POSTDOC WORKSHOP



Sep.7 - 8. 2024 C548 Shuangqing

YMSC

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Postdoc Workshop III 2024

Time September 7-8, 2024 Purpose Promote interaction and communication among postdocs and researchers

Scientific Committee

清华大学丘成桐数学科学中心博士后工作组

Organizing Committee

清华大学丘成桐数学科学中心博士后工作组

Support Fundings

清华大学丘成桐数学科学中心博士后活动经费 Funds for Postdoc Academic Activities, YMSC, Tsinghua University

Conference location

清华大学双清综合楼C548 Room C548, Shuangqing Complex Building, Tsinghua University

Contact information

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September 7, Saturday

Time	me Welcome to Tsinghua			
9:40 - 9:50	丘成桐	Opening		
Shing-Tung Yau				
9:50 - 10:15	你我儿 Conglong Lin	Degenerate Hessian type equations on compact		
10.15 - 10.45		roup photo /Prook		
10.13 - 10.43	本今校	Hyperkähler geometry of the Hitchin moduli		
10:45 - 11:10	子心(十 Nianzi Li			
11:10 - 11:35	而阳	Einding hirational contractions between Eano		
		fibrations		
	刘志文	Torelli-type questions arising from the		
11:35 - 12:00	Zhiwen Liu	deformations of singularities		
		Lunch		
		Chair: TBA		
13:30 - 13:55	Aimeric Malter	Toric exoflops and derived categories		
10.55 14.00	孟成	Numerical invariants of local rings in		
13:55 - 14:20	Cheng Meng	characteristic p		
14:20 - 14:45	青成昊	The cohomology groups of line bundles and		
	Chenghao Qing	over holomorphically convex manifolds		
14:45 - 15:10	陈飞 Fei Chen	On Restriction from $\widetilde{\operatorname{GL}}_r$ to $\widetilde{\operatorname{SL}}_r$		
15:10 - 15:40		Break		
15:40 - 16:05	阮宸炜 Chenwei Ruan	The positive part of $U_q(\widehat{\mathfrak{sl}}_2)$ and its embedding into a q -shuffle algebra		
16:05 - 16:30	张笑然 Xiaoran Zhang	Wave equation on hyperbolic spaces		
16:30 - 16:55	何翔 Xiang He	On Pólya conjecture for product domains		
16:55 - 17:15	胡金金 Jinjin Hu	L^2 theory and its applications in several complex variables		
17:15 - 17:40	Thomas Wetere Tulu	Machine Learning-Based Prediction of COVID-19 Mortality Using Immunological and Metabolic Biomarkers		
Dinner				

September 8, Sunday

Time	We	lcome to Tsinghua	
Chair: TBA			
9:30 - 9:55	王路瑶 Luyao Wang	W-representations of partition functions	
9:55 - 10:20	Jack Holden	Partial deconfinement in AdS/CFT and the quark-gluon plasma	
10:20 - 10:45		Break	
10:45 - 11:10	赵博文 Bowen Zhao	Wang-Yau quasi-local energy toward and cross an apparent horizon	
11:10 - 11:35	陈良玉 Liangyu Chen	Dissecting Quantum Chaos in the Krylov Space	
11:35 - 12:00	张蒙蒙 Mengmeng Zhang	Homotopy Groups and Puppe Sequence of Digraphs	
		Lunch	
	-	Chair: TBA	
13:30 - 13:55	Monu Kadyan	Four Types of Integrality on Directed Graphs	
13:55 - 14:20	Ben-Michael Kohli	Improving the Seifert inequality for the genus of a knot using the Links-Gould invariant of links	
14:20 - 14:45	靳安然 Anran Jin	A Unified Perspective on Discrete and Continuous Quantum Cryptography	
14:45 - 15:15		Break	
15:15 - 15:40	秦硕 Shuo Qin	Recurrence and Transience of Multidimensional Elephant Random Walks	
15:40 - 16:05	孙楠 Nan Sun	New Comparative Analysis Methods and Applications Research on Biological Sequence Data	
16:05 - 16:30	王玉 Yu Wang	The Statistical Mechanics of Forest Growth	
16:30 - 16:55	吴双 Shuang Wu	The metabolomic networks of complex diseases	
16:55 - 17:15	Yueyao Li	Globalized distributionally robust optimization with multi core sets	
17:15 - 17:40	Mainak Ghosh	Peripheral Poisson boundary on full Fock space	
Dinner			

