2022 年泛函分析及空间理论
天元暑期研讨班

程序册

哈尔滨工业大学数学研究院

8 月 8 日 - 8 月 20 日

简介

泛函分析及空间理论天元暑期研讨班每年举行一次，由哈尔滨工业大学数学研究院主办，旨在汇聚泛函分析及空间理论领域的专家学者，围绕当前该领域的国际主流问题进行深入探讨，搭建年轻学者交流合作的平台，助力该领域更多年轻学者的快速成长。

2022 年度的研讨班将围绕非交换分析及相关方向的主流问题展开。二十余位优秀专家和年轻学者将就该方向若干热门课题进行专题系列讲座和学术报告，内容将涉及非交换 L_p 空间、调和分析、自由概率、几何群论及遍历论等非交换分析的重要理论或关联工具。

研讨班鼓励参会成员之间进行充分讨论及课题合作。本手册的**内容安排将根据研讨班的进度、成员兴趣及客人的行程变更情况作实时调整**，请关注研讨班网页（`http://im.hit.edu.cn/2022/0723/c8389a279350/page.htm`）上的最新版本。

此次研讨班受国家自然科学基金委员会数学天元基金的大力资助。

日期

2022 年 8 月 7 日报到，8 月 8 日开始，8 月 20 日自由活动、离会。

讲座及报告地点

8 月 8 日至 9 日上午：哈尔滨工业大学活动中心 410 室

8 月 9 日下午至 20 日：哈尔滨工业大学数学研究院明德楼 B201-1 报告厅

联系人

学术安排：王斯萌（simeng.wang@hit.edu.cn）、熊枭（xxiong@hit.edu.cn）

食宿、财务：闫墨（yanmo@hit.edu.cn）

日程表

8 月 8 日（周一）		
9:30	**洪桂祥** 武汉大学	An introuction to noncommutative harmonic analysis (1)
14:30	**李文娟** 西北工业大学	L^p-improving bounds and weighted estimates for maximal functions associated with curvature
16:00	**王会菊** 河南大学	Sharp convergence for sequences of Schrödinger means and related generalizations

8 月 9 日（周二）		
9:00	**洪桂祥** 武汉大学	An introuction to noncommutative harmonic analysis (2)
14:30	**吴恋** 中南大学	Noncommutative continuous differentially subordinate martingales
16:00	**周德俭** 中南大学	Cesàro summability of double Fourier series on quantum tori

8 月 10 日（周三）		
9:00	**洪桂祥** 武汉大学	An introuction to noncommutative harmonic analysis (3)
14:30	**王文华** 武汉大学	A Complete Theory of Operator-Valued Hardy Spaces
15:30	**景圆圆** 武汉大学	Campanato Spaces via Quantum Markov Semigroups: I. Finite case

8 月 11 日（周四）		
8:30	**刘伟华** 浙江大学	算子值自由概率简介 (1)
10:30	**王亮** 武汉大学	Fourier restriction estimates on quantum Euclidean spaces
16:00	**韩亚洲** 太原理工大学	A paley's inequalities for discrete group

8 月 12 日（周五）		
9:00	**刘伟华** 浙江大学	算子值自由概率简介 (2)
14:30	**谢广亨** 中南大学	The endpoint estimates of martingale commutators
16:00	**罗思捷** 中南大学	On Lipschitz retractions of the space of bounded linear operators

8 月 13 日（周六）		
9:00	**刘伟华** 浙江大学	算子值自由概率简介 (3)
下午	**自由活动**	

8 月 14 日（周日）		
9:00	**江永乐** 大连理工大学	Introduction to measure equivalence (1)
14:30	**王斯萌** 哈尔滨工业大学	Rigidity of quantum group actions on compact connected spaces
16:00	**黄辉斥** 重庆大学	Amenable fusion algebraic actions on compact quantum spaces

8 月 15 日（周一）		
9:00	**江永乐** 大连理工大学	Introduction to measure equivalence (2)
14:30	**刘伟** 复旦大学	Quantitative mean ergodic inequalities I: power bounded operators acting on one noncommutative L_p space
15:30	**龚雨辉** 华中科技大学	Noncommutative martingale ergodic and ergodic martingale theorems
16:30	**范智杰** 武汉大学	Sharp endpoint L_p estimate of Schrodinger groups under noncommutative algebraic framework

