

Workshop on high-accuracy and structure-preserving numerical methods and theory

April 26, 2026 – May 1, 2026

**Tianyuan Mathematical Research Center
Yunnan, China**

Organizers (alphabetical order by last name):

Yong Liu (Chinese Academy of Sciences, China)

Yan Xu (University of Science and Technology of China, China)

Quan Zhao (University of Science and Technology of China, China)

会议日程概览 (Schedule Overview)

	04.27	04.28	04.29	04.30	05.01
09:00-09:40	汤华中	谢资清	张庆海	钱铁铮	自由讨论
09:40-10:20	芮洪兴	陈黄鑫	谢小平	邱建贤	
休息(Break)					
10:50-11:30	苏春梅	吴开亮	郭瑞晗	许现民	自由讨论
11:30-12:10	李逸飞	赵泉	刘水根	陈刚	
午餐(Lunch)					
14:30-15:10	王汉权	杜洁	自由讨论	14:00-14:40 蔡勇勇	自由讨论
15:10-15:50	魏朝桢	赵蒙		14:40-15:20 卢金洋	
休息(Break)					
16:20-17:00	付培	自由讨论	自由讨论	自由讨论	自由讨论
17:00-17:40	张茜				

会议日程 (Conference Schedule)

2026.04.27 星期一 (Monday)			
08:50-09:00	欢迎致辞(Welcome Speech)		
时间 (time)	报告人 (Speaker)	题目(Title of talk)	主持人 (Chair)
09:00-09:40	Huazhong Tang	A high-order bound-preserving active flux method on adaptive moving meshes	Yan Xu
09:40-10:20	Hongxing Rui	Pressure-robust and conservative finite element methods for Stokes and coupled Stokes-Darcy problems	
10:20-10:50	休息(Break)		
10:50-11:30	Chunmei Su	Temporal high-order structure-preserving parametric finite element methods for curvature flows	Quan Zhao
11:30-12:10	Yifei Li	Convergence of finite elements for a bulk-surface coupled free boundary problem	
12:10-14:30	午餐(Lunch)		
14:30-15:10	Hanquan Wang	An asymptotic preserving method for the weakly nonlinear Klein-Gordon equation	Qian Zhang
15:10-15:50	Chaozhen Wei	A JKO approach for gradient flows	
15:50-16:20	休息(Break)		
16:20-17:00	Pei Fu	High order structure preserving cut discontinuous Galerkin method for hyperbolic conservation laws in higher dimensions	Chaozhen Wei
17:00-17:40	Qian Zhang	Discontinuous Galerkin methods for the Ostrovsky–Hunter type equations	
17:40-19:00	晚餐(Dinner)		

2026.04.28 星期二 (Tuesday)

时间 (time)	报告人 (Speaker)	题目(Title of talk)	主持人 (Chair)
09:00-09:40	Ziqing Xie	Second-order flows for variational minimization via several discretization strategies	Hongxing Rui
09:40-10:20	Huangxin Chen	Physics-preserving numerical methods for compressible gas flow in poroelastic media	
10:20-10:50	休息 (Break)		
10:50-11:30	Kailiang Wu	Geometric quasi-linearization (GQL) and structure-preserving analysis: From a general framework to unveiling algebraic-differential relations in MHD	Qinghai Zhang
11:30-12:10	Quan Zhao	Stable fully discrete parametric finite element methods for Willmore flow with applications	
12:10-14:30	午餐(Lunch)		
14:30-15:10	Jie Du	Well-balanced positivity-preserving high-order discontinuous Galerkin methods for Euler equations with gravitation	Pei Fu
15:10-15:50	Meng Zhao	Dynamics of Hele-Shaw flow in Multi-connected Regions	
15:50-16:20	休息(Break)		
16:20-17:40	自由讨论 (Free discussion)		
17:40-19:00	晚餐(Dinner)		

2026.04.29 星期三 (Wednesday)