List of Abstracts

September 7, Saturday

Degenerate Hessian type equations on compact complex manifolds

林耿龙 Genglong Lin

BIMSA

Degenerate Monge-Ampere/Hessian equations play an important role in recent Differential Geometry and Complex Algebraic Geometry. In this talk we will review recent progress on Monge-Ampère equation and talk about a class of degenerate Monge-Ampère equations. As an application, we give an generalization on a solution of Dinew-Guedj-Zeriahi's conjecture due to Darvas-Di Nezza-Lu. Secondly, we will give an characterization of finite energy range of Hessian operator, which generalized the Monge-Ampere ones proved by Darvas-Di Nezza-Lu. The talk is based on my thesis, part of which is joint with Yinji Li and Prof. Xiangyu Zhou.

Hyperkähler geometry of the Hitchin moduli space

李念梓 Nianzi Li

YMSC

In 1987, Hitchin constructed a complete hyperkähler metric on the moduli space of Higgs bundles, which can be generalized to singular cases. In this talk, we mainly consider the moduli space of rank-two Higgs bundles with irregular singularities over the projective line. Along a generic curve, we prove that Hitchin's hyperkähler metric is asymptotic to a simpler semi-flat metric at an arbitrary polynomial rate, based on the foundational works of Fredrickson, Mazzeo, Swoboda, Weiss, and Witt. As a corollary, we show that every irregular 4d Hitchin moduli space is ALG or ALG^{*} by explicitly computing the asymptotic limit of the semi-flat metric. Joint work with Gao Chen.

Finding birational contractions between Fano fibrations

何阳 Yang He

BIMSA

We explain some methods to find birational contractions between Fano fibrations, and how it's related to computing the group (co)homology of Cremona groups.

Torelli-type questions arising from the deformations of singularities

刘志文 Zhiwen Liu

BIMSA

In this talk, I will introduce some basic definitions and concepts regarding the deformations of singularities and their associated algebraic structures, with a particular emphasis on the deformation of Yau algebras. Additionally, I will present and discuss several results on Torelli-type questions related to singularities.

Toric exoflops and derived categories

Aimeric Malter

BIMSA

In this talk I will motivate and discuss the use of exoflops (especially their toric variants) in studying derived categories.

Numerical invariants of local rings in characteristic p

孟成 Cheng Meng

YMSC

In commutative algebra, the Hilbert-Kunz multiplicity and the F-signature are two important numerical invariants that measure the singularity of a Noetherian local ring of characteristic p. In particular, they describe the local singularities of varieties in characteristic p, and many types of such singularities have their counterparts in characteristic O. In this talk, we will introduce another numerical invariant called the h-function. It is a function attached to a triple (R, I, J) where R is a Noetherian local ring and I, J are two R-ideals such that I(R/I+J) is finite. We will explain how the h-function recovers both the Hilbert-Kunz multiplicity and the F-signature. This is joint work with Alapan Mukhopadhyay.

The cohomology groups of line bundles and vector bundles with singular Hermitian metrics over holomorphically convex manifolds

青成昊 Chenghao Qing

YMSC

We obtain Nadel type and Bogomolov type vanishing theorems on non-compact manifolds for logarithmic sheaves by Guan-Zhou's strong openness property. And we show that when the vector bundles over holomorphically convex Kähler manifolds admit singular Hermitian metrics with some positivity, the injectivity theorems between cohomology groups also hold.

On Restriction from $\widetilde{\operatorname{GL}}_r$ to $\widetilde{\operatorname{SL}}_r$

陈飞 Fei Chen

YMSC

Let G be a reductive group and let G_{der} be its derived subgroup. It is a conjecture of Borel that the restriction of a representation of G to G_{der} should give a special case of Langlands functoriality principle. Recently, Gao-Shahidi-Szpruch considered analogous restriction problem in the setting of covering groups. In this talk, we will report our result on restriction problem for a large class of covers of GL_r : Kazhdan–Patterson covers. Under assumption on the degree of cover, we are able to describe the restriction of discrete series genuine representations using metaplectic correspondence of Flicker-Kazhdan.

