数学科学学院
School of Mathematical Sciences,ECNU

“AI时代数学进展”数学科学论坛

程　序　册

2025年3月14日—16日

华东师范大学数学科学学院

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“AI时代数学进展”数学科学论坛

在华东师大数学科学学院成立七周年之际，由张伟平院士和江松院士联合组织的“AI 时代数学进展”数学科学论坛于 2025 年 3 月 14 日—16 日在华东师范大学闵行校区数学楼举办。本次论坛立足人工智能时代发展，聚焦数学科学前沿探索与学科交叉创新，重点围绕数学核心领域，搭建深度对话平台，推动数学理论与应用研究的协同发展。本次论坛由数学与工程应用教育部重点实验室、上海市核心数学与实践重点实验室、华东师范大学几何与代数基础科学研究中心资助。

一、 会议时间：

2025年3月14日-16日

二、 会议地点：

上海市闵行区东川路500号 华东师范大学数学楼102报告厅

三、 特邀专家（按姓氏字母顺序）

陈兵龙	教授	中山大学
陈增敬	教授	山东大学
邓伟华	教授	兰州大学
杜　洁	教授	华东师范大学
郭少明	教授	南开大学
何旭华	教授	香港大学
黄　文	教授	中国科学技术大学
黄云清	教授	湘潭大学
金　石	教授	上海交通大学
李鹏辉	教授	清华大学
林芳华	教授	纽约大学
刘　钢	教授	华东师范大学
刘若川	教授	北京大学
楼　元	教授	上海交通大学

吕克宁	教授	四川大学
吕　鑫	教授	华东师范大学
麻小南	教授	南开大学
戚　鲁	教授	华东师范大学
乔中华	教授	香港理工大学
秦厚荣	教授	南京大学
屈长征	教授	宁波大学
沈维孝	院士	复旦大学
孙　剑	教授	西安交通大学
孙树瑜	教授	同济大学
孙　崧	教授	浙江大学
席南华	院士	中国科学院
熊金钢	教授	北京师范大学
杨志坚	教授	武汉大学
袁亚湘	院士	中国科学院
赵会江	教授	武汉大学
张　平	院士	中国科学院

四、 主办单位：

华东师范大学数学科学学院

五、会议主席

张伟平	院士	南开大学
江　松	院士	北京应用物理与计算数学研究所

六、组织委员会

吕长虹，罗　栗，郑海标，张红艳，刘欣雨，曹思圆

会议日程

2025 年 3 月 14 日 周五		
时间	会议内容	主持人
8:30-9:00	**开幕式**	吕长虹
大会报告		主持人： 张伟平
9:00-9:40	沈维孝：一致扩张映射上遍历优化问题的研究	
9:40-10:20	何旭华：机器学习辅助下的仿射Deligne-Lusztig簇研究	
10:20-10:40	茶 歇	
大会报告		主持人：袁亚湘
10:40-11:20	林芳华：Pure vs Applied Mathematics	
11:20-12:00	刘若川：数学形式化与自动定理证明	
午餐 时间：12:00 – 14:30 地点：紫竹万怡酒店		
大会报告		主持人：林芳华
14:30-15:10	吕克宁：Turbulence, Lyapunov exponents, and SRB measures in infinite-dimensional dynamical systems	
15:10-15:50	麻小南：Comparison of two equivariant eta forms	
15:50-16:30	屈长征：Integrability and Dynamical Behavior of Solutions to Nonlinear Dispersive Equations	
16:30-16:50	茶 歇	
大会报告		主持人：黄云清
16:50-17:30	孙树瑜：Robust and Efficient Schemes for Porous Media Flow using Dissipation Principles and Deep Learning	
17:30-18:10	刘 钢：Complete Kähler manifolds with nonnegative Ricci curvature	
晚餐 时间：18:30 – 20:00 地点：教师之家		

2025 年 3 月 14 日 15：00 周五		
科普报告		
华二紫竹音乐厅	袁亚湘： 数学、艺术与创造力	主持人：吕长虹
数学楼 401	席南华： 朗兰兹纲领寻根之旅	主持人：罗　栗
一教 214	秦厚荣： 数学与人类文明的演进	主持人：程　涛