时间 (time)	报告人 (Speaker)	题目(Title of talk)	主持人 (Chair)
09:00-09:40	Qinghai Zhang	Fourth-order, optimal-complexity, and structure-preserving numerical solutions of PDEs on irregular and moving domains with arbitrary topology and geometry	Ruihan Guo
09:40-10:20	Xiaoping Xie	A globally divergence-free HDG method for the Smagorinsky model	
10:20-10:50	休息 (Break)		
10:50-11:30	Ruihan Guo	Thermodynamically consistent modeling and energy-stable LDG schemes for semi-permeable interface flows	Meng Zhao
11:30-12:10	Shuigen Liu	Exploiting locality structure in high-dimensional diffusion models	
12:10-14:30	午餐(Lunch)		
14:30-17:40	自由讨论 (Free discussion)		
17:40-19:00	晚餐(Dinner)		

2026.04.30 星期四 (Thursday)

时间 (time)	报告人 (Speaker)	题目(Title of talk)	主持人 (Chair)
09:00-09:40	Tiezheng Qian	Dynamic flow structures in active viscoelastic liquids: modeling and simulation	Xianmin Xu
09:40-10:20	Jianxian Qiu	Provably convergent Newton-Raphson method: theoretically robust recovery of primitive variables in relativistic MHD	
10:20-10:50	休息(Break)		
10:50-11:30	Xianmin Xu	Structure preserving numerical schemes for dissipative systems by the Onsager principle	Yifei Li
11:30-12:10	Gang Chen	An incremental SVD method for non-Fickian flows in porous media: addressing storage and computational challenges	
12:10-14:00	午餐(Lunch)		
14:00-14:40	Yongyong Cai	Improved error bounds of time-splitting Hermite spectral method for the highly-oscillatory Gross-Pitaevskii equation	Gang Chen
14:40-15:20	Jinyang Lu	A coupled high-order continuous and discontinuous Galerkin finite element scheme for the Davey-Stewartson system	
15:20-15:50	休息(Break)		
15:50-17:40	自由讨论 (Free Discussion)		
17:40-19:00	晚餐(Dinner)		

Attachment: Report information (Sort in order of presentation time)

A high-order bound-preserving active flux method on adaptive moving meshes

Huazhong Tang, Peking University

Abstract: The active flux (AF) method is a compact high-order finite volume method that simultaneously evolves cell averages and point values at cell interfaces. This talk will introduce a high-order bound-preserving active flux method on adaptive moving meshes for hyperbolic conservation laws, based on the active flux method with FVS for point value updates [Duan et al, SISC 2025]. A key is the careful discretization of mesh motion metrics, which is designed to ensure the exact preservation of free-stream states on dynamically evolving grids. Mesh adaptation is driven by the iterative solution of the Euler-Lagrange equations associated with a mesh adaptation functional. Furthermore, a general BP framework is adeptly extended to the context of adaptive moving meshes. The strategy, which combines the high-order AF scheme with a first-order Lax-Friedrichs scheme in a convex manner and incorporates an artificial viscosity to maintain the positivity of the mesh transformation Jacobians, ensures the numerical solutions remain within the physically admissible set. It is rigorously proven that the resulting method, under a suitable CFL condition, satisfies the maximum principle for scalar conservation laws and preserves the positivity of density and pressure for the compressible Euler equations. The accuracy, efficiency, and robustness of the proposed scheme are validated through numerical experiments, demonstrating its superior performance compared to computations on uniform static meshes. It is a joint work with Mr. Yixiao Tang.

Pressure-robust and conservative finite element methods for Stokes and coupled Stokes-Darcy problems

Hongxing Rui, Shandong University

Abstract: In this talk, we first propose a divergence free discretization method for the Stokes equations based on $P_1 \oplus RT_0 - P_0$ on general simplicial meshes in 2D/3D, which yields an divergence-free and pressure independent velocity approximation with optimal order. The global number of the degrees of freedom is the same as the low order Bernardi-Raugel element. Then we present a pressure-robust and conservative mixed element method for the coupled Stokes-Darcy problems using $P_1 \oplus RT_0$ and RT_0 elements for velocity on Stokes and Darcy regions respectively. Also we present a pressure-robust and conservative VEM methods for Stokes problems which can be extended to solve coupled Stokes-Darcy problems. Numerical experiments illustrate the robustness and accuracy of our method.

