The helicity and the generation of large scale flows in confined plasma

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The formation of quasi-coherent, large scale structures in turbulent plasma is known from numerical simulations and from experimental observations. In particular, formation of a layer of sheared quasi-laminar poloidal rotation which acts as a transport barrier (ITB, Internal Transport Barrier) has been observed. It is not always clear what are the conditions which trigger ITB formation and in gyrokinetic simulations some additional factor, beyond the Reynolds stress, appears to be necessary.

We prove that an essential element leading to the formation of coherent, sheared poloidal flows, is the turbulent helicity. Currently, this term is absent from the statistical analysis of the turbulence, with the consequence that the Reynolds stress seems ineffective to convert the turbulence into Internal Transport Barrier. In a basic statistical analysis of turbulence the two-point correlations must include a term which breaks the parity invariance and in spectral representation is purely imaginary. It is not possible to include this contribution in a renormalization of the linear propagator.

We propose a fundamental justification and a detailed description of the helical content of the fluctuating field for current turbulent models, like ITG.

The connection between laminar sheared flow (like in the H-mode rotation layer) and the filamentary structures (like in Edge Localized Modes or, more generally, in Kelvin-Helmholtz fluid instability) is examined as a conversion of the uniform vorticity into topological linking of helical streamlines. We will provide a quantitative description of this process. Conversely, the effect of turbulent distribution of Gaussian linking is shown to contribute to an inverse cascade.

The approach developed in this work is inspired by neutral turbulent fluids. However, the plasma instabilities have a natural helical content at the scale of the vorticity advection (of the order of sonic Larmor radius).