St.-Petersburg Department
of V.A. Steklov Mathematical Institute
Euler International Mathematical Institute

International Conference
**“MATHEMATICAL HYDRODYNAMICS:
EULER EQUATIONS AND RELATED TOPICS”**
EEC-300

Abstracts

St.-Petersburg, Russia
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2007

International Conference EEC-300 "Mathematical Hydrodynamics: Euler Equations and Related Topics"

The conference is dedicated to 300th birthday of Leonard Euler. This conference is organized at the Euler International Mathematical Institute by Petersburg Department of Steklov Mathematical Institute. The conference will take place from Thursday, June 7 to Saturday, June 9, 2007 in St.-Petersburg, RUSSIA. The purpose of the conference is to bring together researchers working in mathematical hydrodynamics, mainly on the Euler equations and all the problems concerning the effect that the convection term brings to the fluid dynamics. The conference is held in St.-Petersburg in the frame of the International Mathematical Congress dedicated to the 300th Anniversary of Leonhard Euler's Birth.

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NO TALK

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On the Ladyzhenskaya-Smagorinsky Turbulence Model. The Regularity Problem

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In the forthcoming paper [2] we consider the question of regularity up the boundary of solutions to boundary value and initial boundary value problems for the modified Navier- Stokes equations. By regularity up to the boundary, we mean the existence of the second derivatives of the velocity and the rst derivatives of the pressure which are summable up to the boundary with some exponent. In [1] we give a solution to this problem for half-space, in the stationary case. The scheme proposed by us in [1] is as follows. At first, the steady state problem with no convection term is considered. It is a kind of the nonlinear Stokes problem. For values of the exponent $p \in [2; 3]$, characterizing the growth of the dissipative potential, the starting regularity is proved. More precisely, it is shown that the second derivatives of the velocity field are summable with power $p' = p/(p-1)$. Then this exponent is improved up to some exponent $l > p'$ if $p < 3$, with help of bootstrap arguments. For $p = 3$ one has $l = p'$, and bootstrap is not needed. For $p = 2$, the result is the same as in the case of the classical Stokes problem with the right hand side from L_2. All the results remain to be true in the presence of the convective term. For $p > 2$, its role is not so crucial. The main aim of [2] is to extend the above scheme to the case of curvilinear boundaries. This is a quite difficult technical problem. Especially, it is complicated for nonlinear equations containing viscosity depending on the module of $\mathcal{D}$, the symmetric part of the gradient. Actually, the latter circumstance makes the given problem so difficult even in the case of flat boundaries. For it, the known scheme developed for the case in which coefficients in the equations depends on the module of the gradient (Lions model), does not work. The proof of our results is done via a very careful analysis up to boundary, and a suitable application of a modified difference quotient method (and this is the relevant novelty of the paper) overcoming the simultaneous appearance of three difficulties: boundary regularity (that is, how to recover the vertical derivatives of $\mathcal{D}$ from the tangential ones), the divergence constraint to be met at each choice of the test functions, and the fact that the system actually depends on the symmetric part of the gradient, rather than on the gradient itself. This leads to the introduction of a certain number of interesting new tricks. The results are anyway proved by first arguing locally, via a suitable flattening of the boundary, and then by a covering argument to recover the final global estimate. A main scientific importance of our work is that it shows that all the results being valid for flat boundaries remain to be valid for general smooth domains. In a paper in preparation we prove corresponding results for the shear thinning case, $p < 2$:

Keywords: Navier-Stokes equations, Shear thickening viscosity, Regularity up to the boundary.

References:

[1] H. Beirao da Veiga, *On the regularity of flows with Ladyzhenskaya shear dependent viscosity and slip and non-slip boundary conditions*, Comm. Pure Appl. Math., 58 (2005), 552-577.

[2] H. Beirao da Veiga, *On the Ladyzhenskaya-Smagorinsky turbulence model of the Navier- Stokes equations in smooth domains. The regularity problem*, J. Euro. Math. Soc., submitted.

Probabilistic Approaches to the Solution of the Navier-Stokes System

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We study the probabilistic interpretation of some solutions to the Cauchy problem of the Navier-Stokes system described in the book ny Lemarie-Riesset and develop an alternative representation to the same classes of solutions based on stochastic diffeomorhisms preserving the volume. As the result we construct local in time generalized solutins in the Morrey type spaces.

