Dissipation of Quantum Resources

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TEAM-NET Online Workshop
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Geographic Nutshell

Brasil

210 millions of people

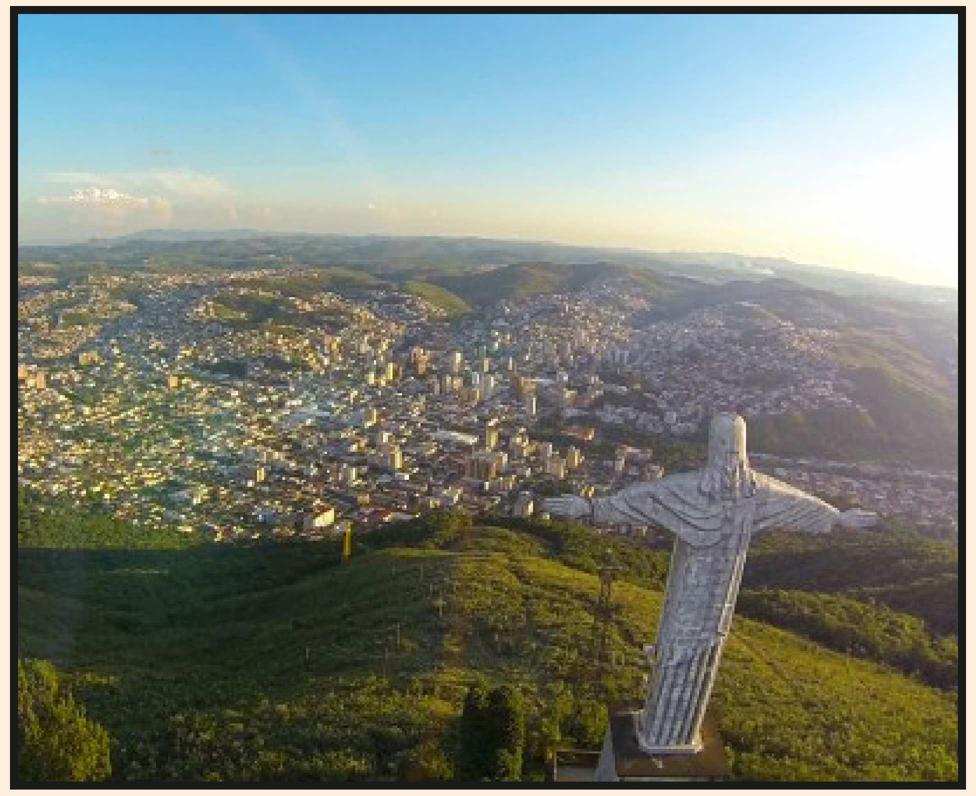
8.516.000 km²

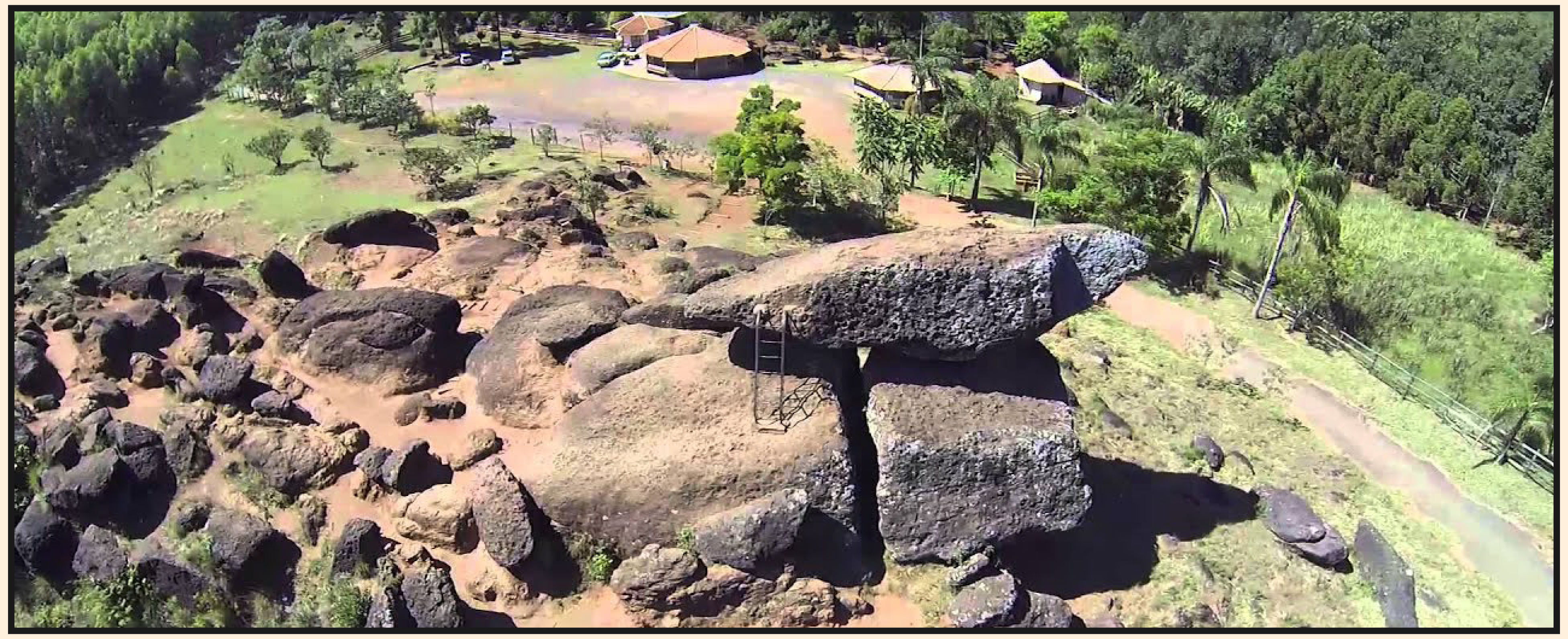
RIO DE JANEIRO

SÃO PAULO

Geographic Nutshell

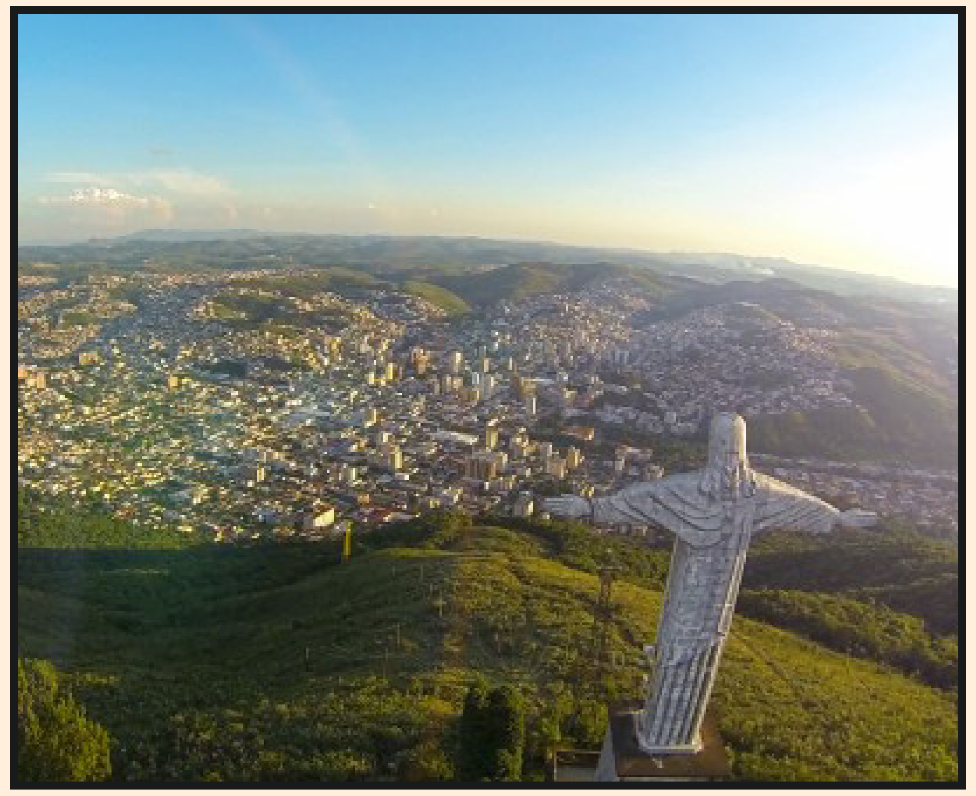
Poços de Caldas





Geographic Nutshell

Poços de Caldas



INSIDE THE CRATER
OF A LARGE
EXTINCT VOLCANO

Geographic Nutshell

São Paulo

Geographic Nutshell

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INSTITUTE OF PHYSICS "GLEB WATAGHIN"

