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Direct and inverse energy transfers in superfluid turbulence

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Three dimensional isotropic homogeneous turbulence is characterized by a direct cascade of energy from large to small length scales. A reversed flux of energy from small to large length scales is observed in two dimensional turbulence, and, in three dimensions, in the presence of strong anisotropy, rotation or stratification. Biferale et al. (2012) demonstrated that the three dimensional inverse cascade arises by artificially restricting the nonlinearity of the Navier-Stokes equation to the interaction of helical modes of the same sign; they concluded that all three dimensional flows contain nonlinearities which may lead to an inverse cascade, but one has to break the mirror symmetry of the interactions. In superfluid helium at very low temperature the nature of turbulence is particularly simple: the flow is inviscid and the vorticity is constrained to thin, quantum vortex filaments of atomic thickness which interact with each according to the classical Euler equation; unlike classic Euler vortices, due to their quantum nature, superfluid vortices undergo reconnection events when they approach each other by a distance of the order of the vortex core thickness. Recent experimental, theoretical, and numerical studies have demonstrated evidence of the direct energy cascade in superfluid turbulence. In this work we show that in superfluid turbulence the more subtle inverse energy transfer described by Biferale et al. can be directly understood in physical space from the geometry of reconnecting vortex filaments, and argue that the effect has been detected in experiments with liquid helium.