INTERNATIONAL CONGRESS OF BASIC SCIENCE
国际基础科学大会
求真务实 止于至善 | TRUTH & BEAUTY

学术手册

Scientific Program

2023年7月16日—28日
July 16-28, 2023

中 国 · 北 京
Beijing, China

国 际 基 础 科 学 大 会
INTERNATIONAL CONGRESS OF BASIC SCIENCE

INTERNATIONAL CONGRESS OF BASIC SCIENCE
国际基础科学大会
TRUTH & BEAUTY

A7
3F Lecture Room 13
3F Lecture Room 12
2F Lecture Room 11
1F Lecture Room 10

A3-4
3F Lecture Room 8
1F Lecture Room 7

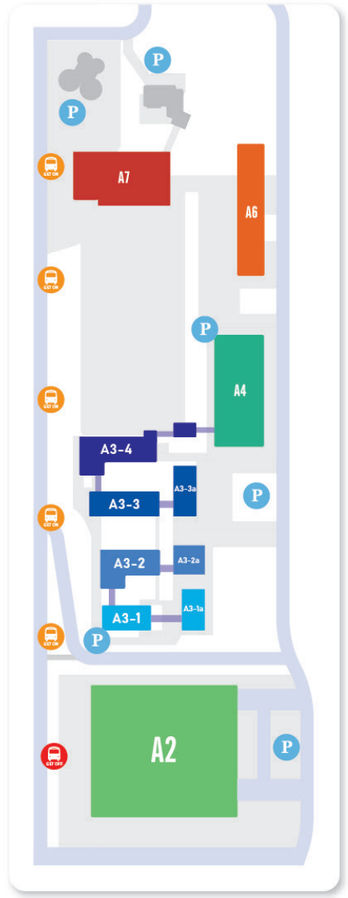
A3-2a
3F Lecture Room 6

A3-2
3F Lecture Room 5
1F Lecture Room 4

A3-1a
2F Lecture Room 3
2F Lecture Room 2

A3-1
3F Lecture Room 1

Connecting Bridge



A6
1F Lecture Room 9

A4
Dining Hall

Shuttle Pick-up Point

Shuttle Drop-off Point

A2
Lecture Hall A
Dining Hall

Scan the code to access the most up-to-date ICBS Scientific Program

MATHEMATICS (WEEK1)

	Mon. 07-17	Tue. 07-18	Wed. 07-19	Thu. 07-20	Fri. 07-21	Sat. 07-22	Sun. 07-23
08:00 - 09:00		Caucher Birkar LR9 (A6 1F)	Maxim Kontsevich LR9 (A6 1F)	LR3 (A3-1a 2F) Svetlana Jitomirskaya LR7 (A3-4 1F) Guozhen Lu LR9 (A6 1F) Kenji Fukaya	LR2 (A3-1a 2F) Guoliang Yu LR3 (A3-1a 2F) Bassam Fayad LR9 (A6 1F) Junyi Xie		
Break							
09:15 - 10:15	Basic Science Lecture David Mumford LH A (A2) 09:00 - 10:00	LR7 (A3-4 1F) Alexandra Skripchenko LR9 (A6 1F) Camillo De Lellis LR10 (A7 1F) Mikhail Khovanov	LR2 (A3-1a 2F) Sergiu Klainerman LR7 (A3-4 1F) Jonathan Keating LR8 (A3-4 3F) Akito Futaki	LR9 (A6 1F) Andrei Okounkov	LR9 (A6 1F) Laurent Lafforgue		
Break							
10:30 - 11:30	Basic Science Lecture Adi Shamir LH A (A2) 10:00 - 11:00	LR7 (A3-4 1F) Anton Zorich LR9 (A6 1F) Hiraku Nakajima LR10 (A7 1F) András Stipsicz	LR7 (A3-4 1F) Alexander Bobenko LR8 (A3-4 3F) Song Sun LR9 (A6 1F) Jun Liu	LR8 (A3-4 3F) Benjamin Sudakov LR9 (A6 1F) Sergei Gukov LR10 (A7 1F) Michael Hutchings	LR2 (A3-1a 2F) Matthias Keller LR3 (A3-1a 2F) Dipendra Prasad LR9 (A6 1F) Christopher Hacon		
Break							
	Basic Science Lecture Alessio Figalli LH A (A2) 11:20 - 12:20						
Lunch							
13:00 - 13:45	LR1 (A3-1 3F) Thomas Nikolaus 13:30 - 14:15 LR2 (A3-1a 2F) Frank Merle 13:30 - 14:15 LR3 (A3-1a 2F) Umberto Zannier 13:30 - 14:15 LR6 (A3-2a 3F) Karim Adiprasito 13:30 - 14:15 LR7 (A3-4 1F) Motoko Kotani 13:30 - 14:30 LR8 (A3-4 3F) Nick Trefethen 13:30 - 14:15 LR9 (A6 1F) Alex Eskin 13:30 - 14:15 LR10 (A7 1F) Jianqing Fan 13:30 - 14:30 LR11 (A7 2F) Jian Ding 13:30 - 14:15	LR1 (A3-1 3F) Laurent Fargues LR2 (A3-1a 2F) Jan Philip Solovej 13:00 - 14:00 LR3 (A3-1a 2F) Damin Wu LR7 (A3-4 1F) Amol Aggarwal LR9 (A6 1F) Mohammed Abouzaid	LR1 (A3-1 3F) Simon Riche LR2 (A3-1a 2F) Jan Sbierski LR3 (A3-1a 2F) Nobuo Sato LR7 (A3-4 1F) Xu-Jia Wang 13:00 - 14:00 LR8 (A3-4 3F) Sebastien Boucksom	LR1 (A3-1 3F) Sebastian Hurtado LR2 (A3-1a 2F) Hao Huang LR3 (A3-1a 2F) Hugo Falconet LR7 (A3-4 1F) Hamid Hezari LR8 (A3-4 3F) Wencai Liu	LR1 (A3-1 3F) Theodore Slaman 13:00 - 14:00 LR2 (A3-1a 2F) Yuchen Liu LR3 (A3-1a 2F) Hongjie Yu LR7 (A3-4 1F) Gunther Uhlmann 13:00 - 14:00 LR8 (A3-4 3F) Paul Horn 13:00 - 14:00		
Break							
14:00 - 14:45	LR1 (A3-1 3F) David Asperó & Ralf Schindler 14:30 - 15:15 LR2 (A3-1a 2F) Qian Wang 14:30 - 15:30 LR3 (A3-1a 2F) Dimitrios Koukoulopoulos 14:30 - 15:15 LR6 (A3-2a 3F) Louis-Hadrien Robert 14:30 - 15:15 LR7 (A3-4 1F) Monica Vişan 14:30 - 15:15 LR8 (A3-4 3F) Chi-Wang Shu 14:30 - 15:30 LR9 (A6 1F) Dylan Thurston 14:30 - 15:15 LR10 (A7 1F) Stefan Wager 14:30 - 15:15	LR2 (A3-1a 2F) Philip Isett 14:15 - 15:00 LR3 (A3-1a 2F) Jingrui Cheng LR7 (A3-4 1F) Manuel Krannich LR9 (A6 1F) Tobias Ekholm	LR1 (A3-1 3F) Ben Davison LR2 (A3-1a 2F) Peter Hintz LR3 (A3-1a 2F) Peter Jossen LR7 (A3-4 1F) Shibing Chen LR8 (A3-4 3F) André Neves 14:00 - 15:00 LR9 (A6 1F) Stephen Yau 14:00 - 15:00	LR1 (A3-1 3F) Bruno Martelli LR2 (A3-1a 2F) Jiapeng Zhang LR3 (A3-1a 2F) Scott Sheffield LR7 (A3-4 1F) Christopher Sogge LR8 (A3-4 3F) Huaxin Lin	LR1 (A3-1 3F) Andreas Weiermann 14:00 - 15:00 LR2 (A3-1a 2F) Alexey Bondal 14:00 - 15:00 LR7 (A3-4 1F) Or Hershkovits 14:15 - 15:00		
Break							
15:15 - 16:00	LR1 (A3-1 3F) Hugh Woodin 15:30 - 16:30 LR2 (A3-1a 2F) Mahir Hadžić 15:45 - 16:30 LR3 (A3-1a 2F) Vadim Kaloshin & Alfonso Sorrentino 15:45 - 16:30 LR6 (A3-2a 3F) Myungho Kim 15:45 - 16:30 LR7 (A3-4 1F) Bruno Nachtergaele 15:30 - 16:30 LR8 (A3-4 3F) Mahesh Kakde 15:45 - 16:30 LR9 (A6 1F) John Pardon 15:45 - 16:30 LR10 (A7 1F) Xihong Lin 15:30 - 16:30 LR11 (A7 2F) George Karniadakis 15:45-16:30	LR1 (A3-1 3F) Ngaiming Mok LR3 (A3-1a 2F) Stefan Kebekus & Christian Schnell LR7 (A3-4 1F) Jérôme Buzzi & Sylvain Crovisier LR9 (A6 1F) David Gabai	LR1 (A3-1 3F) Ioannis Emmanouil 15:00 - 16:00 LR2 (A3-1a 2F) Siyuan Ma LR3 (A3-1a 2F) Nikos Frantzikinakis LR7 (A3-4 1F) Yanyan Li 15:00 - 16:00 LR8 (A3-4 3F) Xin Zhou LR9 (A6 1F) Benedikt Bauer	LR1 (A3-1 3F) Marek Kaluba LR2 (A3-1a 2F) Nima Anari LR3 (A3-1a 2F) Takashi Kumagai 15:00 - 16:00 LR7 (A3-4 1F) Ruixiang Zhang LR8 (A3-4 3F) Yuhei Suzuki 15:00 - 15:45 LR10 (A7 1F) Nai Chung Leung 15:00 - 16:00	LR2 (A3-1a 2F) Yuri Tschinkel LR7 (A3-4 1F) Nikolai Nadirashvili LR8 (A3-4 3F) Peng Ding 15:00 - 16:00		
Break							
16:15 - 17:00		LR1 (A3-1 3F) Yihang Zhu 16:00 - 17:00 LR7 (A3-4 1F) Dinh Tien Cuong 16:00 - 17:00 LR9 (A6 1F) Lisa Piccirillo	LR3 (A3-1a 2F) Simon Kristensen 16:00 - 17:00 LR7 (A3-4 1F) Xavier Cabré LR8 (A3-4 3F) Richard Bamler LR9 (A6 1F) Zuowei Shen 16:00-17:00	LR1 (A3-1 3F) Jia (Hana) Kong LR2 (A3-1a 2F) Máté Matolcsi LR3 (A3-1a 2F) Aran Raoufi LR7 (A3-4 1F) Marina Iliopoulou LR8 (A3-4 3F) Yasuyuki Kawahigashi 16:00 - 17:00	LR2 (A3-1a 2F) Vyacheslav V Shokurov 16:00 - 17:00 LR7 (A3-4 1F) Aleksandr Logunov LR8 (A3-4 3F) Tony Cai		
		Basic Science Lecture David Gross LH A (A2) 17:00 - 18:00					Basic Science Lecture Greg Yang Chaoyang Kexie Blue Hall 16:00-16:45

