



Contribution ID: 126

Type: **Poster**

AI Optimised scalable process matrix tomography

Tuesday 2 December 2025 15:30 (1 hour)

Noise characterisation is a critical bottleneck in scaling quantum technologies. While uncorrelated errors are relatively well understood, correlated or non-Markovian noise, where memory effects persist across multiple operations remains far harder to capture. This non-Markovian noise has been detected in state-of-the-art quantum devices like those of IBM and Google. However, standard characterisation techniques fail to capture these multi-time dynamics.

The process matrix formalism provides a powerful operational framework for modelling arbitrary multi-time quantum processes, including those with non-Markovian noise. Full knowledge about a multi-time process matrix tells us about both the amount and the type of noise present in the process. However, performing full process matrix tomography requires performing informationally complete operations at each time-step. This implies an exponential increase in the size of the process matrix and the number of operations required.

Here, we use the full characterisation offered by the process matrix approach, but avoid the curse of exponential scaling of resource. We overcome this challenge by combining tensor network techniques with AI-driven optimisation to perform scalable process matrix tomography. Tensor decompositions exploit the underlying structure of correlated noise to compress its representation, while machine learning strategies optimise measurement selection and parameter estimation. This hybrid approach drastically reduces resource requirements, enabling multi-time process reconstruction far beyond the reach of conventional methods.

Our method aims to offer a resource-efficient route to characterise non-Markovian noise in large multi-time processes. It offers not only to quantify the degree of non-Markovianity present, but also to predict future experimental outcomes with high fidelity. These predictive capabilities open new pathways for noise-aware control, error mitigation, and design of adaptive experiments; the essential steps to robust, large-scale quantum technologies.

Author: MAHANTI, Soumik (University of Technology Sydney)

Co-authors: GIARMATZI, Christina (Macquarie University); GILCHRIST, Alexei (Macquarie University)

Presenter: MAHANTI, Soumik (University of Technology Sydney)

Session Classification: Poster Session

Track Classification: Topical Groups: Quantum Science and Technology