Temporal high-order structure-preserving parametric finite element methods for curvature flows

Chunmei Su, Tsinghua University

Abstract: The quality of the mesh is crucial for simulating curvature flows, as standard approaches may fail due to mesh distortion. We first present a series of high-order parametric finite element methods based on the BGN formulation for solving various types of flows involving curves and surfaces. Extensive numerical experiments demonstrate the anticipated high-order accuracy while maintaining favorable mesh quality throughout the evolution process. Secondly, for flows involving multiple geometric structures, such as surface diffusion—which reduces area while preserving volume—we propose a type of structure-preserving method that incorporates two scalar Lagrange multipliers along with two evolution equations related to area and volume, respectively. These schemes effectively preserve the geometric structure at a fully discrete level. Comprehensive numerical experiments illustrate that our methods achieve the desired temporal accuracy, while simultaneously preserving the geometric structure of the surface diffusion.

Convergence of finite elements for a bulk-surface coupled free boundary problem

Yifei Li, Tübingen University

Abstract: In this talk, we present a numerical analysis of the Eyles-King-Styles tumor growth model, a free boundary problem coupling a Poisson equation in the bulk Ω with a forced mean curvature flow on its boundary Γ . Unlike existing evolving surface analyses based on integer-order Sobolev spaces, this bulk-surface coupling requires $H^{1/2}$ -order regularity on Γ . We establish a fractional Sobolev framework that admit a rigorous convergence analysis for continuous finite elements of polynomial degree at least three.

An asymptotic preserving method for the weakly nonlinear Klein-Gordon equation

Hanquan Wang, Yunnan University of Finance and Economics

Abstract: In this talk, we propose an asymptotic preserving (AP) method for the weakly nonlinear Klein-Gordon equation (NKGE). Firstly, we apply a multi-scale expansion for the weakly NKGE and obtain the equation for the leading-order term, for which an error estimate has been provided. Secondly, by solving the equation for the leading-order term numerically, we construct an AP method for the weakly NKGE. Finally, numerical results in one spatial dimension are provided to show that: (i) The method is asymptotic preserving, i.e., the error between the leading-order term and the solution of the weakly NKGE behaves as $O(\epsilon)$

as epsilon goes to 0. (ii) It is uniformly accurate since the numerical solution obtained by the method is independent of the small parameter, epsilon. (iii) It can make correct predictions about the solution of the original NKGE. Theoretical analysis also shows that the leading-order approximation is asymptotic preserving. Moreover, extension of the method to the two-dimensional weakly NKGE are also provided.

A JKO approach for gradient flows

Chaozhen Wei, University of Electronic Science and Technology of China

Abstract: In this talk, I will present a novel numerical approach based on minimizing movement (JKO) schemes for a class of gradient flows arising widely in applications in material science and biology such as porous medium, tumor growth, phase separation, crystal defects migration, solid-state wetting/dewetting, and thin film surfactant dynamics. By leveraging the variational structure, along with the dynamical characterization of optimal transport distances, we construct fully discrete JKO scheme that ends up with a minimization problem with convex objective function and linear constraint, which can be solved by efficient primal dual operator splitting schemes. Our method has built-in positivity or bounds preserving, mass conservation, and entropy decreasing properties, and overcomes stability issue due to the strong nonlinearity and degeneracy. I will show a suite of simulation examples to demonstrate the effectiveness and extensibility of our algorithm.

