数学科学学院
School of Mathematical Sciences, ECNU

# 数学进展与问题驱动

## 数学科学论坛暨华东师范大学 70 周年校庆

# 程序册

**2021年3月20–22日**

华东师范大学

# 目录

# "数学进展与问题驱动"数学科学论坛

华东师范大学　　数学科学学院

2021年3月20-22日

在华东师范大学成立70周年和数学科学学院成立3周年之际，华东师范大学数学科学学院和上海市核心数学与实践重点实验室特于2021年3月20-22日举办由江松院士和谈胜利教授联合组织的"数学进展与问题驱动"数学科学论坛。本次论坛旨在为数学学科多个领域的专家学者提供一个交流平台，分享和探讨涉及应用数学与计算数学、运筹优化、代数几何、微分几何、表示论、数论、偏微分方程和连续介质力学的数学问题等多个领域最新研究进展以及对数学科学的发展和研究方向的见解，促进多学科交叉、融合与创新，推进数学学科发展建设。

一、 会议时间：

2021年3月20日－22日

二、 会议地点：

上海市闵行区东川路500号 华东师范大学（闵行） 数学楼102

三、特邀嘉宾（按姓氏字母顺序）

| | | |
|---|---|---|
| 程　晋 | 教授 | 复旦大学、上海财经大学 |
| 戴彧虹 | 研究员 | 中国科学院 |
| 韩德仁 | 教授 | 北京航空航天大学 |
| 黄艾香 | 教授 | 西安交通大学 |
| 黄云清 | 教授 | 湘潭大学 |
| 江文帅 | 博士 | 浙江大学 |
| 金　石 | 教授 | 上海交通大学 |
| 李从明 | 教授 | 上海交通大学 |
| 李　骏 | 教授 | 复旦大学 |
| 李开泰 | 教授 | 西安交通大学 |
| 刘　博 | 教授 | 华东师范大学 |

刘　钢　　教授　　　　华东师范大学
刘若川　　教授　　　　北京大学
吕长虹　　教授　　　　华东师范大学
缪　爽　　教授　　　　武汉大学
莫则尧　　研究员　　　北京应用物理与计算数学研究所
倪维明　　教授　　　　香港中文大学（深圳）
屈长征　　教授　　　　宁波大学
王　兵　　教授　　　　中国科学技术大学
席南华　　院士　　　　中国科学院
郗　平　　教授　　　　西安交通大学
尹景学　　教授　　　　华南师范大学
于　品　　教授　　　　清华大学
张　波　　研究员　　　中国科学院
张平文　　院士　　　　北京大学
张伟平　　院士　　　　南开大学

四、 主办单位：

华东师范大学数学科学学院　　上海市核心数学与实践重点实验室

五、会议主席

江　松　　院士　　　　北京应用物理与计算数学研究所
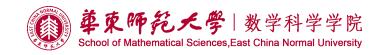谈胜利　　教授　　　　华东师范大学数学科学学院

六、组织委员会

　吕长虹　　郑海标　　袁富荣
　张红艳　　曹思圆　　刘欣雨

七、联系人

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# 会议日程

| 2021 年 3 月 20 日 周六 | | |
|---|---|---|
| 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：江 松 | |
| 9:00-9:40 | 席南华：代数群的表示 | |
| 9:40-10:20 | 张平文：数值模式能彻底解决天气预报的问题吗？ | |
| 10:20-10:40 | 茶 歇 | |
| | **大会报告** 主持人：席南华 | |
| 10:40-11:20 | 李 骏：New developments in Gromov-Witten invariants of Calabi-Yau threefold | |
| 11:20-12:00 | 黄云清： | |
| | 午餐 时间：12:00－14:30 地点：艺悦酒店 | |
| | **大会报告** 主持人：张平文 | |
| 14:30-15:10 | 张伟平： Positive scalar curvature on manifolds and foliations | |
| 15:10-15:50 | 莫则尧：高性能 CAE 软件平台—茉莉平台 | |
| 15:50-16:10 | 茶 歇 | |
| | **大会报告** 主持人：张伟平 | |
| 16:10-16:50 | 金 石：Accurate and Efficient Simulations of Hamiltonian Mechanical Systems with Discontinuous Potentials | |
| 16:50-17:30 | 李开泰： 流体固壁边界几何形状控制数学模型、算法和应用 | |
| | 晚餐 时间：18:00－20:00 地点：艺悦酒店 | |
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| **2021 年 3 月 21 日 周日** | |
|---|---|
| **大会报告** 主持人：叶 东 | |
| 8:30-9:10 | 倪维明：Some Recent Progress on Dispersal Related Issues in Mathematical Ecology |
| 9:10-9:50 | 尹景学：Dynamical Behaviour of the Lane-Emden Heat Flow with Linear and Nonlinear Diffusion |
| 9:50-10:30 | 屈长征：Invariant Geometric Flows and Integrable Systems |
| 10:30-10:50 | 茶 歇 |
| **大会报告** 主持人：屈长征 | |
| 10:50-11:30 | 李从明：A priori estimates and Liouville type theorems |
| 11:30-12:10 | 张 波：Asymptotic Property of Phaseless Total-Field Operators and Phaseless Inverse Scattering Problems |
| 午餐 时间：12:10 – 14:30 地点：艺悦酒店 | |
| **大会报告** 主持人：李 韬 | |
| 14:30-15:10 | 程 晋：用带噪声的部分短期观测数据进行非线性动力系统的参数辨识的理论和算法——以Lorenz63模型为例 |
| 15:10-15:50 | 韩德仁： Approximate first-order primal-dual algorithms for saddle point problems |
| 15:50-16:10 | 茶 歇 |
| **大会报告** 主持人：韩德仁 | |
| 16:10-16:50 | 戴彧虹：整数规划若干理论和应用进展 |
| 16:50-17:30 | 吕长虹：A bridge between the coin weighing problem and the minimal doubly resolving set problem in graphs |
| 晚餐 时间：17:30 – 19:00 地点：艺悦酒店 | |

