

Vortex Dynamics in Plasmas and Fluids

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Abstract The existence and dynamics of vortical structures in both homogeneous and inhomogeneous systems will be discussed. In particular the dynamics of monopolar and dipolar vortices in a plasma with nonuniform density and in a rotating fluid with varying Coriolis force is described. The role of vortical structures in connection with electrostatic plasma turbulence and the associated cross-field plasma transport will also be addressed.

1. Introduction

The existence of coherent vortical structures is a characteristic feature of two-dimensional or quasi-two-dimensional flows [1], such as planetary atmospheres and oceans, laboratory experiments with rotating or stratified fluids and strongly magnetized plasmas. The structures have life times much longer than their own period of internal rotation. They are dominating the large scale dynamics and are naturally of great importance in connection with the transport of mass, heat and momentum. Since they can trap particles and convect them over distances much larger than their own scale size they provide a transport mechanism, which in its nature is essentially different from classical diffusion dominated transport. Coherent structures are likely to form after external forcing and seem to be the universal outcome of any regular as well as irregular forcing in two-dimensional systems. They are easily excited in laboratory experiments in rotating [2,3] and stratified fluids [4]. They also appear spontaneously in two-dimensional turbulence [5] due to self-organization processes characterizing two-dimensional flows. The simultaneous conservation of energy and enstrophy (mean squared vorticity) for two-dimensional flows leads to an inverse spectral cascade, by which energy is cascading to smaller and smaller wavenumbers, whereas enstrophy is cascading to larger and larger wavenumbers. This effect is clearly demonstrated in high resolution numerical simulations of two-dimensional flows [6,7,8]. Vortical structures have also been excited in magnetized plasmas [9], where the low-frequency electrostatic dynamics is well described by a two-dimensional model, and the coalescence of like signed vortices, which is mediating the inverse cascade, was directly demonstrated [10]. In this connection the structures have often been termed convective cells [11]. Vortical structures are further found to appear spontaneously in low-frequency electrostatic turbulence [12,13] and to play an important role in connection with the plasma confinement by the magnetic field.

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