QUANTUM THERMODYNAMICS

Geographic Nutshell

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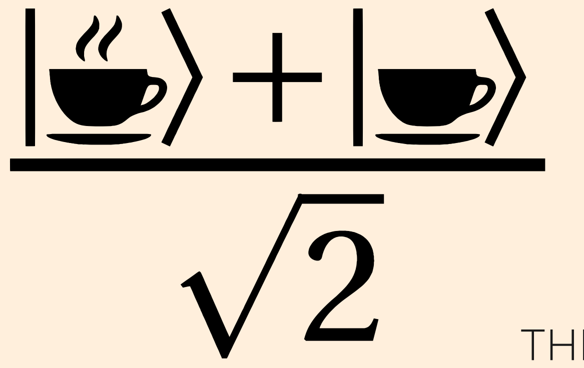
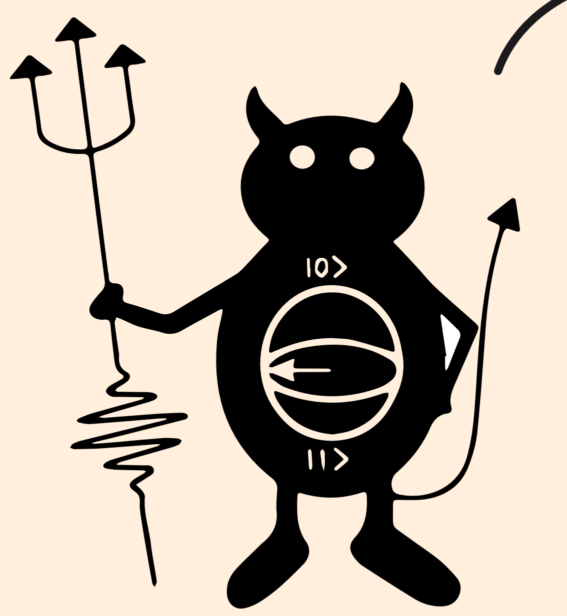
- Resource theories
- Open quantum systems
- Continuous variable quantum information



QUANTUM THERMODYNAMICS

Quantum Thermodynamics



How **thermodynamic quantities** can be carried over to the quantum realm?

The laws of thermodynamics
retain their place?

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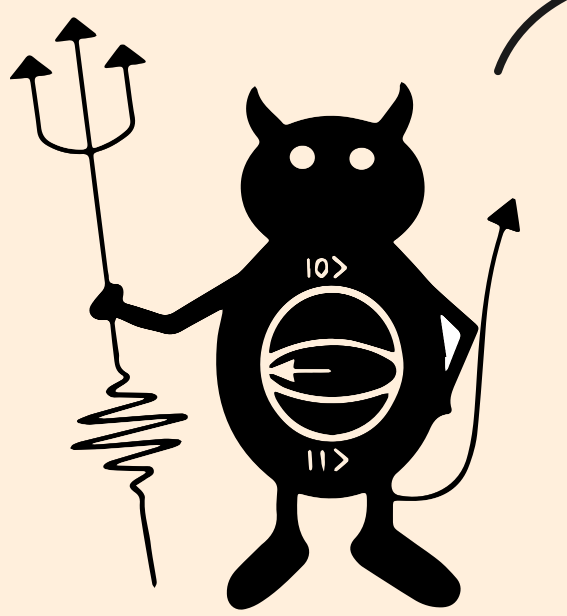
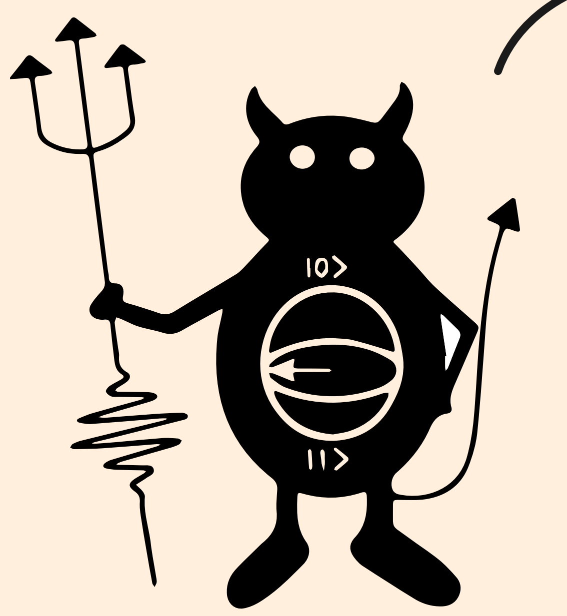


The laws of thermodynamics retain their place?