2025 年 3 月 15 日 周六	
大会报告	主持人：赵会江
8:30-9:10	张　平：On the global stability of large Fourier mode for 3-D anisotropic Navier-Stokes equations
9:10-9:50	陈增敬：非线性中心极限定理及其应用
9:50-10:30	乔中华：Sidecar: A structure-preserving framework for solving PDEs with neural networks
10:30-10:50	茶 歇
大会报告	主持人：陈兵龙
10:50-11:30	黄　文：Mean Complexity and Sarnak Conjecture
11:30-12:10	熊金钢：Lojasiewicz inequalities near bubbles and an application
午餐　时间：12:20 – 14:30　地点：紫竹万怡酒店	
大会报告	主持人：何旭华
14:30-15:10	李鹏辉：Geometric representation of the Hecke categories
15:10-15:50	孙　崧：Geometry of gravitational instantons
15:50-16:30	吕　鑫：Lower bounds of the volume of a foliated surface of general type
16:30-16:50	茶 歇
大会报告	主持人：麻小南
16:50-17:30	郭少明：流形上的 Kakeya 问题
17:30-18:10	戚　鲁：Stable degeneration of Fano fibrations
晚餐　时间：18:30 – 20:00　地点：教师之家	

2025 年 3 月 16 日 周日	
大会报告	主持人：江　松
8:40-9:20	金　石：基于“薛定谔化”的偏微分方程的量子算法
9:20-10:00	杨志坚：高精度地图制作中的数学问题
10:00-10:20	茶 歇
大会报告	主持人：楼　元
10:20-11:00	邓伟华：Multiscale Modelling and Simulation for Anomalous and Nonergodic Dynamics: From Statistics to Mathematics
11:00-11:40	孙　剑：生成式人工智能数学基础及其应用
11:40-12:20	杜　洁：High order bound preserving methods for compressible multispecies flow with chemical reactions
午餐　时间：12:30 – 14:00　地点：教师之家	

非线性中心极限定理及其应用

陈增敬
(山东大学)

自从 De Moivre (1733)、 Gauss（1809）和 Laplace（1810）最早发现正态分布以来，中心极限定理作为概率统计中的“核心” 定理得到广泛的应用和推广。一批数学家在Kolmogorov公理体系下，证明了独立同分布（IID）随机变量服从正态分布。因此，正态分布在概率统计享有着“中心”地位。然而，经济界的三大经济悖论：诺奖得主 Allias 提出Allias 悖论（1953）、经济学家 Ellsberg 提出的著名 Ellsberg 悖论 (1961)和 诺奖得主 Prescott发现的股票溢价之谜 (1985)显示了经济界的很多现象不符合Kolmogorov公理体系和IID的假设。数学和经济界已经认识到：在Kolmogorov公理体系中，假设概率空间只有一个概率测度Kolmogorov公理体系是产生经济悖论的主要原因。如何在多概率测度条件下发展概率统计是发展Kolmogorov公理体系重要研究问题之一。在这次报告中，我们主要介绍在多概率测度和非IID条件下的非线性中心极限定理及其在金融、统计和机器学习中的应用。我们的研究结果显示：在多概率测度下，经典的正态分布不再占有“中心”地位了。

Multiscale Modelling and Simulation for Anomalous and Nonergodic Dynamics: From Statistics to Mathematics

邓伟华
(兰州大学)

In recent decades, anomalous and nonergodic dynamics are topical issues in almost all disciplines. In 2004, the phrase " anomalous is normal" was used in a title of a PRL paper, which reveals that the diffusion of classical particles on a solid surface has rich anomalous behavior controlled by the friction coefficient, meaning that anomalous dynamics phenomena are ubiquitous in the natural world. This talk first introduces the dynamics from a physical and atomistic way, by considering the random walk of the diffusing particles, then derives the partial differential equations with integral-differential operators governing the PDFs of the various statistical observables. Finally, we discuss the (traditional and deep learning based) numerical methods for the newly build PDEs.

High order bound preserving methods for compressible multi-species flow with chemical reactions

杜洁
（华东师范大学）

In this talk, we consider bound preserving problems for multispecies and multireaction chemical reactive flows. In this problem, the density and pressure are nonnegative, and the mass fraction should be between 0 and 1. The mass fraction does not satisfy a maximum principle and

hence it is not easy to preserve the upper bound 1. Also, most of the bound-preserving techniques available are based on Euler forward time integration. Therefore, for problems with stiff source, the time step will be significantly limited. Some previous ODE solvers for stiff problems cannot preserve the total mass and the positivity of the numerical approximations at the same time. In this work, we will construct third order conservative bound-preserving methods to overcome all these difficulties. Moreover, we will discuss how to control numerical oscillations.

