A background trend to ordered states in confined plasmas

F. Spineanu, M. Vlad

Association Euratom-MEC Romania,
National Institute of Laser, Plasma and Radiation Physics,
P.O. Box MG-36, Magurele, Bucharest, Romania
spineanu@ifin.nipne.ro

From turbulent initial states the relaxation process in fluids and plasmas leads to stationary structures consisting of very regular vortical flows. For quasi-ideal fluids these are stable for a long period and at only very late stages the dissipative decay of the motion takes place. This has been shown by experiments and by numerical simulation of quasi-ideal fluids, two dimensional plasmas, MHD and planetary atmosphere. For few cases it has been possible to identify exact equations governing the stationary ordered structures reached in the asymptotic regime : for the Euler fluid the streamfunction obeys the sinh-Poisson equation and for the distribution of current in cylindrical approximation of tokamak, the Liouville equation has been proposed. No such equation is known for the relaxation in the Hasegawa-Mima problem or planetary atmosphere (Charney) although there is clear evidence of organized motion.

There is no reason to consider that these tendencies are suppressed when the system is far from equilibrium or it is driven by external forces. In these cases the real evolution results from mixing of the ordering tendencies and the turbulence driven by unstable modes. However differences in time scales and in the amplitudes of these processes make the instabilities to appear dominant. Again, this does not mean the former are suppressed. In most of the practically interesting cases (for example in strongly turbulent states), the organizing processes are simply overwhelmed by faster and stronger fluctuation. In other regimes however, the weak excitation of unstable modes may be dominated by the ordering processes, as is the case for the density pinch in tokamak and for the generation of force-free configurations.

We review a series of recent results in the formalism for describing the trends toward organization and structuring for fluid and plasma flows: an unexpected Lagrangean formulation for fluids, obtained recently by field-theorists, the role of the helicity density and unified treatments for fluids and electromagnetic fields. We develop in detail the model describing stationary states of Charney-Hasegawa-Mima equation (for two-dimensional plasmas and planetary atmosphere) and derive the exact form of the equation governing the stationary flows (the equivalent of the sinh-Poisson equation of the Euler fluid). We present detailed results for the vortex solutions of this equation (equally interesting in the physics of the atmosphere and in non-neutral plasmas).