| 2021 年 3 月 22 日 周一 |
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| 大会报告　　　　　　　　　　　　　　主持人：邱瑞峰 |

| 8:30-9:10 | 刘若川：　Toppological cyclic homology for p-adic local fields |
|---|---|
| 9:10-9:50 | 王　兵：　The local entropy along Ricci flow |
| 9:50-10:30 | 郗　平：　Geometric and algebraic aspects of analytic number theory |
| 10:30-10:50 | 茶　歇 |
| | 大会报告　　　　　　　　　　　　　　主持人：刘若川 |
| 10:50-11:30 | 于　品：稳态黑洞的刚性问题 |
| 11:30-12:10 | 刘　钢：　Gromov-Hausdorff convergence of Kahler manifolds |
| | 午餐　时间：12:10－14:30　地点：艺悦酒店 |
| | 大会报告　　　　　　　　　　　　　　主持人：王　兵 |
| 14:30-15:10 | 缪　爽：Stability and rigidity of blow-up solutions to energy critical Wave Maps |
| 15:10-15:50 | 江文帅：Regularity and Singularity of Ricci limit Spaces |
| 15:50-16:30 | 刘　博：K-theory, eta invariant and localization |
| 16:30-17:30 | 自由讨论 |
| | 晚餐　时间：17:30－19:00　地点：艺悦酒店 |

代数群的表示

席南华

本报告围绕代数群表示的核心问题--不可约特征标开展，包括基本的内容和一些进展。

数值模式能彻底解决天气预报的问题吗？

张平文

数值天气预报是目前天气预报最主要的手段之一，也是气象预报员进行天气预报最重要的参考信息。但是由于数值模式的初始场，边界条件，参数化方案等都会引入误差，又由混沌理论，导致数值模式很难进行长时间精准预报。一方面，参数化方案引入的误差会随着分辨率的增高而变大，所以数值模式的分辨率不能无限增高，只能用有限的分辨率来进行计算；另一方面，由于湍流的尺度会超出数值模式的分辨率，湍流的误差也会由蝴蝶效应放大。

因而在实际预报业务中，数值模式的预报数据往往和实况观测存在系统性偏差，即数值模式进行天气预报的能力存在极限、不能彻底解决天气预报的问题的。这就需要预报员要进行天气会商来对数值模式预报结果进行订正，进一步提高预报准确率，实现精准天气预报。用算法来模拟预报员对数值天气预报订正的过程，就是模式后处理。
以往预报员多使用传统统计方法进行模式后处理，近些年，随着人工智能的蓬勃发展，很多基于人工智能技术如机器学习/深度学习的模式后处理方法得到了应用，因其相对于传统统计方法具有可以隐式提取气象要素时空特征和多尺度物理过程的特点，显示了其在模式后处理方面的显著的优越性。

New developments in Gromov-Witten invariants of Calabi-Yau threefold

李骏

待定

黄云清

Positive scalar curvature on manifolds and foliations

张伟平

A famous vanishing theorem of due to Lichnerowicz states that if a closed spin manifold admits a Riemannian metric of positive scalar curvature, then its A-hat genus equals to zero. In this talk we will describe some recent advanced generalizing this kind of results to other manifolds as well as foliations.

