Quantum signatures

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My work is mainly about quantum thermodynamics and stochastic thermodynamics. Quantum mechanics is a subject to study small particles in the microscopic world. In the quantum world, there are many new phenomenon including coherence and entanglement. In our macroscopic world, we never find a cat who is both dead and alive (known as "Schrödinger's cat"). However, in the quantum world, we can find a particle has multiple states at the same time. This is called coherence. Entanglement is another feature of the quantum world. It is a kind of super strong coupling of particles. When two particles are in entanglement, we can observe non-local interactions between them. Nonlocal interaction means that the interaction can appear suddenly even if one particle is on the moon while another one is on the earth. These two features can never be observed in our macro-world.

Thermodynamics is another exciting subject. It is to study temperature, energy, and information. It is quite interesting to study the combination of quantum physics and thermodynamics. With the development of quantum technology including quantum computing and quantum teleportation, we are more and more interested in the thermodynamics of a quantum system. For example, how do information and energy flow between two quantum systems? There is already much theoretical work done about this, however, it is still very hard to observe any significant quantum effect of a system since quantum systems are very small and easy to disturb. My work is focusing on finding a system such that we can observe a genuine quantum effect so called the genuine quantum signature. The approach is to find a physical law that is always true in our classical world. Then we experimentally find a quantum system where the law can be violated. Then we can say that we do find a quantum effect. Thus our tasks are: firstly find a physical law and secondly find a good small quantum system.

The physical law I am considering is called the work fluctuation-dissipation relation. This law is about fluctuation of a small system. This law comes from stochastic thermodynamics, which studies the thermal properties of small systems including a protein or an atom. I am constructing models theoretically of a quantum system such that the relation can be violated. To find a such system, one obvious method is to consider a system with quantum features including coherence or entanglement. Since these phenomena can not appear in a non-quantum world. My project is to study two systems one with quantum coherence and one with both quantum coherence and entanglement. I compare them and show that the work fluctuation-dissipation relation is violated in both of these systems.