Complex Singularities for Inviscid Incompressible Flow

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We are attempting to construct singular solutions of the Euler equations using a combination of numerical computation and mathematical analysis. In the first approach, we perform highly accurate numerical computation of complex travelling wave solutions with singularities. Assuming the validity of these numerical solutions, the next step is construction of a real solution through an asymptotic expansion. The second approach is a desingularization of the Euler equations that allows direct construction of a singular solution. This talk will describe preliminary results for these constructions.

On the Self-Similar Singularities for the Euler and Related Equations

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We discuss nonexistence of the self-similar singularityies of solutions to the Euler, Navier-Stokes and the MHD equations for the incompressible fluid flows.

Euler Equations with Non-Homogeneous Navier Slip Boundary Condition

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We consider the motion of an ideal fluid in a 2D-bounded domain, *admitting flows through the boundary* of this domain. The motion of the fluid in a domain $\Omega \subseteq \mathbb{R}^2$ is described by the Euler equations

$$\mathbf{v}_t + \operatorname{div}(\mathbf{v} \otimes \mathbf{v}) - \bigtriangledown p = 0, \qquad (\mathbf{x}, t) \in \Omega_T := \Omega \times (0, T), \tag{0.1}$$

$$\operatorname{div} \mathbf{v} = 0, \qquad (\mathbf{x}, t) \in \Omega_T \tag{0.2}$$

with a given initial condition

$$\mathbf{v}(\mathbf{x},0) = \mathbf{v}_0(\mathbf{x}), \quad \text{such that} \quad \text{div } \mathbf{v}_0 = 0, \quad \mathbf{x} \in \Omega, \tag{0.3}$$

and *non-homogeneous* Navier slip boundary conditions on the boundary of the domain Ω:

$$\mathbf{v} \cdot \mathsf{n} = a, \qquad \mathbf{x} \in \Gamma_T := \Gamma \times (0,T), \tag{0.4}$$

$$2D(\mathbf{v})\mathsf{n} \cdot \mathsf{s} + \alpha \mathbf{v} \cdot \mathsf{s} = b, \qquad \mathbf{x} \in \Gamma_T^- := \Gamma^- \times (0,T). \tag{0.5}$$

Here $\mathbf{v}(\mathbf{x},t)$ is the velocity of the fluid at $(\mathbf{x},t) \in \Omega_T$; $p(\mathbf{x},t)$ is the pressure; the tensor $D(\mathbf{v})$ is the rate-of-strain of the fluid's velocity $\mathbf{v}$; (n,s) is the pair formed by the outside normal and tangent vectors to the boundary Γ of Ω; Γ^- is the part of Γ, where $\mathbf{v}\,\mathsf{n} = a < 0$.

The results:

1) We establish the solvability of this problem (0.1)-(0.5) realizing the passage to the limit in the Navier-Stokes equations with vanishing viscosity;
2) The solvability is proved in the class of weak solutions with L_p-bounded vorticity, $p \in (2,\infty]$;
3) It is shown that the weak solution satisfies the Navier slip boundary conditions (0.4)-(0.5).

This is the joint work with S.N. Antontsev

TBA

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Contour Dynamics for Incompressible Flows

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The Correlation of Statistical Solutions of the Hydrodynamic Equations

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The talk will present some rigorous results regarding the correlation function of statistical solutions of the Navier-Stokes equations. It will also review some of the tenets of the theory and possible ways to providing rigorous proofs.

Asymptotic Analysis of Equations Describing the Dynamics of Compressible Viscous Fluids

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We shall discuss several asymptotic limits of solutions to the complete system of the Navier-Stokes-Fourier equations describing the motion of a viscous, compressible, and heat conductive fluids. We focus on the so-called low Mach number regime when the limit system is represented by the equations of incompressible fluid flows. This general situtation will be supplemeted with other singular parameters: the Froude number, the Damkoehler number, among others. In particular, we recover some models of stratified fluids used in meteorology.

Incompressible Flow Around a Small Obstacle

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In this talk I will describe recent work concerning the limiting behavior of solutions of the incompressible Navier-Stokes equations, in the exterior of a small obstacle, as both the diameter of the obstacle and the viscosity vanish. Our objective is to obtain conditions for the limiting flow to satisfy the incompressible Euler equations in the full space, both in two and three space dimensions.

