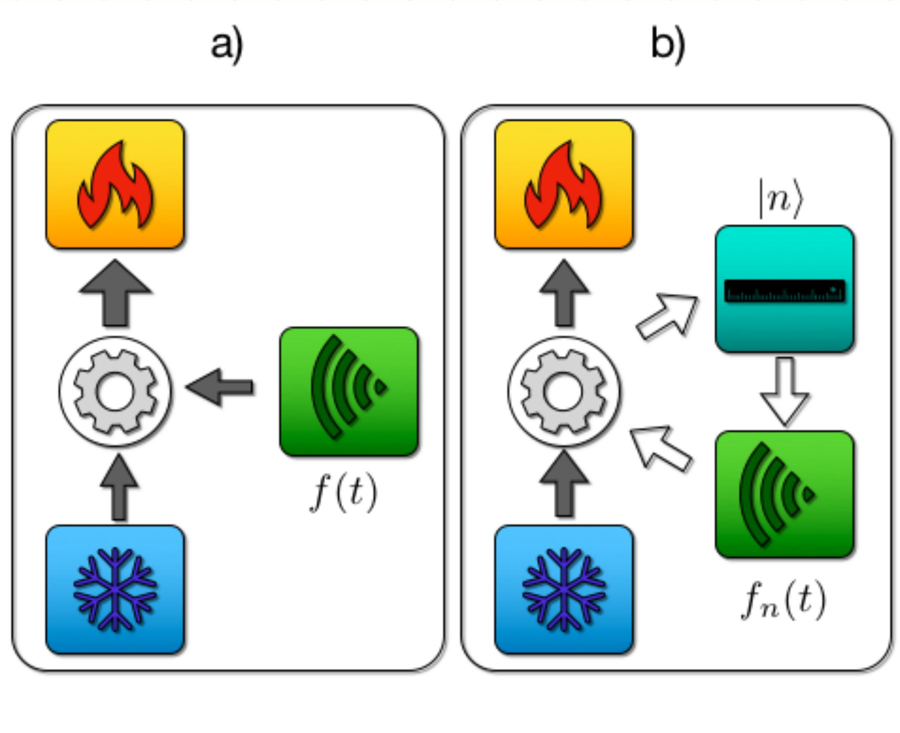
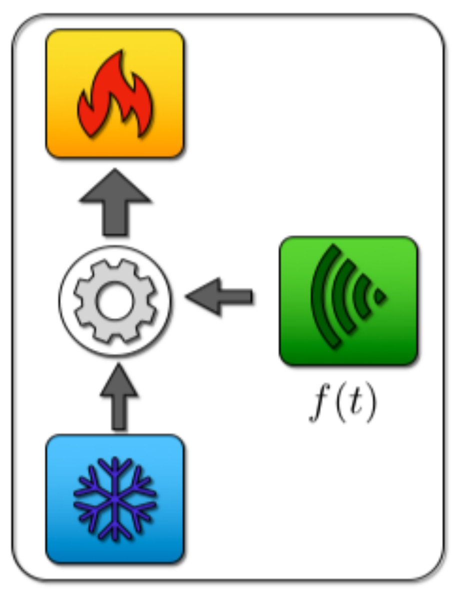
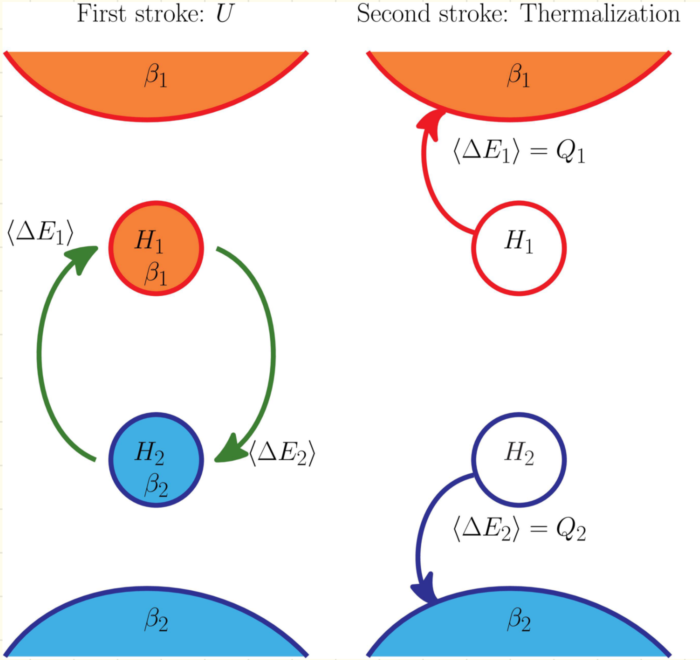
Standard cooling concepts