THEORETICAL PHYSICS (WEEK1)

	Mon. 07-17	Tue. 07-18	Wed. 07-19	Thu. 07-20	Fri. 07-21	Sat. 07-22	Sun. 07-23
08:00 - 09:00		LR4 (A3-2 1F) Tadashi Takayanagi	LR4 (A3-2 1F) Dong Lai	LR4 (A3-2 1F) Yue Zhao	LR4 (A3-2 1F) John Ellis		
Break							
09:15 - 10:15	Basic Science Lecture David Mumford LH A (A2) 09:00 - 10:00	LR4 (A3-2 1F) Mukund Rangamani	LR4 (A3-2 1F) Bin Chen	LR4 (A3-2 1F) Michael Berry	LR4 (A3-2 1F) Jonathan Feng (online)		
Break							
10:30 - 11:30	Basic Science Lecture Adi Shamir LH A (A2) 10:00 - 11:00	LR4 (A3-2 1F) Bingsong Zou	LR4 (A3-2 1F) Rong-Gen Cai	LR4 (A3-2 1F) Tao Xiang	LR4 (A3-2 1F) Gary Shiu		
Break							
	Basic Science Lecture Alessio Figalli LH A (A2) 11:20 - 12:20						
Lunch							
13:00 - 13:45	LR4 (A3-2 1F) Irene Valenzuela 13:15 - 14:00	LR4 (A3-2 1F) Nikita Nekrasov 13:00 - 14:00	LR4 (A3-2 1F) Brian Skinner	LR4 (A3-2 1F) Xiao Chen	LR4 (A3-2 1F) Francesco Sannino 13:00 - 14:00		
Break							
14:00 - 14:45	LR4 (A3-2 1F) Thomas Rudelius 14:00 - 14:45	LR4 (A3-2 1F) Matthias Gaberdiel	LR4 (A3-2 1F) Jonathan Ruhman	LR4 (A3-2 1F) Liujun Zou	LR4 (A3-2 1F) Song He		
Break							
15:15 - 16:00	LR4 (A3-2 1F) Ahmed Eid Khamis Thani Almheiri 15:00 - 15:45	LR4 (A3-2 1F) Yifang Wang 15:15 - 16:15	LR4 (A3-2 1F) Hugo Duminil-Copin (online) 15:15 - 16:15	LR4 (A3-2 1F) Petr Kravchuk	LR4 (A3-2 1F) Kimyeong Lee 15:15 - 16:15		
Break							
16:15 - 17:00	LR4 (A3-2 1F) Mirjam Cvetic 15:45 - 16:45		LR4 (A3-2 1F) Geoffrey Penington (online)	LR4 (A3-2 1F) Mao Zeng	LR4 (A3-2 1F) Chi-Ming Chang 16:15 - 17:00		
		Basic Science Lecture David Gross LH A (A2) 17:00 - 18:00					Basic Science Lecture Greg Yang Chaoyang Kexie Blue Hall 16:00-16:45

THEORETICAL COMPUTER AND INFORMATION SCIENCES (WEEK1)

	Mon. 07-17	Tue. 07-18	Wed. 07-19	Thu. 07-20	Fri. 07-21	Sat. 07-22	Sun. 07-23
08:00 - 09:00		LR12 (A7 3F) Kazuhiro Kosuge LR13 (A7 3F) Mina Teicher	LR12 (A7 3F) Noga Alon	LR12 (A7 3F) Xianfeng Gu	LR12 (A7 3F) David Brady		
Break							
09:15 - 10:15	Basic Science Lecture David Mumford LH A (A2) 09:00 - 10:00	LR12 (A7 3F) Philip S. Yu LR13 (A7 3F) Ningsheng Xu	LR12 (A7 3F) Yu Sun LR13 (A7 3F) Xiaotie Deng	LR12 (A7 3F) Song-Chun Zhu	LR12 (A7 3F) Bing Liu		
Break							
10:30 - 11:30	Basic Science Lecture Adi Shamir LH A (A2) 10:00 - 11:00	LR12 (A7 3F) Bo Huang LR13 (A7 3F) Jin-Yi Cai	LR12 (A7 3F) Darwin G Caldwell LR13 (A7 3F) Jintai Ding	LR12 (A7 3F) Jiebo Luo	LR12 (A7 3F) Xiang-Gen Xia		
Break							
	Basic Science Lecture Alessio Figalli LH A (A2) 11:20 - 12:20						
Lunch							
13:00 - 13:45		LR12 (A7 3F) Jun Wu LR13 (A7 3F) Keisuke Goda	LR11 (A7 2F) Meng Xu LR12 (A7 3F) Han Hu LR13 (A7 3F) Muli Safra	LR12 (A7 3F) Sushant Sachdeva LR13 (A7 3F) Florian Jug	LR12 (A7 3F) Zheng Yao LR13 (A7 3F) Yifan Peng		
Break							
14:00 - 14:45	LR12 (A7 3F) Michael Jordan 13:30 - 14:30 LR13 (A7 3F) Vivek Goyal 13:30 - 14:15	LR12 (A7 3F) Yue Wang LR13 (A7 3F) Heng Li	LR11 (A7 3F) Ke Xu LR12 (A7 2F) Yixin Hu	LR12 (A7 3F) László Végh LR13 (A7 3F) Alexander Mathis	LR12 (A7 3F) Junhui Law LR13 (A7 3F) Ethan Tseng		
Break							
15:15 - 16:00	LR12 (A7 3F) Hongyu Zhao 15:15 - 16:15 LR13 (A7 3F) Lu Fang 14:30 - 15:45	LR12 (A7 3F) Ravi Ramamoorthi LR13 (A7 3F) Ting Chen	LR12 (A7 3F) Antonio Loquercio LR13 (A7 3F) Shai Evra	LR12 (A7 3F) Yisroel Mirsky LR13 (A7 3F) Daniel Zügner	LR13 (A7 3F) Jinbo Xu		
Break							
16:15 - 17:00	LR12 (A7 3F) Jiangzhou Wang 16:30 - 17:30 LR13 (A7 3F) Tie Jun Cui 16:00 - 16:45	LR12 (A7 3F) Namiko Saito LR13 (A7 3F) Cho-Jui Hsieh	LR12 (A7 3F) Bradley Nelson LR13 (A7 3F) Ayush Bhandari	LR12 (A7 3F) Kan Li LR13 (A7 3F) Xiang Wang			
		Basic Science Lecture David Gross LH A (A2) 17:00 - 18:00					Basic Science Lecture Greg Yang Chaoyang Kexie Blue Hall 16:00-16:45

MATHEMATICS (WEEK2)

