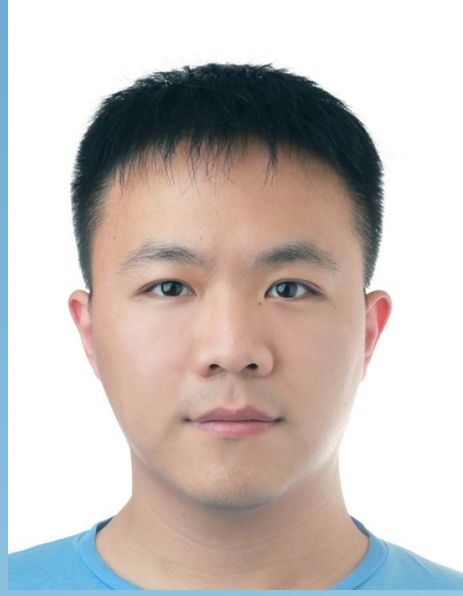
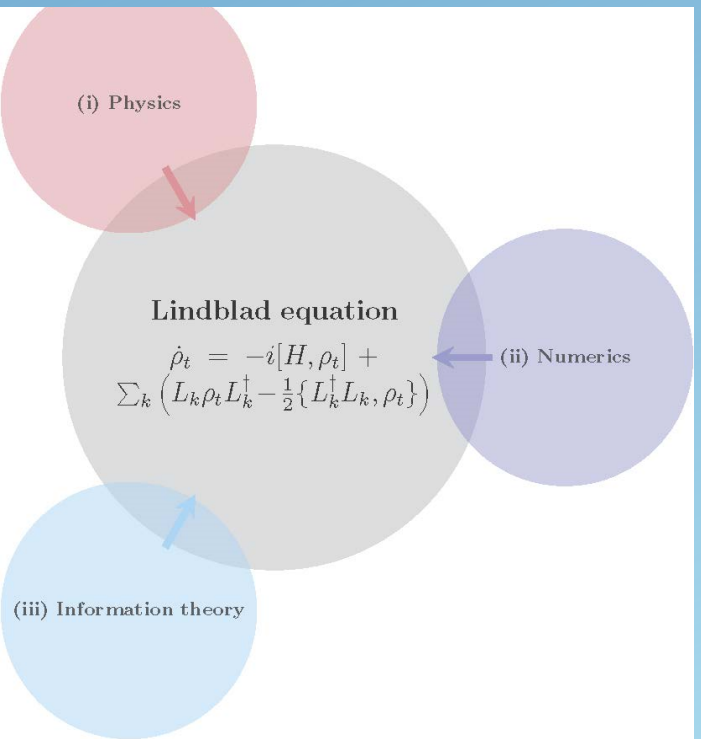
Analytical and Numerical Study of Lindblad Equations



Yu Cao

PhD Thesis

My research focuses on the mathematical study of Lindblad equations, which are famous quantum dynamics to capture and approximate the evolution of open quantum systems. The mathematical structure of Lindblad equations was initially studied by Lindblad, and by Gorini, Kossakowski, and Sudarshan back into 1976. Since then, Lindblad equations have received much attention, and have found profound applications in, for instance, quantum optics, dissipative quantum computation, quantum thermodynamics. This dissertation is devoted into studying Lindblad equations from three perspectives: (i) physical, (ii) numerical, and (iii) information-theoretical, as shown in the figure.



Firstly, under the weak coupling limit, we derive a Lindblad equation for a simplified Anderson-Holstein model arising from quantum chemistry. A classical master equation in the Lindbladian formalism is also derived and studied. Secondly, we study numerical methods for high-dimensional Lindblad equations. We propose a new method called stochastic dynamical low-rank approximation method, and we show a commuting relation between dynamical low-rank methods and Monte Carlo (unraveling) methods. Thirdly, we prove that primitive Lindblad equations with GNS-detailed balance are gradient flow dynamics of sandwiched Rényi divergences, and we also quantify their exponential convergence behavior in the large time region.

Duke UNIVERSITY MATH