8 月 16 日（周二）		
14:30	**江永乐** 大连理工大学	Introduction to measure equivalence (3)

16:30	**刘敏曾** 南开大学	交换函数空间和非交换算子空间的球覆盖性质

8 月 17 日（周三）		
9:00	**熊枭** 哈尔滨工业大学	量子微分 (1)
下午	**自由讨论**	

8 月 18 日（周四）		
9:00	**熊枭** 哈尔滨工业大学	量子微分 (2)
14:00	**王建权** 哈尔滨工业大学	Primitivity for random quantum channels
15:00	**赖旭东** 哈尔滨工业大学	Noncommutative weak (1,1) estimates for singular integral operators
16:30	**Problem session**	

8 月 19 日（周五）		
9:00	**熊枭** 哈尔滨工业大学	量子微分 (3)
14:30	**李建阁** 哈尔滨工业大学	Forward and reverse entropy power inequalities
16:00	**姚永胜** 哈尔滨工业大学	The Tight Exponent Analysis for Quantum Privacy Amplification

专题系列讲座

An introuction to noncommutative harmonic analysis

洪桂祥（武汉大学） 8 月 8 日至 10 日

In this series of talks, I shall start with the Fourier analytic topics on integers and Euclidean spaces such as Hilbert transform, Fejer means, Littlewood-Paley theory, and then present the corresponding topics on group algebras and quantum tori/Euclidean spaces. The square and maximal functions will be the central reseach objects. And we will see that it is the martingale theory, semicommutative harmonic analysis and the variaous transference techniques that play important roles.

算子值自由概率简介

刘伟华（浙江大学） 8 月 11 日至 13 日

算子值自由概率是对经典自由概率论的自然推广，使得相关问题得到形式上的简化，丰富了冯诺依曼代数的构造，也让很多经典的数学概念得到相应的推广。本次课程将介绍算子值自由概率的背景和相关应用，然后分别从组合和分析两个方面着重介绍该理论现在所关心的问题。

Introduction to measure equivalence

江永乐（大连理工大学） 8 月 14 日至 16 日

In these lectures, we introduce some basis on measure equivalence of countable groups, which was introduced by Gromov in 1990s as a measure-theoretic analog of quasi-isometries in geometric group theory. Due to the close connection between measure equivalence and orbit equivalence, we also discuss orbit equivalence theory, which was initiated by Dye in the late 1950s. In lecture 1, we review the definition of measure equivalence between two countable discrete groups, basic examples and some properties of measure equivalence. In lecture 2, we review (stable) orbit equivalence and show measure equivalence is the same as stable orbit equivalence and review some elasticity results on orbit equivalence of amenable group actions. In lecture 3, we review some rigidity results on measure equivalence of nonamenable group actions and survey some recent work and open problems related to measure equivalence.

Resources: There are no standard textbooks that focus on measure equivalence theory, but there are several excellent surveys ([4-8, 16]) and books on related materials, say on orbit equivalence ([9, 13, 14]) and von Neumann algebras ([1, 10]). Some basic training in ergodic theory for general group actions may be helpful, see e.g. [11, 12, 14]. For Geometric Group Theory, see the standard textbooks [2, 3].

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量子微分

熊枭（哈尔滨工业大学） 8 月 17 日至 19 日

第一讲：量子环及其上的函数空间，包括 Sobolev 空间和 Besov 空间的嵌入、插值、庞加莱不等式等内容。并会简要提及后面两次课程所关注的重点内容：量子微分。

第二讲：量子可微性的描述及其证明，会简要介绍该刻画两个方向不等式的证明。所用的工具主要有：Cwikel 型估计、拟微分算子理论。

第三讲：量子微分的谱渐近估计，介绍我和 Sukochev、Zanin 的最新结果，简要介绍该结果的大致思路，并将这个结果与第二讲内容联系起来。

详细内容

8 月 8 日（周一）

An introuction to noncommutative harmonic analysis (1)