	Mon. 07-24	Tue. 07-25	Wed. 07-26	Thu. 07-27	Fri. 07-28
08:00 - 09:00	LR7 (A3-4 1F) Feida Jiang LR8 (A3-4 3F) Zhengwei Liu LR9 (A6 1F) Xi-Ping Zhu LR10 (A7 1F) Chi Tat Chong	LR7 (A3-4 1F) Ping Zhang LR8 (A3-4 3F) Nicolai Reshetikhin	LR7 (A3-4 1F) Lei Fu LR8 (A3-4 3F) Weiping Li	LR7 (A3-4 1F) Nanhua Xi LR8 (A3-4 3F) Yi Liu	LR7 (A3-4 1F) Yong Lin LR8 (A3-4 3F) Guiqiang Chen
Break					
09:15 - 10:15	LR7 (A3-4 1F) Zuoqiang Shi LR8 (A3-4 3F) Wen-An Yong LR9 (A6 1F) Jungkai Chen LR10 (A7 1F) Kui Ren	LR7 (A3-4 1F) Fangyang Zheng LR8 (A3-4 3F) Youjin Zhang	LR7 (A3-4 1F) Zhi Jiang LR8 (A3-4 3F) Jian Zhou	LR7 (A3-4 1F) Lars Andersson LR8 (A3-4 3F) Jianfeng Lin	LR7 (A3-4 1F) Shiping Liu LR8 (A3-4 3F) Hao Wu
Break					
10:30 - 11:30	LR7 (A3-4 1F) Zhiming Chen LR8 (A3-4 3F) Zhijie Chen LR9 (A6 1F) Haizhong Li LR10 (A7 1F) Lan-Hsuan Huang	LR8 (A3-4 3F) Changzheng Li	LR7 (A3-4 1F) Weizhe Zheng LR8 (A3-4 3F) Jie Zhou	LR7 (A3-4 1F) Junbin Li LR8 (A3-4 3F) Jie Wu	LR7 (A3-4 1F) Hehui Wu LR8 (A3-4 3F) Yuval Peres
Lunch					
13:00 - 14:00	LR7 (A3-4 1F) Weizhu Bao LR8 (A3-4 3F) Zhouping Xin LR9 (A6 1F) Bing-Long Chen LR10 (A7 1F) Piotr Chrusciel 13:00 - 14:00	LR7 (A3-4 1F) Hongwei Xu LR8 (A3-4 3F) Jie Gu	LR7 (A3-4 1F) Kang Zuo LR8 (A3-4 3F) Babak Haghigat	LR7 (A3-4 1F) Kefeng Liu LR8 (A3-4 3F) Peng Shan	LR7 (A3-4 1F) Jie Ma LR8 (A3-4 3F) Tadahisa Funaki
Break					
14:15 - 15:15	LR7 (A3-4 1F) Bin Dong LR8 (A3-4 3F) Yitwah Cheung LR9 (A6 1F) Hui Ma LR10 (A7 1F) Elena Giorgi 14:15 - 15:00	LR7 (A3-4 1F) Hao Xu LR8 (A3-4 3F) Okazaki Tadashi	LR7 (A3-4 1F) Chenglong Yu LR8 (A3-4 3F) Sen Hu	LR7 (A3-4 1F) Bing Wang LR8 (A3-4 3F) Yongquan Hu	LR7 (A3-4 1F) Liying Kang LR8 (A3-4 3F) Rongling Wu
Break					
15:30 - 16:30	LR7 (A3-4 1F) Lingyun Qiu LR8 (A3-4 3F) Kazuyuki Tanaka LR9 (A6 1F) Fusheng Deng LR10 (A7 1F) Georgios Moschidis 15:15-16:00	LR7 (A3-4 1F) Sebastian Heller LR8 (A3-4 3F) Liang Kong	LR7 (A3-4 1F) Yu-Wei Fan LR8 (A3-4 3F) Shuai Guo	LR7 (A3-4 1F) Yi Li LR8 (A3-4 3F) Koji Shimizu	LR7 (A3-4 1F) Hongliang Lu LR8 (A3-4 3F) Yi Zhu
Break					
16:45 - 17:45	LR7 (A3-4 1F) Chenglong Bao LR8 (A3-4 3F) Ping Ma LR9 (A6 1F) Ge Xiong LR10 (A7 1F) Po-Ning Chen 16:15 - 17:00	LR7 (A3-4 1F) Entao Zhao LR8 (A3-4 3F) Sperling Marcus	LR8 (A3-4 3F) Tian Lan	LR7 (A3-4 1F) Lynn Heller LR8 (A3-4 3F) Xu Shen	LR7 (A3-4 1F) Jianfeng Hou LR8 (A3-4 3F) Fan Yang

THEORETICAL PHYSICS (WEEK2)

	Mon. 07-24	Tue. 07-25	Wed. 07-26	Thu. 07-27	Fri. 07-28
08:00 - 09:00	LR4 (A3-2 1F) Andrei Linde (online)	LR4 (A3-2 1F) Jianxin Lu	LR4 (A3-2 1F) Wei Wang	LR4 (A3-2 1F) Qikun Xue	LR4 (A3-2 1F) Philip Candelas
Break					
09:15 - 10:15	LR4 (A3-2 1F) Henry Tye	LR4 (A3-2 1F) Li-Lin Yang	LR4 (A3-2 1F) Wei Song 09:15-10:00	LR4 (A3-2 1F) Fuchun Zhang	LR4 (A3-2 1F) Yan-Qing Ma
Break					
10:30 - 11:30	LR4 (A3-2 1F) Yue-Liang Wu	LR4 (A3-2 1F) Qingguo Huang	LR4 (A3-2 1F) Ling Yan Hung 10:15-11:00	LR4 (A3-2 1F) Xin-Cheng Xie	LR4 (A3-2 1F) Hong Yao
Lunch					
13:00 - 13:45	LR4 (A3-2 1F) Hai Lin	LR4 (A3-2 1F) Yi Wang	LR4 (A3-2 1F) Haipeng An	LR4 (A3-2 1F) Erik Aldape	LR4 (A3-2 1F) Zhong Wang
Break					
14:00 - 14:45	LR4 (A3-2 1F) Huaxing Zhu	LR4 (A3-2 1F) Junya Yagi	LR4 (A3-2 1F) Jing Ren	LR4 (A3-2 1F) Glenn Wagner	LR4 (A3-2 1F) Zhong-Zhi Xianyu
Break					
15:15 - 16:00	LR4 (A3-2 1F) Qiang Yuan	LR4 (A3-2 1F) Shun Zhou	LR4 (A3-2 1F) Yunfeng Jiang	LR4 (A3-2 1F) Mikhail Otrokov	LR4 (A3-2 1F) Hossein Yavartano
Break					
16:15 - 17:00	LR4 (A3-2 1F) Pengfei Zhang	LR4 (A3-2 1F) Qiang Wen	LR4 (A3-2 1F) Yinan Wang	LR4 (A3-2 1F) Shuo Yang	

THEORETICAL COMPUTER AND INFORMATION SCIENCES (WEEK2)

	Mon. 07-24	Tue. 07-25	Wed. 07-26	Thu. 07-27	Fri. 07-28
08:00 - 09:00	LR12 (A7 3F) Min Wu	LR12 (A7 3F) Min Zhang			
Break					
09:15 - 10:15	LR13 (A7 3F) Michael Zhang	LR12 (A7 3F) Jie Tang		LR12 (A7 3F) Lei Guo	
Break					
10:30 - 11:30	LR12 (A7 3F) Michail Vazirgiannis	LR12 (A7 3F) Raymond Yeung			
Lunch					
13:00 - 13:45		LR12 (A7 3F) Dongling Deng			
Break					
14:00 - 14:45		LR12 (A7 3F) Xiaoming Zhang			
Break					
15:15 - 16:00					
Break					
16:15 - 17:00					

Table of Contents

Category Taxonomy

BSL	Basic Science Lecture
FSA	Frontiers of Science Award Lecture
plenary	Plenary Lecture
math	Mathematics
math.AC	Commutative Algebra and Algebraic Geometry
math.AP	Partial Differential Equations
math.AT	Algebraic and Geometric Topology
math.CA	Ordinary Differential Equations and Special Functions, D Module
math.CM	Mathematics of String Theory and Condensed Matter
math.CO	Combinatorics, Discrete Geometry, and Graph theory
math.CV	One and Several variables, Complex Dynamical System
math.DG	Differential Geometry
math.DS	Dynamics Systems, Ergodic Theory and Diophantine Approximation
math.FA	Functional Analysis and Operator Theory
math.GA	Geometric Analysis
math.GR	General Relativity
math.HA	Fourier Analysis and Harmonic Analysis
math.KT	Homological Algebra, K-Theory and Noncommutative Algebra
math.LO	Mathematical Logic, Foundations and Category Theory
math.NA	Numerical Analysis and Scientific Computation
math.NT	Number Theory
math.OC	Calculus of Variations and Optimal Control
math.PR	Probability Theory and Stochastic Processes
math.RT	Lie Theory and Representation Theory
math.SG	Symplectic and Differential Topology
math.ST	Statistics
phys	Theoretical Physics
phys.CM	Condensed Matter Theory
phys.QT	Quantum gravity and Quantum field theory
tcis	Theoretical Computer and Information Sciences
tcis.AI	Artificial intelligence
tcis.BD	Big data technology
tcis.BIO	Bioinformatics
tcis.BP	Biophotonics
tcis.CO	Computational optics
tcis.CR	Cryptography and information security
tcis.GR	Graphics and geometric computing
tcis.RO	Robotics Science and System
tcis.SP	Signal processing
tcis.TH	Theoretical computer science

To locate a speaker by name, please refer to the speaker index.

Basic Science Lectures

Mathematics Lectures

Theoretical Physics Lectures

Theoretical Computer and Information Sciences Lectures

Basic Science Lectures

Titles and Abstracts

Monday, July 17

Consciousness, robots and DNA

David Mumford (Division of Applied Mathematics, Brown University)

Date: 7.17 Time: 09:00-10:00 Venue: Lecture Hall A (A2)

Consciousness was not even considered a scientific term until recently. But with the prospect of fully intelligent humanoid robots, one must confront the question of whether they are conscious. This question has many sides but here I want to focus on what physics has to say and, in particular, whether DNA creates cat-states.

Manifolds in machine learning

Adi Shamir (Weizmann Institute of Science)

Date: 7.17 Time: 10:00-11:00 Venue: Lecture Hall A (A2)

The talk should be accessible and of interest to both computer scientists and mathematicians, and in fact, this research was inspired by a talk by Prof. Shing-Tung Yau about the geometry of machine learning that I attended a few years ago.

Generic regularity of free boundaries for the obstacle problem

Alessio Figalli (ETH Zürich)

Date: 7.17 Time: 11:20-12:20 Venue: Lecture Hall A (A2)

The classical obstacle problem consists of finding the equilibrium position of an elastic membrane whose boundary is held fixed and which is constrained to lie above a given obstacle. By classical results of Caffarelli, the free boundary is C^∞ outside a set of singular points. Explicit examples show that the singular set could be in general (n-1)-dimensional —that is, as large as the regular set. In a recent paper with Ros-Oton and Serra we show that, generically, the singular set has zero H^{n-4} measure (in particular, it has codimension three inside the free boundary), solving a conjecture of Schaeffer in dimension $n \leq 4$. The aim of this talk is to give an overview of these results.

