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An uncertainty view on complementarity and a complementarity view on uncertainty

Quantum phenomena are manifestly unpredictable. While classical uncertainty arises from ignorance, quantum uncertainty is intrinsic. Even for pure quantum states that represents the maximal knowledge that one could have about quantum states, we can only make probabilistic predictions. In addition, when the state is mixed, the variance is a hybrid of quantum and classical uncertainties. Another intriguing aspect of quantum mechanics is the wave-particle duality. This characteristic is generally captured, in a qualitative way, by Bohr's complementarity principle, and more recently, quantified by the well known complementarity relations. Complementarity relations are saturated only for pure, single-quanton, quantum states. For mixed states, the wave-particle quantifiers never saturate the complementarity relation and can even reach zero for a maximally mixed state. So, to fully characterize a quanton it is not sufficient to consider its wave-particle aspect; one has also to regard its correlations with other systems. In [1], we discussed the relation between quantum correlations and local classical uncertainty measures, as well as the relation between quantum coherence and quantum uncertainty quantifiers. Beyond, we obtained a complete complementarity relation for quantum uncertainty, classical uncertainty, and predictability. The total quantum uncertainty of a d-paths interferometer is shown to be equivalent to the Wigner-Yanase coherence and the corresponding classical uncertainty is shown to be a quantum correlation quantifier.

[1] M. L. W. Basso, J. Maziero, An uncertainty view on complementarity and a complementarity view on uncertainty, arXiv:2007.05053 [quant-ph] (2020).

Presenter: BASSO, Marcos (Federal University of Santa Maria)

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