# 2016 YOUNG MATHEMATICIAN FORUM

# 2016 年 数 学 青 年 学 者 论 坛

**Dec. 18-19, 2016**

## Introduction

To promote academic communication and cooperation between young staffs from the SMS and the BICMR of Peking University and overseas outstanding young scholars, a Young Mathematician Forum will be held at Peking University during Dec.18 -- 19, 2016. This forum is jointly sponsored by the SMS and the BICMR of Peking University. There will be two parallel sections of the forum, one for pure math, another one for applied math. Active young researchers from all disciplines of mathematics will present talks in this forum.

## Academic Committee

| | |
|---|---|
| **Dayue Chen** | *School of Mathematical Sciences, Peking University* |
| **Weinan E** | *Beijing International Center for Mathematical Research* |
| **Xiaobo Liu** | *Beijing International Center for Mathematical Research* |
| **Gang Tian** | *School of Mathematical Sciences, Peking University* |
| | *Beijing International Center for Mathematical Research* |
| **Pingwen Zhang** | *School of Mathematical Sciences, Peking University* |

## Organizing Committee

### for Pure Math

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|---|---|
| **Ruochuan Liu** | *Beijing International Center for Mathematical Research* |
| **Yi Liu** | *Beijing International Center for Mathematical Research* |
| **Chenyang Xu** | *Beijing International Center for Mathematical Research* |
| **Zhifei Zhang** | *School of Mathematical Sciences, Peking University* |

### for Applied Math

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| **Bin Dong** | *Beijing International Center for Mathematical Research* |
| **Wei Lin** | *School of Mathematical Sciences, Peking University* |
| **Lei Zhang** | *Beijing International Center for Mathematical Research* |

## Participants

### for Pure Math

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| **Junyan Cao** | *University Paris 6* |
| **Yiwen Ding** | *Imperial College London* |
| **Yu Deng** | *New York University* |
| **Ziyang Gao** | *CNRS(France) and Princeton University(USA)* |
| **Long Jin** | *Purdue University* |
| **Chunyi Li** | *University of Edinburgh* |
| **Jianfeng Lin** | *Massachusetts Institute of Technology* |
| **Zhen Lei** | *Fudan University* |
| **Linquan Ma** | *University of Utah* |
| **Hongbin Sun** | *University of California at Berkeley* |
| **Song Shao** | *University of Science and Technology of China* |
| **Zhenqi Wang** | *Michigan State University* |
| **Jian Xiao** | *Northwestern University* |
| **Xiaomeng Xu** | *Massachusetts Institute of Technology* |
| **Fei Yu** | *Zhejiang University* |
| **Jiagang Yang** | *Universidade Federal Fluminense* |
| **Tian Yang** | *Stanford University* |
| **Tengren Zhang** | *California Institute of Technology* |
| **Zhenlei Zhang** | *School of Mathematical Sciences Capital Normal University* |

### for Applied Math

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|---|---|
| **Chenglong Bao** | *National University of Singapore* |
| **Hongyuan Cao** | *University of Missouri* |
| **Xiuyuan Cheng** | *Yale University* |
| **Peng Ding** | *University of California, Berkeley* |
| **Jingwei Hu** | *Purdue University* |
| **Xiaodong Li** | *University of California, Davis* |
| **Junchi Li** | *Princeton University* |
| **Qiang Sun** | *Yale University and Princeton University* |
| **Ruoyu Sun** | *University of Illinois Urbana Champaign* |
| **Shuonan Wu** | *Penn State* |
| **Wanjie Wang** | *National University of Singapore* |
| **Ke Wei** | *University of California, Davis* |
| **Ming Yan** | *Michigan State University* |
| **Zhijian Yang** | *Wuhan University* |
| **Qinghai Zhang** | *Zhejiang University* |
| **Wei Zhang** | *Free University of Berlin* |
| **Yuan Zhang** | *Texas A&M University* |
| **Zhennan Zhou** | *Duke University* |

## Contacts


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北京大学数学科学学院 **School of Mathematical Sciences（SMS）, Peking University**

北京国际数学研究中心 **Beijing International Center for Mathematical Research (BICMR)**

# 2016 Young Mathematician Forum

## Dec. 18-19, 2016

## Introduction

To promote academic communication and cooperation between young staffs from School of Mathematical Sciences (SMS) and Beijing International Center for Mathematical Research (BICMR) of Peking University (PKU) and overseas outstanding young scholars, a Young Mathematician Forum will be held at Peking University during Dec. 18-19, 2016. This forum is jointly sponsored by SMS and BICMR of PKU. There will be two parallel sections of the forum, one for pure math, the other for applied math. Active young researchers from all disciplines of mathematics will present talks in this forum.