Tuesday, July 18

TBA

David Gross (Kavli Institute for Theoretical Physics, University of California, Santa Barbara)

Date: 7.18 Time: 17:00-18:00 Venue: Lecture Hall A (A2)

TBA

The unreasonable effectiveness of mathematics in large scale deep learning

Greg Yang (xAI)

Date: 7.23 Time: 16:00-16:45 Venue: Chaoyang Kexie Blue Hall

Recently, the theory of infinite-width neural networks led to the first technology, muTransfer, for tuning enormous neural networks that are too expensive to train more than once. For example, this allowed us to tune the 6.7 billion parameter version of GPT-3 using only 7% of its pretraining compute budget, and with some asterisks, we get a performance comparable to the original GPT-3 model with twice the parameter count. In this talk, I will explain the core insight behind this theory. In fact, this is an instance of what I call the *Optimal Scaling Thesis*, which connects infinite-size limits for general notions of "size" to the optimal design of large models in practice. I'll end with several concrete key mathematical research questions whose resolutions will have incredible impact on the future of AI.

Mathematics

Titles and Abstracts

Inference for heteroscedastic PCA with missing data

Jianqing Fan (Princeton University)

Date: 7.17 Time: 13:30-14:30 Venue: Lecture Room 10 (A7 1F)

This paper studies how to construct confidence regions for principal component analysis (PCA) in high dimension, a problem that has been vastly under-explored. While computing measures of uncertainty for nonlinear / nonconvex estimators is in general difficult in high dimension, the challenge is further compounded by the prevalent presence of missing data and heteroskedastic noise. We propose a novel approach to performing valid inference on the principal subspace, on the basis of an estimator called HeteroPCA (Zhang et al., 2022). We develop non-asymptotic distributional guarantees for HeteroPCA, and demonstrate how these can be invoked to compute both confidence regions for the principal subspace and entrywise confidence intervals for the spiked covariance matrix. Our inference procedures are fully data-driven and adaptive to heteroskedastic random noise, without requiring prior knowledge about the noise levels. (Joint work with Yuling Yan and Yuxin Chen)

Discrete geometric analysis and its application to materials science

Motoko Kotani (Tohoku University)

Date: 7.17 Time: 13:30-14:30 Venue: Lecture Room 7 (A3-4 1F)

We discuss recent progresses in discrete geometric analysis, which has been developed as a discrete version of geometric analysis. It targets not only discrete objects but also methods to bridge discrete and continuum. Its applications to materials science are being presented.

Hard Lefschetz type theorems without the geometry

Karim Adiprasito (Hebrew University of Jerusalem)

Date: 7.17 Time: 13:30-14:15 Venue: Lecture Room 6 (A3-2a 3F)

I will survey recent results in combinatorial algebraic geometry, and its applications.

Frontiers of Science Award Paper: Karim Adiprasito, June Huh, and Eric Katz. Hodge theory for combinatorial geometries. *Ann. of Math. (2)*, 188(2):381–452, 2018

TBA

Jian Ding (Peking University)

Date: 7.17 Time: 13:30-14:15 Venue: Lecture Room 11 (A7 2F)

TBA

Frontiers of Science Award Paper: Jian Ding, Allan Sly, and Nike Sun. Proof of the satisfiability conjecture for large k. *Ann. of Math. (2)*, 196(1):1–388, 2022

The $\mathrm{SL}(2,\mathbb{R})$ action on moduli space

Alex Eskin (University of Chicago)

Date: 7.17 Time: 13:30-14:15 Venue: Lecture Room 9 (A6 1F)

The $\mathrm{SL}(2,\mathbb{R})$ action on the Moduli space of compact Riemann surfaces exhibits some features which are usually associated with dynamics on homogeneous spaces. I will describe some of the parallels and connections.

Frontiers of Science Award Paper: Alex Eskin and Maryam Mirzakhani. Invariant and stationary measures for the $\mathrm{SL}(2,\mathbb{R})$ action on moduli space. *Publ. Math. Inst. Hautes Études Sci.*, 127:95–324, 2018

On the implosion and singularity formation of a 3D compressible fluid

Frank Merle (Institut des Hautes Études Scientifiques (IHÉS) & CY Cergy Paris Université)

Date: 7.17 Time: 13:30-14:15 Venue: Lecture Room 2 (A3-1a 2F)

In this talk, we investigate strong singularity formation in compressible fluids. We will consider the compressible three-dimensional Navier-Stokes and Euler equations. In a suitable regime of barotropic laws, we construct a set of finite energy smooth initial data for which the corresponding solutions to both equations implode (with infinite density) at a later time at a point, and completely describe the associated formation of singularity. An essential step in the proof is the existence of smooth self-similar solutions to the compressible Euler equations for quantized values of the speed. All blow up dynamics are then obtained by perturbation, for the Navier-Stokes problem are of type II (non self-similar).

Frontiers of Science Award Paper: Frank Merle, Pierre Raphaël, Igor Rodnianski, and Jeremie Szeftel. On the implosion of a compressible fluid II: Singularity formation. *Ann. of Math. (2)*, 196(2):779–889, 2022

On topological cyclic homology

Thomas Nikolaus (University of Muenster)

Date: 7.17 Time: 13:30-14:15 Venue: Lecture Room 1 (A3-1 3F)

We will explain the new theory of topological cyclic homology and cyclotomic spectra. This has sparked a lot of breakthrougs in the area and led to some new insights into algebraic K-theory. We review these developments.

Frontiers of Science Award Paper: Thomas Nikolaus and Peter Scholze. On topological cyclic homology. *Acta Math.*, 221(2):203–409, 2018

The AAA algorithm for rational approximation

Nick Trefethen (University of Oxford)

Date: 7.17 Time: 13:30-14:15 Venue: Lecture Room 8 (A3-4 3F)

With this new algorithm, approximation by rational functions has become fast and practical in a way it was not before. We will discuss many examples and applications including to the solution of partial differential equations.

Frontiers of Science Award Paper: Yuji Nakatsukasa, Olivier Sète, and Lloyd N. Trefethen. The AAA algorithm for rational approximation. *SIAM J. Sci. Comput.*, 40(3):A1494–A1522, 2018

Integration in finite terms for families of algebraic differentials.

Umberto Zannier (Scuola Normale Superiore)

Date: 7.17 Time: 13:30-14:15 Venue: Lecture Room 3 (A3-1a 2F)

We shall recall in short a history of the problem of integration by elementary functions (i.e. "in finite terms"). Then we shall discuss a problem of specialization concerning integration in finite terms along a pencil of algebraic differentials on a curve, an issue posed by James Davenport. We shall briefly discuss joint work with David Masser, giving counterexamples to the question whether a non-elementary generic integral remains non elementary for almost all specializations, and giving also many positive results. We shall present several explicit examples constructed out of special functions.

Frontiers of Science Award Paper: David Masser and Umberto Zannier. Torsion points, Pell's equation, and integration in elementary terms. *Acta Math.*, 225(2):227–313, 2020

Monday, July 17, Afternoon Session II

High order numerical methods for hyperbolic equations

Chi-Wang Shu (Brown University)

Date: 7.17 Time: 14:30-15:30 Venue: Lecture Room 8 (A3-4 3F)

Hyperbolic equations are used extensively in applications including fluid dynamics, astrophysics, electro-magnetism, semi-conductor devices, and biological sciences. High order accurate numerical methods are efficient for solving such partial differential equations, however they are difficult to design because solutions may contain discontinuities. In this talk we will survey several types of high order numerical methods for such problems, including weighted essentially non-oscillatory (WENO) finite difference and finite volume methods, discontinuous Galerkin finite element methods, and spectral methods. We will discuss essential ingredients, properties and relative advantages of each method, and provide comparisons among these methods. Recent development and applications of these methods will also be discussed.

Rough solutions of the 3-D compressible Euler equations

Qian Wang (University of Oxford)

Date: 7.17 Time: 14:30-15:30 Venue: Lecture Room 2 (A3-1a 2F)

I will talk about my work on the compressible Euler equations. We prove the local-in-time existence the solution of the compressible Euler equations in 3-D, for the Cauchy data of the velocity, density and vorticity $(v,\rho,\omega)\in H^s\times H^s\times H^{s'}$, $2<s'<s$. The result extends the sharp result of Smith-Tataru and Wang, established in the irrotational case, i.e $\omega=0$, which is known to be optimal for $s>2$. At the opposite extreme, in the incompressible case, i.e. with a constant density, the result is known to hold for $\omega\in H^s$, $s>3/2$ and fails for $s\leq 3/2$, see the work of Bourgain-Li. It is thus natural to conjecture that the optimal result should be $(v,\rho,\omega)\in H^s\times H^s\times H^{s'}$, $s>2$, $s'>\frac{3}{2}$. We view our work as an important step in proving the conjecture. The main difficulty in establishing sharp well-posedness results for general compressible Euler flow is due to the highly nontrivial interaction between the sound waves, governed by quasilinear wave equations, and vorticity which is transported by the flow. To overcome this difficulty, we separate the dispersive part of sound wave from the transported part, and gain regularity significantly by exploiting the nonlinear structure of the system and the geometric structures of the acoustic spacetime.

Martin's Maximum^{++} implies Woodin's Axiom (*)

David Asperó (University of East Anglia) and Ralf Schindler (Universität Münster)

Date: 7.17 Time: 14:30-15:15 Venue: Lecture Room 1 (A3-1 3F)

There are two sets of prominent set theoretical hypotheses, strong forcing axioms and the P_{max} axiom (*), which both decide CH and in fact determine the value of the continuum to be $\aleph_2$. Prior to our work, the relationship between those forcing axioms and (*) was a mystery. We showed in 2019 that MM^{++}, the strongest forcing axiom, implies the P_{max} axiom (*). We will present the theorem in the title of our paper and explain why this theorem makes Woodin's axiom (*) into a natural axiom for mathematics.