Unlocal Stable Invariant Manifolds for Semilinear Parabolic Equation with Quadratic Nonlinearity

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In a bounded domain $\Omega \subset \mathbb{R}^3$ the following equation is considered:

$$\partial_t v(t,x) - \nu\Delta v + v^2 = 0, \quad x \in \Omega,\ t > 0 \tag{1}$$

with zero Dirichlet condition on $\partial\Omega$, where parameter $\nu > 0$ is small enough. Then (1) has several steady-state solutions. Let $\widehat{v}$ be one of them. Let $\{e_j, \lambda_j\}$ $\lambda_1 \leq \dots \lambda_N < 0 < \lambda_{N+1} \leq \dots \lambda_k \to \infty$ as $k \to \infty$ be eigenfunctions and eigenvalues of linearization on $\widehat{v}$ of space part of (1). We decompose the phase space $V = H^2(\Omega) \cap H_0^1(\Omega)$ of (1) on $V_+ \oplus V_-$ where $V_+ = [e_1, \dots e_N], V_- = [e_{N+1}, \dots]$. The set $M_- \subset V$ contained $\widehat{v}$ is called stable invariant manifold if for each $v_0 \in M_-$ the solution $v(t,\cdot,v_0)$ of (1) with initial condition v_0 belongs to M_- for every $t > 0$, and $\|v(t,\cdot,v_0) - \widehat{v}\|_V \leq \exp(-rt)$ as $t \to \infty$ for certain $r > 0$. Moreover $M_- = \{\widehat{v} + v_- + F(v_-), v_- \in \mathcal{O}(V_-)\}$ where $\mathcal{O}(V_-)$ is a neighborhood of the origin in V_-, and $F : \mathcal{O}(V_-) \to V_+$ is a map satisfying $\|F(v_-)\|/\|v_-\| \to 0$ as $\|v_-\| \to 0$.

We prove existence of M_- with neighborhood $\mathcal{O}(V_-)$ which is not contained to the ball $B(V_-, r)$ with arbitrary big r. Introduce the following subspace V_-^k of V_- : $V_-^k = [e_k, e_{k+1}, \dots]$ with $k > N$, and in the space V_- define the following "'cruciform"' set: $CR_{r,\rho}(k) = B(V_-, r) \cup B(V_-^k, \rho)$.

Theorem 1. *For a certain $r > 0$ and arbitrary $\rho > 0$ one can find $k > N$ such that there exists a neighborhood $\mathcal{O}(V_-)$ satisfying conditions: i) $CR_{r,\rho}(k) \subset \mathcal{O}(V_-)$, ii) There exists a stable invariant manifold (2) with this $\mathcal{O}(V_-)$.*

On the Controllability of the Isentropic Euler Equation

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Regularization by Compensated Compactness for Conservation Laws

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I shall explain how the compensated compactness method proposed by L. Tartar and R. DiPerna to prove global existence of entropy solutions of hyperbolic systems of conservation laws provides quantitative regularity estimates for these solutions.

L^2-Stability of the Ekman Spiral and the Eqautions of Navier-Stokes in the Rotational Framework

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In this talk we consider the stability of the Ekman spiral in the halfspace with respect to L^2-perturbations and discuss related results concerning the Stokes-Coriolis-Ekman operator.

Dynamic Depletion of Vortex Stretching and Nonlinear Stability of 3D Incompressible Flows

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Whether the 3D incompressible Euler or Navier-Stokes equations can develop a finite time singularity from smooth initial data has been an outstanding open problem. Here we review some existing computational and theoretical work on possible finite blow-up of the 3D Euler equations. We show that the geometric regularity of vortex filaments, even in an extremely localized region, can lead to dynamic depletion of vortex stretching, thus avoid finite time blowup of the 3D Euler equations. Further, we perform large scale computations of the 3D Euler equations to re-examine the two slightly perturbed anti-parallel vortex tubes which is considered as one of the most attractive candidates for a finite time blowup of the 3D Euler equations. We found that there is tremendous dynamic depletion of vortex stretching and the maximum vorticity does not grow faster than double exponential in time. Finally, we present a new class of solutions for the 3D Euler and Navier-Stokes equations, which exhibit very interesting dynamic growth property. By exploiting the special nonlinear structure of the equations, we prove nonlinear stability and the global regularity of this class of solutions.