## 高性能CAE软件平台—茉莉平台
### 莫则尧

面向重大装备数值模拟，高性能CAE软件自主快速研发是卡脖子的瓶颈问题。本报告提出高性能CAE软件的层次框架栈，给出基于软件平台的高性能CAE软件自主快速研发新途径，介绍报告人及其团队在软件平台方面的近期进展。

## Accurate and Efficient Simulations of Hamiltonian Mechanical Systems with Discontinuous Potentials
### 金石

Newtonian mechanical systems with potential functions admitting jump discontinuities. The focus is on an accurate and efficient numerical approximation of their solutions, which will be defined via the laws of reflection and refraction. Despite of the success of symplectic integrators for smooth mechanical systems, their construction for these discontinuous ones is nontrivial, and numerical convergence order can be impaired too. Several rather-usable numerical methods are proposed, including: a first-order symplectic integrator for general problems, a thirdorder symplectic integrator for problems with only one linear interface, arbitrarily high-order reversible integrators for general problems (no longer symplectic), and an adaptive time-stepping version of the previous high-order method. Interestingly, whether symplecticity leads to favorable long time performance is no longer clear due to discontinuity, as traditional Hamiltonian backward error analysis does not apply any more. Therefore, at this stage, our recommended default method is the last one. Various numerical evidence, on the order of convergence, long time performance, momentum map conservation, and consistency with the computationally-expensive penalty method, are supplied. A complex problem, namely Sauteed Mushroom, is also proposed and numerically investigated, for which multiple bifurcations between trapped and ergodic dynamics are observed.

## 流体固壁边界几何形状控制数学模型、算法和应用
### 李开泰

整个研究工作是建立在嵌入高维空间里二维流形上的张量分析基础之上。在建立了二个特殊的曲线坐标系下给出了控制方程分别为内流和外部流动NS方程的目标泛函给出了第一变分和欧拉拉格朗日方程和求解控制问题的共轭梯度算法，对内流给出一个谱有限元方法和对外流给出一个不重叠的区域分裂方法在无穷远领域化解为一个人工边界上的积分方程分析了它的适定性问题在固壁边界领域内运用维数分裂方法和给出膜算子的边界层方程。介于边界层和无限运领域的中间地带可运用现成的各种算法。叶片结构分析和流固耦合的振动问题运用三维壳体问题的微分几何方法建立了维数分裂方法。总之整个研究工作是建立在微分几何-偏微分方程、控制论、流体力学，弹性力学、计算数学交叉学科之上，最后研发基于CAE的有自主智识产权的软件包。

## Some Recent Progress on Dispersal Related Issues in Mathematical Ecology
倪维明

Dispersal has been considered important in ecological dynamics to predict species adaptation/competition under changing environments, but accurately incorporating movement into ecological models remains an ongoing challenge due to the limited field data.

Mathematical theories of movement in heterogeneous environments exist, but they tend to over-simplify the situations and, sometimes give rise to results inconsistent with, or even opposite to, empirical data, which has led to improvements of some of the existing mathematical models.

In principle, the tested theories can then be used where experimental work is limited. Such knowledge would advance our understanding of dispersal in determining, facilitating, or prohibiting species adaptation in changing environments, ultimately to forecast change in biodiversity.

We will use examples to illustrate some of such recent interactions in this lecture.

## Dynamical Behaviour of the Lane-Emden Heat Flow with Linear and Nonlinear Diffusion
尹景学

We consider the Lane-Emden heat flow with linear and nonlinear diffusion, and discuss the dynamical behaviour of solutions, including the periodicity, complexity of the asymptotic behaviour and chaos of solutions, etc.

## Invariant Geometric Flows and Integrable Systems
屈长征

It is well-known that a number of integrable systems and heat equations arise from geometric flows in various geometries. Invariant geometric flows in those geometries have been studied extensively from different points of view. In this talk, we are mainly concerned with the invariant integrable geometric flows in certain geometries. First, we show that the specific invariant geometric flows in those geometries are related respectively to the wellknown integrable systems. Second, the geometric formulations to integrability features of the resulting systems are discussed. Third, the geometric flows corresponding to the Camassa-Holm-type equations are also presented. Finally, new heat flows in certain geometries will be investigated.

## A priori estimates and Liouville type theorems
李从明

A priori estimates and Liouville type theorems are two very interesting and closely related research areas. We give a brief introduction on the problems, some related methods, and some results. As an example, we present some of our work on classififications and point-wise estimates of solutions to some nonlinear elliptic type equations.

