UNDERSTANDING CRITICAL METROLOGY

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Critical metrology relies on preparing the ground state of the system close to the critical point of a phase transition. This facilitates creation of robust squeezing. Unfortunately, since at the critical point of a phase transition the energy gap closes, creation of such squeezing is limited by the so-called critical slowing down. Therefore, the closing energy gap is often considered as an obstacle. Here, I will show how to turn the closing energy gap into an advantage. I will explain step by step creation of squeezing related to phase transitions and how even more squeezing can be generated much faster once the critical point of a phase transition is crossed.
I will show that this approach can lead to an exponential increase of the quantum Fisher information in time with respect to existing critical quantum metrology protocols relying on quenching close to the critical point and observing power law behaviour. I will demonstrate that the Cramér-Rao bound can be saturated in the protocol through the standard homodyne detection scheme. I will explicitly show its advantage using the archetypal setting of the Dicke model and explore a quantum gas coupled to a single-mode cavity field as a potential platform. In this case an additional exponential enhancement of the quantum Fisher information can in practice be observed with the number of atoms N in the cavity, even in the absence of N-body coupling terms.

[1] Karol Gietka, Lewis Ruks, and Thomas Busch, Understanding and Improving Critical Metrology. Quenching Superradiant Light-Matter Systems Beyond the Critical Point, Quantum 6, 700 (2022).