

WHEN VORTICES DO NOT COMMUTE: STABLE QUANTUM KNOTS IN SPINOR BOSE–EINSTEIN CONDENSATES

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Abstract

More than 150 years ago, Lord Kelvin proposed that atoms might be knots of vortex lines. Although this idea was superseded by modern atomic theory, it left a fundamental question: can a knot made of fluid vortices remain stable? In ordinary fluids and superfluids, vortex knots typically unravel through reconnections, even when individual vortex lines are topologically protected.

In this talk, I will introduce non-Abelian vortices, whose topological charges belong to a noncommutative group. Unlike conventional vortices, two vortices with noncommuting charges cannot simply reconnect or pass through each other. Instead, their collision produces a connecting vortex segment, called a rung. I will explain how this unusual collision rule opens a route to stable vortex knots. Combining ideas from knot theory and vortex dynamics, we identify conditions for stability involving both noncommuting topological charges and the orientation of vortex braids. Numerical simulations of spin-2 spinor Bose–Einstein condensates demonstrate the dynamical stability of a trefoil vortex knot, in striking contrast to conventional vortex knots.

These results illustrate how the algebraic properties of topological charges can fundamentally change the dynamics and stability of complex structures in quantum fluids.