## Asymptotic Property of Phaseless Total-Field Operators and Phaseless Inverse Scattering Problems

张波

Inverse scattering with full data have been studied extensively in the past decades. However, in many practical applications, the phase of the measured data can not be obtained accurately compared with its modulus and sometimes is even impossible to be obtained. Thus it is often desirable to consider inverse scattering with the modulus or intensity of the measured data (called phaseless data). In recent years, many work has been done on inverse scattering with phaseless far-field and total-field data, including uniqueness issues and numerical algorithms. In this talk, we consider inverse scattering with phaseless total-field data at a fixed frequency. We will propose a new framework to study this problem, including the uniqueness issue and a factorization-type imaging algorithm. Precisely, we will establish the asymptotic property in an operator norm of the phaseless total-field operator defined in terms of the phaseless total-field data measured on a large enough ball, employing the theory of oscillatory integrals. As far as we know, this is the first result on the asymptotic behavior in an operator norm of the phaseless total-field operator though pointwise asymptotic results of the phased scattered field have been previously obtained. This asymptotic property of the phaseless total-field operators is then used to establish uniqueness results and an approximate factorization method for inverse scattering with phaseless total-field data at a fixed frequency. This talk is based on the following recent results with Xu Xiaoxu and Haiwen Zhang.

1. Bo Zhang and Haiwen Zhang, An approximate factorization method for inverse acoustic scattering with phaseless total-field data, SIAM Journal of Applied Mathematics 80(5) (2020), 2271-2298.
2. Xiaoxu Xu, Bo Zhang and Haiwen Zhang, Uniqueness and Direct Imaging Method for Inverse Scattering by Locally Rough Surfaces with Phaseless Near-Field Data, SIAM Journal of Imaging Sciences 12(1) (2019), 119-152.

## 用带噪声的部分短期观测数据进行非线性动力系统的参数辨识的理论和算法
### ——以 Lorenz63 模型为例

程晋

　　复杂非线性动力系统的参数辨识问题是一个理论上非常重要的问题，具有重要的实际背景和潜在的应用价值，也是大气科学等重要研究领域学者所关心的问题之一。我们考虑非线性动力系统的一个重要例子Lorenz63系统，基于我们提出的处理带有大的随机噪声数据的方法，提出了一种利用部分低维短期观测数据反演动力系统参数的方法，并给出的相应的理论分析和误差估计。数值结果表明我们的算法具有较好的稳定性、精确性和有效性。

# Approximate first-order primal-dual algorithms for saddle point problems

韩德仁

We propose two approximate versions of the first-order primal-dual algorithm (PDA) for solving a class of convex-concave saddle point problems. The introduced approximate criteria are easy to implement in the sense that they only involve the subgradient of a certain function at the current iterate. The first approximate PDA solves both subproblems inexactly and adopts absolute error criteria, which are based on nonnegative summable sequences. The second approximate PDA, assuming that one of the PDA subproblems can be solved exactly, solves the other subproblem approximately and adopts a relative error criterion. The relative error criterion only involves a single parameter ranging in [0, 1), which makes the method more applicable. For both versions, we establish the global convergence and O(1/N) rate of convergence measured by the iteration complexity, where N counts the number of iterations. Under further assumptions that partial of the underlying functions and the whole underlying functions are strongly convex, we show the accelerated 1 over N square and linear rate of convergence, respectively, for the inexact PDA with absolute error criteria. We then prove that these inexact criteria can also be extended to solve a class of more general problems. Finally, we perform some numerical experiments on sparse recovery and image processing problems, and the results demonstrate the feasibility and superiority of the proposed methods.

## 整数规划若干理论和应用进展

戴彧虹

整数规划在工业、经济、能源、通信等各行各业应用广泛。本报告将介绍中科院CMIP整数规划及其应用团队最近在预处理法、割平面法等方面理论进展，同时也将介绍在社交网络影响最大化问题、通信基站选址问题以及热油管道输运问题等方面成功应用案例。

## A bridge between the coin weighing problem and the minimal doubly resolving set problem in graphs

吕长虹

硬币称重问题（Coin-weighing problem）是一个经典的组合优化问题：给定n个硬币，假定真硬币的重量和假硬币的重量均已知，现在需要制定一个称重策略，能用最少的称重次数将所有的假币找出来。硬币称重问题得到Erdos、Renyi、Lindstrom等在内的很多学者的研究。图的2-分辨集（Double resolving set）是Caceres 等人为了研究图的维数在2007年才提出的一个工具性的新概念。最近，我和博士生叶青杰发现了图的2-分辨集问题与硬币称重问题的存在紧密联系。我们利用硬币称重问题上著名的Lindstrom方法解决了图的2-分辨集问题上的猜想，并给出了计算超方体和折叠超方体2-分辨集问题的快速算法。另一方面，2-分辨集问题的图论结果反过来也提供了硬币称重问题的一些新进展。

