Quantum probe advantage of learning many-body systems

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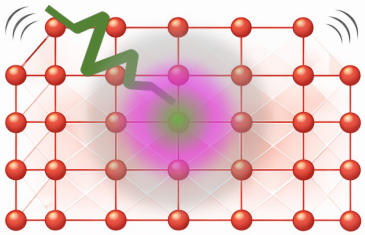
Understanding which physical properties of a quantum many-body system are operationally accessible is a foundational question underlying spectroscopy, thermodynamics, and quantum information science. Conventional response theory, a cornerstone of many-body physics, perturbs and measures the system itself, yielding susceptibilities constructed exclusively from causally ordered

(a)



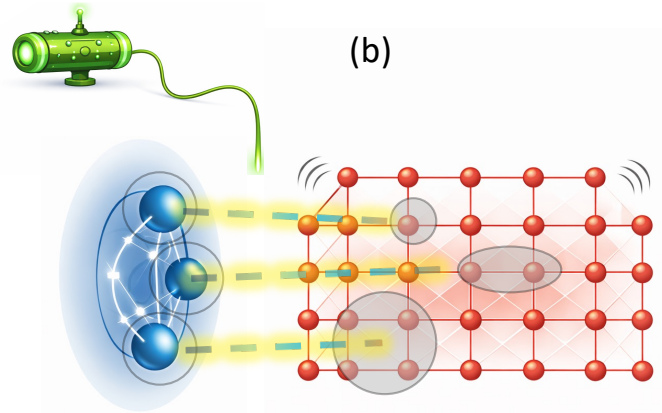
many-body system (M)

$[M(t_1), M(t_2)]$

....

1 *k*-point correlator

(b)



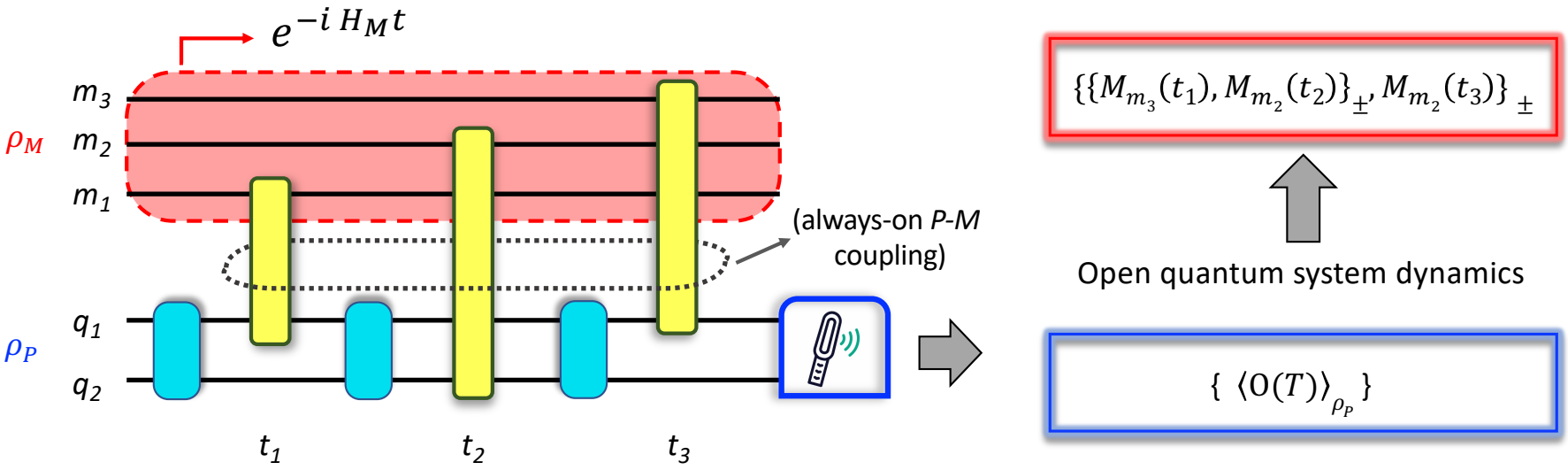
quantum probe (P)

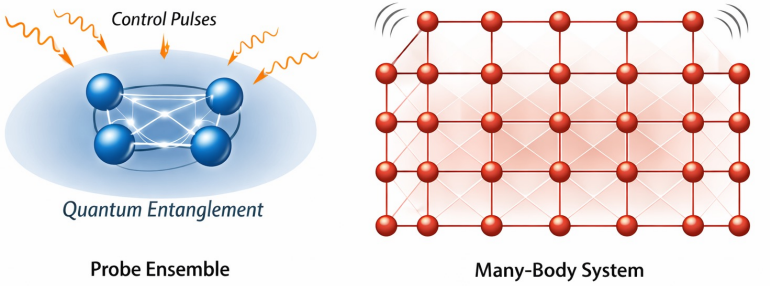
many-body system (M)

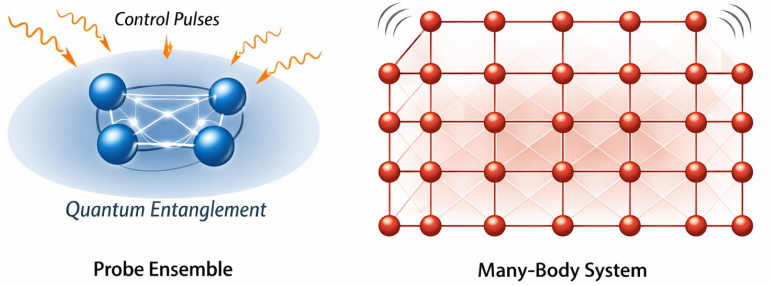
$[M(t_1), M(t_2)], \{M(t_1), M(t_2)\}$

....

2^{k-1} *k*-point correlators


$e^{-i\,H_M t}$
m_3
m_2
m_1
ρ_M
(always-on *P-M* coupling)
q_1
q_2
ρ_P
t_1
t_2
t_3
$\{\{M_{m_3}(t_1), M_{m_2}(t_2)\}_{\pm}, M_{m_2}(t_3)\}_{\pm}$
Open quantum system dynamics
$\{\ \langle \mathrm{O}(T)\rangle_{\rho_P}\ \}$


Control Pulses
Quantum Entanglement
Probe Ensemble
Many-Body System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