

Closed Quantum Systems

Schrödinger Equation

$$\frac{\partial}{\partial t} \overset{1}{|\psi(t)\rangle} = -\frac{i}{\hbar} H |\psi(t)\rangle$$

Liouville-von Neumann Equation

$$\frac{\partial}{\partial t} \rho(t) = -\frac{i}{\hbar} [H, \rho(t)]$$

2

Open Quantum Systems

Quantum Master Equation in Lindblad Form

$$\frac{\partial}{\partial t} \rho(t) = -\frac{i}{\hbar} [H, \rho(t)] + \sum_k \left(L_k \rho(t) L_k^\dagger - \frac{1}{2} \{L_k^\dagger L_k, \rho(t)\} \right)$$

$$\frac{\partial}{\partial t} \vec{\rho}(t) = \mathcal{L} \vec{\rho}(t)$$

3 4

1 State Vector (Ket)

$$|\psi\rangle = \sum_i c_i |\phi_i\rangle = \begin{pmatrix} \text{dark gray} \\ \text{white} \\ \vdots \end{pmatrix} + \begin{pmatrix} \text{white} \\ \text{gray} \\ \vdots \end{pmatrix} + \dots = \begin{pmatrix} \text{dark gray} \\ \text{gray} \\ \vdots \end{pmatrix}$$

2 Density Operator

$$\rho = \sum_j p_j |\psi_j\rangle \langle \psi_j| = \begin{pmatrix} \text{green} & \text{blue} & \dots \\ \text{red} & \text{orange} & \\ \vdots & & \end{pmatrix}$$

Further Operators: Hamiltonian,
Collapse Operators

$$H, L_k$$

3 Vectorized Operator

$$\vec{\rho} = \begin{pmatrix} \text{green} \\ \text{red} \\ \vdots \\ \text{blue} \\ \text{orange} \\ \vdots \end{pmatrix}$$

4 Superoperator

$$\mathcal{L} = \begin{pmatrix} \square & \square & \square & \square & \\ \square & \square & \square & \square & \dots \\ \square & \square & \square & \square & \\ \square & \square & \vdots & \square & \\ & & & & \end{pmatrix}$$

$$\mathcal{L} = -i (\mathbb{1} \otimes \mathcal{H} - \mathcal{H}^T \otimes \mathbb{1}) + \sum_k \gamma_k \left[L_k^* \otimes L_k - \frac{1}{2} (\mathbb{1} \otimes L_k^\dagger L_k + L_k^T L_k^* \otimes \mathbb{1}) \right]$$