洪桂祥（武汉大学） 9:30

L^p-improving bounds and weighted estimates for maximal functions associated with curvature

李文娟（西北工业大学） 14:30

In this paper, we establish weighted estimates for a wide class of maximal functions along some finite type curves and hypersurfaces. In particular, various impacts of non-isotropic dilations are considered. Via the methodology of sparse domination, the weighted estimates for the global maximal functions can be reduced to the L^p-improving properties of the corresponding localized maximal functions. We mainly focus on proving the $L^p \to L^q$ bounds $(q > p)$ for localized maximal functions with non-isotropic dilations of curves and hypersurfaces whose curvatures vanish to finite order at some points. As a corollary, we obtain the weighted inequalities for the corresponding global maximal functions, which generalize the known unweighted estimates. This is a joint work with Dr. Huiju Wang and Dr. Yujia Zhai.

Sharp convergence for sequences of Schrödinger means and related generalizations

王会菊（河南大学） 16:00

For decreasing sequences $\{t_n\}_{n=1}^{\infty}$ converging to zero, we obtain the almost everywhere convergence results for sequences of Schrödinger means $e^{it_n\Delta}f$, where $f \in H^s(\mathbb{R}^N), N \geq 2$. The convergence results are sharp up to the endpoints, and the method can also be applied to get the convergence results for the fractional Schrödinger means and nonelliptic Schrödinger means. This is a joint work with Dr. Huiju Wang and Prof. Dunyan Yan.

8 月 9 日（周二）

An introuction to noncommutative harmonic analysis (2)

洪桂祥（武汉大学） 9:00

Noncommutative continuous differentially subordinate martingales

吴恋（中南大学） 14:30

We introduce the notion of differential subordination in the context of noncommutative continuous-time martingales and show that for $2 < p < \infty$ this domination enforces the corresponding L^p bound between the two processes. As applications, we obtain best-order L^p inequalities for the second-order Riesz transforms on a class of group von Neumann algebras equipped with a conditionally negative length function.

Cesàro summability of double Fourier series on quantum tori

周德俭（中南大学） 16:00

In 1939, Marcinkiewicz and Zygmund proved that

$$\Big\| \sup_{(m,n)\in\Sigma_\beta} |\sigma_{m,n}(f)| \Big\|_{L_{1,\infty}(\mathbb{T}^2)} \le c_\beta \|f\|_{L_1(\mathbb{T}^2)},$$

where $(\sigma_{m,n}(f))_{m,n\ge1}$ are the Cesàro means of the rectangular partial sums of $f \in L_1(\mathbb{T}^2)$ and $\Sigma_\beta = \{(m,n) \in \mathbb{N}^2 : m/n \le \beta, n/m \le \beta\}$ for fixed $\beta > 0$. In this paper, we establish the Marcinkiewicz-Zygmund theorem on the quantum torus $\mathbb{T}^2_\theta$, which implies bilateral almost uniform convergence with initial data in $L_1(\mathbb{T}^2_\theta)$. Meanwhile, we also study the Cesàro means $(F_n(x))_{n\ge1}$ of the square partial sums of $x \in L_1(\mathbb{T}^2_\theta)$ and get the following noncommutative weak type maximal inequality:

$$\|(F_n(x))_{n\ge1}\|_{\Lambda_{1,\infty}(\mathbb{T}^2_\theta,\ell_\infty)} \le c\|x\|_{L_1(\mathbb{T}^2_\theta)},$$

which implies bilateral almost uniform convergence of $F_n(x)$ with $x \in L_1(\mathbb{T}^2_\theta)$.

8 月 10 日（周三）

An introuction to noncommutative harmonic analysis (3)

洪桂祥（武汉大学） 9:00

A Complete Theory of Operator-Valued Hardy Spaces

王文华（武汉大学） 14:30

In this talk, we study the operator-valued Hardy spaces introduced by Tao Mei, and establish their wavelet characterizations. In addition, we introduced two kinds of general Hardy spaces, one is the operator-valued Hardy spaces associated with anisotropic dilations, and the other is the operator-valued Hardy spaces on spaces of homogeneous type, and we also establish the classical Fefferman's duality theorem between Hardy and BMO spaces in our setting. As applications, we

also obtain the real and complex interpolations theory on these spaces. This is joint work with Prof. Guixiang Hong and Prof. Xinfeng Wu.