流形上的Kakeya问题

郭少明
（南开大学）

我们会讨论调和分析中的Kakeya问题以及它的几个推广， 尤其是在一般黎曼流形及更一般几何上的推广。

机器学习辅助下的仿射Deligne-Lusztig簇研究

何旭华
（香港大学）

仿射Deligne-Lusztig簇(ADLV)是算术几何的重要研究对象，在志村簇和朗兰兹纲领中扮演重要角色。我们与北京大学董斌教授的研究团队合作开展了机器学习辅助框架用于ADLV相关的基础问题的研究。在本次报告中，我们将讨论如何使用机器学习工具来生成数据集、训练模型并分析数据，以便发现ADLV的几何性质。我们还将强调数据生成过程的重要性，包括如何选择有意义的子集和适当的特征集。

Mean Complexity and Sarnak Conjecture

黄文
（中国科学技术大学）

In this talk, we will review the mean complexity and the progress related to the Sarnak conjecture. In particular, we will discuss the logarithmic Sarnak conjecture and its equivalent forms, as well as our characterization by the ploynomial mean complexity.

基于“薛定谔化”的偏微分方程的量子算法

金石
（上海交通大学）

Quantum computers have the potential to gain algebraic and even up to exponential speed up compared with its classical counterparts, and can lead to technology revolution in the 21st century. Since quantum computers are designed based on quantum mechanics principle, they are most suitable to solve the Schrodinger equation, and linear PDEs (and ODEs) evolved by unitary operators. The most efficient quantum PDE solver is quantum simulation based on solving the Schrodinger equation. It will be interesting to explore what other problems in scientific computing, such as ODEs, PDEs, and linear algebra that arise in both classical and quantum systems, can be handled by quantum simulation. We provide a novel and generic method, called "Schrodingerization", that maps, in one-higher dimension, any linear ODEs and PDEs to Schrodinger type PDEs with unitary evolution. This allows quantum simulation for general linear PDEs and ODEs, in both continuous varialble (qumodes) and qubits based frameworks, the former suitable for analog quantum computing. We will also present other dimension lifting techniques that transfer nonlinear PDEs to linear ones, and and non-autonomous PDEs and ODEs with time-dependent coefficients to autonomous ones.

Geometric representation of the Hecke categories

李鹏辉
（清华大学）

Hecke categories are the geometrization/categorification of Hecke algebras and play a key role in geometric representation theory. We shall survey some recent progress regarding Hecke categories and their applications in related fields such as number theory, combinatorics, Lie theory, and topology. Part of this talk is based on joint work with Quoc P. Ho, David Nadler, and Zhiwei Yun.

Pure vs Applied Mathematics

林芳华
（纽约大学）

What is Math and what is Applied Math really, particularly in the age of AI? Should we think/worry about the future of our profession/education? Let’s talk about it.

Complete Kahler manifolds with nonnegative Ricci curvature

刘钢
（华东师范大学）

We discuss some recent results on complete Kahler manifolds with nonnegative Ricci curvature, including the existence of limit of scalar curvature integral, rigidity of Ricci flat metrics, as well as algebraic compactification.

数学形式化与自动定理证明

刘若川
（北京大学）

报告主要介绍当前数学形式化与自动定理证明的发展状况。

Turbulence, Lyapunov exponents, and SRB measures in infinite-dimensional dynamical systems

吕克宁
（四川大学）

In this talk, I will present several results related to Lyapunov exponents, SRB measures, entropy, and horseshoes in the context of infinite-dimensional dynamical systems. I will also discuss recent work on the ergodicity and statistical dynamics of the 2D Navier-Stokes equation, driven by both time-dependent deterministic and stochastic forces. Additionally, I will explore the connection between SRB measures and turbulence.