Cooling by time-dependent driving





$$\underbrace{}_{}\quad \frac{\omega_1}{2}\sigma_1^z \qquad \frac{\omega_2}{2}\sigma_2^z$$

$$H = \underset{\frac{\omega_1}{2}\sigma_1^z}{H_1} + \underset{\frac{\omega_2}{2}\sigma_2^z}{H_2} + V(t) \rightarrow U$$

$$\langle \Delta E_1 \rangle = \mathrm{Tr}_1 \mathrm{Tr}_2\, H_1 (U \rho U^\dagger - \rho)$$

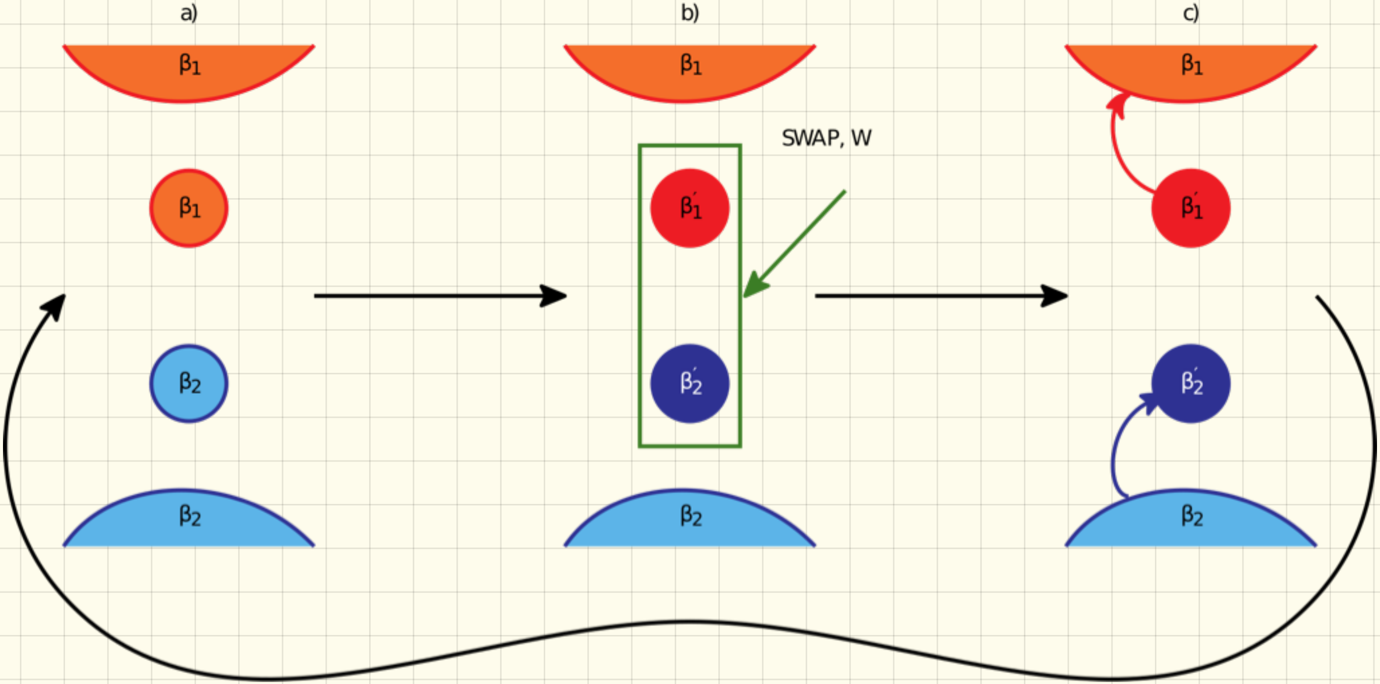
$$+$$

$$\langle \Delta E_2 \rangle = \mathrm{Tr}_1 \mathrm{Tr}_2\, H_2 (U \rho U^\dagger - \rho)$$

$$=$$

$$\langle W \rangle$$

Campisi, Pekola, Fazio, NJP $\underline{17}$ 035012 (2015)

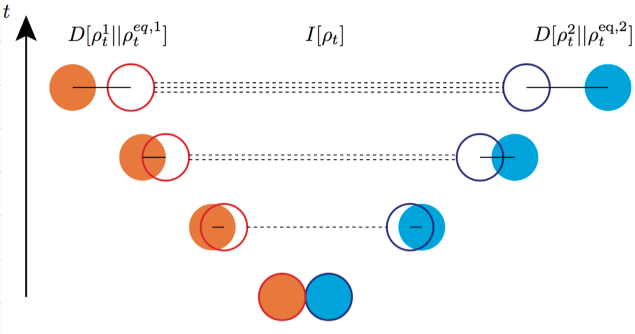


$$\beta_1' = \beta_2 \frac{\omega_2}{\omega_1} \qquad \beta_2' = \beta_1 \frac{\omega_1}{\omega_2} \qquad \frac{\omega_2}{\omega_1} < \frac{\beta_1}{\beta_2}$$

refrigerator

DISSIPATION, CORRELATIONS AND LAGS IN HEAT ENGINES

Campisi e Fazio, JPA 49 345002 (2016)



$$\rho_0 = \rho_0^1 \otimes \rho_0^2 = \frac{e^{-\beta_1 H_1(0)}}{Z_1} \otimes \frac{e^{-\beta_2 H_2(0)}}{Z_2}$$

$$\beta_1 Q_1 + \beta_2 Q_2 = D[\rho_t^1 || \rho_0^1] + D[\rho_t^2 || \rho_0^2] + I_{1/2}[\rho_t] \geq 0$$

$$\mathrm{Tr}_i [H_i(\tau)\rho_\tau^i - H_i(0)\rho_0^i] = \langle \Delta E_i \rangle = Q_i$$

