Contribution ID: **139** Type: **Contributed Oral**

Grand Unification of All Discrete Wigner Functions on d×d Phase Space

Friday 5 December 2025 10:40 (15 minutes)

Discrete Wigner functions (DWFs) are central tools for visualising states, signifying nonclassicality, and supporting quantitative analysis in quantum information, yet many inequivalent constructions coexist for each Hilbert-space dimension. This fragmentation obscures which features are fundamental and which are artefacts of representation, and it impedes quantitative comparison of operational properties such as negativity. We present a unifying, dimension-preserving framework that exhausts all possible dxd DWFs for a single qudit. The key result (Stencil Theorem) shows that every valid DWF arises by cross-correlating a single parent function—the "doubled"Wigner function defined on a 2dx2d phase space—with a suitable stencil, and that all valid choices of stencils are characterised by simple projection criteria. This construction also yields explicit, invertible linear maps connecting any two DWF definitions at fixed d, enabling representation-independent benchmarking of resource measures and side-by-side comparison of physical predictions, further unifying the landscape.

We illustrate the approach with concrete stencils. For odd d, a reduction stencil reproduces standard frames (Wootters, Leonhardt, Gross). For even d, a coarse-grain stencil averages neighbouring cells—to remove existing redundant information within the doubled phase space—and generates a novel dxd DWF that lies outside previously studied families. A third, Dirichlet-kernel stencil produces a DWF valid for odd-d yet distinct from Gross'construction.

Beyond unification, stencils convert redundancy removal from a nuisance into a design choice. The framework organises the landscape of DWFs to a landscape of easily constructible stencils. Furthermore, by relaxing certain criteria, our framework also extends to other quasidistributions (e.g., Kirkwood–Dirac). Overall, this work clarifies what is truly representation-independent at fixed dimension and opens new avenues for studying dimension-agnostic features in discrete phase space.

Author: ANTONOPOULOS, Lucky (RMIT)

Co-authors: LEWIS, Dominic (RMIT); DAVIS, Jack (INRIA); FUNAI, Nicholas (RMIT University); MENICUCCI, Nicolas (RMIT)

Presenter: ANTONOPOULOS, Lucky (RMIT)

Session Classification: Quantum Science and Technology

Track Classification: Topical Groups: Quantum Science and Technology