New devices

How **thermodynamic quantities** can be carried over to the quantum realm?

How **quantum features** can be used to optimize thermodynamic tasks?



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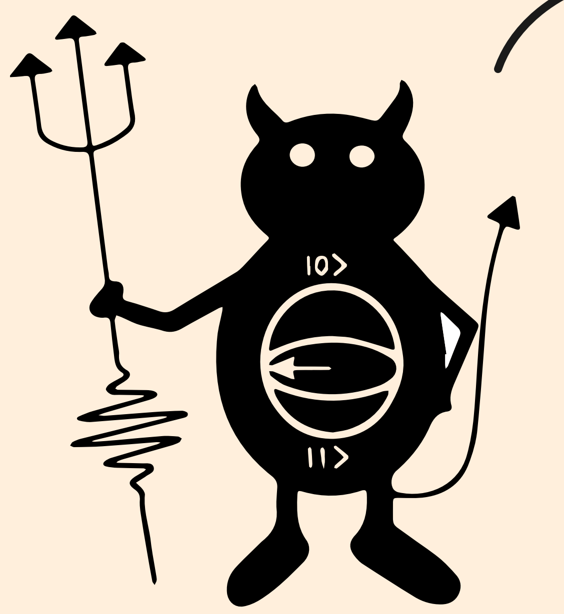

- This field is **extremely broad**

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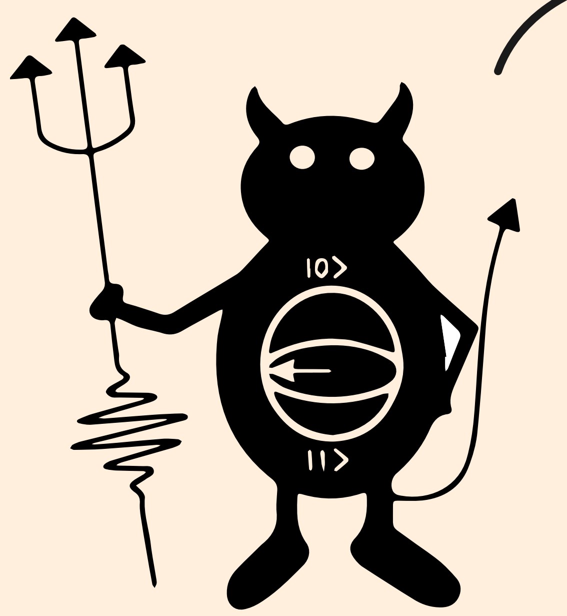
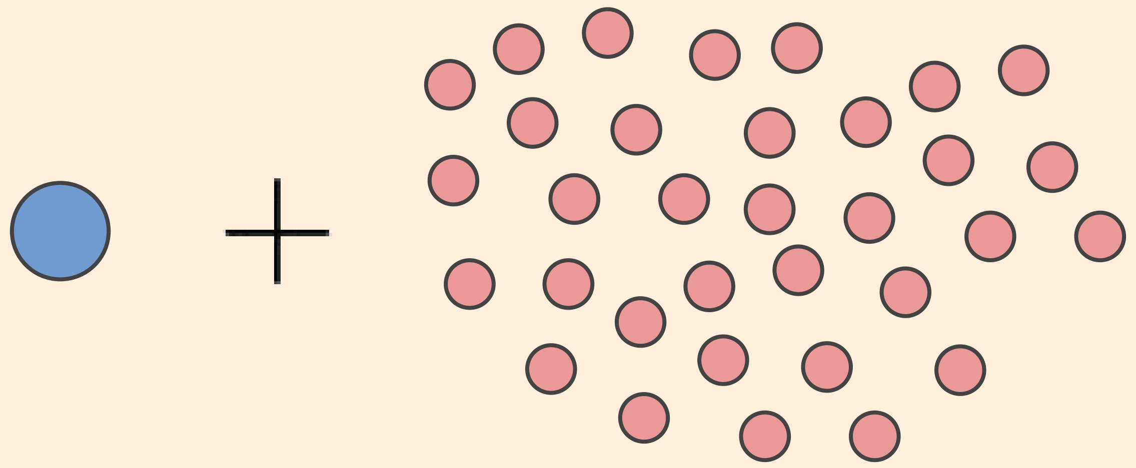


- This field is **extremely broad**
- Thermodynamics as a theory of restrictions $\longrightarrow$ resource theory approach

Resource theory of thermodynamics

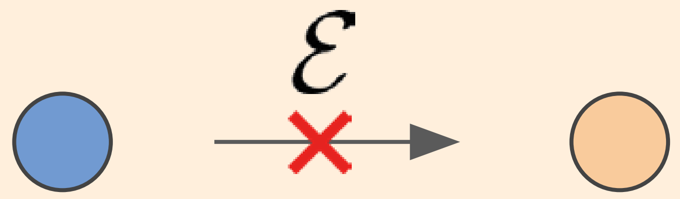
- Free States



,

$$\gamma = \frac{e^{-\beta H}}{Z}$$

,



Resource theory of thermodynamics

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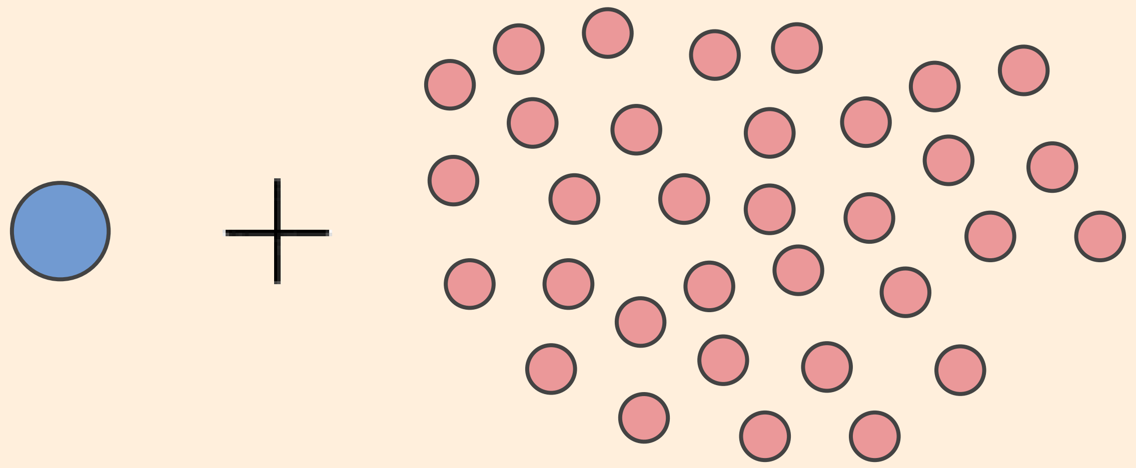