Frontier of Science Award Paper: David Asperó and Ralf Schindler. Martin's Maximum^{++} implies Woodin's axiom $(*)$. *Ann. of Math. (2)*, 193(3):793–835, 2021

Rational approximations of irrational numbers

Dimitrios Koukoulopoulos (University of Montreal)

Date: 7.17 Time: 14:30-15:15 Venue: Lecture Room 3 (A3-1a 2F)

Given quantities $\Delta_1, \Delta_2, \cdots \geqslant 0$, a fundamental problem in Diophantine approximation is to understand which irrational numbers x have infinitely many reduced rational approximations a/q such that $|x - a/q| < \Delta_q$. Depending on the choice of Δ_q and of x, this question may be very hard. However, Duffin and Schaeffer conjectured in 1941 that if we assume a "metric" point of view, the question is governed by a simple zero–one law: writing φ for Euler's totient function, we either have $\sum_{q=1}^{\infty} \varphi(q)\Delta_q = \infty$ and then almost all irrational numbers (in the Lebesgue sense) are approximable, or $\sum_{q=1}^{\infty} \varphi(q)\Delta_q < \infty$ and almost no irrationals are approximable. I will present the history of the Duffin–Schaeffer conjecture and the main ideas behind the recent work of Koukoulopoulos–Maynard that settled it.

Frontiers of Science Award Paper: Dimitris Koukoulopoulos and James Maynard. On the Duffin-Schaeffer conjecture. *Ann. of Math. (2)*, 192(1):251–307, 2020

Foam evaluation and its applications

Louis-Hadrien Robert (Université Clermont Auvergne)

Date: 7.17 Time: 14:30-15:15 Venue: Lecture Room 6 (A3-2a 3F)

Foams are surfaces with singularities which can be thought of as cobordisms between graphs. Foam evaluation is a combinatorial formula which associates a symmetric polynomial to any closed foam. I will describe this combinatorial formula and explain how it can be used to construct various link homology theories and additional structures on them.

Frontiers of Science Award Paper: Louis-Hadrien Robert and Emmanuel Wagner. A closed formula for the evaluation of foams. *Quantum Topol.*, 11(3):411–487, 2020

Floer homology beyond borders

Dylan Thurston (Indiana University Bloomington)

Date: 7.17 Time: 14:30-15:15 Venue: Lecture Room 9 (A6 1F)

Heegaard Floer homology was developed as an extension of the Seiberg-Witten invariant of closed 4-manifolds to closed 3-manifolds and 4-manifolds with boundary, in the style of topological field theories. As originally conceived, Bordered Heegaard Floer homology is a further extension of the simplest version of Heegaard Floer homology to 3-manifolds with boundary. In this talk, we will survey the formal structure of bordered Heegaard Floer homology, applications to topology, and connections to other fields.

Frontiers of Science Award Paper: Robert Lipshitz, Peter S. Ozsvath, and Dylan P. Thurston. Bordered Heegaard Floer homology. *Mem. Amer. Math. Soc.*, 254(1216):viii+279, 2018

Recent progress on completely integrable systems

Monica Visan (University of California, Los Angeles)

Date: 7.17 Time: 14:30-15:15 Venue: Lecture Room 7 (A3-4 1F)

I will survey recent work on low regularity conservation laws, equicontinuity, and optimal well-posedness for completely integrable systems. The centerpiece of my presentation is the method of commuting flows that we introduced to answer the well-posedness question in the non-perturbative regime of these equations. I will then describe the increasingly sophisticated techniques that have been required in order to achieve sharp results across a spectrum of integrable models. This is based on joint work with B. Harrop-Griffiths, R. Killip, T. Laurens, and M. Ntekoume.

Frontiers of Science Award Paper: Rowan Killip and Monica Vişan. KdV is well-posed in H^{-1}. *Ann. of Math. (2)*, 190(1):249–305, 2019

TBA

Stefan Wager (Stanford University)

Date: 7.17 Time: 14:30-15:15 Venue: Lecture Room 10 (A7 1F)

TBA

Frontiers of Science Award Paper: Stefan Wager and Susan Athey. Estimation and inference of heterogeneous treatment effects using random forests. *J. Amer. Statist. Assoc.*, 113(523):1228–1242, 2018

Monday, July 17, Afternoon Session III

Differences in global tests for dense and sparse alternatives when testing multiple outcomes vs multiple explanatory variables in genetic studies

Xihong Lin (Harvard University)

Date: 7.17 Time: 15:30-16:30 Venue: Lecture Room 10 (A7 1F)

Set-based association tests are widely popular in genetic association settings for their ability to aggregate weak signals and reduce multiple testing burdens. In particular, a class of set-based tests including the Kernel-Machine tests for dense alternatives and Higher Criticism and Berk–Jones for sparse alternatives. Such tests have been applied in two subtly different settings: (a) associating a set of genetic variants with a single outcome and (b) associating a single genetic variant with a set of multiple outcomes. A significant issue in practice is the choice of test. For dense alternatives, one needs to decide which and how many PCs to use. For sparse alternatives, one needs to decide between innovated and generalized type methods for detection boundary tests. Conflicting guidance is present in the literature. This work describes how correlation structures generate marked differences in relative operating characteristics for settings (a) and (b). The implications for study design are significant. We also develop novel power bounds that facilitate the aforementioned calculations and allow for analysis of individual testing settings. In more concrete terms, our investigation is motivated by translational expression quantitative trait loci (eQTL) studies in lung cancer. These studies involve both testing for groups of variants associated with a single gene expression (multiple explanatory factors) and testing whether a single variant is associated with a group of gene expressions (multiple outcomes). Results are supported by a collection of simulation studies and illustrated through lung cancer eQTL examples.

Quantum states of matter

Bruno Nachtergaele (University of California, Davis)

Date: 7.17 Time: 15:30-16:30 Venue: Lecture Room 7 (A3-4 1F)

Ground states of quantum lattice systems describe a wide variety of states of matter. They provide theoretical models of physical systems with unusual and interesting properties. We review recent progress in the mathematical study of these systems.

The axiom V = Ultimate-L and Goldberg's Ultrapower axiom

Hugh Woodin (Harvard University)

Date: 7.17 Time: 15:30-16:30 Venue: Lecture Room 1 (A3-1 3F)

The axiom V = Ultimate-L is the leading candidate for the maximum possible generalization of Gödel's axiom, V = L. The Ultimate Program is the program to show that the axiom V = Ultimate-L is not refuted by large cardinal axioms. This involves a series a rather specific conjectures, which is the family of Ultimate-L Conjectures. A key part of this program is to develop the structure theory of Ultimate-L. Goldberg's Ultrapower Axiom holds in all the current generalizations of L which have been constructed in the Inner Model Program which is another major program of Set Theory to identify generalizations of L. The Ultrapower Axiom has deep structural consequences in the context of large cardinal axioms. For example, it implies the Generalized Continuum Hypothesis must hold above the least strongly compact cardinal and it implies the least strongly compact cardinal is supercompact. By recent theorem, if V = Ultimate-L then the Ultrapower Axiom holds. The unexpected feature here is that this can be proved without settling the Ultimate-L Conjectures.

Stabilisation via expansion: global-in-time solutions for compressible Euler flows

Mahir Hadzic (University College London)

Date: 7.17 Time: 15:45-16:30 Venue: Lecture Room 2 (A3-1a 2F)

We will review several recent results on the existence of global-in-time solutions to the compressible Euler and the gravitational Euler-Poisson system. The stabilising mechanism is the expansion of the fluid particle trajectories, which generates a strong dispersive effect in the problem. Our focus is on the decisive role of scaling invariances and their interaction with the nonlinearities. To conclude, we will mention several recent results in the opposite direction, with focus on the problem of stellar collapse. These include the existence of finite-time implosion singularities for the gravitational Euler-Poisson system in the supercritical regime and its relativistic analogue - the Einstein-Euler system.

Frontiers of Science Award Paper: Mahir Hadžić and Juhi Jang. Expanding large global solutions of the equations of compressible fluid mechanics. *Invent. Math.*, 214(3):1205–1266, 2018

On the conjectures of Stark

Mahesh Kakde (Indian Institute of Science)

Date: 7.17 Time: 15:45-16:30 Venue: Lecture Room 8 (A3-4 3F)

In the 1970s Stark formulated conjectures giving formulas for leading terms of Artin L-functions at $s = 1$ and $s = 0$. Tate and Gross formulated p-adic analogues of these conjectures in the 1980s. Our lecture will concentrate on the ideas that are behind the proofs of these p-adic analogues.

Frontiers of Science Award Paper: Samit Dasgupta, Mahesh Kakde, and Kevin Ventullo. On the Gross-Stark conjecture. *Ann. of Math. (2)*, 188(3):833–870, 2018

Inverse problems and rigidity questions in Billiard dynamics

Vadim Kaloshin (Institute of Science and Technology Austria) and Alfonso Sorrentino (University of Rome Tor Vergata)

Date: 07.17 Time: 15:45-16:30 Venue: Lecture Room 3 (A3-1a 2F)

A mathematical billiard is a system describing the inertial motion of a point mass inside a domain, with elastic reflections at the boundary. The study of the associated dynamics is profoundly intertwined with the geometric properties of the domain (e.g. the shape of the billiard table). While it is evident how the shape determines the dynamics, a more subtle and difficult question is to which extent the knowledge of the dynamics allows one to reconstruct the shape of the domain. This translates into many intriguing unanswered questions and difficult conjectures that have been the focus of active research over the last decades. In this talk, we shall describe several of these questions, with particular emphasis on results obtained related to the classification of integrable billiards (also known as Birkhoff conjecture) and to the possibility of inferring dynamical information on the billiard map from its Length Spectrum (i.e., the lengths of its periodic orbits).

Frontier of Science Award Paper: Vadim Kaloshin and Alfonso Sorrentino. On the local Birkhoff conjecture for convex billiards. *Ann. of Math. (2)*, 188(1):315–380, 2018

From physics informed machine learning to physics informed machine intelligence: Quo vadimus?

