Conference Program

Advances in Mathematical Fluid Dynamics

Time

June 23--27, 2025

Venue

Ding Shisun Lecture Hall, Zhi-Hua building, Peking University

北京大学智华楼丁石孙教室

Organizing Committee

De Huang (Peking University)

Xiaoyutao Luo (Chinese Academy of Sciences)

Jiajun Tong (Peking University)

Dongyi Wei (Peking University)

Speaker List

Ken Abe (Osaka Metropolitan University)

Ángel Castro (Instituto de Ciencias Matemáticas, Consejo Superior de Investigaciones Científicas)

Jiajie Chen (New York University)

Alexey Cheskidov (Westlake University)

Kyudong Choi (Ulsan National Institute of Science and Technology)

Diego Córdoba (Instituto de Ciencias Matemáticas, Consejo Superior de Investigaciones Científicas)

Gianluca Crippa (University of Basel)

Mimi Dai (University of Illinois at Chicago)

Hongjie Dong (Brown University)

Emmanuel Grenier (Beijing Institute of Technology)

In-Jee Jeong (Seoul National University)

Hao Jia (University of Minnesota)

Wojciech Ożański (Florida State University)

Fei Wang (Shanghai Jiao Tong University)

Sijue Wu (University of Michigan)

Chunjing Xie (Shanghai Jiao Tong University)

Xiaoqian Xu (Duke Kunshan University)

Ping Zhang (Chinese Academy of Sciences)

Andrej Zlatoš (University of California, San Diego)

Schedule Overview

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Conference dinner: June 24 (Tuesday), starting at 6:30pm, invited only

Schedule by Date

June 23 (Monday)

Time	Speaker	Talk title
8:40am-9am	Opening	
Morning session	Chair: Jiajun Tong	
9am-10am	Gianluca Crippa	Weak, renormalized, and vanishing-viscosity solutions of the two-dimensional Euler equations
10am-10:30am	Tea break	
10:30am-11:30am	Xiaoqian Xu	Mixing flow and advection-diffusion-reaction equations
	Lunch break	
Afternoon session	Chair: Chao Wang	
2pm-3pm	Andrej Zlatoš	Stable regime singularity for the Muskat problem
3pm-4pm	Ángel Castro	Global-in-time estimates for the 2D one-phase Muskat problem with contact points
4pm-4:30pm	Tea break	
4:30pm-5:30pm	Hongjie Dong	On the one-phase Muskat problem

June 24 (Tuesday)

Time	Speaker	Talk title
Morning session	Chair: Zhifei Zhang	
9am-10am	Ping Zhang	A refined estimate of the analyticity radius for 3D Navier-Stokes equations
10am-10:30am	Group photo & tea break	
10:30am-11:30am	Wojciech Ożański	Instantaneous continuous loss of regularity for the SQG equation
	Lunch break	

Afternoon session	Chair: Ling-Bing He	
2pm-3pm	Kyudong Choi	Existence and stability of a Sadovskii dipole as a maximizer of kinetic energy
3pm-4pm	In-Jee Jeong	Long time dynamics and stability of multi-vortex solution
4pm-4:30pm	Tea break	
4:30pm-5:30pm	Chunjing Xie	Rigidity for steady incompressible Euler system and its applications
	Conference dinner (starting at 6:30pm)	

June 25 (Wednesday)

Time	Speaker	Talk title
Morning Session	Chair: Pin Yu	
9am-10am	Sijue Wu	The quartic integrability and long time existence of water waves
10am-10:30am	Tea break	
10:30am-11:30am	Mimi Dai	Onsager type theorem for SQG
	Lunch break	
	Excursion (departing at 1:30pm)	

June 26 (Thursday)

Time	Speaker	Talk title
Morning Session	Chair: De Huang	
9am-10am	Diego Córdoba	Finite time singularities for incompressible fluids
10am-10:30am	Tea break	
10:30am-11:30am	Jiajie Chen	Self-similar singularities in fluids and related equations
	Lunch break	
Afternoon session	Chair: Zhen Lei	
2pm-3pm	Hao Jia	Uniform in viscosity depletion and inviscid damping near periodic shear flows
3pm-4pm	Emmanuel Grenier	Nonlinear instabilities of shear layers
4pm-4:30pm	Tea break	
4:30pm-5:30pm	Fei Wang	Asymptotic Stability of Shear Flows Near Couette with Navier Boundary Conditions

June 27 (Friday)

Time	Speaker	Talk title
Morning Session	Chair: Xiaoyutao Luo	
9am-10am	Alexey Cheskidov	Energy cascade in fluids: from convex integration to mixing
10am-10:30am	Tea break	
10:30am-11:30am	Ken Abe	MHS equilibria in the small non-resistive limit to the randomly forced resistive magnetic relaxation equations
	Lunch break	
	Free afternoon for discussion	

