Weak measurements and new perspectives in quantum measurement

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In the last years, new quantum measurement paradigms emerged, that permit avoiding wave function collapse by means of a weak coupling between the state and the pointer. A first example is represented by weak values [1, 2], firstly realized in [3, 4, 5], that correspond to the matrix element of an observable evaluated between a pre- and a post-selected state. Beyond addressing foundational questions like Contextuality, weak values can also be seen as a quantum metrology tool able to achieve high-precision measurements, as tiny spin Hall effect [**?**] or small beam deflections [6, 7, 8, 9], and quantum states characterization [10].Furthermore, since weak measurements do not make the wave function collapse, they may allow gathering simultaneous information of non-commuting observables [11], impossible with traditional strong measurements. After an initial introduction to weak measurements and a discussion of the regime of their application [12], in this talk we present an experiment addressed to explore the connection between anomalous weak values and Contextuality [13] following the theoretical proposal of Ref. [14]. A clear violation of the inequality proposed in [14] is obtained while satisfying all the theoretical requests, unequivocally demonstrating the contextual nature of weak measurements. Then, we show the results related to the first experimental realization of sequential weak measurements [15], i.e. a joint measurement of the weak value of (incompatible) polarizations of a single photon, discussing possible future applications.As a first application of this scheme, we describe our work concerning a test of Leggett-Garg inequalities based on sequential weak values [16], a result that can be used as a measure of quantumness. A second example of measurement in weak coupling regime is represented by protective measurements [17], a new paradigm granting the possibility of measuring the expectation value of a quantum observable with a single measurement on a single particle. They are realized coupling the state to a pointer in weak coupling regime and providing a protection of the state (e.g. through quantum Zeno effect or adiabatic evolution) based on some a priori information on state itself. This idea prompted a wide debate on the interpretation of the wave function (e.g on its ontic nature), but we have also demonstrated a significant advantage of this measurement protocol in certain experimental configurations. Finally, we will discuss our first experimental realization of protective measurements [18], where this advantage is properly discussed, showing a certain analogy with genetic algorithm leading to the realization of genetic quantum measurements [19].

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