CONTENT

Program Coordinator:

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Conference Venue: 6F Sky Meeting Room, Joyze Hotel Xiamen, Curio Collection by Hilton

Accommodation: Joyze Hotel Xiamen, Curio Collection by Hilton (in Chinese:厦门佳逸希尔顿格芮精选酒店)

Schedule

Conference Venue: 6F Sky Meeting Room, Joyze Hotel Xiamen, Curio Collection by Hilton (in Chinese:厦门佳逸希尔顿格芮精选酒店)

Jan. 16	All Day	**Check-in, in hotel**	
	18:30	**Dinner, in Dafengyuan Restaurant（大丰苑）**	
The morning of Jan. 17	08:50-09:00	**Chair**	**Shen Jie**
		Opening Ceremony	
	09:00-09:35	**Xie Xiaoping**	Energy-preserving mixed finite element methods for an incompressible ferrofluid flow model
	09:40-10:15	**Rui Hongxing**	A low order divergence-free H(div)-conforming finite element method for Stokes flows
	10:20-10:50	**Group Photo, Tea Break**	
	Chair	**Xu Chuanju**	
	10:50-11:25	**Chen Yanping**	Exponential convergence of hp discontinuous Galerkin method for nonlinear Caputo fractional differential equations
	11:30-12:05	**Dai Shuyang**	Stress calculation for crystals at finite temperature based on Cauchy-Born approximation
	12:10	**Lunch, in hotel**	
The Afternoon of Jan. 17	**Chair**	**Chen Huangxin**	
	14:30-15:05	**Yang Zhiguo**	The mathematical modeling and unconditionally stable gPAV-based numerical schemes for multi-phase flows
	15:10-15:45	**Tang Qinglin**	A spectrally accurate numerical method for computing the

			Bogoliubov-De Gennes excitations of dipolar Bose-Einstein condensates
	15:50-15:25	**Tea Break**	
	Chair	**Huang Can**	
	16:25-17:00	**Zheng Haibiao**	A novel decoupling scalar auxiliary variable (SAV) stabilization technique for some multi-domain, multi-physics time-dependent coupled problems
	17:05-17:40	**He Qiaolin**	Energy-stable Numerical Method for Compressible Flow with Generalized Navier Boundary Condition
18:00, Dinner, in Dafengyuan Restaurant（大丰苑）			
The morning of Jan. 18	**Chair**	**Chen Hongtao**	
	09:00-09:35	**Xu Liwei**	Some results on boundary integral equation methods and their applications in numerics
	09:40-10:15	**Feng Xinlong**	Difference Finite Element Method for the 3D steady Stokes Equations
	10:20-10:50	**Tea Break**	
	Chair	**Shen Jie**	
	10:50-11:25	**Qiu Yue**	Low-rank Methods for Bayesian Inverse Problems
	11:30-12:05	**Sheng Changtao**	Fast implementation of FEMs for Nonlocal Models in Multiple Dimensions
	12:10	**Lunch**	
The afternoon of Jan. 18	**Discussion**		
Jan.19	**Discussion**		
	11:30	**Lunch**	

Titles and Abstracts

Exponential convergence of hp discontinuous Galerkin method for nonlinear Caputo fractional differential equations

Chen Yanping (South China Normal University)

Abstract: We present an hp-discontinuous Galerkin method for solving nonlinear fractional differential equations involving Caputo-type fractional derivative. The main idea behind our approach is to first transform the fractional differential equations into nonlinear Volterra or Fredholm integral equations, and then the hp-discontinuous Galerkin method is used to solve the equivalent integral equations. We derive a-priori error bounds in the L2-norm that are totally explicit with respect to the local mesh sizes, the local polynomial degrees, and the local regularities of the exact solutions. In particular, we prove that exponential convergence can be achieved for solutions with endpoint singularities by using geometrically refined meshes and linearly increasing approximation orders. The theoretical results are confirmed by a series of numerical experiments.

Stress calculation for crystals at finite temperature based on Cauchy-Born approximation

Dai Shuyang (Wuhan University)

Abstract: We present the procedure of generalization and implementation of the Cauchy-Born approximation to the calculation of stress at finite temperature for alloy system in which the effects of inner displacement should be incorporated. With the help of quasi-harmonic approximation, a closed form of the first Piola-Kirchhoff stress is derived as a summation of pure deformation contribution and linear term due to thermal effects. For alloy system with periodic boundary condition, a further simplified formulation of stress based on some invariance constraints is derived in reciprocal space by using Fourier transformation, in which the temperature effect can be efficiently taking account.