$$D[\rho||\sigma] = \mathrm{Tr}(\rho \ln \rho - \rho \ln \sigma)$$

$$I_{1/2}[\rho_t] = \sum_i S[\rho_t^i] - S[\rho]$$

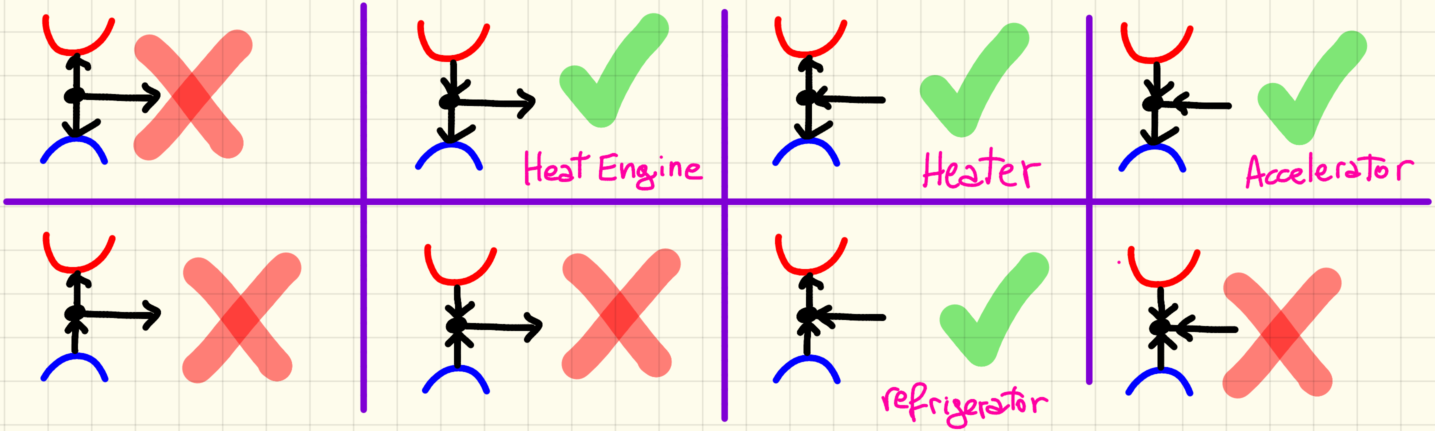
$$S[\rho] = -\mathrm{Tr}\,\rho \ln \rho$$