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## Invited Speakers

### For Pure Math

**Junyan Cao**
**Yu Deng**
**Yiwen Ding**
**Ziyang Gao**
**Long Jin**
**Zhen Lei**
**Chunyi Li**
**Jianfeng Lin**
**Linquan Ma**
**Song Shao**
**Hongbin Sun**
**Zhenqi Wang**
**Jian Xiao**
**Xiaomeng Xu**
**Jiagang Yang**
**Tian Yang**
**Fei Yu**
**Tengren Zhang**
**Zhenlei Zhang**

### For Applied Math

**Chenglong Bao**
**Hongyuan Cao**
**Xiuyuan Cheng**
**Peng Ding**

# Schedule

***Dec. 18-19, 2016***

## Opening Ceremony

***December 18, 2016 Sunday***

***Venue: Conference Room, Second Floor, Jia Yi Bing Building, No. 82 Jing Chun Yuan, PKU***

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|---|---|
| 08:00-08:50 | Sign in |
| 08:50-09:20 | Opening Ceremony(Collective Photo) |
| 09:20-09:50 | Tea Time |

## *Pure Math*

***December 18, 2016 Sunday***

***Venue: Conference Room, Second Floor, Jia Yi Bing Building, No. 82 Jing Chun Yuan, PKU***

| **Morning** | Chair: Yi Liu ( Beijing International Center for Mathematical Research) |
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| 09:50-10:20 | Jianfeng Lin (Massachusetts Institute of Technology) |
| 10:20-10:50 | Hongbin Sun (University of California , Berkeley) |

# 2016 YOUNG MATHEMATICIAN FORUM

# Abstract

## For Pure Math

### Kodaira dimension of algebraic fiber spaces over abelian varieties and surfaces

Junyan Cao

University Paris 6

**Abstract:** Let $p : X \to Y$ be a fibration between two projective manifolds. The Iitaka conjecture states that k($X$) $\geq$ k($Y$) + k($X/Y$), where k($X$) is the Kodaira dimension of $X$ and k($X/Y$) is the Kodaira dimension of the general fiber. By using mainly the recent work of M. Paun and S. Takayama about the positivity of relatively canonical bundles, we give a proof of the Iitaka conjecture for algebraic fiber spaces over abelian varieties or over surfaces. This is joint work with M. Paun.

### Long time Strichartz estimates on irrational tori

Yu Deng

New York University

**Abstract:** Recently Bourgain-Demeter proved the sharp (time 1) Strichartz estimates for the linear Schrödinger equation on general rectangular tori. These estimates are optimal in the rational case, but for irrational tori the same estimates actually hold on longer time intervals. In this talk we will discuss progress in this direction, and an application in controlling the growth of higher Sobolev norms for nonlinear Schrödinger equations. This is joint work with P. Germain and L. Guth.

### $L$-invariants and $p$-adic Langlands programme

Yiwen Ding

Imperial College London

**Abstract:** By Fontaine's theory, a semi-stable non-crystalline Galois representation can be explicitly determined by the associated Weil-Deligne representation, its Hodge-Tate weights, and the associated

Fontaine-Mazur $L$-invariants. These $L$-invariants, however, are invisible in the classical local Langlands correspondence. In this talk, we will consider the 2-dimensional case, and explain how to find these $L$-invariants in the completed cohomology group of Shimura curves.

## Height for families of abelian varieties and the Geometric Bogomolov Conjecture

Ziyang Gao

CNRS (France) and Princeton University (USA)

**Abstract:** In the talk we prove a height inequality for a family of abelian varieties over a smooth curve, comparing the canonical heights for the fibers and the height on the base. Then we use this height inequality to prove the Geometric Bogomolov Conjecture. This is joint work with P. Habegger.