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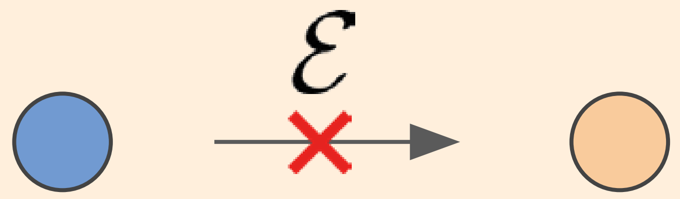
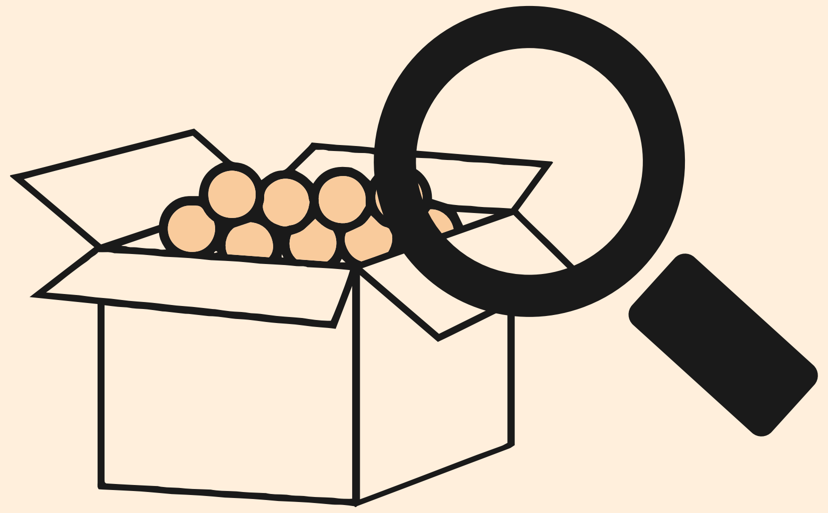


- Thermodynamic monotone



i. $\phi(\mathcal{E}(\rho)) \leq \phi(\rho)$

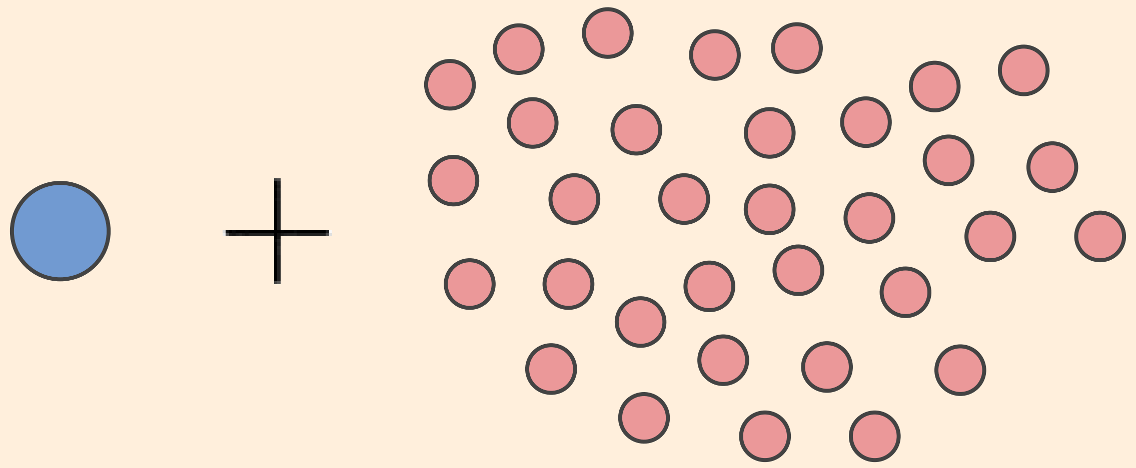
ii. $\phi(\gamma) = 0$

,

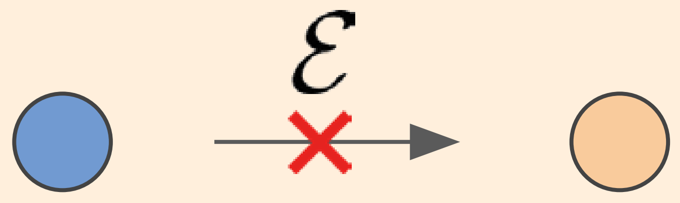
$$D(\rho||\gamma) = \mathrm{tr}[(\rho(\log \rho - \log \gamma)]$$

Resource theory of thermodynamics

- Free States



$$, \qquad \gamma = \frac{e^{-\beta H}}{Z} \qquad ,$$



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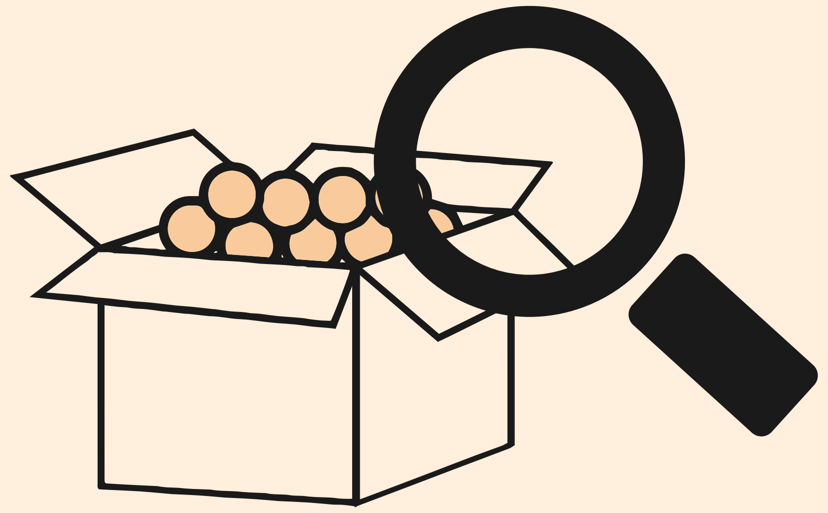