George Karniadakis (Brown University)

Date: 7.17 Time: 15:45-16:30 Venue: Lecture Room 11 (A7 2F)

We will review physics-informed neural networks (NNs) and summarize available extensions for applications in computational science and engineering. We will also introduce new NNs that learn functionals and nonlinear operators from functions and corresponding responses for system identification. The universal approximation theorem of operators is suggestive of the potential of NNs in learning from scattered data any continuous operator or complex system. We first generalize the theorem to deep neural networks, and subsequently we apply it to design a new composite NN with small generalization error, the deep operator network (DeepONet), consisting of a NN for encoding the discrete input function space (branch net) and another NN for encoding the domain of the output functions (trunk net). We demonstrate that DeepONet can learn various explicit operators, e.g., integrals, Laplace transforms and fractional Laplacians, as well as implicit operators that represent deterministic and stochastic differential equations. More generally, DeepOnet can learn multiscale operators spanning across many scales and trained by diverse sources of data simultaneously. Finally, we will present first results on the next generation of these architectures to biologically plausible designs based on spiking neural networks and Hebbian learning that are more efficient and closer to human intelligence.

Frontiers of Science Award Paper: M. Raissi, P. Perdikaris, and G. E. Karniadakis. Physics-informed neural networks: a deep learning framework for solving forward and inverse problems involving nonlinear partial differential equations. *J. Comput. Phys.*, 378:686–707, 2019

Monoidal categorification and quantum affine algebras

Myungho Kim (Kyung Hee University)

Date: 7.17 Time: 15:45-16:30 Venue: Lecture Room 6 (A3-2a 3F)

Cluster algebras are special kinds of commutative algebras introduced by Fomin and Zelevinsky in the early 2000s. Since their introduction, a lot of connections and applications have been discovered in various fields of mathematics. A monoidal category is called a monomial categorification of a given cluster algebra, according to Hernandez and Leclerc, if its Grothendieck ring is isomorphic to the cluster algebra and every cluster monomials corresponds to a simple object in the category. In this talk, I will explain our results on the monoidal categorification of cluster algebras via subcategories of representations of quantum affine algebras, including a criterion for a monoidal

subcategory of finite-dimensional modules of quantum affine algebra to become a monoidal categorification of its Grothendieck ring. This is joint research with Masaki Kashiwara, Se-jin Oh, and Euiyong Park.

Frontiers of Science Award Paper: Masaki Kashiwara, Myungho Kim, Se-jin Oh, and Euiyong Park. Monoidal categorification and quantum affine algebras. *Compos. Math.*, 156(5):1039–1077, 2020

Derived moduli spaces of pseudo-holomorphic curves

John Pardon (Simons Center for Geometry and Physics)

Date: 7.17 Time: 15:45-16:30 Venue: Lecture Room 9 (A6 1F)

Moduli spaces of solutions to nonlinear elliptic pdes (anti-self-dual connections, monopoles, pseudo-holomorphic curves, etc.) are a fundamental tool in low-dimensional and symplectic topology. I will discuss foundational aspects of moduli spaces of pseudo-holomorphic curves, in particular how to construct their derived structure using moduli functors, as conjectured by Joyce. Key tools include derived manifolds, log smoothness, and stacks.

Frontiers of Science Award Paper: John Pardon. Contact homology and virtual fundamental cycles. *J. Amer. Math. Soc.*, 32(3):825–919, 2019

Tuesday, July 18, Morning Session I

Classification of algebraic varieties

Caucher Birkar (Yau Mathematical Sciences Center, Tsinghua University)

Date: 7.18 Time: 08:00-09:00 Venue: Lecture Room 9 (A6 1F)

In this talk I will outline the framework of the classification theory of algebraic varieties and explain some of the recent advances in the field.

Tuesday, July 18, Morning Session II

Area-minimizing integral currents: singularities and structure

Camillo De Lellis (Institute for Advanced Study)

Date: 7.18 Time: 09:15-10:15 Venue: Lecture Room 9 (A6 1F)

Area-minimizing integral currents were introduced by De Giorgi, Federer, and Fleming to build a successfull existence theory for the *oriented* Plateau problem. While celebrated examples of singular minimizers were discovered soon after, a first theorem which summarizes the work of several mathematicians in the 60s and 70s (De Giorgi, Fleming, Almgren, Simons, and Federer) and a second theorem of Almgren from 1980 give general dimension bounds for the singular set which match the one of the examples, in codimension 1 and in general codimension respectively. In joint works with Anna Skorobogatova and Paul Minter we prove that in higher codimension the singular set is $(m-2)$-rectifiable and the tangent cone is unique at $\mathscr{H}^{m-2}$-a.e. point. Independently and at the same time, a proof of the same result has been discovered also by Krummel and Wickramasekera. This theorem is the counterpart, in general codimension, of a celebrated work of Leon Simon in the nineties for the codimension 1 case. Moreover, a recent theorem by Liu proves that the singular set can in fact be a fractal of any Hausdorff dimension $\alpha \leq m-2$, indicating that the above structure theorem is indeed close to optimal.

Link homology and categorification

Mikhail Khovanov (Institut des Hautes Études Scientifiques (IHÉS) & CY Cergy Paris Université)

Date: 7.18 Time: 09:15-10:15 Venue: Lecture Room 10 (A7 1F)

We will review the ideas and structures related to link homology and categorification and explain some fundamental results and problems in that area.

Novikov's problem: from physics of metals to modern dynamical systems

Alexandra Skripchenko (Higher School of Economics)

Date: 7.18 Time: 09:15-10:15 Venue: Lecture Room 7 (A3-4 1F)

I will discuss a famous problem posed by S. P. Novikov in 1982 in connection with the conductivity theory of monocrystals: what one can say about different types of asymptotic behavior of plane sections of a triply periodic surface? Apparently the most efficient approach to this problem is closely related to the techniques used in Teichmuller dynamics. I will try to explain historical perspectives and recent developments as well as challenging questions that still remain open.

Tuesday, July 18, Morning Session III

A mathematical definition of Coulomb branches of 3-dimensional $N = 4$ gauge theories

Hiraku Nakajima (Kavli Institute for the Physics and Mathematics of the Universe (IPMU), University of Tokyo)

Date: 7.18 Time: 10:30-11:30 Venue: Lecture Room 9 (A6 1F)

Consider the 3-dimensional $N = 4$ supersymmetric gauge theory associated with a compact Lie group K and its quaternionic representation M. Physicists study its Coulomb branch, which is a noncompact hyper-Kähler manifold with an $SU(2)$-action, possibly with singularities. We give a mathematical definition of the Coulomb branch as an affine algebraic variety with symplectic form on its regular locus. It is defined as the spectrum of the equivariant BM homology of a certain moduli space with the convolution product.

Knot and surfaces in dimension four

András Stipsicz (Alfréd Rényi Institute of Mathematics)

Date: 7.18 Time: 10:30-11:30 Venue: Lecture Room 10 (A7 1F)

Continuous and smooth differs most drastically in dimension four, and it seems that properties of surfaces (and knots in four-manifolds with boundary) display this difference in the most transparent way. The constructions rely on topological ideas, while obstructions use global analysis and differential geometry. In the lecture I will recall the basic results of the subject, list the most important problems, and report on some advances in these questions.

Large genus universality phenomena in geometry and dynamics of moduli spaces of Riemann surfaces

Anton Zorich (University Paris Cité)

Date: 7.18 Time: 10:30-11:30 Venue: Lecture Room 7 (A3-4 1F)

Geometry and dynamics in the moduli spaces proved to be extremely efficient in the study of surface foliations, billiards in polygons and in mathematical models of statistical and solid state physics like Ehrenfest billiards or Novikov's problem on electron transport. Ideas of study of surface dynamics through geometry of moduli spaces originate in works of Thurston, Masur and Veech. Contributions of Avila, Eskin, McMullen, Mirzakhani, Kontsevich, Okounkov, Yoccoz, to mention only Fields Medal and Breakthrough Prize winners, made geometry and dynamics in the moduli spaces extremely active area of modern mathematics. Moduli spaces of Riemann surfaces and related moduli spaces of Abelian differentials are parameterized by a genus g of the surface. Considering all

associated hyperbolic (respectively flat) metrics at once, one observes more and more sophisticated diversity of geometric properties when genus grows. However, most of metrics, on the contrary, progressively share certain similarity. Here the notion of "most of" has explicit quantitative meaning, for example, in terms of the Weil-Petersson measure. Global characteristics of the moduli spaces, like Weil-Petersson and Masur-Veech volumes, Siegel-Veech constants, intersection numbers of psi-classes were traditionally studied through algebra-geometric tools, where all formulae are exact, but very difficult to manipulate in large genus. Most of these quantities admit simple uniform large genus approximate asymptotic formulae. I will give a survey of recent fundamental discoveries of these large genus universality phenomena and of relations between them.

Tuesday, July 18, Afternoon Session I

The pressure of quantum gases

Jan Philip Solovej (University of Copenhagen)

Date: 7.18 Time: 13:00-14:00 Venue: Lecture Room 2 (A3-1a 2F)

I will discuss the pressure of Bose and Fermi gases in their ground state. I will discuss 1-3 dimensions. The main focus will be on a recent proof of the celebrated Lee-Huang-Yang formula for the pressure of a superfluid Bose gas in 3 dimensions.

Nearby Lagrangians

Mohammed Abouzaid (Stanford University)

Date: 7.18 Time: 13:00-13:45 Venue: Lecture Room 9 (A6 1F)

The problem of determining the topology of C^0 close Lagrangians has guided the development of important techniques in symplectic topology over the last 40 years. I will survey the progress made in the last decade, including joint work with Thomas Kragh.