## Resonances for open quantum maps

Long Jin

Purdue University

**Abstract:** Open quantum maps are useful models in the study of scattering resonances, especially for open quantum chaotic systems. In this talk, we discuss a special family of open quantum maps known as quantum open baker's maps. They are quantizations of the open baker's maps on the torus and given by a family of subunitary matrices. We are interested in the distribution of eigenvalues, which are analogues of scattering resonances in this simple setting. In particular, we show that there exists a spectral gap which improves both the trivial gap and the pressure gap. We also show a fractal Weyl upper bound for the number of eigenvalues in annuli. This is joint work with Semyon Dyatlov.

## Weak turbulence theory

Zhen Lei

Fudan University

**Abstract:** We will report some recent work on the weak turbulence theory. For incompressible Euler equations, classical existence theory suggests that solutions have a double exponential time-growth upper bound, which seems a true phenomenon in the context of weak turbulence theory but leaves open as a long-standing challenging problem. Our recent result shows that the vorticity gradient of

solutions on two-dimensional torus grows at least exponentially in time.

## An introduction to Bridgeland stability conditions and its application

Chunyi Li

University of Edinburgh

**Abstract:** The notion of stability condition on a triangulated category has been introduced by Bridgeland around ten years ago. I'll give an introduction to some related concepts in the study of this field, and explain how to visualize the space of stability condition via some simple cases. I'll mainly talk about three related topics/applications: birational geometry via wall-crossing; Chern classes of stable objects; Brill-Noether theory.

## The unfolded Seiberg-Witten Floer spectra for three-manifolds

Jianfeng Lin

Massachusetts Institute of Technology

**Abstract:** In 2003, Manolescu defined the Seiberg-Witten Floer stable homotopy type for rational homology three-spheres. This powerful invariant has many applications including the disproof of higher dimensional triangulation conjecture (Manolescu 2014). In this talk, I will explain how to generalize Manolescu's construction to define spectrum invariants for general three-manifolds and discuss some applications of these new invariants. This is joint work with Tirasan Khandhawit and Hirofumi Sasahira.

## Multiplicities in commutative algebra

Linquan Ma

University of Utah

**Abstract:** The multiplicities are certain invariants that measure the singularities of local rings. These include intersection multiplicity, the Hilbert-Samuel and Hilbert-Kunz multiplicities. We discuss some major open problems in this field and report recent progress towards these questions.

## Recent progress on the convergence of the multiple ergodic averages

Song Shao

University of Science and Technology of China

**Abstract:** In this talk, we first review the recent progress on the study of convergence of multiple ergodic averages both in $L^2$ norm and pointwisely. Then we show that if $(X, \mathcal{X}, \mu, T)$ is a distal or weakly mixing PID measure preserving system, then for all $d$ and all $f_1, \ldots, f_d \in L^1(X, \mathcal{X}, \mu)$, $\lim_{N\to\infty} \frac{1}{N} \sum_{n=0}^{N} \frac{1}{n} f_1(T^n x) \ldots f_d(T^{dn} x)$ exists almost surely.

## NonLERFness of arithmetic hyperbolic manifold groups

Hongbin Sun

University of California, Berkeley

**Abstract:** We will show that, for "almost" all arithmetic hyperbolic manifolds with dimension $> 3$, their fundamental groups are not LERF. The main ingredient in the proof is a study of certain graph of groups with hyperbolic 3-manifold groups being the vertex groups. We will also show that a compact irreducible 3-manifold with empty or tori boundary does not support a geometric structure if and only if its fundamental group is not LERF.

## Local smooth rigidity of algebraic actions

Zhenqi Wang

Michigan State University

**Abstract:** The study of rigidity phenomenon for group actions is one of the central themes in dynamics. There is a growing interest in recent years for "irreducible" higher rank algebraic actions. In contrast to rank one actions (flow or diffeomorphism), rigidity results are available for a large class of algebraic actions. In the first part of the talk, basic notations and the background for the whole project will be introduced. Then the main results, current tools, open questions and future directions will be presented.

## Correspondences between convex geometry and complex geometry

Jian Xiao

Northwestern University

**Abstract:** We present several (new) correspondences between the theory of convex bodies and the theory of holomorphic line bundles on smooth projective varieties or Kähler manifolds, thus extending the dictionary between convex geometry and complex geometry. An important ingredient is a refined structure of the movable cone of curves. This is joint work with Brian Lehmann.

