Superfluidity in dilute gas Bose-Einstein condensates

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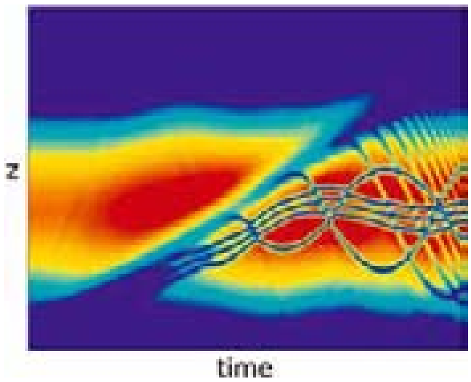
It is generally accepted that dilute gas Bose-Einstein condensates (BECs) in three dimensions are superfluids — they can flow without resistance below a certain critical velocity, and may only rotate by admitting quantised vortices. This project has been investigating a number of aspects of superfluidity in ultra-cold Bose gases in a variety of geometries.

1. A recent experiment by the Engels group at Washington State University has observed evidence for a superfluid critical velocity by dragging both attractive and repulsive obstacles through a harmonically trapped, cigar-shaped BEC [1]. We have modelled these experiments using the 3D Gross-Pitaevskii equation and our results suggest that these experiments do not demonstrate a threshold velocity for the loss of superfluidity [2]. We have also developed a phenomenological model for the energy transferred to a trapped Bose condensate flowing past an obstacle. The image to the right is a plot of the average density in space and time of an obstacle being forced through a BEC showing soliton formation in its wake.



2. We have begun work on aspects of superfluid turbulence in trapped Bose-Einstein condensates. In particular, we have attempted to realise the quantum analogue of classical Taylor-Couette flow. This is the name given to a system where a viscous fluid fills a narrow layer between two concentric cylinders rotating independently at constant angular velocity about a common axis. The classical problem has a rich phase diagram with a number of different stable vortex flows intermixed with turbulence. It would be intriguing to compare the quantum phase diagram with that of the classical fluid.

3. We have been working on understanding the relationship between superfluidity, Bose condensation, and the Berezinskii-Kosterlitz-Thouless phase in two-dimensional ultra-cold gases. Prior work has suggested that the BEC phase occurs before the superfluid phase which seems counter-intuitive [3]. However it is difficult to accurately determine the superfluid fraction in a harmonically trapped Bose gas. We have been simulating toroidal systems containing a persistent current at finite temperature, where the observable mass flow gives an accurate measurement of the superfluid fraction. This has lead to interesting questions about the Penrose-Onsager definition of Bose-Einstein condensation in non-equilibrium systems.

4. Our work in collaboration with the the Anderson group at the University of Arizona on the formation of vortex dipoles when an obstacle is dragged through a highly oblate BEC has been published [4].

References

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