Asmeeta Prakash Sayaji Research Portfolio

Noise, Verification, and Quantum Advantage

Asmeeta Prakash Sayaji

Independent Researcher — Quantum Information Theory

Email: asmitasayaji21@gmail.com
GitHub: github.com/asmeeta-quantum/ETH_Qiskit_Workspace
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Abstract

This portfolio synthesizes my independent research in quantum information theory, focusing on how realistic noise constrains quantum computation and verification. My work connects smooth entropy methods and quantum channel divergences with simulation tools informed by ISRO hardware experience, targeting noise-adapted verification and quantum advantage boundaries.

1 Research Alignment with ETH Zürich

My research aligns with the Quantum Information Group at ETH Zürich, especially the work of Prof. Dominik Hangleiter and Prof. Renato Renner on verification complexity, quantum advantage certification, noise-adapted resource theories, and practical simulation boundaries.

2 Core Research Projects

2.1 Noise-Induced Classical Simulability Transitions

Objective: Understand how T_1, T_2, and leakage influence the boundary between classical simulability and quantum advantage.
Methods: Lindbladian simulations using QuTiP; channel divergence measures; verification complexity scaling.
Key Insight: Existence of noise thresholds beyond which shallow circuits become efficiently simulable classically.

2.2 Hardware-Informed Noise Modeling

Objective: Translate microwave component stability data into quantum noise parameters.
Methods: ML-based drift prediction; mapping phase noise to dephasing; composite channel modeling.
Key Insight: Phase noise dominates verification failure more than amplitude decay.

2.3 Verification Complexity Under Realistic Noise

Objective: Study verification overhead under structured physical noise.
Methods: Sample-complexity scaling; entropy production; shallow-circuit verification.
Key Insight: Noise introduces phase transitions in verification complexity.

2.4 Leakage-Aware Quantum Control

Objective: Suppress non-computational excitations in weakly anharmonic qubits.
Methods: DRAG pulse optimization; Lindblad-Sim toolkit development.
Achievement: >90% leakage suppression in simulation.

3 Technical Implementation

3.1 Software Tools Developed

- **Noise-Bench QC:** Benchmarking suite for verification under realistic noise.
- **Lindblad-Sim:** Non-Markovian and leakage-aware simulation toolkit.
- **ZNE Toolkit:** Approx. 20% fidelity boost via zero-noise extrapolation.
- **DRAG Pulse Optimizer:** >90% leakage suppression.

3.2 Mathematical Methods

- Smooth entropies for quantifying information leakage
- Quantum channel divergences for recoverability characterization
- Lindbladian dynamics for composite noise evolution
- Resource-theoretic modeling of noisy advantage

4 Research Contributions and Future Directions

4.1 Summary of Contributions

1. Analytical bounds linking physical noise to verification scalability
2. Open-source tools for realistic quantum noise simulation
3. Hardware-to-quantum modeling pipeline from ISRO experience
4. Identification of noise-triggered simulability transitions

4.2 Proposed PhD Research Agenda

Planned work under Prof. Hangleiter:

- Noise-adapted verification protocols
- Resource thresholds for genuine quantum advantage
- Calibration-efficient experimental certification

4.3 Why ETH Zürich?

ETH connects theoretical foundations with experimental collaborations, uniquely enabling research on noise-aware quantum verification.

Repository and Code Availability

https://github.com/asmeeta-quantum/ETH_Qiskit_Workspace