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# ICFO COLLOQUIUM MORGAN MITCHELL 'Evading Quantum Measurement Back-Action, from Gravitational Wave Detectors to Atomic Sensors'

MORGAN MITCHELL

June 01, 2017

Thursday, June 1, 2017, 12:00. ICFO Auditorium

**MORGAN MITCHELL**

ICREA Professor at ICFO

$$Morgan Mitchell got his PhD from University of California at Berkeley in 1999 in the group of Raymond Y. Chiao, one of the pioneers of nonlinear and quantum optics. His thesis Dynamics of photon-photon scattering in rubidium vapor studied four-wave mixing as a source of entangled photons. As a post-doc in the group of Serge Haroche and Jean-Michel

Raimond at the Laboratoire Kastler Brossel he studied interaction of cold rubidium atoms with whispering-gallery resonators. He taught for two years at Reed College and there developed the first diode-laser-pumped entangled photon source. As a post-doc with Aephraim Steinberg at the University of Toronto he did pioneering experiments in quantum process tomography, quantum state tomography, generation of multi-photon NooN states, and measurements of photon distinguishability. He has been a Group Leader at ICFO since 2004.

Efforts to detect gravitational waves, one of the most spectacular predictions of Einstein?s theory of general relativity, have over the last 40 years shaped our understanding of quantum measurement and sensing. I will describe how one idea, back-action evasion, has evolved over the decades, dating from Braginsky and Vorontsov?s original 1974 insight that gravitational wave searches are in fact a problem in quantum measurement: while the space-time variables of interest are purely classical, the instruments to measure them are necessarily quantum mechanical. Measurement of quantum systems inevitably introduces randomness, and this "quantum measurement back-action" usually results in random measurement errors. Back action evasion is the art of designing measurements that get the right answer despite the quantum measurement noise, an art practiced already by Braginsky in the 1970s. Back-action evasion was a major topic of quantum optics in the 1980s and 1990s, with pretty much every famous name making a contribution. Almost as soon as the quantum optics community was finished with the topic, it became a hot topic in atomic physics, and then quantum optomechanics. I will describe a significant new twist to back-action evasion, the use of "uncertainty depositories" to sequester the introduced quantum noise. Two recent experiments (one at ICFO) have demonstrated this capability in atoms and opto-mechanical systems, and a gravitational-wave detector based on the principle is being seriously studied as next-generation gravitational-wave observatory. I will describe the ICFO experiment, which measures simultaneously the azimuthal angle and amplitude of a precessing spin ensemble, the same variables that are used in magnetic resonance imaging, while putting the back-action noise into the polar angle, which is never measured. In this way we implement a measurement almost completely undisturbed by quantum effects. I will also likely speculate on the application in atomic clocks, which, perhaps inevitably, are also candidates for detection of gravitational waves.

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