The positive part of $U_q(\widehat{\mathfrak{sl}}_2)$ and its embedding into a q-shuffle algebra

阮宸炜 Chenwei Ruan

BIMSA

The q-deformed enveloping algebra $U_q(\widehat{\mathfrak{sl}}_2)$ and its positive part U_q^+ are studied in both mathematics and mathematical physics. In 1995, Rosso obtained an embedding of the algebra U_q^+ into a q-shuffle algebra. From 2018 to 2022, Terwilliger used the Rosso embedding to study two PBW bases for U_q^+ obtained earlier by Damiani and Beck. He also obtained the alternating PBW basis for U_q^+ . The three PBW bases are related via exponential formulas. In recent years, we used the Rosso embedding to obtain a uniform approach to the PBW bases and the exponential formulas aforementioned. We also studied some elements of interest related to the alternating PBW basis. We will discuss these results in this talk.

Wave equation on hyperbolic spaces

张笑然 Xiaoran Zhang

BIMSA

In light of the exponential decay of solutions of linear wave equations on hyperbolic spaces \mathbb{H}^n , to illustrate the critical nature, we investigate nonlinear wave equations with logarithmic nonlinearity, which behaves like $(ln1/|u|)^{-(p-1)}|u|$ near u = 0, on hyperbolic spaces. Concerning the global existence vs blow up with small data, we expect that the problem admits a critical power $p_c(n) > 1$. When n = 3, we prove that the critical power is 3, by proving global existence for p > 3, as well as generically blow up for $p \in (1, 3)$.

On Pólya conjecture for product domains

何翔 Xiang He

YMSC

In 1954 Pólya proposed a conjecture for any bounded Euclidean domain that compares each Dirichlet and Neumann eigenvalue with the leading term in the Weyl asymptotic formula. In this talk I will review some backgrounds and known results on this conjecture, and discuss our result on this conjecture for thin products. This is a joint work with Zuoqin Wang.

L^2 theory and its applications in several complex variables

胡金金 Jinjin Hu

YMSC

We consider the curvature strict positivity of the direct image bundle associated to a pseudoconvex family of bounded domains. The main result is that the curvature of the direct image bundle associated to a strictly pseudoconvex family of bounded circular domains or Reinhardt domains, with arbitrary plurisubharmonic weights, are strictly positive in the sense of Nakano. This result gives a new geometric insight about the property of strict pseudoconvexity, and has some applications in complex analysis and convex analysis. It implies a remarkable result of Berndtsson which states that, for an ample vector bundle E over a compact complex manifold X and any $k \ge 0$, the bundle $S^k E \otimes \det E$ admits a Hermitian metric whose curvature is strictly positive in the sense of Nakano, where $S^k E$ is the k-th symmetric product of E. The two main ingredients in the argument of the main theorems are Berndtsson's estimate of curvature of direct image bundles and Deng-Ning-Wang-Zhou's characterization of the curvature Nakano positivity of Hermitian vector bundles in terms of L^2 -estimate of $\overline{\partial}$.

Machine Learning-Based Prediction of COVID-19 Mortality Using Immunological and Metabolic Biomarkers

Thomas Wetere Tulu

BIMSA

In this talk, I will discuss some recent interesting statistical analysis, mathematical and machine learning models to identify immunological and metabolic biomarkers to predict COVID-19 mortality. Starting with mathematical Model, I examine different Machine learning models that are becoming headlines in the current researching industry.

September 8, Sunday

W-representations of partition functions

王路瑶 Luyao Wang

BIMSA

We construct some partition functions and derive their W-representations. According to W- representation, we further give the exact formula of observables and discuss them in large N limit. In addition, there are some by-products in this process, such as the correspondence between the tree operator and Fredkin spin chain, and the reduction of the multi-character partition function to obtain a tensor model and multi-matrix model.

