Contribution ID: **381**

Type: **Oral Presentation**

Noisy quantum channels fail to rip the fabric of entanglement

Tuesday 8 July 2025 10:50 (20 minutes)

Non-local entangled states are an important resource for future quantum technologies, but their practical use is hindered by the effects of noisy quantum channels. However, recently discovered quantum Skyrmions, topologically structured entangled states, offer a promising solution. In this work, we develop a theoretical framework to study the evolution of entangled states and their topology in general quantum channels. Using photons entangled in orbital angular momentum and polarization as an example, we demonstrate that noise can be interpreted as a smooth geometric transformation of the mapping between the two-photon state spaces. From this, we predict complete resilience of the topology of the states against both depolarizing and non-depolarizing noise. Additionally, we identify specific sources of local noise that may destabilize the topology and discuss mitigation strategies. Our results have direct implications for quantum information distribution in noisy environments, including quantum computing and quantum networks.

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Session Classification: Photonics

Track Classification: Track C - Photonics