Contribution ID: **61** Type: **Oral**

Spin Glass Dynamics on Complex Hardware Topologies: A Bond-Correlated Percolation Approach

Thursday, 16 April 2026 11:30 (20 minutes)

Understanding how frustration and disorder shape relaxation in complex systems is a central challenge in statistical physics and directly relevant to quantum annealing. Spin-glass models provide a natural setting to address this problem, as their energy landscapes are governed by competing interactions and constrained network topologies. In this talk, I explore the non-exponential relaxation dynamics of spin glasses defined on hardware-relevant graphs such as Chimera, Pegasus and Zephyr. These architectures impose finite connectivity and embedding constraints that strongly influence how correlations propagate and how metastable states are organized. Using the Fortuin–Kasteleyn–Coniglio–Klein (FKCK) cluster framework, I show that even in the absence of a conventional finite-temperature spin-glass transition, frustration and disorder generate multiple dynamical time scales. The emergence and fragmentation of large-scale clusters provide a geometric interpretation of slow relaxation and reveal how topology controls the onset of collective dynamics. This perspective offers a physically transparent way to characterize energy landscapes on realistic annealing hardware and provides quantitative insight into how graph connectivity and frustration jointly determine the performance and limitations of quantum annealing architectures.

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Session Classification: Contributed talks

Track Classification: Statistical Physics