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Quantum parameter estimation affected by unitary disturbance

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The ultimate bound on the precision attainable by any estimation procedure, aimed at reconstructing the parameters governing the dynamics of a physical system, is formally expressed in terms of the quantum Fisher information (QFI), quantifying the instantaneous velocity variation of the system with respect to the parameter of interest. Finding a closed formula for the QFI is usually cumbersome. As far as we know, up to now the only case in which this has been done for an arbitrary system is when such parameter denotes the phase of a unitary evolution [see S. L. Braunstein and C. M. Caves, Phys. Rev. Lett. 72, 3439 (1994)]. In this work, we generalize this analysis by taking into account the effects of a unitary disturbance, represented by the addition of a linear term to the system Hamiltonian. This models, for instance, the action of an external force applied on the system. In the specific, we determine the analytical expression of the QFI, both for pure and mixed states. Then, we reframe our analysis in the more general context of multiparametric estimation, and provide a compact expression of both diagonal and off-diagonal elements of the QFI matrix. We introduce a No-Go theorem according to which the best possible estimation for a parameter multiplying one of the generators of the global unitary dynamics corresponds to the case in which the other parameters are null (no unitary disturbance). Finally we show that, quite counterintuitively, enhancing the level of a unitary disturbance already affecting the system does not necessarily yield a worse estimation strategy, and can reveal itself helpful for estimation purposes.

Our study can be foreseen as a starting point in order to handle the more complex case of open quantum systems, for which an exhaustive and systematic approach is missing.