Abstracts

June 23 (Monday)

Gianluca Crippa (University of Basel)

Title: *Weak, renormalized, and vanishing-viscosity solutions of the two-dimensional Euler equations*

Abstract: Let us consider the Euler equations modeling the behavior of an incompressible, homogeneous, inviscid fluid. In the two-dimensional case, the Euler equations can be written in vorticity form as a continuity equation, in which the advecting velocity depends on the vorticity through an integral operator. In my talk, I will introduce several notions of weak solutions for the two-dimensional Euler equations in vorticity form: weak solutions, renormalized solutions, and vanishing-viscosity solutions. Relying on the linear theory for continuity equations with Sobolev velocity field by DiPerna and Lions, I will show that in the subcritical case weak solutions do not exhibit anomalies. In the supercritical case, I will show by means of a duality approach that the same holds for vanishing-viscosity solutions. This has some connections with the two-dimensional theory of turbulence of Kraichnan and Batchelor.

Xiaoqian Xu (Duke Kunshan University)

Title: *Mixing flow and advection-diffusion-reaction equations*

Abstract: In the study of incompressible fluid, one fundamental phenomenon that arises in a wide variety of applications is dissipation enhancement by so-called mixing flow. In this talk, I will give a brief introduction to the idea of mixing flow and the role it plays in the field of advection-diffusion-reaction equation, such as the famous Keller-Segel equation for chemotaxis. I will also discuss about the examples of such flows in this talk.

Andrej Zlatoš (University of California, San Diego)

Title: *Stable regime singularity for the Muskat problem*

Abstract: The Muskat problem on the half-plane models motion of an interface between two fluids of distinct densities in a porous medium that sits atop an impermeable layer, such as oil and water in an aquifer above bedrock. We develop a local well-posedness theory for this model in the stable regime (lighter fluid above

the heavier one), which includes considerably more general fluid interface geometries than even existing whole plane results and allows the interface to touch the bottom. The latter applies to the important scenario of the heavier fluid invading a region occupied by the lighter fluid along the impermeable layer. We also show that finite time singularities do arise in this setting, including from arbitrarily small smooth initial data, by obtaining maximum principles for the height, slope, and potential energy of the fluid interface.

Ángel Castro (Instituto de Ciencias Matemáticas, Consejo Superior de Investigaciones Científicas)

Title: *Global-in-time estimates for the 2D one-phase Muskat problem with contact points*

Abstract: In this talk, we consider the dynamics of a two-dimensional incompressible viscous fluid evolving through a porous medium or a Hele-Shaw cell, driven by gravity and surface tension. The fluid will be confined within a vessel with vertical walls and below a dry region. Consequently, the dynamics of the contact points between the vessel, the fluid and the dry region are inherently coupled with the surface evolution. We present global-in-time a priori estimates for solutions initially close to equilibrium. Taking advantage of the Neumann problem solved by the velocity potential, the analysis is carried out in non-weighted L^2-based Sobolev spaces and without imposing restrictions on the contact angles.

Hongjie Dong (Brown University)

Title: *On the one-phase Muskat problem*

Abstract: We consider the free boundary problem for a 2D and 3D fluid filtered in porous media, which is known as the one-phase Muskat problem. In the periodic setting, we show that if the initial free boundary is the graph of a periodic Lipschitz function, then there exists a unique global Lipschitz strong solution. The proof of the uniqueness relies on a pointwise C^{1,\alpha} estimate near the boundary for harmonic functions. An extension to the whole space case will also be discussed.

This is based on joint work with Francisco Gancedo (Universidad de Sevilla, Spain) and Huy Q. Nguyen (University of Maryland, USA).

June 24 (Tuesday)

Ping Zhang (Chinese Academy of Sciences)

Title: *A refined estimate of the analyticity radius for 3D Navier-Stokes equations*

Abstract: We study the three dimensional incompressible Navier-Stokes equations with general Sobolev initial data in W^{\gamma, p} for \gamma > -1+3/p and 1<p<\infty. We develop a new framework which allows us to prove that locally in time the analyticity radius of the unique local strong solution enjoys the following refined estimate

$$\mathrm{rad}(u(t)) \geq \sqrt{2\,(\gamma + 1 - 3/p)\,t\,(|\ln t| + \ln|\ln t| + t\,K(t)}$$

for any t \in]0,T_0], where K(t) tends to \infty and t K(t) tends to 0 as t tends to 0^+.

In the case p = 2, this refined estimate in particular settles a decade-long conjecture of Herbst and Skibsted. Moreover this refined estimate continues to hold in the critical scenario \gamma = - 1 + 3 / p and 1<p<\infty.

This is a joint work with Dong Li from University of Hong Kong.

