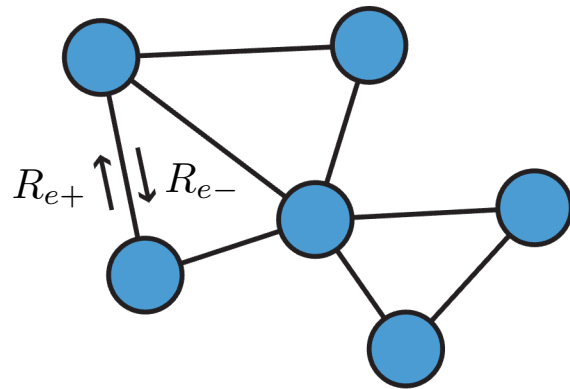


Universal Fluctuation-Response Relations of Non-equilibrium Dynamics: A Trajectory Information Geometry Framework

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System and Setup



| | |
|-------------------|---|
| Master equation | $\frac{\partial \mathbf{p}(t)}{\partial t} = R \cdot \mathbf{p}(t)$ |
| Only Requirement | R is irreducible |
| Control Parameter | $R = R(\xi)$ |

Modeling Response

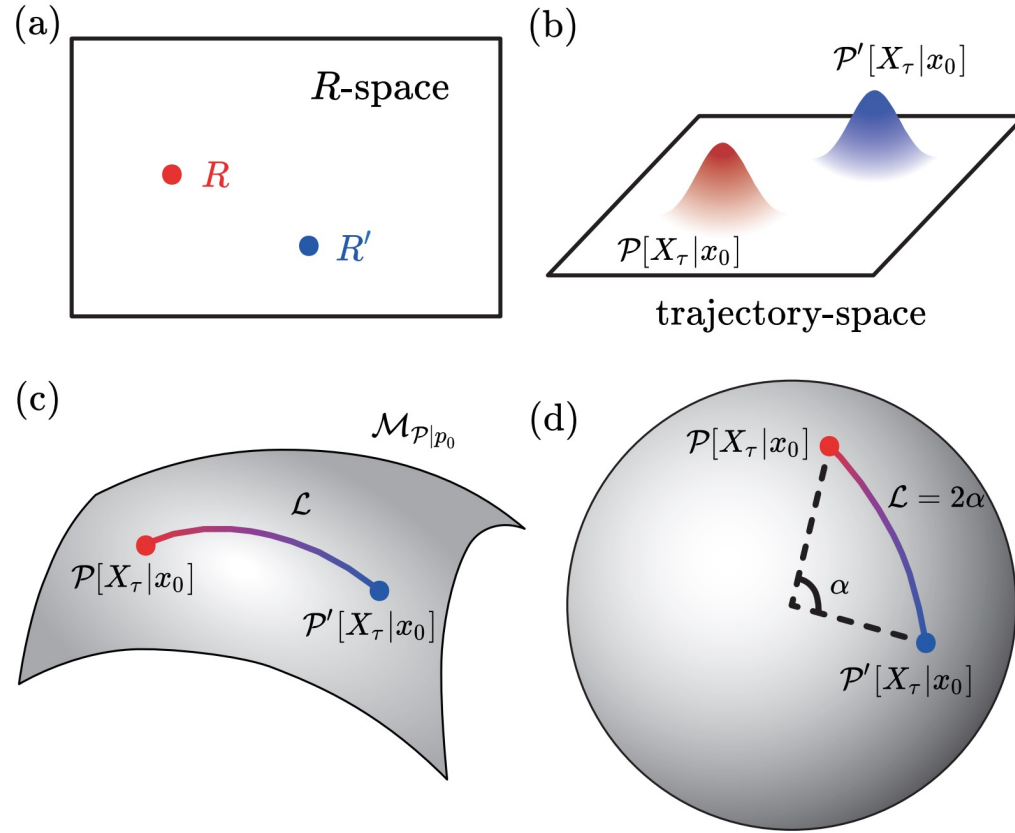
$$\partial_{\xi} \langle Q \rangle \equiv \frac{\partial \langle Q \rangle}{\partial \xi}$$

Sensitivity

$$\Delta \langle Q \rangle = |\langle Q \rangle' - \langle Q \rangle|$$

Non-perturbative Response

Results



Information geometric structure on the stochastic trajectory level

Cramer-Rao Bound

$$|\partial_{R_{e\pm}} \langle Q \rangle| \leq \sqrt{\text{Var}[Q]} \cdot \frac{\sqrt{\mathcal{A}_{e\pm}}}{R_{e\pm}}$$

Perturbative Response

Geometric Bound

$$|\langle Q \rangle' - \langle Q \rangle| \leq 2 \max_{X_\tau} |Q| \cdot \overline{\sin}(G_{e\pm})$$

Non-perturbative Response