$$\beta_1 Q_1 + \beta_2 Q_2 \geq 0$$

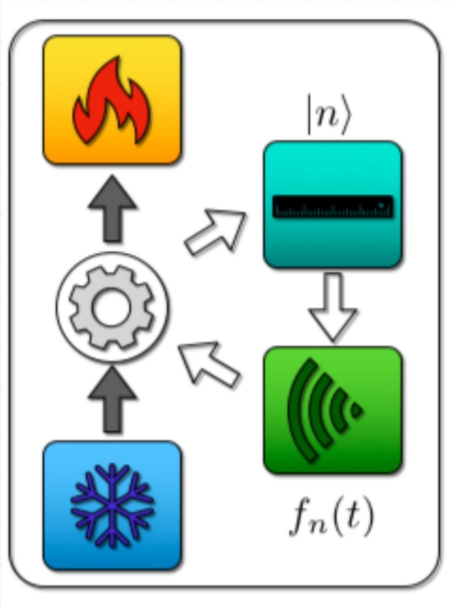
$$W = Q_1 + Q_2$$

A. Solfanelli

B. Sc. thesis UNIFI

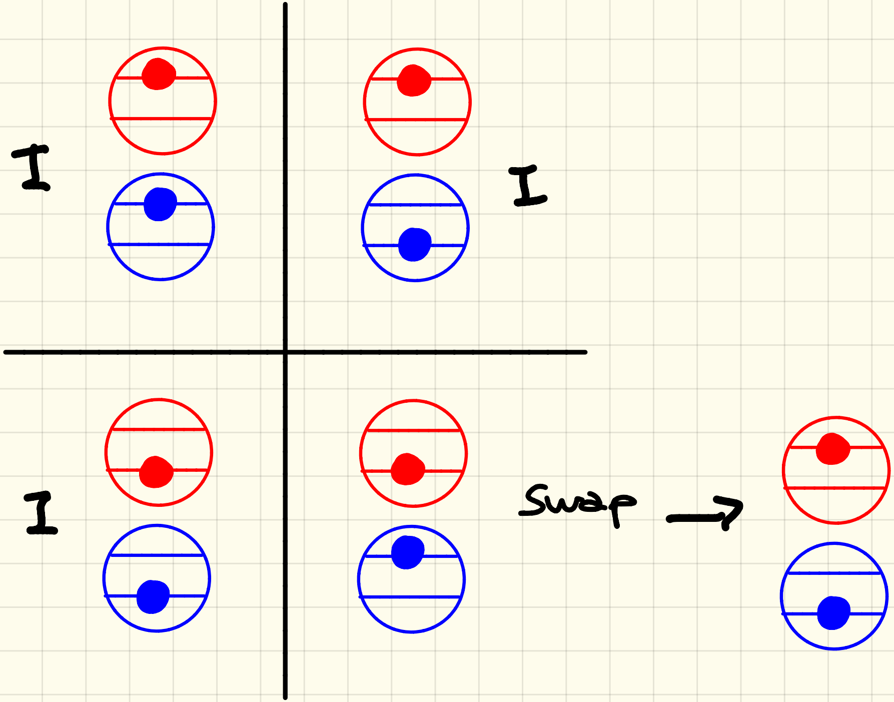


Cooling by feedback control



First stroke

conditional, energy preserving



$\omega_1 = \omega_2$

$$p_{m|n} = \mathrm{Tr}\, P_m U_n^{\dagger} P_n U_n P_m \leftarrow$$ not doubly stochastic!!!

$$\rho \to \sum_n U_n^{\dagger} P_n \rho P_n U_n \leftarrow$$ not unital

