Superfluid Quantum Gases on a Shell

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Quantum gases offer an exquisite playground for the study of superfluid dynamics. Superfluids are characterized by a bunch of fascinating properties, including the absence of viscosity, the possibility of persistent flows in an annular trap or the irrotational character of a superfluid flow.

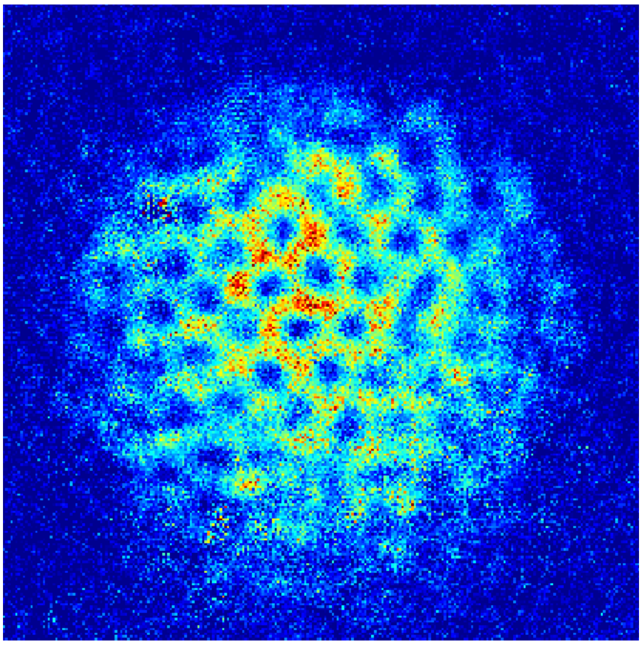

Figure 1: Vortex lattice in a rotating superfluid Bose gas

When submitted to a large enough forced rotation, trapped superfluid develop a number of quantum vortices of quantized circulation that arrange at very low temperature in a regular triangular lattice, known as the Abrikosov lattice. As temperature increases, however, the Abrikosov lattice is expected to be gradually destroyed, by displacement of the vortex centers and eventually strong phase fluctuations. In our experiment, we rotate a quasi two-dimensional quantum gas in a very smooth, shell-shaped, adiabatic potential and produce vortex lattices at the bottom of the shell. We characterize the vortex phase by computing the position and angular correlations in the lattice for increasing rotation frequency. We observe the melting of the vortex lattice at large rotation frequency and finite temperature.

In the regime where the quantum gas rotates even faster, the centrifugal force pushes the atoms outwards, up along the shell, resulting in a central hole. The angular momentum per particle reaches several hundreds and the gas forms the precursor of a giant vortex, with a superfluid flowing at speeds strongly exceeding the speed of sound in the gas. We observe a strong deformation of the shape of the annulus when applying a resonant elliptical deformation.

Finally, we compensate the effect of gravity on the shell to populate a large fraction of the surface. In this low gravity limit, the shape of the cloud is dominated by small energy differences on the surface, in particular zero-point energy of the transverse confinement, which results again in the formation on an annular quantum gas.