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Three-dimensional nanoparticle dynamics in superfluid helium[1]

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Quantized vortices have been observed in superfluid ^{4}He and AMO trapped atom systems, and have been infered in superfluid ^{3}He and neutron stars. The dynamics of quantum fluids is substantially controlled by the motion of quantized vortices, which are topological phase defects analogous to crystalline dislocations. Long-range quantum order underlies a number of related physical phenomena, including superfluidity, trapped-atom Bose-Einstein condensates, superconductivity, ferromagnetism, antiferromagnetism, lasers, and the Higgs mechanism. While superfluidity in ^{4}He is one of the first discovered of these, it is one of the least understood, given that the strongly interacting nature of helium makes theory difficult, and that development of local experimental probes is lagging. The advent of three-dimensional flow visualization of particles that trace quantized vortices provides new oportunities to investigate their creation and dynamics. We work to address the following questions using flow visualization in this system: What are field equations that express the coupling of the ordered and disordered parts of the flow? How does vortex reconnection lead to dissipation and breaking of time-reversal invariance? What are the similarities and differences between quantum and classical turbulence at small and large scales? How do quantized vortices form through the lambda transition?

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