Campanato Spaces via Quantum Markov Semigroups: I. Finite case

景圆圆（武汉大学） 15:30

We study Companato spaces associated with a quantum Markov semigroup on a finite von Neumann algebra $\mathcal{M}$. Let $(T_t)_{t\geq 0}$ be a Markov semigroup and $(P_t)_{t\geq 0}$ its associated Poisson semigroup. For $\alpha > 0$, we define the column Campanato space $\mathcal{L}^c_\alpha(\mathcal{P})$ as a subspace of $\mathcal{M}$ with finite norm, where the column norm is given by

$$\|f\|_{\mathcal{L}^c_\alpha(\mathcal{P})} = \|f\|_\infty + \sup_{t>0} \frac{1}{t^\alpha} \left\| P_t|(I-P_t)^{[\alpha]+1} f|^2 \right\|_\infty^{\frac{1}{2}}.$$

The norm $\|f\|_{\mathcal{L}^r_\alpha(\mathcal{P})} = \|f^*\|_{\mathcal{L}^c_\alpha(\mathcal{P})}$ is called the row norm. In this article, we will first show the unexpected equivalence of these two norms of $\mathcal{L}^c_\alpha(\mathcal{P})$ and $\mathcal{L}^r_\alpha(\mathcal{P})$ for $0 < \alpha < 2$ by identifying both of them as the Lipschitz norm, where the Lipschitz norm is given by

$$\|f\|_{\Lambda_\alpha(\mathcal{P})} = \|f\|_{\mathcal{M}} + \sup_{t>0} \frac{1}{t^{\alpha-([\alpha]+1)}} \left\| \frac{\partial^{[\alpha]+1} P_t f}{\partial t^{[\alpha]+1}} \right\|_{\mathcal{M}}.$$

After that, we prove that the little column Campanato space $\ell^c_\alpha(\mathcal{P})$ coincides with the little row Campanato space $\ell^r_\alpha(\mathcal{P})$ when $\Gamma^2 \geq 0$ and $0 < \alpha < \frac{1}{2}$. Furthermore, we define a high-order version of the Campanato norm and show that, for $0 < \alpha < \alpha_0 < 2$, they are all equivalent to each other when the index $[\alpha]+1$ in the Campanato norm replaced by any integer greater than α. These arguments are not an obvious discovery due to the noncommutativity. Last but not least, follows from Mei's work, we explore the Campanato spaces associated with the general semigroups $(T_t)_{t\geq 0}$ satisfying quasi-monotone or the property $\Gamma^2 \geq 0$. It is worth mentioning out that our arguments can also apply in the classical case. This is based on a joint work with the professor Guixiang Hong.

8 月 11 日（周四）

算子值自由概率简介 (1)

刘伟华（浙江大学） 8:30

Fourier restriction estimates on quantum Euclidean spaces

王亮（武汉大学） 10:30

In this talk, we study the Fourier restriction phenomena on quantum Euclidean spaces, and establish the analogues of the Tomas-Stein restriction theorem and the two-dimensional full restriction theorem. This is based on a joint work with Guixiang Hong and Xudong Lai.

A paley's inequalities for discrete group

韩亚洲（太原理工大学） 16:00

In this report, we first review some properties of lacunary Fourier series in L_p spaces associated with the unit circle. Then, we will try to introduce a Paley's inequality of lacunary Fourier series for von Neumann algebra of discrete group. This resul unify and generalize the work of Rudin for abelian discrete ordered groups and the work of Lust-Piquard and Pisier for operator valued functions. The report will be based on the joint work with Chuah Chianyeong, Liu Zhenchuan and Mei Tao.

