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Uniformly rotating regular vortex structures

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The 2D and quasi-2D vortex structures are largely observed under the geophysical conditions. Typical examples are cyclones, ouragans etc. The essential characteristic of such structures is that they develop and form in a medium with a very weak dissipation.

In laboratory conditions, systems with very weak dissipation can be realized in strongly magnetized plasma systems which permit to obtain 2D vortex structures. So, "vortex crystals" - multi-petal uniformly rotating regular vortex structures - have occasionally been observed in experiments (Fine and al., 1995). It has been suggested that this phenomenon occurs in a turbulent, without forcing or dissipation, system when relaxation stops because the system reaches its metastable statistical equilibrium. Using analytical approach and numerical simulations, we show that nonlinear vortex structures form under certain circumstances which can be connected no with the statistical equilibrium of the system, but with other mechanisms. We find an exact analytical solution of the self-correlated field equations in the two-dimensional turbulence. This solution describes a stationary rotating N-petal vortex structures. One of the key factors that allowed us to find the analytical solution was that we were able to arbitrarily choose the distribution function. The form of the solution must be compatible with the initial conditions, which are imposed not only on the coordinates, but also on the particle velocities distribution. When the initial distribution of velocities is fixed, it follows from the structural form of the argument in the distribution function that the coordinate distribution of the particles is fixed as well.

The analytical solution qualitatively resembles the experimental results. Our theoretical analysis confirmed the essential qualitative aspect of the experiments: multi-petal vortex structures can be observed in a medium with a very weak dissipation, but with specific initial conditions.