Wojciech Ożański (Florida State University)

Title: *Instantaneous continuous loss of regularity for the SQG equation*

Abstract: The issue of loss of regularity of unique solutions to the 3D incompressible Euler equations is an important open question of fluid mechanics, and is closely related to the emergence of turbulence. We will discuss recent results regarding loss of regularity of solutions of the 2D and 3D Euler equations, and of the surface quasi-geostrophic equations (SQG), which is a well-established 2D model equation of the 3D Euler equations. We will discuss a result of continuous-in-time loss of Sobolev regularity of solutions to the SQG equation. Namely, given $s\in (3/2,2)$ and $\varepsilon>0$, we will describe a construction of a compactly supported initial data θ_0 such that $\| \theta_0 \|_{H^s}\leq \varepsilon$ and there exist $T>0$, $c>0$ and a local-in-time solution θ of the SQG equation such that $\theta(\cdot,t)$ belongs to ${H^{s/(1+ct)}}$ and does not belong to any other H^β, where $\beta > s/(1+ct)$. Moreover θ is continuous and differentiable on $\R^2\times [0,T]$, and is unique among all solutions with initial condition \theta_0$ which belong to $C([0,T];H^{1+\alpha})$ for any $\alpha>0$.

This is the first result of this kind in incompressible fluid mechanics. It is also the first ill-posedness result in the supercritical regime which has compact support in space.

Kyudong Choi (Ulsan National Institute of Science and Technology)

Title: *Existence and stability of a Sadovskii dipole as a maximizer of kinetic energy*

Abstract: The Sadovskii vortex patch is a traveling wave for the two-dimensional incompressible Euler equations consisting of an odd symmetric pair of vortex patches touching the symmetry axis. Its existence was first suggested by numerical computations of Sadovskii in [J. Appl. Math. Mech., 1971], and has gained significant interest due to its relevance in the inviscid limit of planar flows via Prandtl--Batchelor theory and as the asymptotic state for vortex ring dynamics.In this talk, I will sketch a proof of the existence of such a vortex and stability in the class using an energy maximization approach under the exact impulse condition and an upper bound on the circulation. (For reference, a completely different proof of the same existence result with more information via a fixed point method appeared around the same time by Huang and Tong. The uniqueness of such a vortex remains open.) This talk is based on joint work with In-Jee Jeong (SNU), Youngjin Sim (UNIST), and Kwan Woo (SNU).

In-Jee Jeong (Seoul National University)

Title: *Long time dynamics and stability of multi-vortex solution*

Abstract: Classical variational approach of maximizing the kinetic energy with various constraints provides vortex stability in several special cases, but in general this approach fails when the vorticity is concentrated at several points ("multi-vortex") in the fluid domain. This is simply because such configurations are not local kinetic energy maximizers, even when we restrict the admissible class using all the other coercive conserved quantities of fluid motion. In this talk, we present several results on the stability of multi-vortex solutions, obtained by combining the classical variational approach with dynamical bootstrapping schemes. We focus on the case of multiple Lamb dipoles weakly interacting with each other. This is based on joint works with Ken Abe, Kyudong Choi, and Yao Yao.

Chunjing Xie (Shanghai Jiao Tong University)

Title: *Rigidity for steady incompressible Euler system and its applications*

Abstract: When the steady flows are away from stagnation, the associated Euler equations can be locally reduced to a semilinear equation. On the other hand, stagnation of flows is not only an interesting phenomenon in fluid mechanics, but also plays a significant role in understanding many important properties of fluid equations. It also induces many challenging problems in analysis. First, we give a classification of steady

incompressible Euler flows via the set of flow angles. Second, we discuss the senario when the Euler equations can be reduced to a single semilinear equation in terms of stream function. The applications for these classifications will also be addressed.

June 25 (Wednesday)

Sijue Wu (University of Michigan)

Title: *The quartic integrability and long time existence of water waves*

Abstract: It is known since the work of Dyachenko & Zakharov in 1994 that for weakly nonlinear 2d infinite depth water waves, there are no 3-wave interactions and all of the 4-wave interaction coefficients vanish on the non-trivial resonant manifold. In this talk I will present a recent result that proves this partial integrability from a different angle. We construct a sequence of energy functionals $E_j(t)$, directly in the physical space, which are explicit in the Riemann mapping variable and involve material derivatives of order j of the solutions for the 2d water wave equation, so that $\frac d{dt} E_j(t)$ is quintic or higher order. We show that if some scaling invariant norm, and a norm involving one spacial derivative above the scaling of the initial data are of size no more than ϵ, then the lifespan of the solution for the 2d water wave equation is at least of order $O(\epsilon^{-3})$, and the solution remains as regular as the initial data during this time. If only the scaling invariant norm of the data is of size ϵ, then the lifespan of the solution is at least of order $O(\epsilon^{-5/2})$. Our long time existence results do not impose size restrictions on the slope of the initial interface and the magnitude of the initial velocity, they allow the interface to have arbitrary large steepnesses and initial velocities to have arbitrary large magnitudes.

