Quench-induced topological defects in a uniform Bose gas confined in two dimensions

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While ultra-cold gases have been traditionally confined in harmonic potentials, trapping atoms in spatially uniform potentials has recently received growing interest as it opens up new possibilities to measure long-range correlations or study the dynamics of phase transitions by looking at the establishment of phase coherence over the entire system.

To further explore the physics of two-dimensional Bose gases in which our group has a long standing interest, we have developed a technique to confine an atomic gas in a 2D "box-like potential" with arbitrary geometry. After presenting the experimental setup, I will report on a series of experiments where we study the dynamics of the coherence establishment by imposing a temperature quench on the system across the normal-to-superfluid transition for two different geometries: a ring and a square.

Quenches across a phase transition lead to the stochastic nucleation of topological defects as it was put forward by Kibble and Zurek. In the annular geometry these topological defects are quantized supercurrents, whose amplitude and direction are measured by a new interferometric method [1] (see Figure). For the square, the topological defects manifest themselves as free "bulk" vortices which are revealed using a standard time-of-flight technique [2] (see Figure). After demonstrating the stochastic nature of these topological defects, I will show that their production rate is directly linked to the cooling rate and compare our findings with the prediction of the Kibble-Zurek mechanism [1,2].

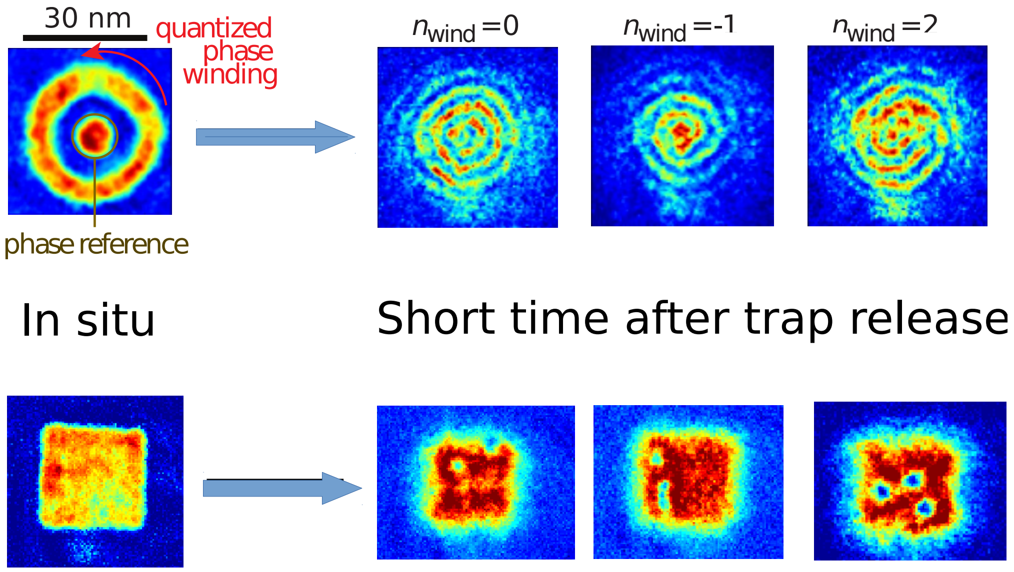

Figure: Top Left – In-situ image of the gas trapped in the ring geometry (plus a central disk serving as phase reference). Top Right – Interference patterns after a short expansion revealing the topological charges of the supercurrents for three different experimental realizations with charge 0, -1, and 2 respectively. Bottom Left – In-situ image of the gas in the square geometry. Bottom Right – Density holes in the atomic density distribution appear after a short expansion. They are vortices whose number and position are random depending on the experimental realization. Here we show 2, 4 and 3 vortices respectively.

[1] L. Corman, L. Chomaz, T. Bienaimé, R. Desbuquois, C. Weitenberg, S. Nascimbene, J. Dalibard, J. Beugnon, *Quench-induced supercurrents in an annular Bose gas*, Phys. Rev. Lett. **113**, 135302 (2014)

[2] L. Chomaz, L. Corman, T. Bienaimé, R. Desbuquois, C. Weitenberg, S. Nascimbène, J. Beugnon, J. Dalibard, Emergence of coherence in a uniform quasi-two-dimensional Bose gas, Nat. Commun. **6**, 6162 (2015)