Eulerian Limit for Randomly Forced 2D Navier-Stokes Equation

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Eulerian limit for randomly forced 2D Navier-Stokes equation Abstract: The Eulerian limit is the inviscid limit for the randomly forced 2D Navier-Stokes equation with small viscosity under periodic boundary conditions. Under this limit stationary in time solutions of the 2D NSE converge to a stationary in space and time random field, formed by smooth solutions of the free 2D Euler equation, and the distribution of this random field, evaluated at a fixed time, is a measure in the space of 2D vector fields, invariant for the Euler equation. In my talk I will discuss recent results on this limit, their relevance for the theory of stationary space periodic 2D turbulence and some related conjectures.

A Numerical Study to Kida-Pelz Type High-Symmetric Configuration

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The Kida-Pelz type high symmetric initial value for 3D incompressible flow is a very attractive candidate as the invisible flow with possible finite time blowup behavior. The numerical results for the Navier-Stokes equations indicate strongly that there will be a finite time blowup. In 1997, Pelz presented a filament model to mimic this blowup behavior observed in the Navier-Stokes computation and a finite time blowup with certain scaling properties was produced. To check if the blowup of the filament model is due to the modelling error of the filament model equation, or due to the nature of the Euler equations, we revised this filament model to a periodic configuration, which can be numerical solved by both the filament model equation and the full 3D Euler solver. The periodic filament model equation was numerical solved with an Ewald summation technique. The blowup behavior with the same scaling properties reported by Pelz was observed again in our computation, which appeared quite robust to the perturbation on the profile of the initial filament. The full Euler equations were solved with a standard pseudo-spectral code with a recently developed high order Fourier filter to remove the aliasing error. To our surprise, the numerical results of the full Euler equations deviated from the numerical results of the filament model simulation and behaved as a comparative stable structure. Therefore, the most possibility based on current numerical results is that the high symmetric filament model missed certain intrinsic properties in the Euler equation to produce the strange numerical behavior observed in the Navier-Stokes computation.

3D Euler Equations in Cylindrical Domains with Uniformly Large Initial Vorticity

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On Variational Principle in Dissipative Hydrodynamics of the Hydrodynamic Equations

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The generalization of the Hamilton's and Osager's variational principles for dissipative hydrodynamical systems is represented in terms of the mechanical and thermal displacement fields. A system of hydrodynamical equations for these fields is derived from the stationary condition for action with a Lagrangian in the form of the difference between the kinetic and free energies which include the time integral of the dissipation function containing quadratic forms of all the terms. The hydrodynamic equation system is then evaluated on the basis of the generalized variational principle and describes propagation of acoustical and thermal modes with the finite propagation velocities in the high frequency limit.

Bursting Dynamics and Nonlinearity Depletion for the 3D Euler Equations

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A class of three-dimensional initial data characterized by uniformly large vorticity is considered for the 3D incompressible Euler equations in bounded cylindrical domains. The fast singular oscillating limits of the 3D Euler equations are investigated for parametrically resonant cylinders. Resonances of fast oscillating swirling Beltrami waves deplete the Euler nonlinearity. These waves are exact solutions of the 3D Euler equations. We construct the 3D resonant Euler systems; the latter are countable uncoupled and coupled $SO(3;\mathbb{C})$ and $SO(3;\mathbb{R})$ rigid body systems. They conserve both energy and helicity. The 3D resonant Euler systems are vested with bursting dynamics, where the ratio of the enstrophy at time $t = t^*$ to the enstrophy at $t = 0$ of some remarkable orbits becomes very large for very small times t^*; similarly for higher norms H^s, s_2. These orbits are topologically close to homoclinic cycles. For the time intervals where H^s norms, $s \geq 7/2$ of the limit resonant orbits do not blow up, we prove that the full 3D Euler equations possess smooth solutions close to the resonant orbits uniformly in strong norms.

This is the joint work with F. Golse and A. Mahalov.