Partial deconfinement in AdS/CFT and the quark-gluon plasma

Jack Holden

YMSC

I will introduce partial deconfinement and discuss its significance within AdS/CFT and its conjectured role in the quark-gluon plasma. Partial deconfinement is a phase of Yang-Mills theories between confinement and deconfinement in which only a subset of the internal 'colour' degrees of freedom deconfine. It is expected to be a general feature of gauge theories, including real-world QCD. After reviewing some unique dynamical behaviour associated with the phase, I will briefly outline ongoing work to identify its gravitational dual descriptions, mentioning in particular efforts to use the superconformal index to identify the dual of the partially confined phase in the BPS black hole phase diagram.

Wang-Yau quasi-local energy toward and cross an apparent horizon

赵博文 Bowen Zhao

BIMSA

We first prove the positivity of Wang-Yau quasi-local mass in the presence of apparent horizons. We then examine the limit of the Wang-Yau quasi-local energy as the defining spacelike 2-surface approaches an apparent horizon from outside. Assuming C^2 or $W^{2,1}$ isometric embedding, we find that either 1) if the horizon is not embeddable into R^3 , the Wang-Yau quasi-local energy blows up while the optimal embedding equation does not admit a solution near the horizon or 2) if the horizon is embeddable into R^3 , the optimal embedding equation admits a constant solution (unique up to translation) while the Wang-Yau quasi-local mass admits a finite limit that agrees with the limit of the Brown-York mass. We also propose an extension of Wang-Yau quasi-local energy inside an horizon, i.e. for surfaces with time-like mean curvature vector.

Dissecting Quantum Chaos in the Krylov Space

陈良玉 Liangyu Chen

YMSC

The growth of simple operators is essential for the emergence of chaotic dynamics and quantum thermalization. Recent studies have proposed different measures, including the out-of-time-order correlator and Krylov complexity. It is established that the out-of-time-order correlator serves as the signature of quantum many-body chaos, while the Krylov complexity provides its upper bound. However, there exist non-chaotic systems in which Krylov complexity grows exponentially, indicating that the Krylov complexity itself is not a witness of many-body chaos. In this letter, we introduce the missing ingredient, named as the Krylov metric K_{mn} , which probes the size of the Krylov basis. We propose that the universal criteria for fast scramblers include (i) the exponential growth of Krylov complexity, (ii) the diagonal elements $K_{nn} \sim n^h$ with $h \in (0, 1]$, and (iii) the negligibility of off-diagonal elements K_{mn} with $m \neq n$. We further show that $h = \varkappa/2\alpha$ is a ratio between the quantum Lyapunov exponent \varkappa and the Krylov exponent α . This proposal is supported by both generic arguments and explicit examples, including solvable SYK models, Luttinger Liquids, and many-body localized systems. Our results provide a refined understanding of how chaotic dynamics emerge from the Krylov space perspective.

Homotopy Groups and Puppe Sequence of Digraphs

张蒙蒙 Mengmeng Zhang

BIMSA

In 2014, Alexander Grigor'yan, Yong Lin, Yury Muranov and Shing-Tung Yau introduced the homotopy theory for digraphs. Based on their work, we (joint with Jingyan Li, Jie Wu and Shing-Tung Yau) gave a 'grid' definition for homotopy groups of digraph and constructed a long exact sequence of homotopy groups for any based digraph map. In this talk, I will firstly give a brief introduction to the classical homotopy theory of topological space and GLMY homotopy theory of digraph. Then I will present our recent progress on homotopy groups and Puppe sequence of digraphs.

Four Types of Integrality on Directed Graphs

Monu Kadyan

YMSC

A directed graph is called H-integral (resp. HS-integral) if the eigenvalues of its Hermitian-adjacency matrix (resp. Hermitian-adjacency matrix of second kind) are integers. Similarly, a directed graph is said to be Gaussian integral (resp. Eisenstein integral) if the eigenvalues of its (0,1)-adjacency matrix are Gaussian integers (resp. Eisenstein integers). In this talk, I will present a characterization of all four types of integrality (H-integrality, HS-integrality, Gaussian integrality, and Eisenstein integrality) of a particular class of digraph graph, namely normal Cayley digraphs. This is joint work with Dr. Bikash Bhattacharjya.