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ii. $\phi(\gamma) = 0$

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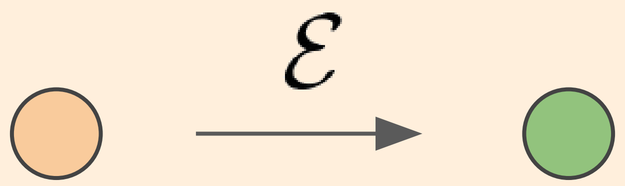
$$\boxed{D(\rho||\gamma) = \mathrm{tr}[(\rho(\log\rho - \log\gamma)]}$$

- Thermal operations



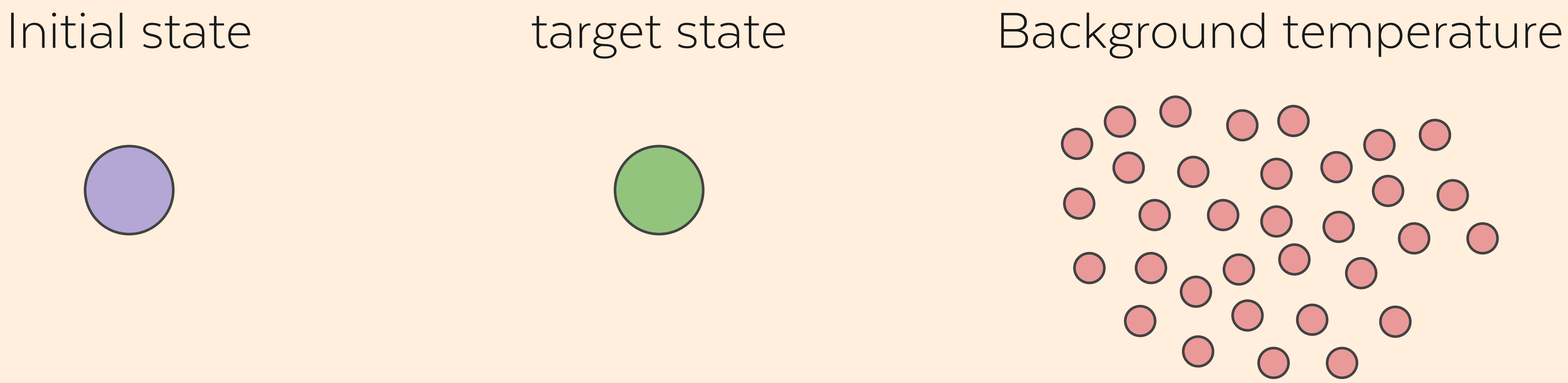
$$\mathcal{E}(\rho) = \mathrm{tr}(U(\rho \otimes \gamma_B)U^\dagger)$$

I. $\mathcal{E}(\gamma) = \gamma$

II. $\mathcal{E}(e^{-iHt}\rho e^{iHt}) = e^{-iHt}\mathcal{E}(\rho)e^{iHt}$

State interconversion: work extraction

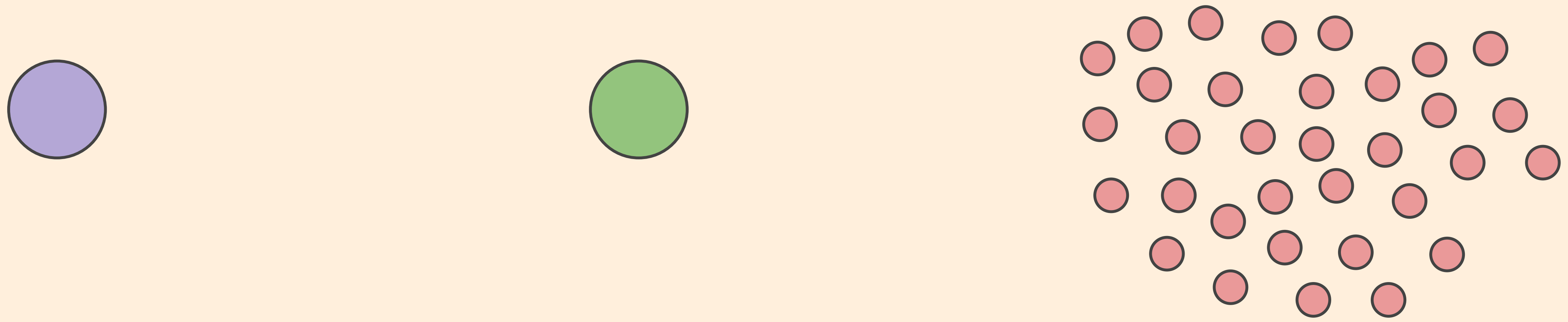
- Setting



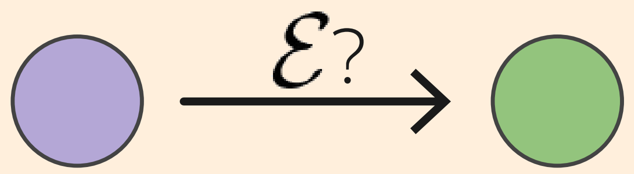
State interconversion: work extraction

- Setting

Initial state target state Background temperature



General interconversion problem:



State interconversion: work extraction

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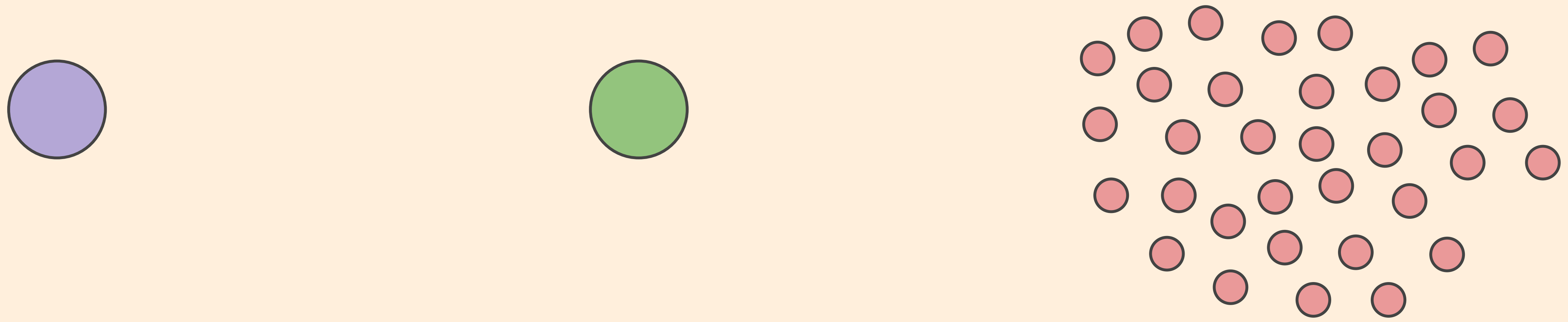

