Anomalous momentum diffusion of strongly interacting bosons in optical lattices

R. Bouganne[1],M. Bosch Aguilera[1], A. Ghermaoui[1], J. Beugnon[1] and F. Gerbier[1]
[1] *Laboratoire Kastler Brossel, Collège de France, ENS-PSL Research University, Sorbonne Université, CNRS, 11 place Marcelin-Berthelot, 75005 Paris.*
E-mail: fabrice.gerbier@lkb.ens.Fr

Dissipative quantum systems are subject to decoherence, the disappearance of interference phenomena due to irreversible loss of information. This plays a role in many modern areas of research, from research on the foundations of quantum mechanics to quantum information processing (and quantum technologies in general), where decoherence is a threat that must be countered. While decoherence has been extensively studied for simple systems, such as a two-level atom or a harmonic oscillator, much less is known for many-body systems of interacting particles.

In this talk, I will report on an experimental study of how the spatial coherence of a superfluid gas of bosonic atoms in an optical lattice disappears when the gas is exposed to a near-resonant laser driving absorption-spontaneous emission cycles. Spontaneous emission introduces random momentum changes leading to diffusion in momentum space; with a momentum width scaling as $t^{1/2}$. This momentum diffusion process is well-known in quantum optics and limits the temperature achievable in laser cooling. Equivalently, the spatial coherences on distances larger than the wavelength of the optical transition become blurred. This can be interpreted as weak, continuous measurements of the atomic positions.

For strongly interacting bosons, we observed that the momentum diffusion is anomalously slow : After a short time, the decay of spatial coherences slows down, and momentum space dynamics becomes sub-diffusive with a momentum width scaling as $t^{1/4}$. We explain this behavior in terms of a model proposed by Poletti *et al.*[1, 2], where the long-times dynamics is understood in terms of a sub-diffusion in Fock space. Dissipation leads to the formation of "long-lived" clusters of atoms with higher occupancy than the average site. These clusters decay slowly (through high-order processes) due to their energy mismatch with more typical configurations. In classical statistical mechanics, the transport dynamics of systems with a distribution of lifetimes featuring a slow tail typically shows sub-diffusion[3]. Using three-body losses as a probe of on site statistics, we provide a direct evidence of this anomalous diffusion in Fock space which underlies the anomalous momentum diffusion.

[1] Dario Poletti, Jean-Sébastien Bernier, Antoine Georges, and Corinna Kollath. Interaction-induced impeding of decoherence and anomalous diffusion. *Physical Review Letters* **109** (4), 045302 (2012).

[2] Dario Poletti, Peter Barmettler, Antoine Georges, and Corinna Kollath. Emergence of glasslike dynamics for dissipative and strongly interacting bosons. *Physical Review Letters* **111** (19), 195301 (2013).

[3] Jean-Philippe Bouchaud and Antoine Georges. Anomalous diffusion in disordered media: Statistical mechanisms, models and physical applications. *Physics Reports* **195** (4), 127 – 293 (1990).