## Toppological cyclic homology for p-adic local fields
刘若川

Toppological cyclic homology, which was introduced by Bokstedt-Hsiang-Madsen in early 90s, is an important tool to compute algebraic K-groups via the cyclotomic trace map. It is also closely related to p-adic cohomology theories as revealed by the recent work of Bhatt-Morrow-Scholze. In this talk, we will give a brief introduction to topological cyclic homology and present a new approach to computing it in the case of p-adic local fields. Joint work with Guozhen Wang.

## The local entropy along Ricci flow
王兵

Inspired by Li-Yau estimates, we localize the entropy functionals of G. Perelman and generalize his no-local-collapsing theorem and pseudo-locality theorem. The improved no-local-collapsing theorem can be used to solve a convergence conjecture of K\"ahler Ricci flow due to Song-Tian. The improved pseudo-locality theorem can be used to show the continuous dependence of the Ricci flow with respect to the initial metric in Gromov-Hausdorff topology with Ricci curvature bounded below, and to show the compactness of the moduli of Kähler manifolds with bounded scalar curvature and a rough locally almost Euclidean condition.

## Geometric and algebraic aspects of analytic number theory
郗平

Analytic number theory has witnessed fruitful developments in recent years by borrowing many geometric, algebraic, probabilistic and even dynamical ideas. In this talk, we will focus on several aspects of interactions among analytic number theory, algebraic number theory and algebraic geometry. In particular, we will discuss, with some examples on hand, how analytic number theory tools are used to deal with problems in algebraic geometry and how analytic number theorists borrow deep tools from algebraic geometry (such as Deligne's proof of RH for algebraic varieties over finite fields) to deal with primes.
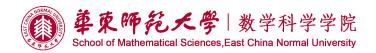
## 稳态黑洞的刚性问题
于品

在合理的几何假设下，物理学家们猜想时空在Einstein方程演化下最终渐近地趋于某个（稳定的）Kerr-Newman黑洞。我们将利用关于波动方程的Carleman型估计证明，Kerr-Newman黑洞在稳态意义下的扰动仍然是Kerr-Newman黑洞。

## Gromov-Hausdorff convergence of Kahler manifolds
刘钢

we discuss some recent development of Gromov-Hausdorff convergence of Kahler manifolds with geometric applications.

## Stability and rigidity of blow-up solutions to energy critical Wave Maps

缪爽

Blow-up solutions to energy critical dispersive PDEs have attracted a lot of attention in recent years. In 2006, Krieger, Schlag and Tataru (KST) constructed a family of energy concentrating blow up solutions to the 2+1 dimensional wave map equation with unit sphere as its target. This construction gives the first example of blow up solutions to the energy-critical Wave Maps. A key feature of this family is that it exhibits a continuum of prescribed blow up rates. However, from the way it was constructed, the stability of this family was not clear and it was believed to be non-generic. In this talk I will present our recent work on proving the stability and rigidity of the KST family. This talk is based on joint works with Joachim Krieger and Wilhelm Schlag.

## Regularity and Singularity of Ricci limit Spaces

江文帅

In this talk, we will survey some recent developments of the study of Ricci limit spaces. We will discuss both the structure of Einstein limits and the structure of lower Ricci curvature limits. At the end, we will discuss some open problems of this project.

## K-theory, eta invariant and localization

刘博

Grothendieck introduced K-theory to algebraic geometry in 1957. Later, Atiyah and Singer employed the real counterpart of K-theory—the topological K-theory, to give a proof of the famous index theorem. In 1990's, in the fields of Arakelov geometry and arithmetic algebraic geometry, K-theory had been extended to arithmetic K-theory. Early this century, motivated by the study of superstring theory and quantum field theory, people extended topological K-theory to the differential K-theory which considered as the real analogue of arithmetic K-theory. Naturally, one may expect that a property works in the other three if it works in one of the four K-theories, and then implies the nontrivial consequences in their corresponding fields. In this talk, we will compare the properties among the four K-theories, taking Riemann-Roch property and the localization as examples. As a consequence of the localization in differential K-theory, we obtain a localization formula of eta invariants, which is a purely geometric formula but have not been proved geometrically until now. This is a joint work with Xiaonan Ma.