Lower bounds of the volume of a foliated surface of general type

吕鑫
（华东师范大学）

We prove two types of inequalities for a foliation of general type on a smooth projective surface, the slope inequality and Noether inequality, both of which provide lower bounds on the volume $\mathrm{vol}(\mathcal F)$. In order to define the slope, we first introduce three birational non-negative invariants $c_1^2(\mathcal F)$, $c_2(\mathcal F)$ and $\chi(\mathcal F)$ for any foliation $\sF$, called the Chern numbers. If the foliation $\mathcal F$ is not of general type, the first Chern number $c_1^2(\mathcal F)=0$, and $c_2(\mathcal F)=\chi(\mathcal F)=0$ except when $\mathcal F$ is induced by a non-isotrivial fibration of genus $g=1$. If $\mathcal F$ is of general type, we obtain a slope inequality when $\mathcal F$ is algebraically integrable, which gives a lower bound on $\mathrm{vol}(\mathcal F)$ by $\chi(\mathcal F)$. On the other hand, we also prove three sharp Noether type inequalities for a foliation of general type, which provides a lower bound on $\mathrm{vol}(\mathcal F)$ by the geometric genus $p_g(\mathcal F)$. As applications, we also give partial solutions to the Poincar\'e and Painlev\'e problems using these two inequalities. This is a joint work with Professor S.L. Tan.

Comparison of two equivariant eta forms

麻小南
（南开大学）

In 2000, Goette compared two equivariant eta invariants in the sense of formal power series when the group action is locally free. Thus he got the the singular behavior of the equivariant eta invariant near the identity element. In this talk, we explain the general comparison formula for two equivariant eta invariants (forms) by a local computable formula. This is a joint work with Bo Liu, and this result is used in our work on the localization formula of the equivariant eta invariants.

Stable degeneration of Fano fibrations

戚鲁
（华东师范大学）

Fano fibrations can be viewed as an interpolation between Fano varieties and klt singularities, for which divisorial contractions and flipping contractions provide more examples.

In this talk, we will talk about the stable degeneration for Fano fibration germs, recently conjectured by Sun-Zhang. If time permits, we will also discuss some boundedness results for Fano fibrations with applications in the minimal model program.

Based on a series of ongoing work joint with Jingjun Han, Jiyuan Han, Minghao Miao, Linsheng Wang, Tong Zhang and Ziquan Zhuang.

Sidecar: A structure-preserving framework for solving PDEs with neural networks

乔中华
（香港理工大学）

Neural network (NN) solvers for partial differential equations (PDE) have been widely used in simulating complex systems in various scientific and engineering fields. However, most existing NN solvers mainly focus on satisfying the given PDEs, without explicitly considering intrinsic physical properties such as mass conservation or energy dissipation. This limitation can result in unstable or nonphysical solutions, particularly in long-term simulations. To address this issue, we propose Sidecar, a novel framework that enhances the accuracy and physical consistency of existing NN solvers by incorporating structure-preserving knowledge. This framework builds upon our previously proposed TDSR-ETD method for solving gradient flow problems, which satisfies discrete analogues of the energy-dissipation laws by introducing a time-dependent spectral renormalization (TDSR) factor. Inspired by this approach, our Sidecar framework parameterizes the TDSR factor using a small copilot network, which is trained to guide the existing NN solver in preserving physical structure. This design allows flexible integration of the structure-preserving knowledge into various NN solvers and can be easily extended to different types of PDEs. Our experimental results on a set of benchmark PDEs demonstrate that it improves the existing neural network solvers in terms of accuracy and consistency with structure-preserving properties.

数学与人类文明的演进：从公理体系到智能时代的思维范式

秦厚荣
（南京大学）

本报告以文明演进史为经，以数学发展为纬，通过梳理几次工业革命中数学起到的关键作用，揭示抽象数学体系如何转化为改造世界的原动力：牛顿力学背后的微积分革命催生机械化浪潮，电磁方程奠基电气化文明，算法理论则铺就数字化社会的基石。报告特别聚焦欧几里得《几何原本》的范式革命，剖析其公理体系在古希腊的诞生如何重塑人类认知结构。报告将介绍《几何原本》汉译本的产生及其深远影响。

Integrability and Dynamical Behavior of Solutions to Nonlinear Dispersive Equations

屈长征
（宁波大学）

Integrable systems including well-known Schrodinger and KdV equations, which admit various interesting properties. One of them is the existence of solitons. Various e ective methods have been applied to study dynamical behavior and stability of solitons of integrable systems. Importantly, integrability properties play key roles in dynamical behavior and stability of solitons. In this talk, we shall present a survey on the issue how integrabilities be utilized in investigating dynamical behavior and stability of solitons and other kinds of solutions. Some open questions related to this talk will be addressed.

