Many-body Open Quantum Systems

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GKSL (Gorini-Kossakowski-Sudarshan-Lindblad) master equation

Fernando Iemini
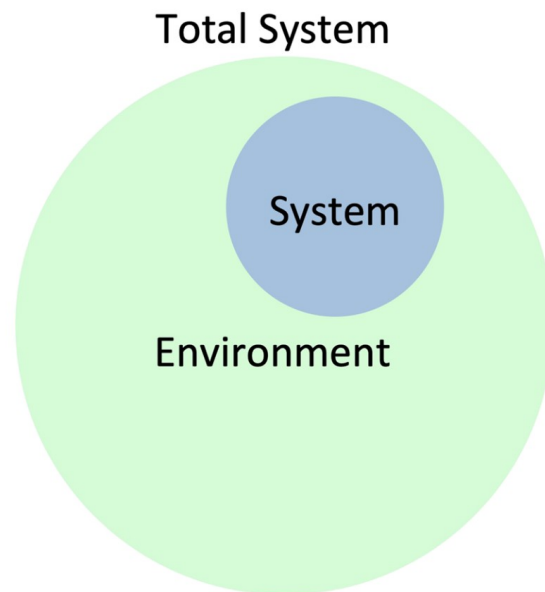
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Introduction

- First of all, what are open systems? In simple words:

Open systems = quantum systems in contact with an external environment.
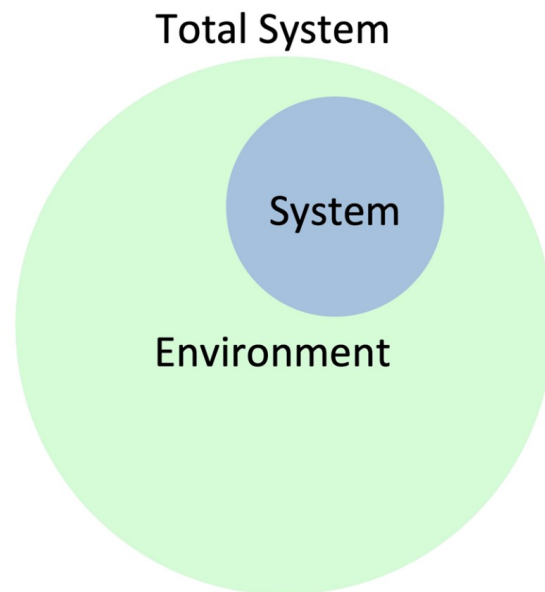
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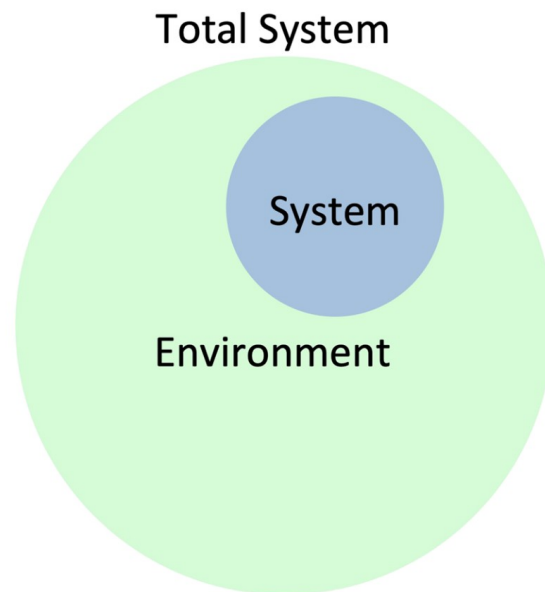
    - decoherence (loss of coherence / information),
        classicality induced in quantum systems by their environments.

