THE KOLMOGOROV' REFINED SCALING IN THE THEORIES OF TURBULENCE AND IN SUBSURFACE HYDRODYNAMICS

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We consider the scaling theory for intermittent turbulent fields in three dimensions. The scaling is complemented by the conformal invariance which is interpreted as the local scale invariance Its application to the turbulence theory is tangled by the scale dependent intermittency that destroys the simple scaling scheme. Our starting point is the Kolmogorov refined scaling [1] for the dimensionless ratios of fields. We study application of the conformal symmetry [2] to the scalar and vector fields and find the expression for the correlation functions of various order. The simplest case is the log-normal theory. Non-Gaussian log-stable conformal fields are also considered.

The fluid turbulence is too complex to verify the present theory by the direct computer experiment. Thus, the related linear problem of the subsurface hydrodynamics is considered [3]. We study the displacement of one fluid by another within a fractal porous medium. Both fluids are incompressible, immiscible and have the same physical properties. Let an incompressible fluid steadily flow through a medium with the fluctuating permeability coefficient $\varepsilon(\mathbf{x})$. At low Reynolds number, Darcy's law gives the velocity $\mathbf{v} = -\varepsilon \nabla p$, where p is pressure. The incompressibility condition brings about the equation for the pressure

$$\nabla \left[\varepsilon(\mathbf{x}) \nabla p(\mathbf{x})\right] = 0. \tag{1}$$

The co-operative flow can be computered by the single Darcy's equation because the fluids have the same physical properties. A subgrid model has been obtained. The model is verified by the direct numerical computation.

Next we compute the evolution of the fluid-fluid interface that is labeled by passive particles. Their paths are found from the Lagrangian equation

$$m(\mathbf{x}) \frac{d\mathbf{x}}{dt} = \mathbf{v}(\mathbf{x}), \tag{2}$$

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where $m(\mathbf{x})$ is porosity, $\mathbf{v}$ is the velocity field that has been found from (1). We consider a model in which the fractal permeability field correlates with the fractal porosity field. The porosity and the permeability satisfy the Kolmogorov's improved scaling hypotheses. The interface moves with some mean velocity and is distorted by the fluctuations of the velocity (see the Figure 1). The simplest statistical parameters of the interface are found. The dispersion of the interface grows as a power function with the index 1.73.

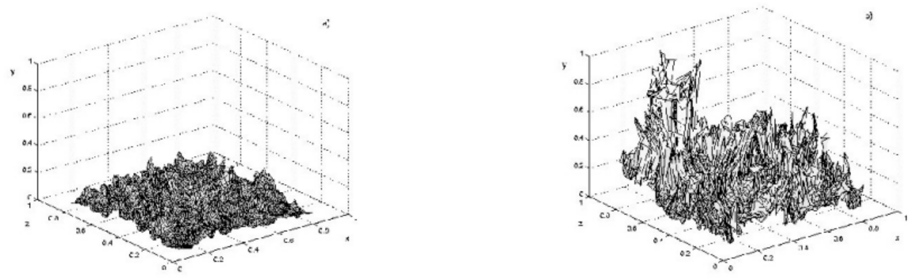

Figure 1: Development of the fluid interface

The above picture corresponds to particular values of parameters which lies in the range of values measured in the natural experiments. For that value the statistical parameters of the interface are found. We plan to study influence of another values of the parameters. To the beginning of the conference, we intend to consider different correlations of permeability and porosity, different viscosities of displacing and displaced fluids and the log-stable multi-scale porous media [4].

The main results of the present paper are the conformal theory of the intermittent fields, the subgrid models, that are supported by the direct computer simulations, and the non-classical scaling behavior of the convective diffusion.

References

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