Structure & Dynamics of Topological Defects in Spinor Bose-Einstein Condensates

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Abstract

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Acknowledgements

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2.1 Introduction

Since the realisation of superfluidity, quantum turbulence (QT) has been studied in systems ranging from superfluid liquid helium [1,2] to quasi-particle condensates in solid-state systems [3]. Due to their unprecedented experimental accessibility, QT in Bose-Einstein condensates (BECs) in dilute, ultracold atomic gases has attracted considerable theoretical [4–9] and experimental [10–15] interest in both 2D and 3D configurations. In a scalar BEC, the QT state is made up of many vortices with quantised circulation. The collective behaviour of the vortices plays a key role in the hydrodynamics, recovering features of classical turbulence that can exhibit the characteristic Kolmogorov power-law spectrum [16].

As we have seen IN RELEVANT PART, the two-component BEC can be treated as a pseudospin-1/2 system. This new system gives rise to novel defects such as a half-quantum vortex otherwise unseen in a scalar condensate. In this chapter we investigate the relaxation dynamics of half-quantum vortices (HQVs) in a two-dimensional, two-component condensate. Our interest is studying the scaling laws that govern the decay rate of the vortices, and consequently the growth of the length scales associated with domains in the system, whilst varying the ratio of inter- to intra-species interactions. We study these scales by starting from an initially turbulent state full of HQVs and subsequently letting the system relax in time. Upon the relaxation, vortices will annihilate leading to domain growth within the system. To extract the appropriate length scales of these domains, we construct correlation functions originally defined for a spin-1 system [SYMES NEMATIC ORDER REF]. These correlation functions then allow us to extract relevant length scales associated with spin and mass order. By investigating these length scales temporally, we reveal interesting, novel dynamics occurring at early times for a sufficiently high ratio of inter- to intra-species interactions. This result is then confirmed by considering the total vortex number of the system.

Recent work has alluded to fascinating inter-vortex forces arising between HQVs of opposite winding within the same condensate component [ETO PAPERS]. We relate this discovery to the interesting dynamics we observe at early time.

Appendix A

Appendix