

Vortices in a Highly Rotating Bose Condensed Gas

by

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Vortices in a Highly Rotating Bose Condensed Gas

Thesis directed by Prof. Eric Cornell

Superfluids, with their dissipationless flow and exotic topologies, have puzzled researchers in diverse fields of physics for almost a century. One of the hallmark features of superfluids is their response to rotation, which requires the fluid to be pierced by an array quantized singularities or vortices. Over the past few years, vortices and the lattices they organize into have become one of the major fields of experimental research with dilute gas Bose-Einstein condensates.

This thesis explores the physics of vortices and vortex lattices in the dilute gas Bose-Einstein condensate while drawing connections to other superfluid systems. In addition to characterizing several equilibrium vortex effects, this work also studies several excitations. By removing atoms from the rotating condensate with a tightly focused, resonant laser, the density can be locally suppressed, creating aggregate vortices containing many units of circulation. These so called “giant vortices” offer insight into the dynamical stability of density defects in this system. Using similar techniques we can excite and directly image Tkachenko waves in the vortex. These low frequency modes are a consequence of the small but nonvanishing elastic shear modulus of the vortex-filled superfluid.

Finally, by working at extremely high rotations we can create a Bose-Einstein condensates in the lowest Landau level. In this regime, which requires rotation rates greater than 99% of the centrifugal limit for a harmonically trapped gas, we are able observe several expected and unexpected shifts in the physical properties of the condensate.

In conclusion the dilute gas Bose-Einstein condensates offers a rich system in which to study vortex physics, and explore dynamical effects common to all rotating

superfluids.

Dedication

To Odele for her love and support, and to my grandfather for getting me thinking about the world.

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