High order structure preserving cut discontinuous Galerkin method for hyperbolic conservation laws in higher dimensions

Pei Fu, Nanjing University of Aeronautics and Astronautics

Abstract: This talk will present a family of high order cut finite element methods based on the discontinuous Galerkin (DG) framework for hyperbolic problems in high dimensions, including scalar problems and system problems. To avoid the small cut cell issue, a ghost penalty stabilization is employed to stabilize the scheme. The strong stability-preserving Runge–Kutta method is used for time discretization, in which the time step is chosen independently of the size of the cut elements. We show that the proposed methods possess stability and accuracy properties as the standard DG methods on fitted meshes. We also prove and verify that the scheme preserves the bound-preserving property for scalar conservation laws when a flux limiting work is applied. The Euler system problems will be also shown. Finally, numerical experiments will be given to demonstrate that the proposed methods achieve high order accuracy for smooth solutions and perform well for problems with discontinuities.

Discontinuous Galerkin Methods for the Ostrovsky–Hunter type equations

Qian Zhang, Harbin Institute of Technology, Shenzhen

Abstract: In this paper, we develop discontinuous Galerkin (DG) methods for solving Ostrovsky–Hunter (OH) type equations, a class of nonlinear dispersive systems that model long-wave dynamics in rotating fluids. The numerical schemes are constructed based on the two conserved quantities inherent to these equations, ensuring high-order accuracy and stability. A rigorous theoretical analysis is provided, which establishes the stability of the proposed methods and derives optimal error estimates. Numerical experiments validate the effectiveness of our approach for simulating a variety of wave phenomena, including shock solutions, singular solitons, oscillatory waves, and solitary wave decay.

Second-order flows for variational minimization via several discretization strategies

Ziqing Xie, Hunan Normal University

Abstract: Second-order flows represent an emerging paradigm for non-convex variational minimization, characterized by damped hyperbolic partial differential equations. In this talk, we provide an overview of several discretization strategies for second-order flows for solving unconstrained variational minimization problem, analyzing the trade-off between theoretical rigor and numerical efficiency.

Physics-preserving numerical methods for compressible gas flow in poroelastic media

Huangxin Chen, Xiamen University

Abstract: Modeling and simulation of gas flows in porous media are of great interest in the fields of underground gas storage, and subsurface contaminant transport. In this talk we will introduce a robust and efficient numerical framework for simulating the single component and multicomponent gas flow in poroelastic media, with a focus on preserving fundamental thermodynamic principles and ensuring computational reliability. The models capture the complex nonlinear coupling between the transport and solid deformation, while addressing critical numerical challenges such as mass conservation, energy stability, and molar density boundedness. We develop a stabilized discretization approach that guarantees the preservation of the original energy dissipation law and ensures the boundedness of each gas component's molar density. Numerical experiments will be presented to demonstrate the performance, robustness, and applicability of the proposed method.

**Geometric quasi-linearization (GQL) and structure-preserving analysis:
from a general framework to unveiling
algebraic-differential relations in MHD**

Kailiang Wu, Southern University of Science and Technology

Abstract: Preserving invariant regions (e.g., positivity of density and pressure, and the subluminal-velocity constraint in relativity) is fundamental to the physical consistency and mathematical well-posedness of hyperbolic conservation laws. However, developing high-order schemes that strictly respect nonlinear constraints remains a significant challenge for hyperbolic systems and computational fluid dynamics. In the first part of this talk, we introduce the Geometric Quasi-Linearization (GQL) framework. Building on key insights from convex geometry, GQL transforms arbitrary nonlinear convex constraints into equivalent linear constraints by introducing free auxiliary variables. Crucially, GQL reveals a geometric insight: nonlinear constraints in the physical space are, in essence, linear when lifted to a higher-dimensional space. We establish the theoretical foundation of this framework and propose three effective construction methods, providing a unified approach to nonlinear invariant-domain-preserving analysis and design. In the second part, we apply GQL to the structure-preserving analysis of (ideal/relativistic) compressible magnetohydrodynamics (MHD), unveiling an intrinsic algebraic–differential coupling between thermodynamic constraints (pressure positivity) and the involution constraint (divergence-free magnetic field) at both the numerical and PDE levels. We prove that the preservation of algebraic bounds is generally conditioned on the discrete divergence-free structure. By deriving the exact compatibility condition, we construct high-order schemes that achieve synergistic preservation of both algebraic and differential constraints. The robustness of these methods is demonstrated through extreme simulations, including low plasma beta ($\approx 10^{-10}$) blast waves and astrophysical jets with Mach numbers up to 10^6 .