8 月 12 日（周五）

算子值自由概率简介 (2)

刘伟华（浙江大学） 9:00

The endpoint estimates of martingale commutators

谢广亨（中南大学） 14:30

In this article, we establish the endpoint estimate of commutators generated by martingale operators and the martingales from BMO. As applications, on the one hand, in the martingale setting, we obtain the endpoint estimates of commutators for both the martingale transform and the martingale fractional integral. On the other hand, in harmonic analysis, we establish the endpoint estimates of commutators both for the dyadic Hilbert transform beyond doubling measure and for the maximal operator of Cesàro means of Walsh-Fourier series.

On Lipschitz retractions of the space of bounded linear operators

罗思捷（中南大学） 16:00

The study of nonlinear projections in Banach spaces has been one of the crucial topics in the Ribe program for quite a long time. One of the essential theorems in this area, due to Lindenstrauss, asserts that c_0 is a Lipshictz retract of ℓ_∞. Quite recently, Tanaka used some deep tools in operator theory to obtain a noncommutative version of Lindenstrauss' result. This talk will mainly focus on Lipschitz retractions in the space of bounded linear operators on Banach spaces. Specifically, we use different approaches, relying on Banach space theory, to further generalize Tanaka's theorem in a general framework. This talk is based on joint work of Prof. Lixin Cheng and Dr. Wuyi He.

8 月 13 日（周六）

算子值自由概率简介 (3)

刘伟华（浙江大学） 9:00

8 月 14 日（周日）

Introduction to measure equivalence (1)

江永乐（大连理工大学） 9:00

Rigidity of quantum group actions on compact connected spaces

王斯萌（哈尔滨工业大学） 14:30

The quantum group theory was initiated in Drinfeld's celebrated work in 1980s. Motivated by noncommutative geometry and harmonic analysis, Woronowicz established around 1990 a relevant analytic theory of quantum groups in the framework of operator algebras, which was later completed by Stefaan Vaes around 2001 under the name of "locally compact quantum groups". This analytic theory has witnessed rapid developments in recent decades, with deep interactions with operator algebras, free probability and quantum information theory. This talk will include a quick review of basic ideas of this theory, and present some recent progress in this field, in particular with an emphasis on some combinatorial approach to compact quantum groups as well as to the rigidity results for their actions on classical spaces.

Amenable fusion algebraic actions on compact quantum spaces

黄辉斥（重庆大学） 16:00

We define fusion algebraic actions on compact quantum spaces and show that a discrete quantum group is amenable iff its fusion algebraic action on a compact quantum space is amenable and admits an invariant state. This is joint work with Xiao Chen and Debashish Goswami.

8 月 15 日（周一）

Introduction to measure equivalence (2)

江永乐（大连理工大学） 9:00

Quantitative mean ergodic inequalities I: power bounded operators acting on one noncommutative L_p space

刘伟（复旦大学） 14:30

In this talk, we study the concrete noncommutative square function for ergodic averages with respect to a large subclass of power bounded operators, including invertible contraction operators and Lamperti operators, on a fixed noncommutative L_p-space for $1 < p < \infty$. As a consequence, we obtain the the quantitative mean ergodic theorems for these operators under consideration. This is joint work with Guixiang Hong and Bang Xu.

Noncommutative martingale ergodic and ergodic martingale theorems

龚雨辉（华中科技大学） 15:30

For a noncommutative probability space $(\mathcal{M}, \tau)$, let $\mathcal{E}_n$ be the conditional expectation with respect to a filtration $(\mathcal{M}_n)_{n\geq 1}$ of $\mathcal{M}$ and A_m be the ergodic average with respect to a Dunford-Schwartz operator T. Then we prove the norm convergence and pointwise convergence for the martingale ergodic average $\mathcal{E}_n(A_m x)$ and ergodic martingale average $A_m(\mathcal{E}_n x)$ where $x \in L_p(\mathcal{M})$. We also prove the maximal inequalities for both $\mathcal{E}_n(A_m x)$ and $A_m(\mathcal{E}_n x)$. Moreover, we try to generalize these results to the continuous parameter case.

