QUANTUM MEASUREMET AND CONTROL

Quantum measurement is generally regarded as an inherently random and irreversible process. In the Copenhagen interpretation of quantum mechanics, a wavefunction $\psi(x)$ on measurement of its position x, collapses to a precisely specified position, with probability density $|\psi(x)|^2$. The nature (or necessity) of this collapse has always been a controversial point in quantum theory, and to this date there is no way to explicitly derive this collapse – the so-called "measurement problem". The peculiar way that measurements work in quantum theory in more recent years is now considered a resource that can be exploited for quantum technologies. Quantum random number generators work on the principle that quantum measurements are fundamentally random, and have potential applications in Monte Carlo simulations. Quantum cryptography schemes such as the BB84 protocol are based on the randomness and repeatability of measurements for non-orthogonal states. In this way, a robust understanding of quantummeasurements are not only a question for understanding the foundations of quantum mechanics, it is fundamental to the next generation of quantum technologies.

The theory of decoherence has given a more quantitative understanding of the quantum-classical transition. The pioneering ideas of Zurek and co-workers have pointed out the generic phenomenology of when a single quantum system interacts with many others. In this picture, one can then understand measurements as being "man-made" decoherence. When a measurement is being performed, an initially pure state of the system becomes entangled with the apparatus (i.e. the reservoir), under standard Schrodinger evolution of the states. On tracing out the apparatus one then obtains a mixed state with probabilities that coincide with the Born rule. The decoherence view of quantum measurements thus gives a way of explicitly calculating the inner workings of a quantum measurement. This has made it an overwhelmingly popular approach particularly in the field of quantum information, where direct experiments have been observed predicting its effects. In addition, decoherence has been proposed as a useful experimental tool, including a method of direct detection of dark matter, whereby dark matter particles interact with atoms in quantum superpositions and destroy the phase information in a detectable interaction.

Publications:

1. *On the role of the measurement apparatus in quantum measurements*, **Muzaffar Qadir Lone**, Chris Nagele, Brad Weslake, and Tim Byrnes, arXiv:1711.10257[quant-ph] (2017).

2. *Transferring quantum information via spin bath,* Wei Huang, **Muzaffar Q. Lone**, and Tim Byrnes, (In preparation).