**Stable fully discrete parametric finite element methods for Willmore
flow with applications**

Quan Zhao, University of Science and Technology of China

Abstract: The numerical approximation of geometric evolution equations that involve the first variation of the Willmore energy is particularly challenging due to the fact that highly nonlinear and fourth order terms appear. Here we present a new parametric finite element method for Willmore flow of hypersurfaces in a unified framework. The method is linear and employs a splitting of the normal and tangential velocity of the flow. The normal velocity is approximated via an evolution equation for the curvature, and follows the arbitrary Lagrangian-Eulerian approach. This enables an unconditional energy stability with respect to the discrete energy. We also incorporate the 'BGN' tangential velocity through a curvature identity. This

helps to preserve the mesh quality. We show various numerical examples to demonstrate the favorite properties of the method. Generalization to a related model describing the dynamics of fluidic biomembranes is also discussed.

Well-balanced positivity-preserving high-order discontinuous Galerkin methods for Euler equations with gravitation

Jie Du, East China Normal University

Abstract: We develop high order discontinuous Galerkin (DG) methods with Lax-Friedrich fluxes for Euler equations under gravitational fields. Such problems may yield steady-state solutions and the density and pressure are positive. There were plenty of previous works developing either well-balanced (WB) schemes to preserve the steady states or positivity-preserving (PP) schemes to get positive density and pressure. However, it is rather difficult to construct WB PP schemes with Lax-Friedrich fluxes, due to the penalty term in the flux. In fact, for general PP DG methods, the penalty coefficient must be sufficiently large, while the WB scheme requires that to be zero. This contradiction can hardly be fixed following the original design of the PP technique. In this talk, we reformulate the source term such that it balances with the flux term when the steady state has reached. To obtain positive numerical density and pressure, we choose a special penalty coefficient in the Lax-Friedrich flux, which is zero at the steady state. The technique works for general steady-state solutions with zero velocities. Numerical experiments are given to show the performance of the proposed methods.

Dynamics of Hele-Shaw flow in multi-connected regions

Meng Zhao, Huazhong University of Science and Technology

Abstract: In this talk, we present the dynamics of Hele-Shaw flow in a multi-connected region. We focus on our study on multiple interfaces in a radial Hele-Shaw cell. To compute the long-time interface morphologies and the motion of interfaces, we develop a spectral-accurate boundary integral method and a non-stiff time updating scheme. Numerical results reveal that the classic Saffman-Taylor instability is heavily influenced by the initial configuration of the interfaces and the physical parameters, e.g. the viscosity of the fluids. In particular, compared to the single-interface scenario, multiple interfaces can be used to promote or inhibit the development of fingering instability, thus facilitating the idea of morphological control in practice. Motivated by the self-similar theory and shape control strategy, one can preselect a limiting morphology, promote the growth of desired symmetry by a multi-interface setup, and realize it with a much smaller interface size by suppressing the unfavorable Saffman-Taylor instability.

Fourth-order, optimal-complexity, and structure-preserving numerical solutions of PDEs on irregular and moving domains with arbitrary topology and geometry

Qinghai Zhang, Zhejiang University

Abstract: This talk is an overview of the framework of MARS (mapping and adjusting regular semianalytic sets) for numerically solving elliptic equations, hyperbolic conservation laws, and the incompressible Navier-Stokes equations (INSE) on arbitrarily complex irregular and moving domains with fourth-order accuracy, optimal complexity, energy stability, and structure-preserving capabilities. Different from current methods that avoid topology and geometry by converting them into numerical ODEs/PDEs, we tackle topological and geometric problems with tools in topology and geometry. In particular, we give complete classification of 2D/3D continua, develop a theoretical framework for interface tracking, and couple high-order approximation of domain geometry (CAD) with high-fidelity finite volume methods (CAE). We show that the integration of numerical analysis, AI, algebraic topology, and differential geometry could be powerful for real-world applications.

