PROJECT Nr. 2-CEX 06-11-47 / 2006

TURBULENCE AND QUASI-COHERENT STRUCTURES IN FLUIDS AND SPACE PLASMAS

The Project is devoted to the development of new approaches to the problems of relaxation from turbulent states and the generation of coherent structures. These are subject of wide interest in the international research effort. In concrete terms we intend to focus on three topics related with basic aspects of turbulence and coherent structures.
Each objective is based on previous original results [1]-[10] obtained by the partners contributing to the present Project.

1) Coherent structures generated at relaxation from turbulent states of two-dimensional fluids

Starting from the suggestive similarity of the continuous version of the point-like vortices model with the theory of a Yang-Mills field interacting with a scalar field it will be constructed a model of the dynamics of fluids/plasmas by associating elements of the Yang-Mills field theory to basic physical variables (velocity, vorticity). In a Lagrangian setting it will be searched for the self-dual states that can provide the most symmetric minimum of the action functional. Physical elements (as for example the common nature of the point-like vortex and the intrinsic magnetic momentum in a strong external field) can be invoked in order to simplify the algebraic structure and reduce the model to a single equation for the scalar potential of the velocity. Derivation of the equations at self-duality will permit a quantitative description of the stationary vortical flows of fluids and plasmas.
The field of applicability of this approach and of the instruments it creates is large: planetary atmosphere, plasma vortices, vortices in non-neutral plasma, ionosphere and astrophysical plasmas.
We intend to provide on this basis a quantitative description of the stable vortex in the two-dimensional atmosphere: tropical cyclone, typhoon, tornado, etc.
We intend to derive quantitative relations connecting the basic characteristics of these vortices: the radial profile of the tangential wind, the radius of the circle of maximum of the tangential wind, the final total energy and the final total vorticity.
We intend to compare these data with observational data provided by research institutions of climate and weather survey (from Japan and USA).

We intend to explain and describe in quantitative terms the results of the experiments with electron plasmas (linear machines: Driscoll, Finn, O' Neal from University of California at San Diego, USA), which have put in evidence the formation of crystals of vortices. The same equation describing the atmospheric vortex (the Charney equation) also describes the stable vortices in plasma (Hasegawa-Mima).

We intend to analyze quantitatively the monopolar structures observed in plasma with low magnetic confinement (experiment National Institute of Fusion Science, Japan) and to provide numerical data that can allow the prediction of similar structures.

These objectives are in conformity with the nature of the proposed Project, since they obtain in practical terms the confirmation of the validity and efficiency of the approach based on field theoretical notions. Results that otherwise are inaccessible will become possible via models that are derived in the new approach, which can be seen as alternative but also complementary to the classical one.

2) Turbulence from the prospect of some gasdynamic interactions

- Noticing the nature of *coherent structures*, candidates in gasdynamic turbulence modelling, of the wave-wave regular interaction.
- Noticing that a degeneracy could be possible in the "algebraic" treatment of a multidimensional extension of the one-dimensional theory of one-dimensional wave-wave regular interaction. Noticing the importance of an admissibility criterion [= a criterion of nondegeneracy] of a "genuinely nonlinear" nature.
- A comparison, in a one-dimensional context, between an "algebraic" approach and a "differential" approach. Inspecting the signification of the differences between the two types of approach.

3) The stochastic advection of particles and fields

The advection of charged particles in stochastic magnetic fields will be investigated and the statistical characteristics of the trajectories will be determined. The statistical properties of the ensembles of field lines will be calculated. The nonlinear effect of the trapping processes will be analyzed. In order to achieve this there will be extended the original methods developed (by contributors to the present Project) for the test particles in the electrostatic turbulence ([5], [6], [7] from the publications listed above). It will be investigated the regime where structures of field lines may be generated: (magnetic islands) or structures of trajectories and it will be analyzed the difference between these structures in terms of the particle energy. The regimes of diffusion will be studied for the range of parameters of the stochastic magnetic field specific to the space plasmas.

In the second part of the Project the advection of passive scalar fields by a stochastic velocity fields will be studied. The process of trajectory trapping will be included and the effect of the structures on the transported scalar field will be analyzed. We expect that the memory and coherence effects in the statistics of trajectories will be reflected in the evolution of the field. We will develop a Lagrangian method based on trajectory statistics.

Project team:

Madalina Olimpia Vlad, INFLPR
Florin Spineanu, INFLPR
Liviu Florin Dinu, IMAR
Gheorghe Minea, IMAR
Marina Ileana Dinu, UP

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