## Stokes phenomena in geometry and representation theory

Xiaomeng Xu

Massachusetts Institute of Technology

**Abstract:** We consider an ordinary differential equation (a Knizhnik-Zamolodchikov type equation) with a pole of order two. It turns out that the Stokes factors at this pole satisfy the Yang-Baxter equation. This implies a surprising relation between irregular singularities and Drinfeld's quantum groups. The semiclassical limit of our construction leads to a connection between Stokes phenomena and certain symplectic varieties arisen in representation theory.

## Diffeomorphism cocycles over expanding map, without domination

Jiagang Yang

Universidade Federal Fluminense

**Abstract:** This is a joint work with Marcelo Viana. We formulate a version of the Avila-Viana Invariance Principle for diffeomorphism cocycles that are not necessary dominated (fiber bunched). As an application, we prove that cocycles having some non-zero Lyapunov exponent are generic in a number of situation, including GL($d$)-cocycles over expanding maps and Di ($M$) cocycles over expanding maps.

## Volume conjectures for the Reshetikhin-Turaev and the Turaev-Viro invariants

Tian Yang

Stanford University

**Abstract:** In a joint work with Qingtao Chen, we conjecture that at the root of unity $\exp(2\pi i/r)$ instead of the usually considered root $\exp(\pi i/r)$, the Turaev-Viro and the Reshetikhin-Turaev invariants of a hyperbolic 3-manifold grow exponentially with growth rates respectively the hyperbolic and the complex volume of the manifold. This reveals a different asymptotic behavior of the relevant quantum invariants than that of Witten's invariants (that grow polynomially by the Asymptotic Expansion

Conjecture), which may indicate a different geometric interpretation of the Reshetikhin-Turaev invariants than the SU(2) Chern-Simons gauge theory. Recent progress toward these conjectures will be summarized, including a joint work with Renaud Detcherry and Effie Kalfagianni.

## Lyapunov exponents and holomorphic subbundles

Fei Yu

Zhejiang University

**Abstract:** Recently Eskin-Kontsevich-Moller-Zorich prove my conjecture that the sum of the top $k$ Lyapunov exponents is always greater or equal to the degree of any rank $k$ holomorphic subbundle (They generalize the original context from Teichmüller curves to any local system over a curve with non-expanding cusp monodromies). Furthermore, they conjecture that equality of the sum of Lyapunov exponents and the degree is related to the monodromy group being a thin subgroup of its Zariski closure. I will introduce some backgrounds on those conjectures and some applications to Teichmüller dynamics and Calabi-Yau type families.

## Positively ratioed representations

Tengren Zhang

California Institute of Technology

**Abstract:** Let S be a closed orientable surface of genus at least 2, and let G be a semisimple Lie group of non-compact type. Positively ratioed representations are Anosov representations from the fundamental group of S to G, that satisfy an additional cross ratio condition. In this talk, I will explain what are positively ratioed representations, give examples of such representations, and explain a systolic inequality that we proved using geodesic currents. This is joint work with Giuseppe Martone.

## Relative isoperimetric inequality

Zhenlei Zhang

School of Mathematical Sciences, Capital Normal University

**Abstract:** In this talk, I will introduce a relative version of the isoperimetric inequality. The analytic counterpart is the so-called weak Sobolev inequality. I will also present an estimate to the corresponding isoperimetric constant for subdomains of a manifold, under the assumption of volume doubling property and a partial Poincare inequality. Some examples will be discussed.

# For Applied Math

## Representation learning in image processing: the sparse coding perspective

Chenglong Bao

National University of Singapore

**Abstract:** In recent years, sparse coding has been widely used in many applications ranging from image processing to pattern recognition. In this talk, I will introduce some sparse coding based dictionary learning methods in image processing. An alternating numerical scheme for solving the resulting minimization problems will be present and show advantages both in convergence theory and numerical experiments over the K-SVD methods.