A globally divergence-free HDG method for the Smagorinsky model

Xiaoping Xie, Sichuan University

Abstract: We develop a globally divergence-free hybridizable discontinuous Galerkin method for the time-dependent Smagorinsky model. The scheme combines interior penalty discretization of the viscous terms, including the nonlinear eddy viscosity, with upwind treatment of the convective terms. We derive a priori Reynolds semi-robust velocity error estimates that are independent of inverse powers of the viscosity and capture pre-asymptotic convergence at high Reynolds numbers. The analysis accounts for the nonlinear effects induced by the solution-dependent eddy viscosity. Numerical experiments confirm the robustness and accuracy of the proposed method.

Thermodynamically consistent modeling and energy-stable LDG schemes for semi-permeable interface flows

Ruihan Guo, Zhengzhou University

Abstract: We develop a thermodynamically consistent phase-field framework, permeating CHNS (pCHNS), for solvent transport across semi-permeable interfaces driven by osmotic and hydrostatic pressure differences. The model establishes a bidirectional coupling: the fluid advects solute, while solute gradients regulate cross-interface solvent flux via osmotic pressure. An energy-variational derivation yields a closed energy-dissipation law, which we leverage to construct fully discrete, energy-stable, high-order algorithms: LDG spatial discretization, a

decoupled first-order scheme with unconditional energy stability, and a semi-implicit spectral deferred correction (SDC) upgrade for high-order temporal accuracy while preserving dissipation. A sharp-interface asymptotic analysis shows that, under natural scalings, the diffuse model converges to a sharp-interface problem with the expected kinematic law, normal-stress jump, and solute impermeability conditions, thereby establishing diffuse-to-sharp consistency. Numerically, a space-time convergence study confirms design orders and energy decay; a 1D no-flow calibration demonstrates quantitative convergence to the sharp-interface prediction as the interface thickness vanishes; and 2D simulations examine how permeability, solute load, and shear shape droplet evolution and equilibrium morphology.

Exploiting locality structure in high-dimensional diffusion models

Shuigen Liu, National University of Singapore

Abstract: Diffusion-based methods provide a flexible framework for approximating and sampling high-dimensional probability distributions, but their practical performance is often limited by the difficulty of learning high-dimensional score functions. In this talk, we consider target distributions with local interaction structure and develop a localized diffusion framework that explicitly exploits this property. The main idea is that, under locality assumptions, the score function can be well approximated using only neighborhood information, leading to a substantial reduction in effective complexity. We discuss both the algorithmic construction and the accompanying theory, with particular emphasis on the trade-off between reduced statistical complexity and the localization error introduced by truncating long-range dependencies. This viewpoint suggests localized diffusion models as a structure-aware approach for high-dimensional probabilistic computation, with promising accuracy and parallel scalability.

Dynamic flow structures in active viscoelastic liquids: modeling and simulation

Tiezheng Qian, The Hong Kong University of Science and Technology

Abstract: Active fluids encompass a wide range of non-equilibrium fluids, in which the self-propulsion or rotation of their units can give rise to large-scale spontaneous flows. Despite the diversity of active fluids, they are commonly viscoelastic. Therefore, we develop a hydrodynamic model of isotropic active liquids by accounting for their viscoelasticity. Specifically, we incorporate an active stress term into a general viscoelastic liquid model to study the spontaneous flow states and their transitions in two-dimensional channel, annulus, and disk geometries. We have discovered rich spontaneous flow states in a channel as a function of activity and Weissenberg number, including unidirectional flow, travelling wave, and vortex-roll states. The Weissenberg number acts against activity by suppressing the spontaneous flow. In an annulus confinement, we find that a net flow can be generated only if the aspect ratio of the annulus is not too large nor too small, consistent with the experiments of microtubule-based

active fluids. In a disk geometry, we observe a periodic chirality-switching of a single vortex flow, resembling the bacteria-based active fluid experiments. As such, our active viscoelastic model offers a unified framework to elucidate diverse active liquids, uncover their connections, and highlight the universality of dynamic active-flow patterns. — This work is supported by Hong Kong RGC and completed through a collaboration with Dr. Zhe Feng and Prof. Rui Zhang at HKUST.