$$\beta_1 Q_1 + \beta_2 Q_2 = D[\rho_t^1 \| \rho_0^1] + D[\rho_t^2 \| \rho_0^2] + I_{1/2}[\rho_t] + \Delta \mathcal{H}$$

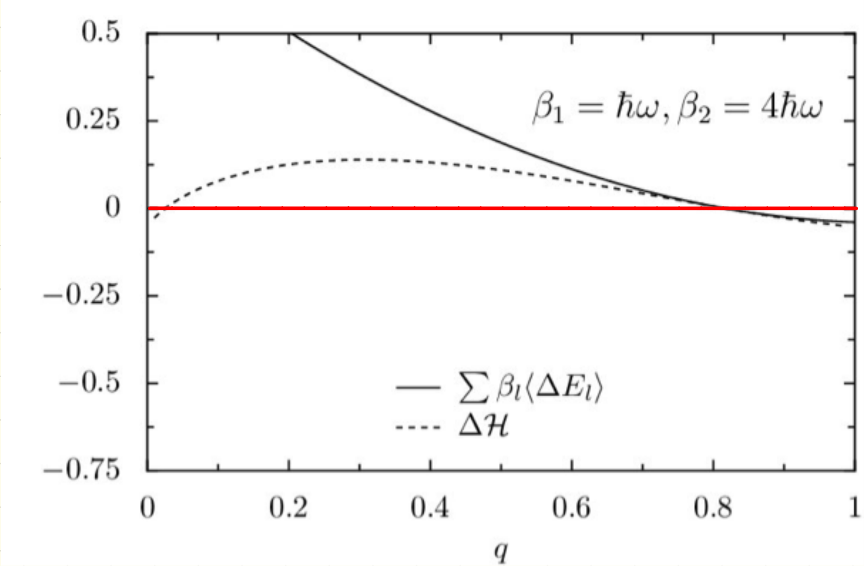
$$\beta_1 Q_1 + \beta_2 Q_2 \geq \Delta \mathcal{H} \qquad \mathcal{H} = -\mathrm{Tr}\,\rho \ln \rho$$

may be negative

measures the intelligence of the demon

$$Q_1 + Q_2 = 0 \quad , \quad \beta_1 Q_1 + \beta_2 Q_2 \geq \Delta \mathcal{H}$$

