A journey through quantum measurement paradigms: From weak measurements to protective measurements, and more

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The Measurement Problem represents a fundamental aspect in quantum theory. Quantum mechanics allows for different measurement protocols. In recent years a peculiar paradigm has gained interest among physicist, namely, the weak measurements (WMs), in which the measurement is operated with an interaction sufficiently weak not to collapse the original state. These kind of measurements result firstly in weak values [1-4], exploited in experiments spanning from fundamental [5-7] to applied physics, and resulting as a powerful tool for quantum metrology [8]. Moreover, protective measurements (PMs) [8] have been experimentally demonstrated [9] as a new technique able to extract information on the expectation value of an observable even from a single measurement on a single (protected) particle. In addition, other novel measurement protocols have stemmed from these measurement paradigms, exploiting a recursive measurement paradigm where some analogies with the typical mechanisms of genetic algorithms [10] appear, yielding uncertainties even below the level fixed by the quantum Cramer-Rao bound for the traditional prepare-and-measure scheme. We present the first experimental implementation of PM [9], together with preliminary experimental results related to aforementioned new protocols actually under investigation in our laboratories.

[1] A. G. Kofman, S. Ashhab, F. Nori, Phys. Rep. 52, 43 (2012).

[2] Y. Aharonov, D. Z. Albert, and L. Vaidman, Phys. Rev. Lett. 60, 1351 (1988).

[3] G. J. Pryde, et al., Phys. Rev. Lett. 94, 220405 (2005).

[4] O. Hosten and P. Kwiat, Science 319, 787 (2008).

[5] R. Mir, et al., New J. Phys. 9, 287 (2007).

[6] F. Piacentini et al., Phys. Rev. Lett. 116, 180401 (2016).

[7] K. J. Resch, Science 319, 733 (2008).

[8] Y. Aharonov and L. Vaidman, Phys. Lett. A 178, 38 (1993).

[9] F. Piacentini et al., Nat. Phys. 13, 1191–1194 (2017).

[10] M. Mitchell, An Introduction to Genetic Algorithms, Cambridge, MA: MIT Press (1996).