Provably convergent Newton--Raphson method: theoretically robust recovery of primitive variables in relativistic MHD

Jianxian Qiu, Xiamen University

Abstract: A long-standing and formidable challenge faced by all conservative numerical schemes for relativistic magnetohydrodynamics (RMHD) equations is the recovery of primitive variables from conservative ones. This process involves solving highly nonlinear equations subject to physical constraints. An ideal solver should be "robust, accurate, and fast—it is at the heart of all conservative RMHD schemes," as emphasized in [S. C. Noble et al., *Astrophys. J.*, 641 (2006), pp. 626-637]. Despite over three decades of research, seeking efficient solvers that can provably guarantee stability and convergence remains an open problem. This paper presents the first theoretical analysis for designing a robust, physical-constraint-preserving (PCP), and provably (quadratically) convergent Newton-Raphson (NR) method for primitive variable recovery in RMHD. Our key innovation is a unified approach for the initial guess, carefully devised based on sophisticated analysis. It ensures that the resulting NR iteration consistently converges and adheres to physical constraints throughout all NR iterations. Given the extreme nonlinearity and complexity of the iterative function, the theoretical analysis is highly nontrivial and technical. We discover a pivotal inequality for delineating the convexity and concavity of the iterative function and establish general auxiliary theories to guarantee the PCP property and convergence. We also develop theories to determine a computable initial guess within a theoretical "safe" interval. Intriguingly, we find that the unique positive root of a cubic polynomial always falls within this "safe" interval. To enhance efficiency, we propose a hybrid strategy that combines this with a more cost-effective initial value. The presented PCP NR method is versatile and can be seamlessly integrated into any RMHD numerical scheme that requires the recovery of primitive variables, potentially leading to a very broad impact in this field. As an application, we incorporate it into a discontinuous Galerkin method, resulting in fully PCP schemes. Several numerical experiments, including random tests and simulations of ultra-relativistic jet and blast problems, demonstrate the notable efficiency and robustness of the PCP NR method.

Structure preserving numerical schemes for dissipative systems by the Onsager principle

Xianmin Xu, Chinese Academy of Sciences

Abstract: Physical systems inherently exhibit critical properties such as energy conservation/dissipation relations, mass conservation, and positive densities. Designing numerical schemes that preserve fundamental characteristics is crucial for accurately modeling and simulating complex systems. It is known that the Onsager principle gives a natural framework to derive partial differential equation models for diverse gradient flow systems. In this talk we will show that this principle also provides a basis for developing numerical schemes that uphold some crucial physical properties. We also present some recent results on developing higher order schemes for the PNP equation.

An incremental SVD method for non-Fickian flows in porous media: addressing storage and computational challenges

Gang Chen, Sichuan University

Abstract: It is well known that the numerical solution of the Non-Fickian flows at the current stage depends on all previous time instances. Consequently, the storage requirement increases linearly, while the computational complexity grows quadratically with the number of time steps. This presents a significant challenge for numerical simulations, and to the best of our knowledge, it remains an unresolved issue. In this talk, we assume that the solution data exhibits approximate low rank. Here, we present a memory-free algorithm, based on the incremental SVD technique, that exhibits only linear growth in computational complexity as the number of time steps increases. We prove that the error between the solutions generated by the conventional algorithm and our innovative approach lies within the scope of machine error. Numerical experiments are showed to confirm accuracy and efficiency gains in terms of both memory usage and computational expenses.