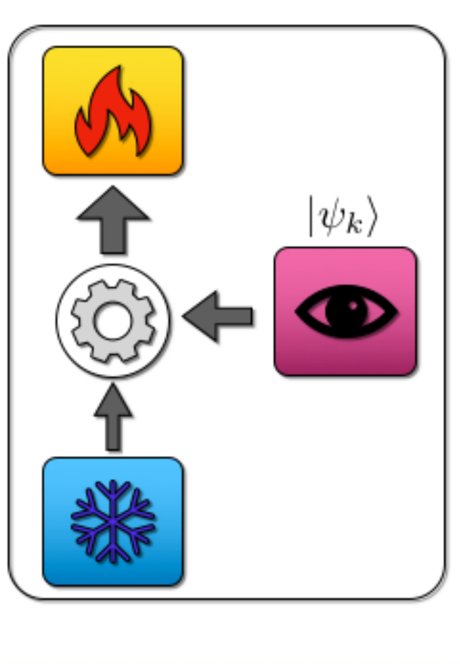
$$(\beta_2 - \beta_1) Q_2 \geq \Delta \mathcal{H} \Rightarrow Q_2 \geq \frac{\Delta \mathcal{H}}{\Delta \beta}$$



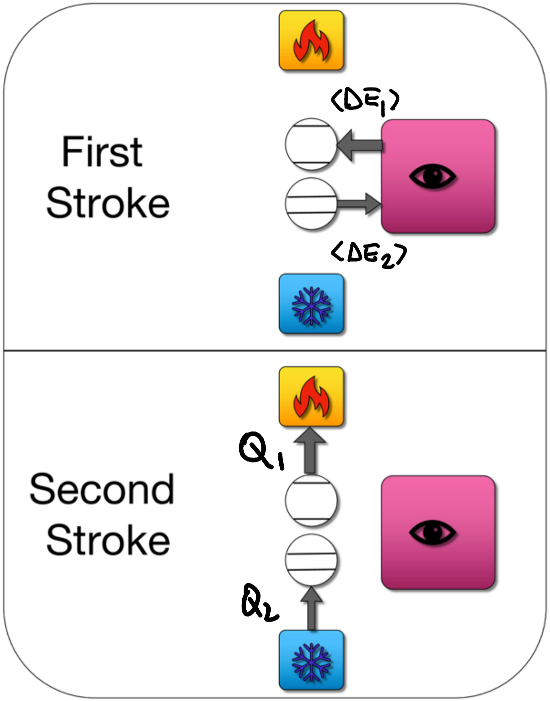
$\mathcal{E}[+|+] = \mathcal{E}[-|-] = q$

$\mathcal{E}[+|-] = \mathcal{E}[-|+] = 1-q$

Campisi, Pekola, Fazio, NJP 19 053020 (2017) quantum measurement cooling



$\Pi_k = |\psi_k\rangle\langle\psi_k|$



$$\langle \Delta E \rangle = \langle \Delta E_1 \rangle + \langle \Delta E_2 \rangle$$

$$= Q_1 + Q_2$$

"quantum heat"

Elouard et al., npj-quantum info, 3 (2017)

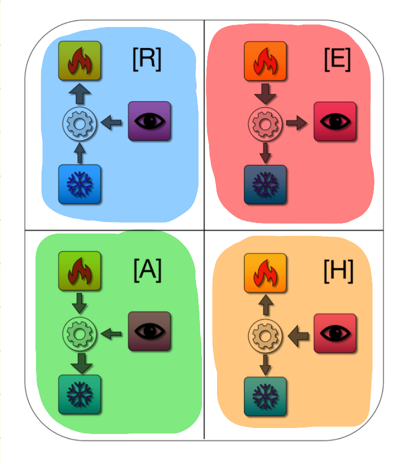
$$\rho \to \rho' = \sum_k \Pi_k \, \rho \, \Pi_k$$ unital !! $\Rightarrow \Delta \mathcal{H} \geq 0$