Difference Finite Element Method for the 3D steady Stokes Equations

Feng Xinlong (Xinjiang University)

Abstract: In this work, a difference finite element (DFE) method is presented for the 3D steady Stokes equations. This new method consists of transmitting the FE solution of the 3D steady Stokes equations into a series of the FE solution of the 2D steady Stokes equations. Here the 2D steady Stokes equations are solved by the FE pair P1b-P1. We design the weak formulation of the DFE method based on the 3D FE pair (P1b,P1b,P1) × P1) × (P1 × P0) under the quasi-uniform mesh condition, prove that the 3D FE pair satisfies the discrete inf-sup condition and provide the existence, uniqueness and stability of the DFE solution and deduce the first order convergence of the DFE solution with respect to the exact solution. Finally, numerical tests are presented to show the accuracy and efficiency for the proposed method.

Energy-stable Numerical Method for Compressible Flow with Generalized Navier Boundary Condition

He Qiaolin (Sichuan University)

Abstract: We derive a dimensionless model for pure-component two-phase compressible flows with Van der Waals equation of state (EoS) and generalized Navier boundary condition (GNBC). We propose three energy-stable numerical schemes. One of them is based on the scalar auxiliary variable (SAV) approach for Helmholtz free energy for bulk and surface free energy, which leads to a modified energy and is proved to be unconditional stable. Another numerical scheme is based on the Lagrange multiplier approach for Helmholtz free energy for bulk and surface free energy, which leads to the original energy and is proved to be unconditional stable. Numerical results are presented to verify the effectiveness of the proposed methods.

Low-rank Methods for Bayesian Inverse Problems

Qiu Yue (Shanghai Tech University)

Abstract: In this talk, I will introduce our recent work on low-rank methods for Bayesian inverse problems. For linear problems with Gaussian noise and Gaussian prior, the posterior is also Gaussian and characterized by the posterior mean and covariance. We propose a low-rank Arnoldi method to approximate the large dense posterior covariance matrix by making use of tensor computations. For nonlinear systems, the posterior is not Gaussian anymore, however, can often be approximated by a Gaussian distribution using the ensemble Kalman filter (EnKF) or the extended Kalman filter (ExKF). We propose a randomized low-rank method to reduce the computational complexity of the EnKF. We use numerical experiments to show the efficiency of our low-rank methods.

This is joint work with Peter Benner, Martin Stoll, and Sara Grundel.

A low order divergence-free H(div)-conforming finite element method for Stokes flows

Rui Hongxing (Shandong University)

Abstract： In this paper, we propose a $P1 \oplus RT0$ - $P0$ discretization of the Stokes equations on general simplicial meshes in two/three dimension, which yields an exactly divergence-free and pressure independent velocity approximation with optimal order. Our method has the following features. Firstly, the global number of the degrees of freedom of our method is the same as the low order Bernardi and Raugel (B-R) finite element method, while the number of the non-zero entries of the former is about half of the latter in the velocity-velocity region of the coefficient matrix. Secondly, our method can be easily transformed into a pressure-robust and stabilized $P1$-$P0$ discretization for the Stokes problem via the static condensation of the $RT0$ component, which has a much smaller number of global degrees of freedom. Numerical experiments illustrating the robustness of our method are also provided. Numerical methods based one the same idea for the N-S equations are under consideration.

Fast implementation of FEMs for Nonlocal Models in Multiple Dimensions

Sheng Changtao (East China Normal University)

Abstract: We introduce a fast and accurate semi-analytic computation of the stiffness matrix associated with the integral fractional Laplacian operator. We show that for the rectangular or L-shaped domains, each entry of the FEM stiffness matrix associated with the tensorial rectangular elements can be expressed explicitly by some one-dimensional integrals, which can be evaluated accurately. The key is to implement the FEM in the Fourier transformed space. Moreover, we extended the proposed method for the Peridynamic models. Hence, we shall also report our recent attempts towards FEM implementation of nonlocal models.

A spectrally accurate numerical method for computing the Bogoliubov-De Gennes excitations of dipolar Bose-Einstein condensates.