Improved error bounds of time-splitting Hermite spectral method for the highly-oscillatory Gross-Pitaevskii equation

Yongyong Cai, Beijing Normal University

Abstract: We establish improved error bounds for the time-splitting Hermite pseudospectral method applied to the highly-oscillatory Gross-Pitaevskii equation on unbounded domains, which corresponds to the strongly confined Gross-Pitaevskii equation. By combining refined Hermite spectral approximation estimates with an extension of the regularity compensation oscillation technique to unbounded domains, we establish an improved error bound. Numerical results are provided to confirm the improved error bounds and demonstrate that they are sharp.

A coupled high-order continuous and discontinuous Galerkin finite element scheme for the Davey-Stewartson system

Jinyang Lu, Shanghai Normal University

Abstract: In this paper, we propose a coupled discontinuous Galerkin (DG) and continuous Galerkin (CG) scheme for solving the nonlinear evolution Davey-Stewartson (DS) system in dimensionless form. The DS system consists of two coupled nonlinear and complex structure partial differential equations. The wave's amplitude in the first equation is solved by the high-efficiency local DG method, and the velocity in the second equation is obtained by a standard CG method. No matching conditions are needed for the two finite element spaces since the normal component of the velocity is continuous across element boundaries. The main strengths of our approach are that we combine the advantage of DG and CG methods, using DG methods handling the nonlinear Schrödinger equation to obtain high parallelizability and high-order formal accuracy, using the continuous finite elements solving the velocity to maintain total energy conservation. We prove the energy-conserving properties of our scheme and error estimates in L^2 -norm. However, the non-linearity terms bring a lot of trouble to the proof of error estimates. With the help of energy-conserving properties, we construct a series of energy equations to obtain error estimates. Numerical tests for different types of systems are presented to clarify the effectiveness of numerical methods.

Participants (alphabetical order by last name)		
Name	Affiliation	Email
Yongyong Cai	Beijing Normal University	yongyong.cai@bnu.edu.cn
Gang Chen	Sichuan University	cglwmdm@scu.edu.cn
Huangxin Chen	Xiamen University	chx@xmu.edu.cn
Jie Du	East China Normal University	jdu@math.ecnu.edu.cn
Pei Fu	Nanjing University of Aeronautics and Astronautics	fu.pei@nuaa.edu.cn
Ruihan Guo	Zhengzhou University	rguo@zzu.edu.cn
Yifei Li	Tübingen University	yifei.li@mnf.uni-tuebingen.de
Shuigen Liu	National University of Singapore	shuigen.liu@nus.edu.sg
Jinyang Lu	Shanghai Normal University	jylu@shnu.edu.cn
Tiezheng Qian	The Hong Kong University of Science and Technology	maqian@ust.hk
Jianxian Qiu	Xiamen University	jxqiu@xmu.edu.cn
Hongxing Rui	Shandong University	hxrui@sdu.edu.cn
Chunmei Su	Tsinghua University	sucm@tsinghua.edu.cn
Huazhong Tang	Peking University	hztang@math.pku.edu.cn
Dong Wang	The Chinese University of Hong Kong, Shenzhen	wangdong@cuhk.edu.cn
Hanquan Wang	Yunnan University of Finance and Economics	hanquan.wang@gmail.com
Chaozhen Wei	University of Electronic Science and Technology of China	cwei4@uestc.edu.cn
Kailiang Wu	Southern University of Science and Technology	wukl@sustech.edu.cn
Xiaoping Xie	Sichuan University	xpxie@scu.edu.cn
Ziqing Xie	Hunan Normal University	ziqingxie@hunnu.edu.cn
Xianmin Xu	Chinese Academy of Sciences	xmxu@lsec.cc.ac.cn
Yan Xu	University of Science and Technology of China	yxu@ustc.edu.cn
Qian Zhang	Harbin Institute of Technology, Shenzhen	zhang.qian@hit.edu.cn
Qinghai Zhang	Zhejiang University	qinghai@zju.edu.cn
Meng Zhao	Huazhong University of Science and Technology	mzhao9@hust.edu.cn
Quan Zhao	University of Science and Technology of China	quanzhao@ustc.edu.cn