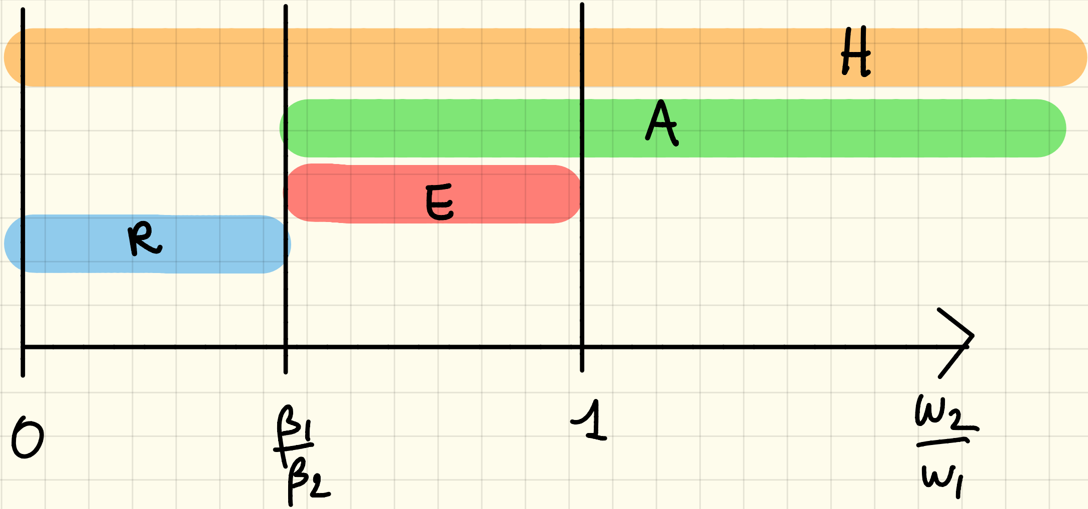
$$\beta_1 Q_1 + \beta_2 Q_2 = D[\rho_t^1 \| \rho_0^1] + D[\rho_t^2 \| \rho_0^2] + I_{1/2}[\rho_t] + \Delta \mathcal{H}$$

$$\beta_1 Q_1 + \beta_2 Q_2 \geq \Delta \mathcal{H} \geq 0$$ $\mathcal{H} = -\mathrm{Tr}\, \rho \ln \rho$

Results

1





Results

2

$$\begin{cases} |\psi_1^*\rangle = |\uparrow\uparrow\rangle \\ |\psi_2^*\rangle = \frac{|\uparrow\downarrow\rangle + |\downarrow\uparrow\rangle}{\sqrt{2}} \\ |\psi_3^*\rangle = \frac{|\uparrow\downarrow\rangle - |\downarrow\uparrow\rangle}{\sqrt{2}} \\ |\psi_4^*\rangle = |\downarrow\downarrow\rangle \end{cases}$$

maximises

$\eta^{[R]}$, $-Q_2$ in [R]-range

$\eta^{[E]}$, $\langle \Delta E \rangle$ in [E]-range

$$\langle \Delta E_{1,2} \rangle = \frac{\pm\omega_i}{2}\left(\frac{1}{1+e^{\beta_1\omega_1}} - \frac{1}{1+e^{\beta_2\omega_2}}\right)$$

