PHYSICS AND ASTRONOMY
COLLOQUIUM

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NIST, Experimental Cold Atoms & Artificial Gauge Fields

"Observation of Zitterbewegung in a Degenerate Quantum Gas"

<u>Abstract</u>

Here I present our experimental work on Bose-Einstein condensates, systems of ultra-cold charge neutral atoms at a temperature of about 100 nano-Kelvin: one billion times colder than room temperature. These condensates - quantum gases - are nearly perfect quantum mechanical systems, and here we demonstrate a technique by which these charge neutral particles have artificial spin-orbit coupling, of a form more well known in material systems.

In one limit, this spin-orbit coupled system is described by the 1D relativistic Dirac equation. Among the earliest predictions of relativistic quantum mechanics is Schrodinger's suggestion that a relativistic quantum particle, such as an electron, should undergo a microscopic trembling - Zitterbewegung - is it moves. For the electron, the $f = m\,c^2/h \approx 1 \times 10^{20}$ Hz frequency and $\delta x = h/mc \approx 2$ pm amplitude of this motion are below any foreseeable threshold for detection. This desperate situation can be happily resolved by working with artificial relativistic systems such as graphene, or as here with ultracold atoms where the effective speed of light c* can be vastly decreased and where the effective mass m* is tunable. In our experiment, where c* ≈11:6 mm=s, $f \sim 1$ kHz and $\delta x \sim$ 0:5 μm, Zitterbewegung is easily observed.

In our engineered system, we observed Zitterbewegung and directly measured the frequency and amplitude of this microscopic motion, and find it to be in agreement with our relativistic model.

Wednesday, January 23, 2013
3:30 p.m.
Bob Wright Centre
Room A104