Internship position

Strongly interacting clouds of few ultracold atoms

Spring-Summer 2024

Location
Laboratoire Kastler Brossel. Collège de France. Paris

Contacts
Co-supervisors: Jérôme Beugnon & Jean Dalibard
Contact: beugnon@lkb.ens.fr
Website: www.quantumgases-pariscdf.fr

Scientific context

Ultracold quantum gases are an ideal platform to investigate quantum phenomena with an unprecedented level of control. Using the flexibility in shaping the spatial profiles of the trapping lasers, the potential landscape and the dimensionality of atomic clouds can be shaped at will. Interactions between particles can also be tuned to achieve regimes with strong interactions between particles. The dynamical behavior of such strongly interacting quantum systems is extremely rich and challenging to explore.

The rubidium team of the Quantum Gases Group at Collège de France has a long-standing experience in the investigation of low-dimensional Bose gases. More specifically, we have developed in the last years new techniques to imprint arbitrary wave functions, spin textures, or to create arrays of microtraps (see [1, 2] and Fig. 1). It has opened many new opportunities for the study of Bose gases. For example, we have recently explored the properties of superfluid state of matter [3–5], the non-linear dynamics of this scale invariant gas [6–8] and few-body physics [9].

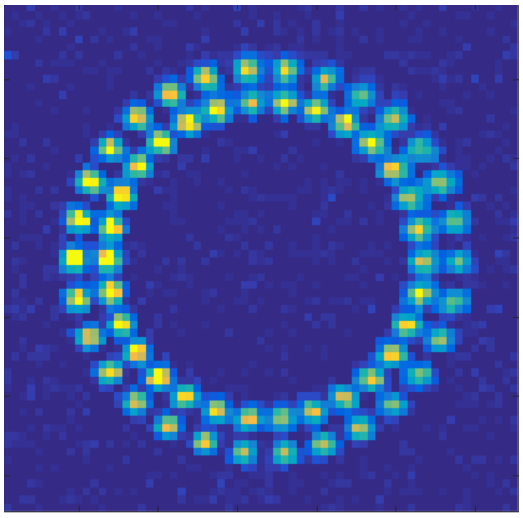

FIGURE 1. *Example geometry of an array of microtraps. The typical size and distance between traps is* $\approx 5\,\mu m$.

Internship project

During the internship we will study rotating mesoscopic ensembles of atoms. The Coriolis force associated to the rotation being mathematically equivalent to the Lorentz force, we can thus apply an effective magnetic field to the clouds leading, in the fast rotation regime, to interesting topological phases of matter. In the regime of low atom numbers, it will give access to strongly interacting topological many-body states whose realization is a current challenge in the field.

The intern will be involved the experimental realization of this project, including the development of the laser beams inducing the rotation or the fluorescence imaging of single atoms.

Application for a PhD after the internship is strongly encouraged.

---

[1] J. L. Ville, T. Bienaimé, R. Saint-Jalm, L. Corman, M. Aidelsburger, L. Chomaz, K. Kleinlein, D. Perconte, S. Nascimbène, J. Dalibard, and J. Beugnon, "Loading and compression of a single two-dimensional Bose gas in an optical accordion," Phys. Rev. A **95**, 013632 (2017).

[2] Y.-Q. Zou, B. Bakkali-Hassani, C. Maury, É. Le Cerf, S. Nascimbene, J. Dalibard, and J. Beugnon, "Tan's two-body contact across the superfluid transition of a planar Bose gas," Nat. Commun. **12**, 760 (2021).

[3] J.L. Ville, R. Saint-Jalm, É. Le Cerf, M. Aidelsburger, S. Nascimbène, J. Dalibard, and J. Beugnon, "Sound propagation in a uniform superfluid two-dimensional Bose gas," Phys. Rev. Lett. **121**, 145301 (2018).

[4] Y.-Q. Zou, É. Le Cerf, B. Bakkali-Hassani, C. Maury, G. Chauveau, P.C.M. Castilho, R. Saint-Jalm, S. Nascimbene, J. Dalibard, and J. Beugnon, "Optical control of the density and spin spatial profiles of a planar Bose gas," J.Phys. B : At. Mol. Opt. **54**, 08LT01 (2021).

[5] G. Chauveau, C. Maury, F. Rabec, C. Heintze, G. Brochier, S. Nascimbene, J. Dalibard, J. Beugnon, S.M. Roccuzzo, and S. Stringari, "Superfluid fraction in an interacting spatially modulated Bose-Einstein condensate," Phys. Rev. Lett. **130**, 226003 (2023).

[6] R. Saint-Jalm, P. C. M. Castilho, É. Le Cerf, B. Bakkali-Hassani, J.-L. Ville, S. Nascimbene, J. Beugnon, and J. Dalibard, "Dynamical symmetry and breathers in a two-dimensional Bose gas," Phys. Rev. X **9**, 021035 (2019).

[7] B. Bakkali-Hassani, C. Maury, Y.-Q. Zou, É. Le Cerf, R. Saint-Jalm, P. C. M. Castilho, S. Nascimbene, J. Dalibard, and J. Beugnon, "Realization of a Townes soliton in a two-component planar Bose gas," Phys. Rev. Lett. **127**, 023603 (2021).

[8] B. Bakkali-Hassani, C. Maury, S. Stringari, S. Nascimbene, J. Dalibard, and J. Beugnon, "The cross-over from Townes solitons to droplets in a 2D Bose mixture," New J. Phys. **25**, 013007 (2023).

[9] C. Maury, B. Bakkali-Hassani, G. Chauveau, F. Rabec, S. Nascimbene, J. Dalibard, and J. Beugnon, "Precision measurement of atom-dimer interaction in a uniform planar Bose gas," Phys. Rev. Res. **5**, L012020 (2023).