Improving the Seifert inequality for the genus of a knot using the Links-Gould invariant of links

Ben-Michael Kohli

YMSC

I will show how the Links-Gould invariant of links can be used to systematically improve the well known lower bound for the 3-genus of a knot known as the Seifert inequality, that is obtained from the Alexander polynomial.For example, this allows us to straightforwardly detect genus for the Kinoshita-Terasaka/Conway pair of mutant knots, where the Seifert inequality and the Levine-Tristram signature fail to do so.I will also try to say a few words about where we can go from there.The talk is based on past and ongoing work involving Stavros Garoufalidis, Matthew Harper, Rinat Kashaev, Jiebo Song and Guillaume Tahar.

A Unified Perspective on Discrete and Continuous Quantum Cryptography

靳安然 Anran Jin

YMSC

Quantum information processing relies on the principles of quantum physics to gain unique advantages in various information processing tasks. Among them, the quantum key distribution (QKD) technique guarantees the information-theoretic security of the task of remote secure key distribution. QKD is generally divided into two categories as discrete-variable (DV) and continuous-variable (CV) based on the dimension of the latent Hilbert space. For long these two realms developed separately with different security techniques, phase-error correction for DV and Devetak-Winter formula for CV. The DV security is simpler due to the finite and low dimensional latent Hilbert space, yet the CV protocols are more practical since realistic physical systems usually have infinite degrees of freedoms. It is thus a trend in the field of QKD to develop DV security analysis for CV protocols. This talk will review the security proofs of DV and CV QKD respectively, before giving a CV protocol that admits DV security analysis.

Recurrence and Transience of Multidimensional Elephant Random Walks

秦硕 Shuo Qin

BIMSA

We prove a conjecture by Bertoin that the multidimensional elephant random walk on \mathbb{Z}^d is transient in dimensions $d \ge 3$. We show that it undergoes a phase transition in dimensions d = 1, 2 between recurrence and transience at p = (2d + 1)/(4d).

New Comparative Analysis Methods and Applications Research on Biological Sequence Data

孙楠 Nan Sun

BIMSA

The rapid development of biotechnology in the 21st century has greatly facilitated the accumulation of biological sequence data. Dealing with these vast datasets, effectively organizing, analyzing, and extracting useful information is a complex and challenging task. Traditional alignment-based methods can provide detailed insights into sequence structure and function but are less efficient when handling large-scale data and struggle with sequences that have significant differences. Therefore, alignment-free methods have gained considerable attention in recent years. This paper consists of two main parts. The first part explores methods for sequence similarity comparison analysis. The traditional natural vector method only describes the distribution of single nucleotides, neglecting the relationship between nucleotides. To address this, this study introduces position covariance components to improve the natural vector method, thereby extracting richer sequence features. Additionally, to tackle the issues of long bacterial sequence lengths and substantial differences between sequences, the density distribution of coding sequences is introduced, which simplifies sequence representation and increases processing speed. The improved natural plot method helps capture the underlying relationships between sequences and has been validated on multiple viral datasets. The second part applies these methods to address important biological problems. Through the k-mer natural vector method, viral sequences and sequences from seven biological realms are feature-embedded, constructing a genome space. This explains the arrangement of genomic sequences in high-dimensional spaces and determines a natural metric for measuring sequence similarity. Furthermore, the study focuses on HIV virus sequences, investigating their mutation patterns, and proposes a new method to describe HIV mutation rates. Statistical analyses of 12 single mutations from multiple perspectives reveal that A>G, G>A, C>T, and T>C mutations dominate.