## Changepoint estimation: another look at multiple testing problems

Hongyuan Cao

University of Missouri

**Abstract:** We consider large scale multiple testing for data that have locally clustered signals. With this structure, we apply techniques from change-point analysis and propose a boundary detection algorithm so that the clustering information can be utilised. Consequently the precision of the multiple testing procedure is substantially improved. We study tests with independent as well as dependent $p$-values. Monte Carlo simulations suggest that the methods perform well with realistic sample sizes and show improved detection ability compared with competing methods. Our procedure is applied to a genome-wide association dataset of blood lipids.

## Patterns on graphs—from images to histograms

Xiuyuan Cheng

Yale University

**Abstract:** This talk is about how to learn representations of data sampled on a graph, where the graph geometry can be leveraged to facilitate pattern recognition tasks. Particularly, we will introduce "Haar scattering net" as a model of unsupervised deep networks. While Mallat's scattering transform employs continuous wavelets and applies to images and audio signals, Haar scattering net uses Haar wavelets and is applicable to discrete data types. Furthermore, when the underlying graph is unknown, Haar scattering net infers the geometry of variables by optimizing the construction of wavelet

basis in a data-adaptively way. Despite its light computational load and simplified architecture, Haar scattering net demonstrates strong classification performance when prior knowledge of the variable geometry is not provided. We will discuss another application in analyzing mass cytometry data, where the mathematical problem is to compare empirical distributions. By constructing histograms on a mesh in the input space, the problem is reduced to analyzing feature vectors which are graph signals.

## Randomization inference for peer effects, with application to the roommate assignment in Peking University

Peng Ding

University of California, Berkeley

**Abstract:** Previous causal inference literature often required no interference among units, that is, the potential outcomes of a unit do not depend on the treatments of other units. This no-interference assumption, however, becomes unreasonable when units are partitioned into groups and they interact with other units within groups. In a motivating education example from Peking University, there are two types of students admitted through the college entrance exam (also known as Gaokao) or through recommendation (often based on Olympiads in various subjects). Right after entering college, students are randomly assigned to different dorms, each of which hosts four students. Because students within the same dorm live together almost every day and they interact with each other intensively, it is very likely that peer effects exist and the no-interference assumption is violated. More importantly, understanding peer effects among students gives useful guidance for future roommate assignment to improve the overall performances of the students. Methodologically, we define peer effects in terms of potential outcomes, and propose a randomization-based inference framework to study peer effects in general settings with arbitrary numbers of peers and arbitrary numbers of the student types. Using a unique dataset collected by the administrative office of Peking University, we investigate two large science departments and find significant peer effects among students. Based on the statistical results, we suggest that the optimal roommate assignment should try to mix different types of students, in order to maximize the overall academic performances of the students in some departments (e.g. physics) in Peking University.

## Fast algorithms for collisional kinetic equations

Jingwei Hu

Purdue University

**Abstract:** Boltzmann and related kinetic equations play a fundamental role in describing the nonequilibrium dynamics of many-particle systems. The prominent challenges associated with numerically

solving these equations are the expense of evaluating the collision operator—a high-dimensional, nonlinear, nonlocal integral operator. In this talk, I will introduce two fast algorithms for Boltzmann-like collision operators, one for the classical, quadratic operator, and one for the quantum, cubic operator. The main feature of these algorithms is to exploit and leverage the convolutional and low-rank structure in the collision integral. The accuracy and efficiency of the proposed algorithms over conventional methods will be demonstrated through a series of examples.

## On the rate of convergence for online principal component estimation and tensor decomposition

Junchi Li

Princeton University

**Abstract:** Principal component analysis (PCA) and tensor component analysis has been a prominent tool for high-dimensional data analysis. Online algorithms that estimate the component by processing streaming data are of tremendous practical and theoretical interests. In this talk, we cast these methods into stochastic nonconvex optimization problems, and we analyze the online algorithms as a stochastic approximation iteration. My talk is divided into two parts. In the first half, we first attempt to understand the dynamics of stochastic gradient method via ordinary and stochastic differential equation approximations. In the second half, we prove for the first time a nearly optimal convergence rate result for both online PCA algorithm and online tensor decomposition. We show that the finite-sample error closely matches the corresponding results of minimax information lower bound.