生成式人工智能数学基础及其应用

孙剑
（西安交通大学）

生成式人工智能是当前通用人工智能发展的重要方向，主要通过设计人工智能算法实现对多模态、高维复杂样本分布的学习与新样本的生成，是当前人工智能用于自动问答、跨模态生成、AI for science等问题的方法基础。生成式人工智能的底层基础是数学与统计学，本报告主要介绍生成式人工智能的背景、数学／统计学原理以及面临的挑战，进一步介绍以最优传输作为基础来构建可控／条件生成的人工智能方法，并应用于医学影像生成、多模态图像文本对齐等问题，最终总结与展望生成式人工智能的发展与前景。

Robust and Efficient Schemes for Porous Media Flow using Dissipation Principles and Deep Learning

孙树瑜
（同济大学）

Porous media flow involving multiple phases and multiple components is central to a wide range of natural and industrial processes, including geologic carbon sequestration, enhanced oil recovery, and water infiltration into soil. In this talk, we report our work in robust and efficient numerical algorithms for porous media flow at Darcy’s scale and at the pore scale. For the Darcy-scale flow, we outline our phase-wise and component-wise conservative and energy-stable semi-implicit numerical algorithms, together with deep learning for robust phase behavior calculations. For the pore-scale flow, we present a novel, efficient, unconditionally energy-stable and structure-preserving Smoothed Particle Hydrodynamics (SPH) method for the two-phase flow modeled by the Navier‐Stokes‐Cahn‐Hilliard (NSCH) system of equations.

Geometry of gravitational instantons

孙崧
（浙江大学）

A gravitational instanton is a complete 4 dimensional Riemannian manifold with vanishing Ricci tensor and suitable curvature decay at infinity. This notion was first introduced by Hawking to study Euclidean quantum gravity and has been extensively studied in mathematics and physics for several decades. There are a variety of constructions of gravitational instantons, generating rich geometry and analysis on this topic. In the past decade substantial progress has been made to the classification problem, with interesting connections to special holonomy and complex geometry. In this talk I will explain some results and open questions in this area.

朗兰兹纲领寻根之旅

席南华
（中国科学院）

朗兰兹纲领是极其重要的研究前沿课题。本报告可以看做是朗兰兹纲领的一个寻根之旅。报告从我们日常生活描述时间的数字背后的算术开始，讲述朗兰兹纲领的一些基本想法，目前的一些成就，还有未解决的问题。

Lojasiewicz inequalities near bubbles and an application

熊金钢
（北京师范大学）

In this talk, we establish a Lojasiewicz-type inequality for the Yamabe functional on a bounded domain near bubbles instead of real critical points. This result, combined with our previous work, allows us to prove the dichotomy property of the Yamabe flow on a bounded domain: it either converges uniformly to a non-trivial stable solution or, if it weakly converges to zero with a fixed number of bubbles in the solution, it presents a so-called Soliton resolution theorem. This work is based on the collaboration with Ning Zhou and Tianling Jin.

高精度地图制作中的数学问题

杨志坚
（武汉大学）

高精度地图也称自动驾驶地图、高分辨率地图，是和普通导航电子地图相对而言的服务于自动驾驶系统的专题地图。普通地图一般采用传统测绘方式进行采集和制作，而高精度地图则往往采用传统测绘与人工智能结合的方式。我将通过实例介绍高精度地图制作中的数学与人工智能问题、对应的解决方案，并解释数学在其中的关键作用。

数学、艺术与创造力

袁亚湘
（中国科学院）

本科普报告介绍数学、艺术以及创造力三者的关系。

On the global stability of large Fourier mode for 3-D anisotropic Navier-Stokes equations

张平
（中国科学院）

In this talk, we shall establish the global existence and stability of solutions to 3-D anisotropic Navier-Stokes equations in an infinite cylindrical domain with large Fourier mode initial data. In particular, for the classical 3-D Navier-Stokes equations, the functional, which we construct in this paper, can be used to improve the polynomial decay in k for the Fourier coefficients of the solution constructed in \cite{LZ6} to be exponential decay in k here.


EAST CHINA NORMAL UNIVERSITY
華東師範大學