Frontiers of Science Award Paper: Mohammed Abouzaid and Thomas Kragh. Simple homotopy equivalence of nearby Lagrangians. *Acta Math.*, 220(2):207–237, 2018

Large genus asymptotics in flat surfaces

Amol Aggarwal (Columbia University & Clay Mathematics Institute)

Date: 7.18 Time: 13:00-13:45 Venue: Lecture Room 7 (A3-4 1F)

In this talk we will describe the behaviors of flat surfaces and geodesics on hyperbolic surfaces, as their genera tend to infinity. We first discuss enumerative results that count the number of such surfaces or geodesics (which can be viewed as volumes of particular moduli spaces) in the large genus limit, and then we will explain how a randomly sampled such object looks. The large genus limits of these counts will rely on asymptotic results on the behaviors of these intersection numbers at high genus, which might be of independent interest.

Frontiers of Science Award Paper: Amol Aggarwal. Large genus asymptotics for volumes of strata of Abelian differentials. *J. Amer. Math. Soc.*, 33(4):941–989, 2020. With an appendix by Anton Zorich

The curve and the Langlands program

Laurent Fargues (Centre National de la Recherche Scientifique (CNRS))

Date: 7.18 Time: 13:00-13:45 Venue: Lecture Room 1 (A3-1 3F)

I will explain the link between the curve and the local Langalnds program in a particular case: the abelian case.

Frontiers of Science Award Paper: Laurent Fargues and Jean-Marc Fontaine. Courbes et fibrés vectoriels en théorie de Hodge p-adique. *Astérisque*, (406):xiii+382, 2018. With a preface by Pierre Colmez

TBA

Damin Wu (University of Connecticut)

Date: 7.18 Time: 13:00-13:45 Venue: Lecture Room 3 (A3-1a 2F)

TBA

Frontiers of Science Award Paper: Damin Wu and Shing-Tung Yau. Invariant metrics on negatively pinched complete Kähler manifolds. *J. Amer. Math. Soc.*, 33(1):103–133, 2020

Tuesday, July 18, Afternoon Session II

Analytic aspect of constant scalar curvature Kähler metric

Jingrui Cheng (Stony Brook University)

Date: 7.18 Time: 14:00-14:45 Venue: Lecture Room 3 (A3-1a 2F)

I will explain the Semmes-Mabuchi-Donaldson picture of the space of plurisubharmonic functions, and how it leads to some natural conjectures about the existence of canonical metrics. Then I will explain how the apriori estimates for the PDE can be used to resolve these conjectures. This is joint work with Xiuxiong Chen.

Frontiers of Science Award Paper: Xiuxiong Chen and Jingrui Cheng. On the constant scalar curvature Kähler metrics (II)—Existence results. *J. Amer. Math. Soc.*, 34(4):937–1009, 2021

The symplectic geometry of knot conormals and knot invariants

Tobias Ekholm (Uppsala Universitet)

Date: 7.18 Time: 14:00-14:45 Venue: Lecture Room 9 (A6 1F)

We start by explaining how holomorphic curves is used to prove that the deformation class of Lagrangian knot conormals characterise knots and then give similar explanations of other knot invariants including, the Alexander and the coloured HOMFLY and Kauffman polynomials.

Frontiers of Science Award Paper: Tobias Ekholm, Lenhard Ng, and Vivek Shende. A complete knot invariant from contact homology. *Invent. Math.*, 211(3):1149–1200, 2018

Diffeomorphism groups of discs

Manuel Krannich (Karlsruhe Institute of Technology)

Date: 7.18 Time: 14:00-14:45 Venue: Lecture Room 7 (A3-4 1F)

The closed n-dimensional disc is the simplest smooth compact n-manifold and yet, despite continuous efforts of geometers and topologists since the beginning of the 60s, its group of symmetries (the topological group of diffeomorphisms) is still little understood. Over time it has become apparent that, although rooted in geometry and topology, the study of these groups is closely linked to several other areas of mathematics. In this talk, after giving a general introduction to the subject aimed at a broad audience, I will outline some of these connections and survey recent advances in the study of diffeomorphism groups of discs in relation to algebraic K-theory, exotic Pontryagin classes, and graph complexes à la Kontsevich.

Frontiers of Science Award Paper: Manuel Krannich. A homological approach to pseudoisotopy theory. I. *Invent. Math.*, 227(3):1093–1167, 2022

A proof of Onsager's conjecture

Philip Isett (California Institute of Technology)

Date: 7.18 Time: 14:15-15:00 Venue: Lecture Room 2 (A3-1a 2F)

In an effort to explain how anomalous dissipation of energy occurs in hydrodynamic turbulence, Onsager conjectured in 1949 that weak solutions to the incompressible Euler equations may fail to exhibit conservation of energy if their spatial regularity is below 1/3-Hölder. I will discuss a proof of this conjecture that shows that there are nonzero, $(1/3-\varepsilon)$-Hölder Euler flows in 3D that have compact support in time. The construction is based on a method known as "convex integration",which has its origins in the work of Nash on isometric embeddings with low codimension and low regularity. A version of this method was first developed for the incompressible Euler equations by De Lellis and Székelyhidi to build Hölder-continuous Euler flows that fail to conserve energy, and was later improved by Isett and by Buckmaster-De Lellis-Székelyhidi to obtain further partial results towards Onsager's conjecture. The proof of the full conjecture combines convex integration using the "Mikado flows" introduced by Daneri-Székelyhidi with a new "gluing approximation" technique. The latter technique exploits a special structure in the linearization of the incompressible Euler equations.

Frontiers of Science Award Paper: Philip Isett. A proof of Onsager's conjecture. *Ann. of Math. (2)*, 188(3):871–963, 2018

Tuesday, July 18, Afternoon Session III

Smooth surface dynamics in positive entropy

Jérôme Buzzi and Sylvain Crovisier (Centre National de la Recherche Scientifique (CNRS))

Date: 07.18 Time: 15:15-16:00 Venue: Lecture Room 7 (A3-4 1F)

The Anosov-Smale uniformly hyperbolic diffeomorphisms form an open set of chaotic dynamical systems well-understood since the 1970s. Newhouse quickly discovered the set of such diffeomorphisms is not dense, prompting the search for larger but tractable classes. Several groundbreaking works by Pesin, Katok, Newhouse, and others led to the idea that all smooth surface diffeomorphisms should behave much like uniformly hyperbolic ones provided one focused on the invariant measures with positive entropy. In our works, we have proved a conjecture by Newhouse (finite number of ergodic measures maximizing entropy) and generalized much of the uniform theory including a spectral gap property and Viana's conjecture (existence of a physical measure if there are positive Lyapunov exponents on a set of positive volume) for all smooth diffeomorphisms on surfaces.

Frontier of Science Award Paper: Jérôme Buzzi, Sylvain Crovisier, and Omri Sarig. Measures of maximal entropy for surface diffeomorphisms. *Ann. of Math. (2)*, 195(2):421–508, 2022

Homotopy vs isotopy in smooth 4-manifold topology

David Gabai (Princeton University)

Date: 7.18 Time: 15:15-16:00 Venue: Lecture Room 9 (A6 1F)

We survey recent results in this long-standing subject. For example, the cited paper showed that under quite general conditions two homotopic smoothly embedded 2-spheres in a 4-manifold with a common dual sphere are in fact isotopic.

Frontiers of Science Award Paper: David Gabai. The 4-dimensional light bulb theorem. *J. Amer. Math. Soc.*, 33(3):609–652, 2020

Extension Theorems for differential forms and applications

Stefan Kebekus (Albert-Ludwigs-Universität Freiburg) and Christian Schnell (Stony Brook University)

Date: 07.18 Time: 15:15-16:00 Venue: Lecture Room 3 (A3-1a 2F)

We present new extension theorems for differential forms on singular complex spaces and explain their use in the study of minimal varieties. We survey several applications pertaining to the classification and characterization of special varieties, non-Abelian Hodge Theory in the singular setting, and quasi-étale uniformization. The extension results are joint with Christian Schnell.

Frontier of Science Award Paper: Stefan Kebekus and Christian Schnell. Extending holomorphic forms from the regular locus of a complex space to a resolution of singularities. *J. Amer. Math. Soc.*, 34(2):315–368, 2021

The Ax-Schanuel Conjecture on Shimura varieties

Ngaiming Mok (University of Hong Kong)

Date: 7.18 Time: 15:15-16:00 Venue: Lecture Room 1 (A3-1 3F)

In the subject of number theory, the classical Lindemann theorem, which established that $e^{\alpha_1},\cdots,e^{\alpha_n}$ are algebraically independent whenever $\alpha_1,\cdots,\alpha_n$ are algebraic numbers linearly independent over the rationals, is a striking discovery in transcendence theory towards the end of the 19th century. As its extensive generalization, the Schanuel conjecture, according to which the field $\mathbb{Q}(\alpha_1,\cdots,\alpha_n;e^{\alpha_1},\cdots,e^{\alpha_n})$ must be of transcendence degree $\geq n$ whenever $\alpha_1,\cdots,\alpha_n$ are $\mathbb{Q}$-linearly independent complex numbers, has become a core problem of transcendental number theory. The Ax-Schanuel conjecture, which was resolved in the affirmative by Ax in 1971, was the analogue of the Schanuel conjecture on function fields dealing with the exponential function. The Ax-Schanuel conjecture on Shimura varieties is the analogue in which the exponential map $\exp:\mathbb{C}^n\to(\mathbb{C}^*)^n$ defined by $\exp(z_1,\cdots,z_n):=(e^{z_1},\cdots,e^{z_n})$ is replaced by the canonical projection map $\pi_\Gamma:\Omega\to\Omega/\Gamma=:X_\Gamma$ from a bounded symmetric domain Ω to a quotient Shimura variety X_Γ corresponding to an arithmetic lattice $\Gamma\subset\mathrm{Aut}(\Omega)$. The theory of o-minimal structures in mathematical logic especially the counting theorem of Pila-Wilkie (2006), coupled with complex differential geometry and monodromy results on Shimura varieties of Deligne, have led to results on functional transcendence theory notably the Ax-Lindemann theorem of Klingler-Ullmo-Yafaev (2016) and the Ax-Schanuel theorem for the j-function of Pila-Tsimerman (2016). Coming from a completely different angle Mok (2019) introduced methods of complex geometry notably those on moduli schemes and their compactifications into functional transcendence theory for not necessarily arithmetic lattices. The latter perspective, coupled with the aforementioned methods and results, together with the theory of tame complex geometry of Peterzil-Strachenko, has led to the proof of the Ax-Schanuel theorem for Shimura varieties by Mok-Pila-Tsimerman (2019). We will also discuss some far-reaching applications of the theorem and its generalizations to number theory notably the uniform Mordell-Lang theorem of Dimitrov-Gao-Habegger (2021) on rational points.