Total System

System

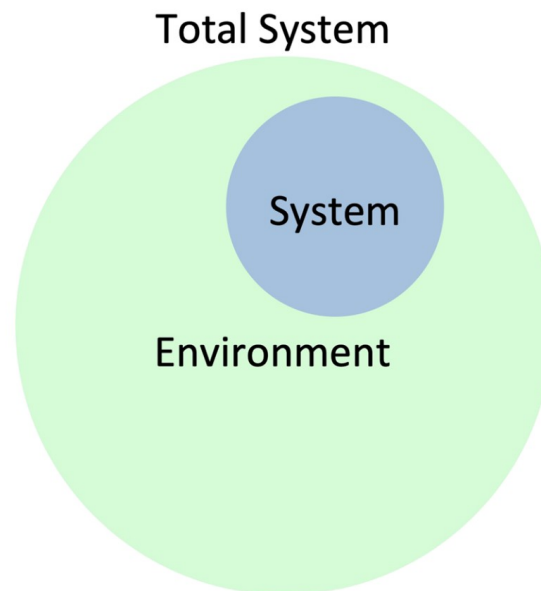Environment

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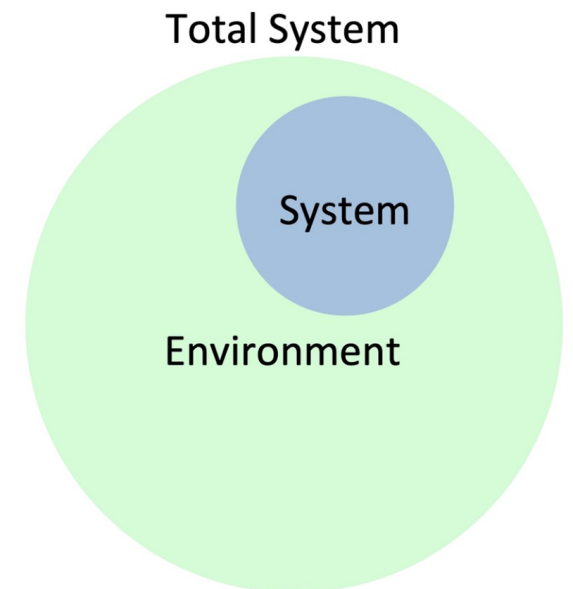
   - quantum information and computation
        operating qubits/gates – reduce unavoidable environmental effects

Total System

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Environment

Introduction

"Change of paradigm:"

    . one side: environment hinders quantum coherence effects;

    . on the other side: **new phenomena** emerge from the competition between

        unitary evolution **vs** dissipative effects.

H.P. Breuer and F. Petruccione, (2007)
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    . on the other side: ***new phenomena*** emerge from the competition between

        unitary evolution ***vs*** dissipative effects.

- ***richer*** phenomenology in the case of ***many-body systems***:

    . exotic phases of matter / dynamical regimes that are not allowed at equilibrium,

    . critical phenomena induced by dissipation;

    . dissipative engineering/manipulation -
        universal quantum computation.

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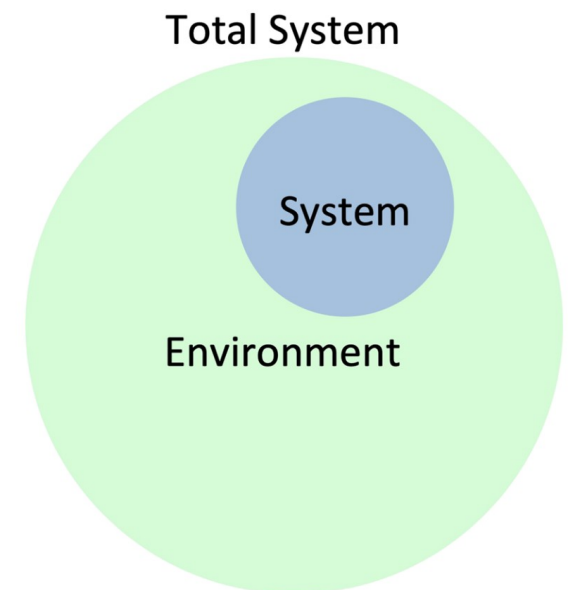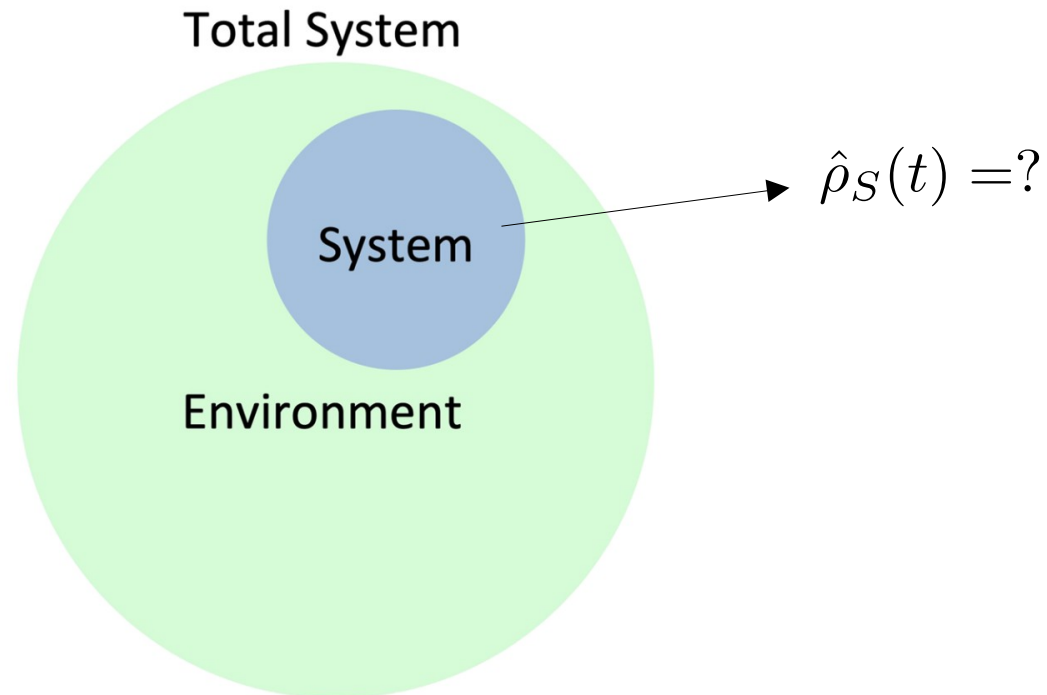R. Fazio, J. Keeling, L. Mazza, M. Schirò, arXiv:2409.10300 (2024)
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Open Systems