$$\eta^{[R]} = \frac{1}{\frac{w_1}{w_2} - 1}$$

$$\eta^{[E]} = 1 - \frac{w_2}{w_1}$$

Results

3

Let $|\psi_K\rangle = U|K\rangle$

Pick U randomly from the invariant $SU(4)$ measure

then

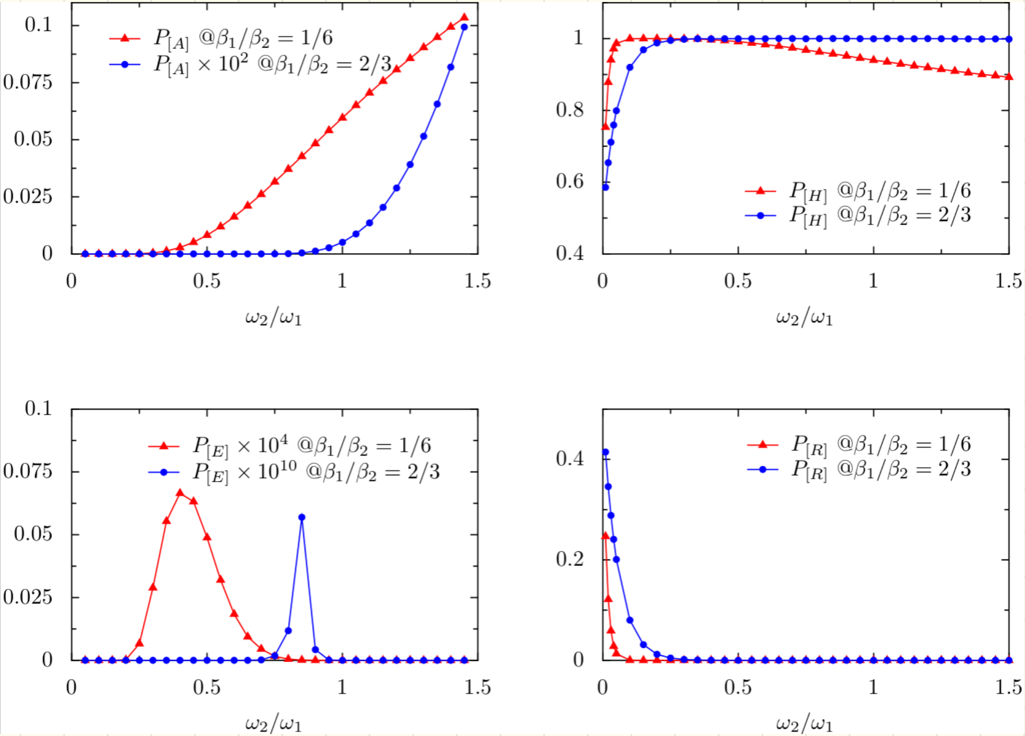
$$\overline{\langle \Delta E_i \rangle} \geq 0 \quad \Rightarrow \quad [H]$$

$$\left(\overline{f} = \int_{SU(4)} dm\, f \right)$$

Results

4

Monte Carlo Sampling of SU(4)



Experiment....

circuit QED + circuit QTD

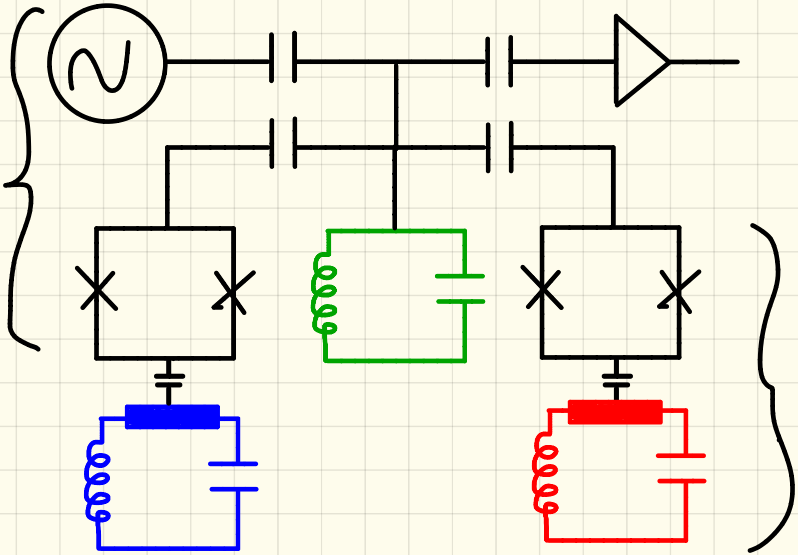
↓

circuit Quantum Thermo Dynamics → Pekola, Giazotto....

$$\rho' = \sum_k \Pi_k \, \rho \, \Pi_k$$

$$= \sum_k U P_k U^\dagger \rho \, U P_k U^\dagger$$

Filipp et al., PRL 102 200402 (2009)



Ronzani et al

arXiv:1801.09312

thank you