

Quantum Decoding Fails Before It Starts

Temporal degeneracy sabotages even the best quantum codes

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$$d_v + 2$$

Minimal degenerate error weight

For regular QLDPC codes, the smallest harmful error pattern has weight equal to the variable-node degree plus two.

This finding reveals a hidden vulnerability in quantum error correction: even with ideal code design, repeated noisy measurements introduce temporal degeneracy. The smallest error patterns that cause decoding failure are not tied to the code's minimum distance, but to its structural node degree. This undermines the assumption that higher distance guarantees robustness.



01

Structure > Distance in Quantum Decoding

The study shows that decoding performance is governed by node degree dynamics, not minimum distance. For bivariate bicycle codes, even weight-4 error patterns — far below the code's theoretical threshold — can trigger local decoding failure under flooding schedules. This shifts the design imperative: we must optimize for temporal stability, not just spatial code distance.



02

Symmetry Drives Failure

The paper identifies a symmetry in the space-time decoding graph: degenerate error patterns arise from vectors in the temporal kernel, generated by elementary codewords of weight $d_v + 2$. These symmetries are not random — they emerge from the repeated measurement structure. This suggests that decoding algorithms must actively break symmetry, not just correct errors, to prevent cascading failures.

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