

Workshop: Analysis of PDEs in Dalian

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Title and Abstract -- Posters

Sharp Ill-posedness of the Euler Equations in a Lorentz Space

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Abstract We investigate vortex stretching in the 3D axisymmetric Euler equations without swirl to determine the sharpness of Danchin's (2007) endpoint condition; Danchin's result established global existence and uniqueness for bounded vorticity ω_0 when $\omega_0/r \in L^{3,1}(\mathbb{R}^3)$ (together with a decay condition of ω_0 for the existence result). We prove this $L^{3,1}$ endpoint is sharp. By constructing specialized multi-ring initial data where $\omega_0 \in L^\infty(\mathbb{R}^3)$ and $\omega_0/r \in L^{3,q}(\mathbb{R}^3)$ for any Lorentz second exponent $q > 1$, we established norm inflation. Furthermore, extending this construction to data with infinitely many rings within the same $L^{3,q}$ class results in complete non-existence (or instantaneous blow-up) of solutions $\omega \in L^\infty(0, T; L^1 \cap L^\infty(\mathbb{R}^3))$.

Liouville-Arnold Integrability in ℓ^∞ -based Banach Spaces and Application to KdV

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Abstract We give a (local) infinite-dimensional version of the Liouville-Arnold theorem with particular focus on the construction of regular foliations by invariant Lagrangian tori in ℓ^∞ -based Banach spaces. We apply this result to introduce an infinite set of analytic action-angle coordinates for the KdV equation on the circle.

A Critical Value for the Viscosity Coefficient: Triggering Oscillatory Traveling Waves in the Pseudo-parabolic Fisher-KPP Equation

Chen, Haomeng

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Abstract The pseudo - parabolic term u_{xxt} serves as a canonical example of higher - order viscosity that provides effective regularization while capturing the refined physical mechanism. How it alters the dynamics of prototype equations remains a fundamental issue, which is not yet fully understood. The goal of this paper is to show that this term induces a sharp transition in traveling wave structure, via studying the pseudo - parabolic Fisher - KPP equation

$$u_t - \tau u_{xxt} = Du_{xx} + u(1 - u)$$

We completely characterize how the parameter ratio τ/D acts as a critical switch: it preserves the monotonic structure of classical traveling waves when $\tau/D \leq 1$, yet it triggers a qualitative shift to oscillatory traveling waves when $\tau/D > 1$. Numerical simulations support these findings.

The threshold $\tau/D = 1$ thus captures the dual role of the pseudo - parabolic term: it acts as a structure - preserving viscosity when small, but when large it reflects dominant capillary hysteresis, generating the oscillations that explain the saturation overshoot, a phenomenon that contradicts classical diffusion models yet is widely observed in two - phase flow.

Growth Estimates for Axisymmetric Euler Equations without Swirl

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Abstract We investigate the long-time behaviour of vorticity in three-dimensional axisymmetric Euler flows without swirl. Despite similarities with 2D Euler equations and global well-posedness for sufficiently smooth data, several vorticity quantities can still grow in time. In particular, for more general initial data under mild integrability assumptions, we prove a t^2 upper bound for the vorticity radial moment, which in turn yields a $t^{4/3}$ upper bound for the L^∞ norm of the vorticity, matching the growth rate conjectured by Childress (2008). For odd initial data with a sign condition, we also obtain a sublinear-in-time (t^{-1}) lower bound for the radial moment, improving the recent $t^{3/4-}$ lower bound of Gustafson--Miller--Tsai (2023). Moreover, we establish power-law growth of the vorticity in L^p norms, indicating that, in the time-integrated sense, nearly all vorticity escapes to infinity. This is joint work with Yao Yao.

Nonlinear Schrödinger Equations with Large Initial Data

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Abstract We study the Nonlinear Schrödinger equation

$$i\partial_t u = -\partial_x^2 u \pm |u|^2, \quad (t, x) \in \mathbb{R} \times \mathbb{R}$$

with initial data that are neither periodic nor localized. In particular, we are interested in initial data of the form $u_0 \in H^s(\mathbb{R}) + H^r(\mathbb{T})$ for $r \geq s \geq 0$ which has no decay for $x \rightarrow \infty$, but is also not periodic in x . In this setting, standard arguments like Strichartz estimates cannot be applied directly. To show local well-posedness results, we use the theory of Young-PDEs. This approach, which originally comes from the theory of controlled rough paths, was introduced by Chouk and Gubinelli in [1].

A second topic concerns the stability of special periodic solutions of the NLS, namely cnoidal waves. Using modified conserved quantities, we can show an orbital stability result of these periodic waves against localized perturbations.

Global Nonlinear Stability of Vortex Sheets for the Navier-Stokes Equations with Large Data

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Abstract: We will discuss several recent results of the inhomogeneous Euler equation from a Lagrangian viewpoint. We start with the Lagrangian formulation of inhomogeneous Euler, motivated by a geometric variational principle, then we establish a novel vorticity formulation based on the geometric formalism. Using our vorticity formulation and Lagrangian formulation, we obtain several analytical results of inhomogeneous Euler, including lifespan estimate, Beale Kato Majda type criteria and Lagrangian analyticity.

Quantitative Stability of Laplacian Eigenstates for the 2D Euler Equation in a Disk or Hexagonal Torus

Wang, Fatao

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Abstract Quantitative stability refers to the quantification of the deviation of solutions from a given state in terms of the initial perturbation. We establish quantitative stability estimates for a class of explicit steady Euler flows in a disk or hexagonal Torus. The proof is divided into two steps.