Sharp endpoint L_p estimate of Schrodinger groups under noncommutative algebraic framework

范智杰（武汉大学） 16:30

In this talk, I will discuss our recent progress on sharp endpoint Lp estimates of Schrodinger groups on general measure spaces. This space may not equipped with good metrics but admit a P-Markov semigroup satisfying purely algebraic assumptions. We shall construct an abstract form of 'P-Markov' metric codifying some sort of underlying metric and position, and then construct a new noncommutative BMO space consisting of all functions with higher cancellation properties. Motivated by noncommutative harmonic analysis, this approach establishes the first form of Schrodinger groups theory for arbitrary von Neumann algebras and can be applied to many examples, including Schrodinger groups associated with non-negative self-adjoint operators satisfying purely Gaussian upper bounds on doubling metric space, standard Schrodinger groups on quantum Euclidean space, matrix algebras and group von Neumann algebras with finite dimensional cocycles. This is a joint work with Guixiang Hong and Wang Liang.

8 月 16 日（周二）

Introduction to measure equivalence (3)

江永乐（大连理工大学） 14:30

交换函数空间和非交换算子空间的球覆盖性质

刘敏曾（南开大学） 16:30

如果赋范空间的单位球面可以被可数个不包含原点的球所构成的并集覆盖，则称该空间具有球覆盖性质。我们给出了球覆盖性质关于局部紧 Hausdorff 空间的拓扑刻画，证明了向量值连续函数空间关于球覆盖性质的二分稳定性定理，判定了几类经典 Banach 空间上有界线性算子空间及其子空间的球覆盖性质，通过以上两类空间的研究否定回答了球覆盖性质关于 1-可补子空间的遗传性问题，并由此引出球覆盖性质与 Banach 空间张量积、函数空间、算子代数有关的一些新问题。（合作者：刘锐、卢霁萌、郑本拓）

8 月 17 日（周三）

量子微分 (1)

熊枭（哈尔滨工业大学） 9:00

8 月 18 日（周四）

量子微分 (2)

熊枭（哈尔滨工业大学） 9:00

Primitivity for random quantum channels

王建权（哈尔滨工业大学） 14:00

In this paper, we consider the empirical spectrum distribution of the output of n-fold composition of random quantum channels. As a corollary, we derive a generic lower bound for the primitive index of random quantum channels. Our method is the graphical Weingarten calculus introduced by Collins and Nechita.

Noncommutative weak (1,1) estimates for singular integral operators

赖旭东（哈尔滨工业大学） 15:00

In this talk, we introduce our recent results on noncommutative weak (1,1) bounds for several singular integral operators. We first show the weak type (1,1) bounds for noncommutative max-

imal truncated singular integral operators with kernels satisfying the L_2-Dini smooth condition. The proofs are based on a new noncommutative Calderón-Zygmund decomposition introduced recently by L. Cadilhac. Next, we state the weak type (1,1) bound for noncommutative maximal operator with a rough kernel. To deal with the rough kernel, we use the microlocal decomposition in the proofs of both bad and good functions.

Problem session 16:30

8 月 19 日（周五）

量子微分 (3)

熊枭（哈尔滨工业大学） 9:00

Forward and reverse entropy power inequalities

李建阁（哈尔滨工业大学） 14:30

Shannon's entropy power inequality, which plays a fundamental role in information theory and probability, may be seen as an analogue of the Brunn-Minkowski inequality in convex geometry. In this talk, we survey various recent developments on forward and reverse entropy power inequalities and discuss close connections with classical inequalities in convex geometry and functional analysis.

The Tight Exponent Analysis for Quantum Privacy Amplification

姚永胜（哈尔滨工业大学） 16:00

The privacy amplification against quantum side information is a vital step in the Quantum Key Distribution which ensure that both parties of communication can share a pair of uniform secret key independent of the adversary. In this talk, I will introduce some recent progress on the reliability of the privacy amplification, i.e., the exponent of the asymptotic decreasing of the leaked information. Specifically, we derive an upper bound for the reliability which complement a earlier lower bound established by Hayashi, and the two bounds match when the rate of randomness extraction is above a critical value. Thus, we determined the exact security exponent for the case of high rate.