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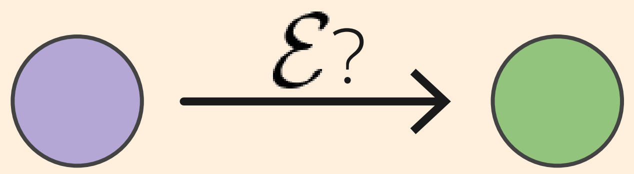
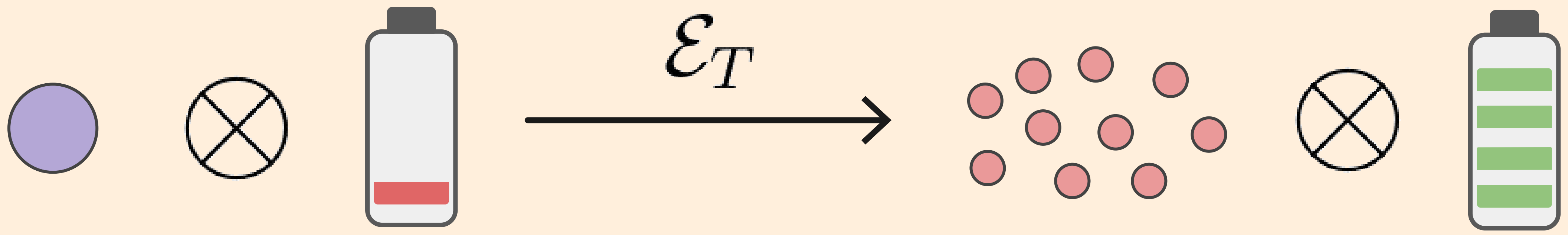
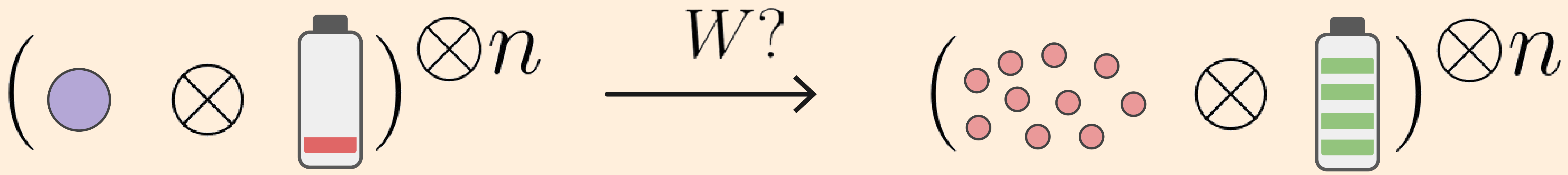


- System + empty battery

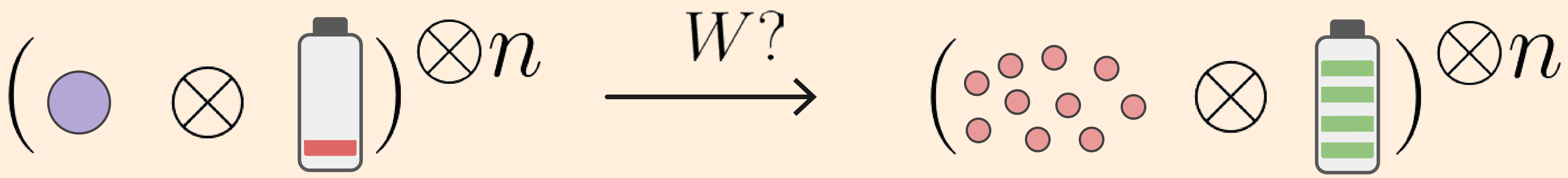


State interconversion: work extraction



JC. T. Chubb, M. Tomamichel, and K. Korzekwa, “Beyond The Thermodynamic Limit: Finite-size Corrections To State Interconversion Rates”, Quantum, vol. 2, p. 108, 2018.

State interconversion: work extraction



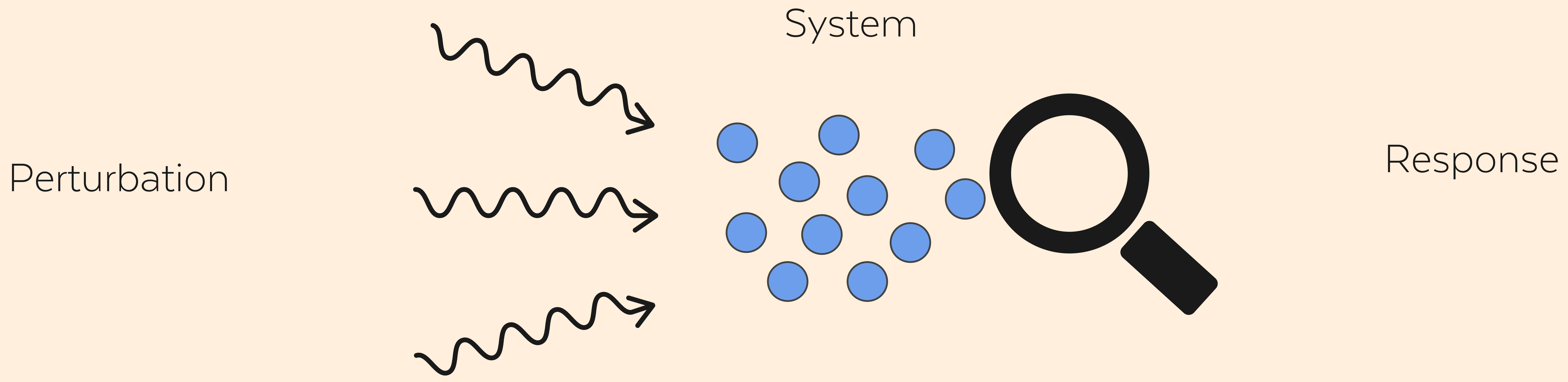
$$W = k_B T \left(D(\mathbf{p}||\gamma) - \sqrt{\frac{V(\mathbf{p}||\gamma)}{n}} \Phi^{-1}(\epsilon) \right)$$

- Fluctuation-dissipation relations in resource theories

JC. T. Chubb, M. Tomamichel, and K. Korzekwa, “Beyond The Thermodynamic Limit: Finite-size Corrections To State Interconversion Rates”, Quantum, vol. 2, p. 108, 2018.

