Magdalena De La Fuente - Topological fault tolerance from a path-integral perspective - 2

Wednesday, 11 March 2026 10:00 (1 hour)

Topological quantum error correction encodes quantum information in the ground space of a topologically ordered lattice system. To use such codes for reliable quantum computation, one must design low-overhead circuits that protect and manipulate the encoded information in a fault-tolerant way.

In these lectures, I focus on two-dimensional topological codes and fault-tolerant protocols implemented by circuits composed of 2D local gates. Representing these protocols as tensor networks local in a 3D spacetime lattice leads to a useful viewpoint. We identify a topological QEC circuit with an imaginary-time topological path integral of a topological gauge theory. Within this picture, both physical errors and non-trivial measurement outcomes appear as certain defects in the path integral. Their combinatorial structure defines the associated classical decoding problem.

In the first part, I introduce the necessary foundations from cellular (co)homology and explain how they give rise to a topological path integral that can be compiled into a 2D local circuit together with a (global) classical decoder.

In the second part, I discuss recent work in which we construct a universal logical gate set for 2D topological codes using the path integral of a non-Abelian twisted quantum double. During the computation, information is transported from an Abelian phase, such as the toric code, into the twisted quantum double via topological domain walls, and back.

The path-integral perspective provides a flexible framework to construct QEC circuits that realize the necessary domain walls and other condensation defects that define the logic gate in spacetime and argue about their fault-tolerance properties.