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Measurement incompatibility in Bayesian multiparameter quantum estimation

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Estimating physical parameters with high precision is a fundamental task in science and technology. In multiparameter scenarios, trade-offs between the precisions of different parameters naturally arise. For quantum systems, an additional intrinsic trade-off originates from measurement incompatibility, whereby the measurements optimal for individual parameters cannot be jointly implemented. This phenomenon hinders multiparameter quantum estimation, both practically and mathematically, making its characterisation essential. While extensively studied in the framework of local estimation theory based on asymptotic Cramér–Rao bounds, its role in Bayesian estimation, valid even at the single-shot level, has received far less attention.
Here we provide a comprehensive account of Bayesian multiparameter quantum estimation. We show that measurement incompatibility can increase the average mean squared error of the estimation by at most a factor of two, thus strictly limiting its impact. This finding mirrors a known result in local estimation theory, but extends its validity beyond the asymptotic regime. We further illustrate our theoretical results with numerical studies of two paradigmatic quantum optical models: discrete phase imaging and joint estimation of phase and phase diffusion.

Presenter: ALBARELLI, Francesco

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