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Helicity and reconnection of vortices in quantum fluids

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Superfluid helium exhibits line-like vortices of a topological nature. They can and do cross and reconnect, leading to a change in their topology. Our group has captured and analyzed this process experimentally using flow visualization of tracer particles[1]. The tracer particles (typically 1 μm or less in diameter) become trapped on the vortices allowing one to study vortex formation and dynamics. The reconnection events also emit Kelvin waves[2]. In doing so, they separate opposite signed helicity and also transport that helicity to long range (Fig. 1).

The singular nature of reconnection events causes large accelerations and velocities close to the event. Quantum turbulent flows are dominated by reconnection. This leads to turbulent velocity distributions with power law tails, i.e. $Pr(v) \sim |v|^{-3}$. Such singular distributions stand in stark contrast to classical turbulence where the velocity is often normally distributed[3]. The difference is due in part to the topological nature of quantum turbulence relative to the classical fluid analog.

On a much larger scale, highly magnetized plasmas also exhibit reconnection of magnetic fields, releasing considerable energy. This process is active in the solar corona and the Earth's magnetosphere. Despite differences in scale and underlying physical processes, the two types of reconnection (quantum and plasma) share several types of phenomenology, topological considerations, dispersion relations, and lead to power law tails of accelerated particles. I will also discuss important considerations of magnetic helicity for plasma reconnection, perhaps influencing the severity of events.

References

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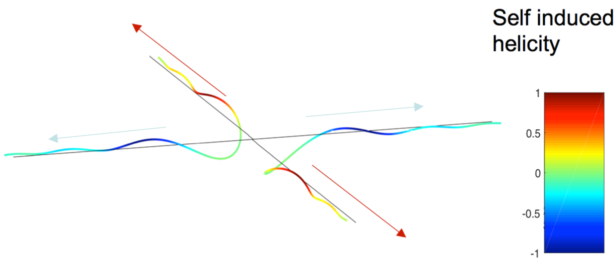

Figure 1: The reconnection of topological quantum vortices in superfluids generates Kelvin waves on the retracting segments. The Kelvin waves separate a quadrupole of helicity, here color coded red for positive helicity and blue for negative helicity. In this way reconnection serves to generate / separate helicity.