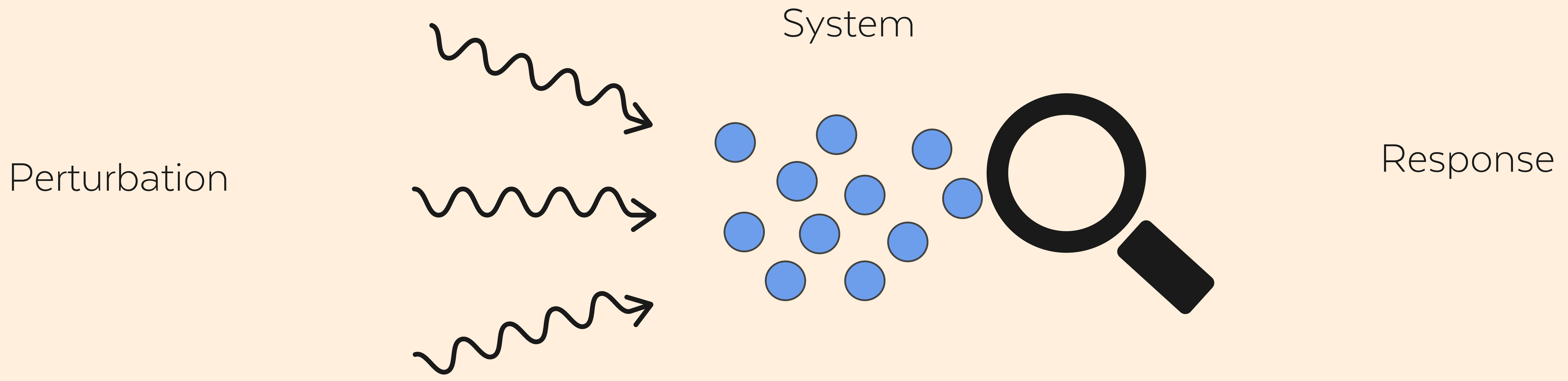
Fluctuation - dissipation relations

- General idea



Fluctuation - dissipation relations

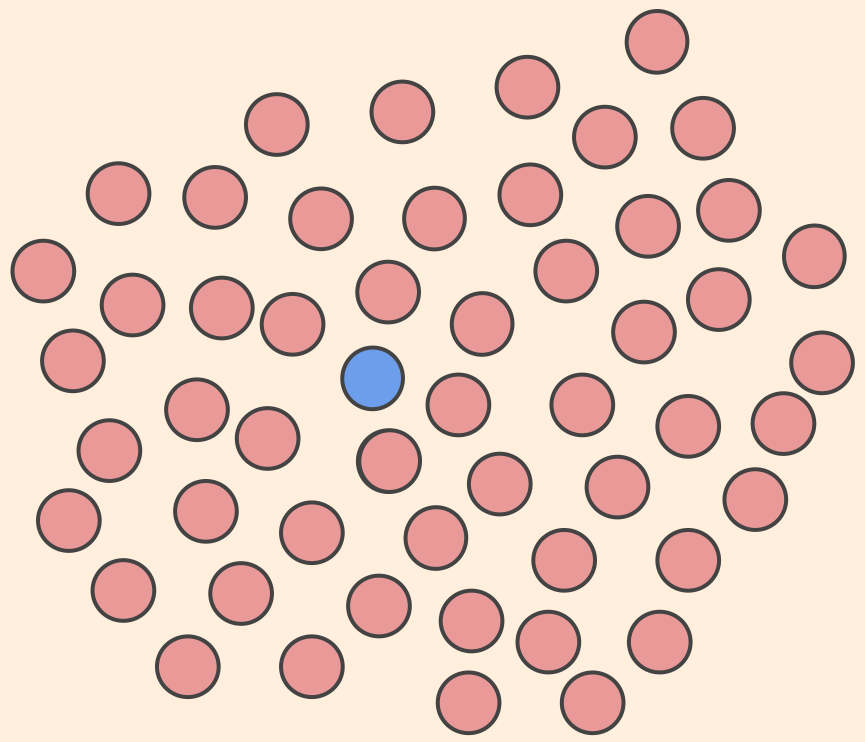
- General idea



Fluctuation - dissipation

Fluctuation - dissipation relations

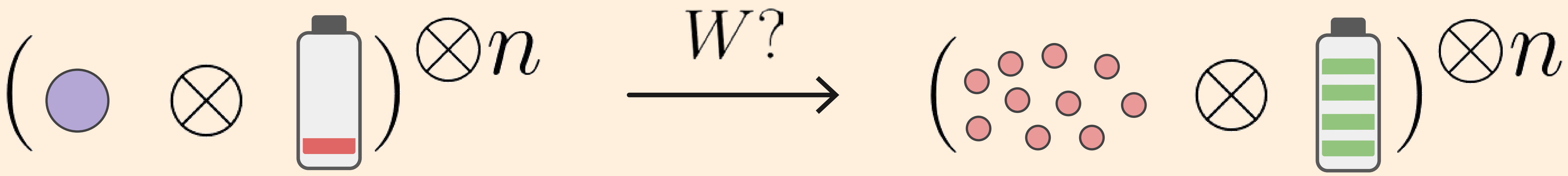
Brownian motion



Drag dissipates kinetic energy, turning it into heat

FDR: when there is a process that dissipates energy, there is a reverse process related to thermal fluctuations.

