Hidden Organization in Quantum Many-Body Hilbert Space: From Interference to Localization

Yi-Ping Huang
National Tsing Hua University

Quantum many-body systems are generally expected to thermalize under their own dynamics, leading to the loss of local information. Over the past decade, however, numerous experiments and theoretical studies have revealed remarkable exceptions to this paradigm, known as quantum many-body scars. Despite extensive investigations, a unified understanding of why such nonergodic states emerge has remained elusive.

In this talk, I will introduce a new framework based on **interference structures in the many-body Hilbert space**. By representing local Hamiltonians as connectivity graphs in configuration space, destructive interference can produce exact cancellation of transition amplitudes, giving rise to compactly localized eigenstates protected by what we call **interference zeros**. This mechanism, termed **Interference-Caged Quantum Many-Body Scars (ICQMBS)**, provides a unified perspective connecting quantum scars, Hilbert-space localization, graph structures, and flat-band physics.

Beyond explaining known examples, this framework suggests a graph-based route toward identifying and designing nonergodic quantum states in a broad class of interacting systems. The talk will highlight the underlying concepts, recent developments, and potential connections to graph theory, topology, and quantum information.