- ***Major requirement/challenge:***

    . find a way *to model* the dynamics of the system ***without having to explicitly represent the dynamics of the environment*** to which the system is coupled;

Total System

$$\hat{\rho}_S(t) = ?$$

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Open Systems

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- ...it ***will not (in general)*** be represented in terms of a ***unitary*** time evolution.

. CPTP maps / operator-sum representation / Kraus decomposition

(handling general representations can be a challenging task!)
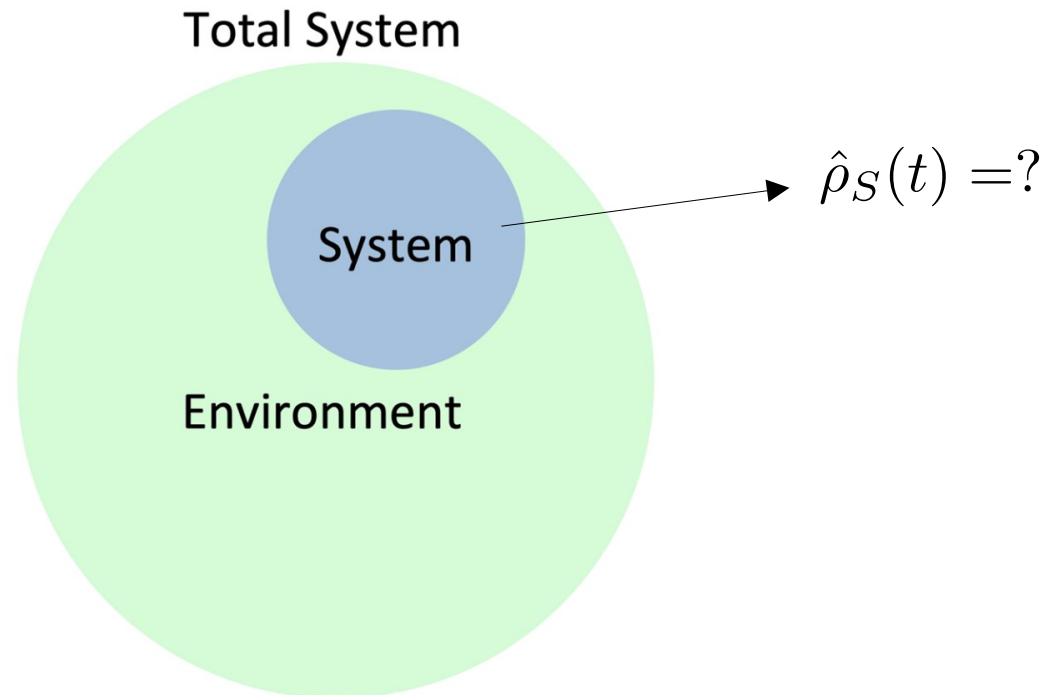
Total System

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Environment

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GKSL equation
(Gorini–Kossakowski–Sudarshan–Lindblad)

$$\frac{d\hat{\rho}}{dt} = -i[\hat{H}, \hat{\rho}] + \sum_i \hat{L}_i \hat{\rho} \hat{L}_i^\dagger - \{\hat{L}_i^\dagger \hat{L}_i, \hat{\rho}\}$$

From left to right: Andrzej Kossakowski,
George Sudarshan and Vittorio Gorini...

Goran Lindblad

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. Let us formalize these concepts...

Goran Lindblad

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