Tang Qinglin (Sichuan University)

Abstract: In this talk, we propose an efficient and robust numerical method to study the elementary excitation of dipolar Bose-Einstein condensates (BEC), which is governed by the Bogoliubov-De Gennes equations (BdGEs) with nonlocal dipole-dipole interaction, around the mean field ground state. Analytical properties of the BdGEs are investigated, which could serve as benchmarks for the numerical methods. To evaluate the nonlocal interactions accurately and efficiently, we propose a new Simple Fourier Spectral Convolution method (SFSC). Then, integrating SFSC with the standard Fourier spectral method for spatial discretization and Implicitly Restarted Arnoldi Methods (IRAM) for the eigenvalue problem, we derive an efficient and spectrally accurate method, named as SFSC-IRAM method, for the BdGEs. Ample numerical tests are provided to illustrate the accuracy and efficiency. Finally, we apply the new method to study systematically the excitation spectrum and Bogoliubov amplitudes around the ground state with different parameters in different spatial dimensions.

Energy-preserving mixed finite element methods for an incompressible ferrofluid flow model

Xie Xiaoping (Sichuan University)

Abstract: We develop a class of mixed finite element methods for the incompressible ferrofluid flow model proposed by Shliomis [Soviet Physics JETP, 1972]. We prove the existence and uniqueness of the semi- and fully discrete solutions, and show that the energy stability of the weak solutions to the model is preserved exactly for the discrete finite element solutions. We also derive optimal error estimates for both the discrete schemes. Numerical experiments confirm the theoretical results. This is a joint work with Yongke Wu (UESTC).

Some results on boundary integral equation methods and their applications in numerics

Xu Liwei (University of Electronic Science and Technology of China)

Abstract: Firstly, we discuss two results on integral equation methods associated to the solution of scattering wave equations. One is the new regularization formulation of the hypersingular boundary integral operators resulting from several elastic wave equations, and another is the well-posedness result of the approximated reduced boundary value problems corresponding to the original scattering transmission problems. Secondly, we present two results on applying integral equation methods to solve Laplace equations. One is on the change of order of integral operators so that some preconditioner of domain discretization methods could be applied to improve the efficiency of surface discretization methods, and another is a new coupling technique, i.e. the Dirichlet-to-Dirichlet or the Dirichlet-to-Neumann mapping defined on two different artificial boundaries, which could preserve the accuracy of the coupling scheme even as the mesh size tends to zero. The application of these theoretical results in numerics will be presented.

The mathematical modeling and unconditionally stable gPAV-based numerical schemes for multi-phase flows

Yang Zhiguo (Shanghai Jiao Tong University)

Abstract: In this presentation, I will talk about the mathematical modeling and numerical methods for the multi-phase flow problems. A framework for devising

unconditionally stable schemes for general dissipative systems based on a generalized positive auxiliary variable (gPAV) is presented. This method requires the solution of a linear equation to be solved for each time step only once, so the computational cost is almost the same with the classical semi-implicit method. Rigorous error estimate and applications of this method to multiphase flow problems are also presented.

Sharp error estimate for nonunform schemes for subdiffusion equations

Zhang Jiwei (Wuhan University)

Abstract: This talk focuses on the numerical analysis of reaction-subdiffusion equations with variable time step by taking the widely used L1 scheme for an example. For the stability analysis, the discrete complementary convolution (DCC) kernels are introduced to prove the discrete fractional-type Gronwall inequality. For the convergence analysis, the goals are theoretically challenging because the numerical Caputo formula always has a form of discrete convolutional summation. To circumvent this difficulty, an error convolution structure (ECS) analysis is proposed to express the consistence error for the discrete Caputo formula, which can significantly reduce consistence analysis for general nonuniform time steps. In addition, the technique here is also useful to extend the knowledge to study multi-step schemes such as BDF2 with variable time step for classical parabolic equations.

A novel decoupling scalar auxiliary variable (SAV) stabilization technique for some multi-domain, multi-physics time-dependent coupled problems

Zheng Haibiao (East China Normal University)

Abstract: This report considers a novel decoupling stabilization method, which cleverly utilizes the scalar auxiliary variable (SAV) approach, for some time-dependent multi-domain, multi-physics coupled problems. The proposed effective numerical schemes produce the unconditional energy stability. Moreover, only the decoupling system with constant coefficients, independent of mesh size, needs to be solved in parallel at each time step. With the first order time discretization, we rigorously derive

the error estimates of this new technique for the Stokes-Darcy coupled problem. Several numerical experiments are conducted to illustrate and validate the exclusive features of the proposed numerical method.

Participants List

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Notebook