Fractional diffusion of cold atoms in optical lattices

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Fractional calculus is an old branch of mathematics which deals with fractional order derivatives, e.g., $d^{1/2}/dt^{1/2}$. Recently Davidson's group (Weizmann) has recorded the spatial diffusion of cold atoms in optical lattices, fitting the results to the solution of a fractional diffusion equation

$$\frac{\partial^\beta P(x,t))}{\partial t^\beta} = K_\mu \nabla^\mu P(x,t).$$

Within the semi classical theory of Sisyphus cooling we derive this fractional equation and discuss its meaning and its limitations [1,2]. An asymptotically weak friction force, induced by the laser field, is responsible for the large deviations from normal transport theory (and from Boltzmann-Gibbs equilibrium concepts [3]) at least below a critical value of the depth of the optical lattice.

1. D. A. Kessler, and E. Barkai *Theory of fractional-Lévy kinetics for cold atoms diffusing in optical lattices* **Phys. Rev. Lett. 108**, 230602 (2012).

2. E. Barkai, E. Aghion, and D. Kessler *From the area under the Bessel excursion to anomalous diffusion of cold atoms* **Physical Review X 4**, 021036 (2014)

3. A. Dechant, D. A. Kessler and E. Barkai *Deviations from Boltzmann-Gibbs equilibrium in confined optical lattices* **Phys. Rev. Lett. 115**, 173006 (2015).