## Provable nonconvex optimization in signal processing and machine learning

Xiaodong Li

University of California, Davis

**Abstract:** Nonconvex optimization methods arise naturally in various fields related to high-dimensional data. In nonlinear signal processing, least squares fitting results in nonconvex optimization; in sensor network localization and manifold learning, fitting to the local distance information leads to nonconvex optimization. However, theoretical properties of nonconvex optimization have not been well explored due to potential local minima. In this talk, the speaker will introduce his past and ongoing projects regarding the mathematical analysis of nonconvex methods for some problems arising from related fields, with focus on justifying their computational feasibility under stochastic setups.

## A new perspective on robust regression

Qiang Sun

Yale University and Princetion University

**Abstract:** Big data are often contaminated by outliers and heavy-tailed errors, which are also a stylized feature of high-dimensional data. To address this challenge, we propose the adaptive Huber regression for robust estimation and inference. The key observation is that the robustification parameter should adapt to the sample size, dimension and moments for optimal tradeoff between biases and robustness. Our framework is able to handle heavy-tailed data with bounded (1 + $\delta$)-th moment for any $\delta > 0$. We establish a sharp phase transition for robust estimation of regression parameters in both finite dimension and high dimension settings: when $\delta \geq 1$, the estimator achieves sub-Gaussian rate of convergence without sub-Gaussian assumptions, while only a slower rate is available in the regime $0 < \delta < 1$ and the transition is smooth and optimal. As a consequence, the non-asymptotic Bahadur representation for finite-sample inference can only be derived when the second moment exists. Numerical experiments lend further support to our obtained theories.

## New analysis of large-scale optimization

Ruoyu Sun

University of Illinois at Urbana-Champaign

**Abstract:** There is an increasing need for solving large-scale optimization problems. The sheer size poses new challenge to the analysis and design of efficient algorithms. In this talk, we examine two different issues arising in large-scale optimization. The first part is about the non-convex matrix factorization formulation for matrix completion. This formulation is very popular in practice, but there is little understanding of why it works well. We prove that with a simple initialization, most algorithms for a certain nonconvex formulation converge to global optima. The key step is to revisit the basic matrix factorization formulation in linear algebra, and establish a local geometrical property of a regularized objective function. The second part is concerned with the convergence analysis of randomly permuted ADMM. One way to solve a linearly constrained optimization problem is by ADMM (Alternating Direction Method of Multipliers). It is known that traditional cyclic order leads to divergence of multi-block ADMM. We prove that RP-ADMM (randomly permuted ADMM) converges in expectation when solving linear systems. Our result proves for the first time that the random permutation rule is strictly better than the cyclic rule. The proof is based on spectral analysis, and indicate s that random permutation can make the distribution of eigenvalues much nicer than a given specific order.

## From simplex to the mathematical modeling and numerical discretization

Shuonan Wu

Penn State

**Abstract:** In this talk, I will talk about several properties of the $n$-dimensional simplex that related to the mathematical modeling and numerical discretization. The first property of simplex is its relationship between the symmetric matrix spaces, which motivates the mixed finite elements for the stress-displacement formulation of linear elasticity. Since the conforming mixed elements can only be constructed for the high order cases, we first propose two classes of nonconforming mixed finite elements for linear elasticity of any order, with interior penalty for nonconforming symmetric stress approximation. By using a hybridization process, namely introducing some Lagrangian multipliers to impose interelement continuity for stress, the solution of the discretized indefinite system is reduced to that of obtaining a symmetric semi-positive-definite (SSPD) system. We then develop an overlapping Schwarz method to the resulting SSPD system and prove its uniform convergence with respect to both the mesh size and Poisson ratio. Another interesting research topic is the simplicial condition we proposed in the multiphase modeling that simulates the phase separation of an $N$-component mixture. For the general choice of phase variables, the unisolvent property of the symmetric coefficient matrix involved in the $N$-phase models based on the pairwise surface tensions is established thanks to the relationship between symmetric matrix spaces and simplex. Moreover, the symmetric positive-definite property of the coefficient matrix on an $(N-1)$-dimensional hyperplane—which is of fundamental importance to the well-posedness of the models—can be proved equivalent to the simplicial condition for pairwise surface tensions. The second property of $n$-dimensional simplex is the similarity, which motivates the universal construction of the nonconforming element for $2m$-th elliptic equation. We give a universal construction for $m = n + 1$, which naturally extends the elements proposed in [M. Wang, J. Xu, Math. Comp. 2013], where $m \leq n$ is required. We prove the unisolvent property by induction by using the similarity properties of both shape function spaces and degrees of freedom on simplex. The elements have the approximability, pass the generalized patch test and hence converge. We also establish optimal orders of convergence in both $H^m$ and $H^{m-1}$ norms.

