Shaken or stirred? Vortices in ultracold fermionic gases

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Atomic gases in extremely low temperatures form a state called condensate and are known for their uncanny features. Let us focus on fermions, particles having half-integer spins. The condensation in the fermionic case takes place thanks to the process of pairing. Two particles of opposite spins form a small system called Cooper pair and, in a huge simplification, these pairs can gather in the lowest energy state, which is exactly what we call condensation.

When we stir an ultracold fermionic gas, it is more energetically favourable for the system to produce a set of quantized vortices rather than one, large vortex as we are used to see in the classical fluids. The vortices form periodic structures called Abrikosov lattices.

But what happens if the number of particles with different spin are different, so that not all of them can form a pair? Well, we can simulate such a system with supercomputers and compare it with the experimental results (see Fig. 1).

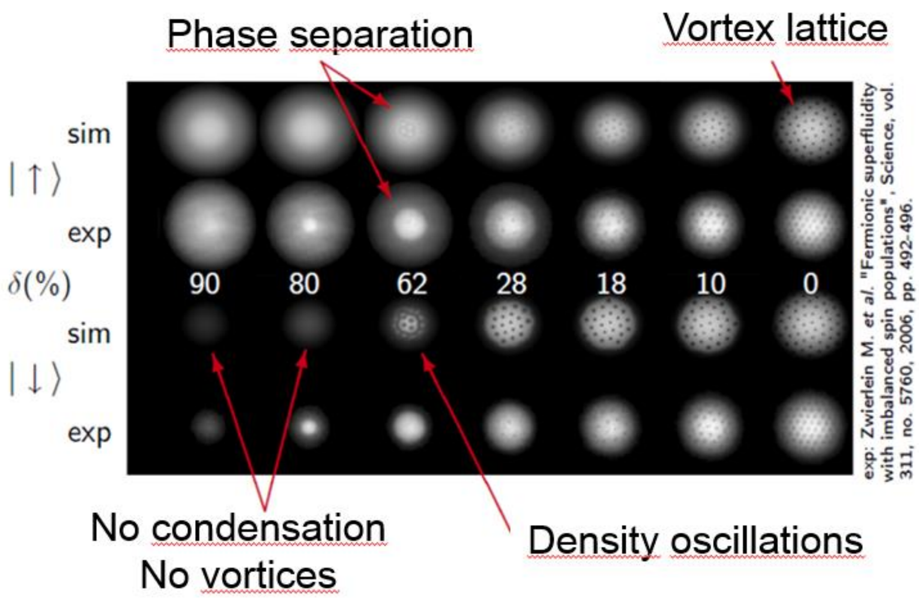

Figure 1. Comparison of the experimental images (exp) and the simulations (sim) of spin-polarized clouds of fermionic gas from populations with atoms of almost one kind only (left side of the plot) to equal spin populations. 2 upper rows show us density of the majority component (spin up atoms), the other ones – the minority component (spin down atoms).

The simulations reveal quite a few interesting phenomena as phase separation, reversed current in the vortex cores or even a coexistence of an exotic Larkin-Ovchinnikov-Fulde-Ferrell (LOFF) phase with vortex lattices. It is very unusual to see the system spontaneously separate into a core with Cooper pairs and a corona with the unpaired particles. Moreover, we can see that inside the vortex, the flow is opposite to the stirring direction (that is what we call reversed current). The LOFF phase reveals itself as density oscillations in Fig. 1.

We can also pose another question: 'What happens if we shake the system with vortices inside'? Then we enter a turbulent regime and the vortices form a spaghetti-like tangle. They connect and disconnect, they twist and swirl, losing their energy, until they manage to reach a stable configuration. In case of a rotating turbulence, this is simply a lattice of straight vortices.