Interaction of localised packets of vorticity with turbulence

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Abstract The evolution of initially weak structures of vorticity as they evolve in an incompressible turbulent flow is investigated. Such objects are candidates for important structures in the inertial range and in the dissipation range of scales. As these structures are strained by the flow, fine-scales of vorticity are produced along the direction of maximum compression with a consequent flow of energy to the high wavenumbers. It is shown that, under certain circumstances, the self-energy spectrum of such a structure may be time-averaged, producing a fractional power law. The exponent of the power law depends on the ratio of the first two Lyapunov exponents of the strain tensor.

I follow a vortical blob
Through stretching and turning and throb;
I can go very far
With pancake or cigar;
You'll see it's a very fine job!

1. Introduction

In this paper we continue our investigation of the evolution of localised structures of initially weak vorticity as they evolve in an incompressible turbulent flow. The first results were presented in Leonard (2000), hereafter known as L2000. Initially, these structures evolve passively by the induced velocity field of the large-scale vorticity field. This field is three-dimensional and time-dependent so that these objects are subjected to straining apropos of lagrangian chaos, characterised by a distribution of finite-time Lyapunov exponents.

Because of compression along at least one direction, fine scales of vorticity are produced. Therefore energy is shifted to higher wave numbers and, as we will see, backscatter of energy also occurs. One question might be - are such structures candidates for inertial range turbulence? Thus we will be concerned with their instantaneous and time-averaged spectral properties. It is shown that the time-averaged energy spectrum