## Primal-dual algorithms for the sum of three operators

Ming Yan

Michigan State University

**Abstract:** In this talk, I will introduce existing primal-dual algorithms for minimizing $f(x) + g(x) + h(Lx)$, where $f$ is convex and Lipschitz differentiable, $g$ and $h$ are convex (possibly non-differentiable), and $L$ is a linear operator. Then, I will propose a new primal-dual algorithm, which is a generalization of two primal-dual algorithms for solving the sum of two operators. In addition, the new algorithm recovers many operator splitting methods involving two and three operators.

## Absorbing interface conditions

Zhijian Yang

Wuhan University

**Abstract:** In this talk, I will discuss absorbing interface conditions, which were proposed either at interfaces between different physical models or the same model with different discretization schemes. The proposed interface conditions permit two-way transmission of low frequency waves across interfaces which can be supported by both models and perform one-way absorption of high frequency waves which can only be supported by fine models when they travel from fine mesh regions to coarse ones. Numerical examples are presented to illustrate the efficiency of the proposed absorbing interface conditions.

## Towards fourth- and higher-order simulations of incompressible multiphase flows with moving boundaries

Qinghai Zhang

Zhejiang University

**Abstract:** This talk concerns three components in simulating multiphase flows with high accuracy and efficiency. First, I will present a fourth-order projection method for solving the incompressible Navier-Stokes equations. To achieve three digits of accuracy for vorticity in a high-Reynold-number flow, it is faster to run my method on a personal desktop than to run some classical second-order projection methods on the fastest supercomputer in the world! The second part concerns a new interface tracking method, which achieves machine precision on a 128x128 grid for several benchmark tests considered as among the most difficult. Lastly, we discuss a new eighth-order method that estimates interface curvature to the best attainable accuracy afforded by double-precision floating point numbers.

## Analysis of ergodic diffusion processes and issues related to model reduction

Wei Zhang

Free University of Berlin

**Abstract:** Projecting a high-dimensional stochastic dynamics on the reaction coordinate space has attracted considerable attentions in the literature. In this talk, I will first discuss some general properties of an ergodic diffusion process whose invariant measure is unique. Then I will discuss the model reduction problem of an ergodic diffusion process along certain given reaction coordinate. The main focus will be the properties which are inherited from the original dynamics, as well as error estimates

of the timescales and reaction rates of the projected dynamics comparing to those of the full dynamics. Algorithmic issues and connections with both the "equation-free" approach and the "heterogeneous multi-scale method" will be discussed as well. This is joint work with Carsten Hartmann and Christof Schuette.

## Connectivity properties of branching interlacements

Yuan Zhang

Texas A&M University

**Abstract:** We consider connectivity properties of the Branching Interlacements model in $\mathsf{Z}^{\mathsf{d}}$, $d \geq 5$, recently defined by Angel, Rath and Zhu. Using stochastic dimension techniques we show that every two vertices visited by the branching interlacements are connected via at most $\lceil d/4 \rceil$ conditioned critical branching random walks from the underlying Poisson process, and that this upper bound is sharp. In particular every two conditioned branching random walks intersect if and only if $5 \leq d \leq 8$. The stochastic dimension of branching random walk result is of independent interest. We additionally obtain heat kernel bounds for branching random walks conditioned on survival.

## Towards a mathematical understanding of surface hopping methods

Zhennan Zhou

Duke University

**Abstract:** We develop a surface hopping algorithm based on frozen Gaussian approximation for semiclassical matrix Schrödinger equations. The algorithm is asymptotically derived from the Schrödinger equation with rigorous approximation error analysis. The resulting algorithm can be viewed as a path integral stochastic representation of the semiclassical matrix Schrödinger equations. Our results provide mathematical understanding to and shed new light on the important class of surface hopping methods in theoretical and computational chemistry. Also, I would like to report our recent progress on the improved surface hopping algorithm with various numerical tests.

# Contacts

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