State interconversion: work extraction



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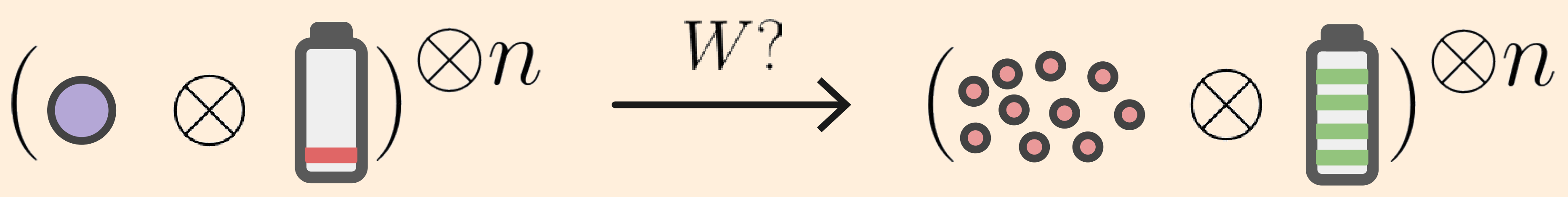
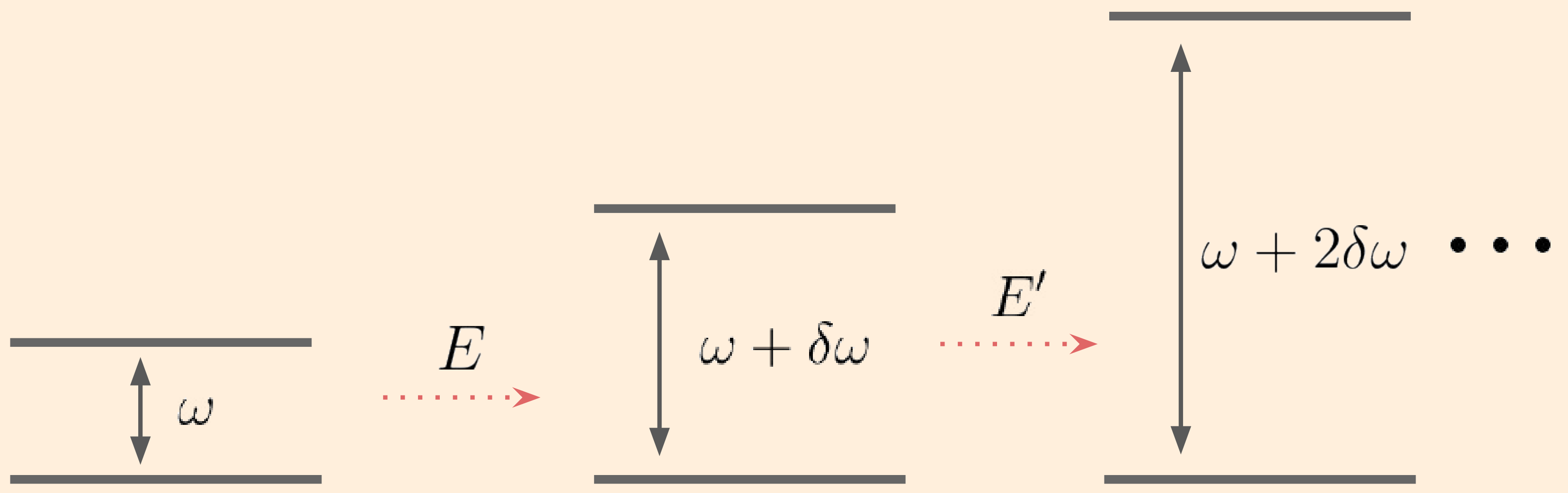
Two frameworks for work extraction

Interconversion Scenario



- Mathematically very clean
- Abstract and hard to implement physically

Level transformation

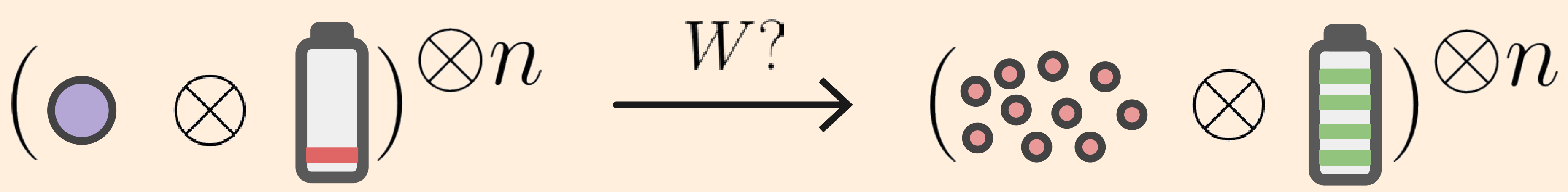


- Strongly physically motivated model

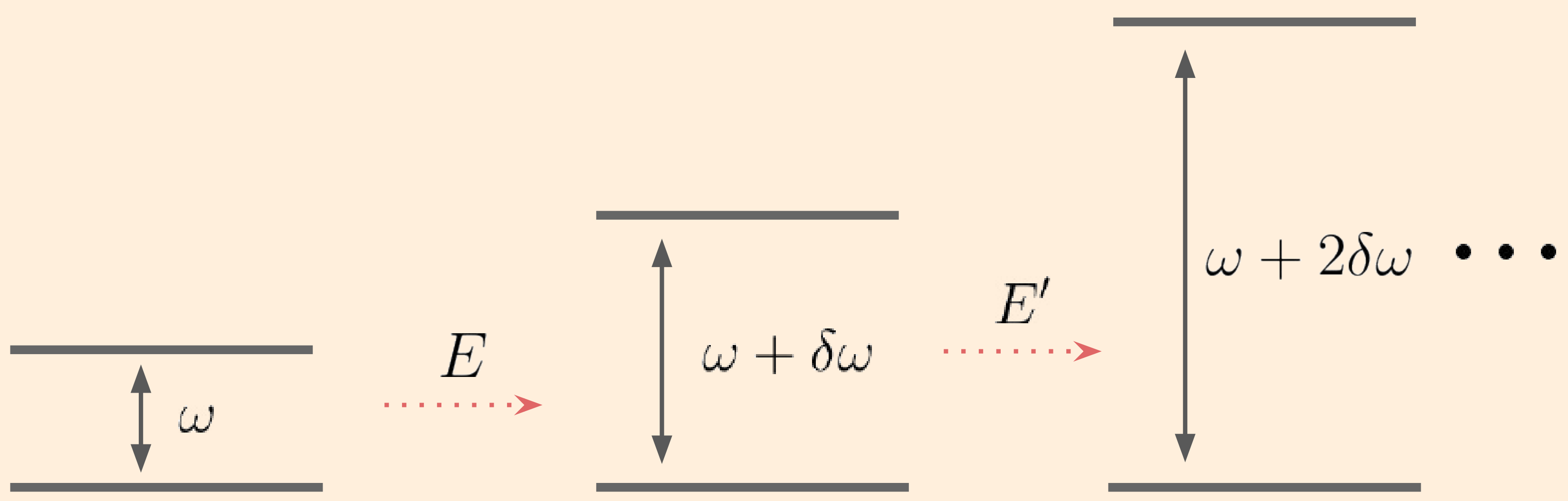
Johan Åberg, "Truly Work-like Work Extraction Via A Single-shot analysis", Nat. Commun. 4, 1925 (2013).

Two frameworks for work extraction

Interconversion Scenario



Level transformation



Why and how these two frameworks are related?

- Resource resonance: under certain circumstances one can avoid unnecessary work fluctuations (dissipation of energy)

K. Korzekwa, M. Tomamichel and JC. T. Chubb, "Avoiding Irreversibility: Engineering Resonant Conversions of Quantum Resources", Phys. Rev. Lett. 122, 110304, 2019.

Conclusions

- Explore the role of the FDR in the resource theory of thermodynamics
- A “dictionary” between the two frameworks
- Design experimental setups that would employ the resource resonance
- What does the fluctuation term means in the resource theory of entanglement when studying transformations between pure bipartite states?
- Work extraction considering coherent states

thanks!