Mimi Dai (University of Illinois at Chicago)

Title: *Onsager type theorem for SQG*

Abstract: We discuss construction of non-trivial weak solutions for SQG which do not conserve the Hamiltonian. Such solutions have the highest possible regularity C^{0-} since solution in C^0 is known to conserve the Hamiltonian. We thus resolve the Onsager type of conjecture for SQG.

June 26 (Thursday)

Diego Córdoba (Instituto de Ciencias Matemáticas, Consejo Superior de Investigaciones Científicas)

Title: *Finite time singularities for incompressible fluids*

Abstract: In this talk, I will review recent progress on the formation of singularities in incompressible fluid equations. The talk is based on work with Luis Martinez-Zoroa, Fan Zheng and Andres Lain-Sanclemente.

Jiajie Chen (New York University)

Title: *Self-similar singularities in fluids and related equations*

Abstract: In this talk, we will discuss recent developments in constructing (nearly) self-similar singularities in the incompressible Euler, compressible Euler, and related equations. Our approach combines computer-assisted construction, weighted energy estimates, compact perturbation methods, and soft functional analysis arguments.

Hao Jia (University of Minnesota)

Title: *Uniform in viscosity depletion and inviscid damping near periodic shear flows*

Abstract: We report a recent result on the asymptotic behavior of solutions to the linearized Navier Stokes equations around a spectrally stable shear flows on a non-square torus. The main result is an essentially sharp description on the inviscid damping of velocity field and depletion of vorticity near the critical points of the background shear flow, uniformly in the limit as viscosity goes to zero. The key difficulty is that the viscosity represents a singular perturbation which changes the spectrum as well as resolvent of the linearized operator completely. We introduce general methods that in principle allow one to have a comprehensive understanding of the linearized operator. Numerical simulations will be given to illustrate the various dynamical behavior that we proved, and to suggest possible further problems.

Emmanuel Grenier (Beijing Institute of Technology)

Title: *Nonlinear instabilities of shear layers*

Abstract: The aim of this talk is to discuss various recent results on the nonlinear instability of shear layers in an half plane, and in particular the onset of unexpected boundary layers

and bifurcations near the marginal stability curves.

Fei Wang (Shanghai Jiao Tong University)

Title: *Asymptotic Stability of Shear Flows Near Couette with Navier Boundary Conditions*

Abstract: We consider the 2D, incompressible Navier-Stokes equations near the Couette flow, $\omega^{(NS)} = 1 + \eps \omega$, set on the channel $\mathbb{T} \times [-1, 1]$, supplemented with Navier boundary conditions on the perturbation, $\omega|_{y = \pm 1} = 0$. We are simultaneously interested in two asymptotic regimes that are classical in hydrodynamic stability: the long time, $t \rightarrow \infty$, stability of background shear flows, and the inviscid limit, $\nu \rightarrow 0$ in the presence of boundaries. Given small ($\eps \ll 1$, but independent of ν) Gevrey 2- datum, $\omega_0^{(\nu)}(x, y)$, that is supported away from the boundaries $y = \pm 1$. This is the first nonlinear asymptotic stability result of its type, which combines three important physical phenomena at the nonlinear level: inviscid damping, enhanced dissipation, and long-time inviscid limit in the presence of boundaries.

June 27 (Friday)

Alexey Cheskidov (Westlake University)

Title: *Energy cascade in fluids: from convex integration to mixing*

Abstract: In the past couple of decades, mathematical fluid dynamics has made significant strides with numerous constructions of solutions to fluid equations that exhibit pathological or wild behaviors. These include the loss of the energy balance, non-uniqueness, singularity formation, and dissipation anomaly. Interesting from the mathematical point of view, providing counterexamples to various well-posedness results in supercritical spaces, such constructions are becoming more and more relevant from the physical point of view as well. Indeed, a fundamental physical property of turbulent flows is the existence of the energy cascade. Conjectured by Kolmogorov, it has been observed both experimentally and numerically, but had been difficult to produce analytically. In this talk I will overview new developments in discovering not only pathological mathematically, but also physically realistic solutions of fluid equations.

Ken Abe (Osaka Metropolitan University)

Title: *MHS equilibria in the small non-resistive limit to the randomly forced resistive*

magnetic relaxation equations

Abstract: We consider randomly forced resistive magnetic relaxation equations (MRE) with a random force on the flat torus for two and three space dimensions. We show the path-wise global well-posedness of the system and the existence of the invariant measures, and construct a random MHS equilibrium as a non-resistive limit of statistically stationary solutions. This talk is based on a joint work with I.J. Jeong (Seoul National University), F. Pasqualotto (UC San Diego), and N. Sato (National Institute for Fusion Science).