The Statistical Mechanics of Forest Growth

$\Xi \Xi$ Yu Wang

BIMSA

Forests play a pivotal role in maintaining our earth ecosystem. Understanding how forest tree grows and the genetic mechanisms underlying this process is crucial for optimal forest management. Given the complexity of growth, the statistical dissection of all growth-related genes is an epistemological challenge. Here, we overcome this issue by developing a statistical physics theory derived from the interdisciplinary combination of evolutionary game theory, functional mapping theory, developmental modularity theory, and graph theory. This new theory enables the coalescing of all genes into multilayer and multiplex networks filled with bidirectional, signed, and weighted interactions, with which to trace the roadmap of how each gene spreads its information towards the phenotype. We design and conduct a genome-wide association study using Tibetan poplar (Populus szechuanica var. tibetica), which have not only validated the biological relevance of this theory, but also gained new insight into the genetic control of growth traits. We anticipate that this theory can potentially open up a new avenue to study growth in forest trees and other species.

The metabolomic networks of complex diseases

吴双 Shuang Wu

BIMSA

Human diseases involve metabolic alterations. Metabolomic profiles have served as a vital biomarker for the early identification of high-risk individuals and disease prevention. We have leveraged a statistical physics model to combine all metabolites into bidirectional, signed, and weighted interaction networks and trace how the flow of information from one metabolite to the next causes changes in health state. We integrate concepts from ecosystem theory and evolutionary game theory to model how the health state-dependent alteration of a metabolite is shaped by its intrinsic properties and through extrinsic influences from its conspecifics. We code intrinsic contributions as nodes and extrinsic contributions as edges into quantitative networks and implement GLMY homology theory to analyze and interpret the topological change of health state from symbiosis to dysbiosis. The application of this model to real data allows us to identify several hub metabolites and their interaction webs, which play a part in the formation of inflammatory bowel diseases.

Globalized distributionally robust optimization with multi core sets

Yueyao Li

YMSC

It is essential to capture the true probability distribution of uncertain data in the distributionally robust optimization (DRO). The uncertain data presents multimodality in numerous application scenarios, in the sense that the probability density function of the uncertain data has two or more modes (local maximums). In this study, we propose a globalized distributionally robust optimization framework with multiple core sets (MGDRO) to handle the complicated situation when the uncertain data is multimodal. This framework captures the multimodal structure, via a penalty function composed of the minimum distance from the random vector to all core sets and penalty coeffcients. Multiple core sets are constructed to capture all clustering regions of the sample points. The penalty item weakens the impact of the regions outside of the core sets on the expectation of the objective function, thereby highlighting the impact of the multimodality. Under some assumptions, the MGDRO model can be reformulated as tractable semi-definite programs for both moment-based and metric-based ambiguity sets. We apply the MGDRO models to a multi-product newsvendor problem with multimodal DRO models and other multimodal models.

Peripheral Poisson boundary on full Fock space

Mainak Ghosh

BIMSA

The operator space generated by peripheral eigenvectors of a unital normal completely positive map P on a von Neumann algebra has a C*-algebra structure. This C*-algebra is known as the *Peripheral Poisson boundary* of P. For a separable Hilbert space H, consider the full fock space $\mathcal{F}(H)$ defined over H. In this talk, I will present the peripheral Poisson boundary of the completely positive map, induced by left creation operators of the basis vectors of H, on $B(\mathcal{F}(H))$ and explore its behavior with respect to the Poisson boundary. This talk is based on the pre-print arXiv:2406.11167

Useful Information

A Guide to Shuangqing Complex Building A



To commute between Jingzhai 静斋 and Shuangqing Building, one can go through the **East Gate** or **Northeast Gate**.



Then follow the red path to the Shuangqing Complex Building A (Yau Mathematics Science Center).



Exterior views of the building.

Address: 双清综合楼A座 北京市海淀区逸清南路西延6号院1号 Shuangqing Complex Building A No. 1, Courtyard 6, West Extension of Yiqing South Road, Haidian District, Beijing

Remarks: 双清公寓马路对面、清华附小(双清校区)西侧 Across the street from Shuangqing Apartments, on the west side of Tsinghua University Primary School (Shuangqing Campus).

请持有效证件(工作证、学生证)进入。访问人员请携带身份证/护照。 Please enter with valid identification (work ID, student ID). Visitors should bring their ID card/passport.

Previous Review



Postdoc Workshop I 2024