Euler Equations in Fluid Dynamics

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This talk reviews the geometric approach to several Euler equations in hydrodynamics. Starting with the Arnold approach, the main results obtained via geometric methods for the ideal incompressible homogeneous fluid flow will be recalled. Then the compressible case will be discussed. Averaged Euler models will be presented and the consequences of the geometric approach for these equations will be explored as well as their link to second order fluids. If time permits the basic equations of chromohydrodynamics will be presented.

Zygmund Spaces, Inviscid Limits and Uniqueness of Euler Flows

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The use of basic properties of the Zygmund space $L \ln L$ leads to an improvement of the classical uniqueness result for the Euler system in the n dimensional case assuming that $\nabla u^E \in L_1(0,T;BMO(\Omega))$, only. Moreover the rate of convergence for the inviscid limit of solutions to the Navier-Stokes equations under slip-type boundary conditions can be obtained, provided the same regularity of the limit Eulerian flow. A key element of the proof is a logarithmic inequality between the Hardy and L_1 spaces. The result is a joint work with Piotr B. Mucha (Warsaw University).

On the Linearized Problem of the Spin-Coating-Process

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The motion of viscous flow on a rotating disc is considered in a domain like infinity layer. The motion of liquid is discribed by the Navier-Stokes equations with Coriolis, and centrifugal-force terms. The Navier's slip boundary conditon is imposed at the bottom of the liquid, which is determined by the altitude of liquid. The motion of the surface of the liquid is determined by the balance of the surface-tension, motion of the liquid on the surface and the evaporation effect. The purpose is to establish the local existence of the solutions to the linearized problem, using the maximal regularity theory.

Decay of Polymer Equations and Poincare Estimates

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We study the decay and existence of solutions to some equations modelling polymeric flow. We consider the case when the drag term is corotational and the solutions are sufficiently regular to satisfy some necessary energy estimates. We analyze the decay when when the space of elongations is bounded, and the spatial domain of the polymer is either a bounded domain $\Omega \subset \mathbb{R}^n, \quad n = 2, 3$ or the domain is the whole space $\mathbb{R}^n, \quad n = 2, 3$. The decay is first established for the probability density ψ and then this decay is used to obtain decay of the velocity u. Consideration also is given to solutions where the probability density is radial in the admissible elongation vectors q. In this case the velocity u, will become a solution to Navier-Stokes equation, and thus decay follows from known results for the Navier-Stokes equations. Some questions in relation to Poincaré type inequalities, and fluid equations in general, will be discussed

Some Stability Theorem for Navier-Stokes Flow Past a Rotating Body

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I would like to talk about some stability theorem of Navier-Stokes flow past a rigid body with and without rotating. One of the main points of my approach is to show the generation of semigroup of corresponding linearized problem - the Oseen equation with and without rotating effects, and its decay properties.

Onsager's Conjecture in Borderline Besov Spaces

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Onsager's conjecture states that no anomalous dissipation of energy occurs in an ideal fluid with velocity field in a Holder space of smoothness higher than 1/3. We show that this holds even in Besov spaces $B^{1/3}_{3,p}$ for all $1 \le p < \infty$. The argument is sharp in view of known examples for $p = \infty$.

Blow Ups of Complex Solutions of Some Equations of Fluid Dynamics

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I shall explain a new approach to the problem of blow ups in complex solutions of Navier-Stokes and Burgers system which is based on ideas of the renormalization group theory.The results were obtained jointly with Dong Li (IAS, Princeton)

Singular Solutions of the Euler Equations

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The talk will be devoted to a review of my old and recent results concerning two-dimensional singular flows of a perfect incompressible fluid. Such flows admit moving singularities of the velocity field $v(x, t)$ like point vortex ($curl\, v(x, t) = \delta(x - a(t))$, δ is the Dirac function) or point source ($div\, v(x, t) = \delta(x - a(t))$). The solvability of the corresponding boundary ? value problems is established. Moreover, a uniqueness result for the problem with point vortex is proved. Besides that, as an application of the problem with point sources and sinks, a solution of the problem on a flow of a perfect fluid through a given domain is obtained.

Global Regularity of Certain Geophysical Models

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In this talk I show the global regularity of certain three-dimensional geophysical models. Based on these results we will conclude some new sufficient conditions regarding the global regularity of the three-dimensional Navier-Stokes equations.

NO TALK

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