First, we establish the quantitative stability of some Laplacian eigenstates by two Poincare-type inequalities and two conserved quantities (the kinetic energy and enstrophy), reducing the problem to estimates within the Laplacian eigenstates.

Second, we perform specific estimates based on appropriate conserved quantities of the Euler equations: in the disk, we utilize the enstrophy and the moment of impulse; in the hexagonal torus, we employ the enstrophy and several higher-order Casimir invariants. The main difficulty in Step 2 is that degeneracy may appear in applying the inverse function theorem. Our results seem to suggest that greater symmetry leads to weaker stability.

A Revisit of Patch Solutions for the 2D loglog -Euler Type Equation

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Abstract In this paper, we revisit the patch solutions for a class of inviscid whole-space active scalar equations that interpolate between the 2D Euler equation and the α -SQG equation. Compared with the 2D Euler equation in vorticity form, there is an additional Fourier multiplier $m(\Lambda)$ ($\Lambda = -\Delta^{1/2}$) in the Biot-Savart law. If the symbol m satisfies the Osgood-type condition

$$\int_2^\infty \frac{1}{r(\log r)m(r)} dr = +\infty$$

and certain mild assumptions, the system is referred to as the 2D loglog -Euler type equation.

First, we prove a Yudovich-type theorem establishing the existence and uniqueness of a global weak solution for the loglog -Euler type equation associated with bounded and integrable initial data. This result directly applies to patch solutions, which are weak solutions corresponding to patch initial data given by characteristic functions of disjoint, regular, bounded domains.

Next, we revisit the seminal result by Elgindi [41] and provide a different proof under explicit assumptions on m , showing that for the 2D loglog -Euler type equation with $C^{1,\mu}$, ($0 < \mu < 1$) single-patch initial data, the evolved patch boundary globally preserves the $C^{1,\mu-\varepsilon}$ regularity for any $\varepsilon \in (0, \mu)$. In contrast to the frequency-space argument in [41], we develop an entirely physicalspace-based approach that avoids the Littlewood-Paley theory and offers advantages for potential extensions to the half-plane or bounded smooth domains.

Furthermore, we investigate the global propagation of higher-order $C^{n,\mu}$ boundary regularity for patch solutions with any $n \in \mathbb{N}^*$, and analyze the evolution of multiple patches.

Local Invariant Structures in the Dynamics of Capillary Water Jet

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Abstract The instability of the water jet system under long-wave perturbation—the Rayleigh-Plateau instability—has been observed and studied in experimental and theoretical physics since the 19th century. This presentation provides a rigorous mathematical justification for this phenomenon. We consider the water jet system, modeled by the incompressible irrotational Euler equation with surface tension, and construct the stable/unstable manifolds and a center invariant set around the zero solution. The core of our method involves a reduction based on paradifferential calculus and the main result follows from a Lyapunov-Perron type argument. This result is one of the first justifications of (local) hyperbolic structure for quasilinear PDEs with or without spectral gap, offering a novel method potentially applicable to other quasilinear equations. This is a joint work with Chengyang Shao.

Global Well-posedness and Scattering of Energy-critical Defocusing Nonlinear Schrödinger Equation on Hyperbolic Spaces

Zhang, Shunqin

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Abstract We will prove global well-posedness and scattering in for the energy-critical defocusing nonlinear Schrödinger equation

$$\begin{aligned}i\partial_t u + \Delta u &= |u|^{\frac{4}{d-2}}u \\ u(0) &= u_0\end{aligned}$$

on hyperbolic space $H^d (d \geq 4)$.

We mainly utilize the concentration-compactness/rigidity method and Morawetz inequality. We establish a linear profile decomposition on high dimensional hyperbolic spaces and prove that the nonlinear profile on hyperbolic spaces can be approximated by the solutions of the energy-critical defocusing nonlinear Schrödinger equation on Euclidean spaces, then obtaining the global well-posedness and scattering for the energy-critical defocusing nonlinear Schrödinger equation on the hyperbolic space. This work joint with Zheng Yunrui (Shandong University).

Superlinear Gradient Growth for 2D Euler Equation without Boundary

Zhou, Tao

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Abstract We consider the vorticity gradient growth of solutions to the two-dimensional Euler equations in domains without boundary, namely in the torus \mathbb{T}^2 and the whole plane \mathbb{R}^2 . In the torus, whenever we have a steady state ω^* that is orbitally stable up to a translation and has a saddle point, we construct $\tilde{\omega}_0 \in C^\infty(\mathbb{T}^2)$ that is arbitrarily close to ω^* in L^2 , such that superlinear growth of the vorticity gradient occurs for an open set of smooth initial data around $\tilde{\omega}_0$. This seems to be the first superlinear growth result which holds for an open set of smooth initial data (and does not require any symmetry assumptions on the initial vorticity). Furthermore, we obtain the first superlinear growth result for smooth and compactly supported vorticity in the plane, using perturbations of the Lamb—Chaplygin dipole.

Partially Dissipative Hyperbolic Systems with Time-dependent Damping

Zhu, Qimeng

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Abstract We consider quasilinear partially dissipative hyperbolic systems with time-dependent damping in the whole space \mathbb{R}^d , with $d \geq 1$.

Using an approach similar to that developed by Crin-Barat and Danchin, we establish the global existence of small-amplitude solutions for systems endowed with a

damping term of the form $-\frac{Kz}{(1+t)^\alpha}$, $0 < \alpha < 1$.

We assume that the linearized system satisfies the Shizuta–Kawashima (SK) condition, which ensures that the dissipation acts on all characteristic components through coupling.

The key idea is to construct a Lyapunov-type functional that compensates for the lack of full dissipation. Such a functional was first introduced by Beauchard and Zuazua in the framework of control theory.

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