Frontier of Science Award Paper: Ngaiming Mok, Jonathan Pila, and Jacob Tsimerman. Ax-Schanuel for Shimura varieties. *Ann. of Math. (2)*, 189(3):945–978, 2019

Tuesday, July 18, Afternoon Session IV

Dynamics of complex Hénon maps

Dinh Tien Cuong (National University of Singapore)
Date: 7.18 Time: 16:00-17:00 Venue: Lecture Room 7 (A3-4 1F)

Hénon maps were introduced by Michel Hénon as a simplified model of the Poincaré section of the Lorenz model. They are among the most studied discrete-time dynamical systems that exhibit chaotic behavior. Complex Hénon maps in any dimension have been extensively studied over the last three decades, in parallel with the development of pluripotential theory. We will present the dynamical properties of these maps such as the behaviour of point orbits, variety orbits, equidistribution of periodic points and fine ergodic properties of the systems. This talk is based on the work of Bedford, Fornaess, Lyubich, Sibony, Smillie, and on recent work of the speaker in collaboration with Bianchi and Sibony.

The Langlands program and Shimura varieties

Yihang Zhu (University Maryland, College Park)
Date: 7.18 Time: 16:00-17:00 Venue: Lecture Room 1 (A3-1 3F)

Shimura varieties play a special role in the Langlands program, especially in the understanding of the relationship between motivic and automorphic L-functions. I will give an overview of the related research and report on some recent progress.

Knot concordance and 4-manifolds

Lisa Piccirillo (Massachusetts Institute of Technology)
Date: 7.18 Time: 16:15-17:00 Venue: Lecture Room 9 (A6 1F)

There is a rich interplay between the fields of knot theory and 3- and 4-manifold topology. In this talk, I will describe a weak notion of equivalence for knots called concordance, and highlight some historical and recent connections between knot concordance and the study of 4-manifolds, with a particular emphasis on applications of knot concordance to the construction and detection of small 4-manifolds which admit multiple smooth structures.

Frontiers of Science Award Paper: Lisa Piccirillo. The Conway knot is not slice. *Ann. of Math. (2)*, 191(2):581–591, 2020

Wednesday, July 19, Morning Session I

Complex metrics in QFT

Maxim Kontsevich (Institut des Hautes Études Scientifiques (IHÉS))
Date: 7.19 Time: 08:00-09:00 Venue: Lecture Room 9 (A6 1F)

I'll review a joint paper with Graeme Segal in which we proposed new axioms for the unitary Quantum Field Theory in curved space-times, allowing complex-valued metrics satisfying point-wise certain angle criterion. I'll also mention parallels with automorphic forms and some functional-analytic aspects.

Wednesday, July 19, Morning Session II

Deformations of Fano manifolds with weighted solitons

Akito Futaki (Yau Mathematical Sciences Center, Tsinghua University)

Date: 7.19 Time: 09:15-10:15 Venue: Lecture Room 8 (A3-4 3F)

We consider weighted solitons on Fano manifolds which include Kähler-Ricci solitons, Mabuchi solitons and base metrics which induce Calabi-Yau cone metrics outside the zero sections of the canonical line bundles (Sasaki-Einstein metrics on the associated $U(1)$-bundles). We show that all the members M_t of the Kuranishi family of a Fano manifold M_0 with a weighted soliton have weighted solitons if and only if the dimensions of T-equivariant automorphism groups of M_t are equal to that of M_0, and also if and only if the T-equivariant automorphism groups of M_t are all isomorphic to that of M_0, where the weight functions are defined on the moment polytope of the Hamiltonian T-action.

Moments of characteristic polynomials of random unitary matrices

Jonathan Keating (University of Oxford)

Date: 7.19 Time: 09:15-10:15 Venue: Lecture Room 7 (A3-4 1F)

I will review recent progress in understanding the moments of characteristic polynomials of random unitary matrices and their connections to solutions of the Painlevé equations. I will also discuss applications to predicting the corresponding moments of the Riemann zeta-function.

Nonlinear stability of slowly rotating Kerr black holes

Sergiu Klainerman (Princeton University)

Date: 7.19 Time: 09:15-10:15 Venue: Lecture Room 2 (A3-1a 2F)

I will talk about recent results which establish the nonlinear stability of slowly rotating Kerr black holes.

Wednesday, July 19, Morning Session III

Discrete conformality and beyond: where geometry meets computer graphics and mathematical physics

Alexander Bobenko (Technische Universität Berlin)

Date: 7.19 Time: 10:30-11:30 Venue: Lecture Room 7 (A3-4 1F)

Structure-preserving discretization in the field of geometry is the paradigm of discrete differential geometry. In some aspects, the discrete theory turns out to be even richer than its smooth counterpart. It focuses on developing constructive methods. The well-established theory of discrete conformal maps and circle patterns is related to discrete integrable models of mathematical physics and has found applications in geometry processing. We present their generalizations beyond the conformal limit: decorated discrete conformal maps and ring patterns, which share the corresponding existence and uniqueness statements. The theory and construction methods are based on convex variational principles. We also briefly explain how structure preserving discretizations recently helped to answer the long-standing question whether a compact surface in three-space is uniquely determined by its metric and curvatures (Bonnet problem).

Heterogeneous Gaussian process modeling with applications

Jun Liu (Harvard University)

Date: 7.19 Time: 10:30-11:30 Venue: Lecture Room 9 (A6 1F)

Although models based on the Gaussian process has been broadly used for flexible nonparametric modeling, they are not suitable for modeling abrupt changes of the smoothness of the target function and relationships with heteroscedastic errors. The heteroscedastic Gaussian process (HeGP) regression attempts to overcome these limitations by assuming that residual variances of the regression model vary over covariates. We here generalize the idea of HeGP so that it is applicable to not only regression problems but also classification and state-space models. We let the Gaussian process be coupled with a covariate-induce precision matrix process that takes a mixture form so as to model the heteroscedastic covariance function over covariates. To cope with excessive computational burdens from sampling, we resort to the variational inference for the posterior approximation in evaluating the posterior predictive model and in training via the EM algorithm with closed-form M-step updates for evaluating the heteroscedastic covariance function. Our model works consistently on the multivariate responses, even if they are of different types (either continuous or categorical). We demonstrate its advantages by both simulations and applications to real-data examples from climatology.

Bubbling of Kähler-Einstein metrics

Song Sun (University of California, Berkeley)

Date: 7.19 Time: 10:30-11:30 Venue: Lecture Room 8 (A3-4 3F)

TBA

Wednesday, July 19, Afternoon Session I

A class of functionals with duality

Xu-Jia Wang (Australian National University)

Date: 7.19 Time: 13:00-14:00 Venue: Lecture Room 7 (A3-4 1F)

We study a class of functionals subject to a duality restriction. The functional is of the form $J(U,V) = \int_U f(x)dx + \int_V g(y)dy$, where f, g are given non-negative functions. This model covers several geometric and physical applications, including the Minkowski problem in the sphere, and Kantorovich's dual functional in optimal transport. The Euler equations of the functionals are of Monge-Ampère type. In this talk, we discuss new methods and developments related to the functionals and their applications.

Recent progress towards the Yau-Tian-Donaldson conjecture

Sebastien Boucksom (Centre National de la Recherche Scientifique (CNRS) & Sorbonne Université)

Date: 7.19 Time: 13:00-13:45 Venue: Lecture Room 8 (A3-4 3F)

The Yau-Tian-Donaldson conjecture predicts that the existence of a canonical (i.e. Kähler-Einstein, constant scalar curvature, or more generally extremal) Kähler metric on a polarized complex manifold is governed by the algebro-geometric notion of K-stability. While the Kähler-Einstein case is by now completely understood, the general case remains open. However, tremendous progress has been accomplished, and the purpose of this talk is to review these recent developments.

Frontiers of Science Award Paper: Robert J. Berman, Sébastien Boucksom, and Mattias Jonsson. A variational approach to the Yau-Tian-Donaldson conjecture. *J. Amer. Math. Soc.*, 34(3):605–652, 2021

Smith-Treumann theory and modular representations of reductive groups

Simon Riche (Université Clermont Auvergne)

Date: 7.19 Time: 13:00-13:45 Venue: Lecture Room 1 (A3-1 3F)

We will explain how one can use a certain "localization theory" called Smith-Treumann theory to use the Geometric Satake Equivalence to prove important results in the representation theory of reductive algebraic groups over fields of positive characteristic. This is joint work with Geordie Williamson

Frontiers of Science Award Paper: Simon Riche and Geordie Williamson. Smith-Treumann theory and the linkage principle. *Publ. Math. Inst. Hautes Études Sci.*, 136:225–292, 2022

Confluence relations for iterated integrals

Nobuo Sato (National Taiwan University)

Date: 7.19 Time: 13:00-13:45 Venue: Lecture Room 3 (A3-1a 2F)

Multiple Zeta Values are iterated integrals on a three-point $(0,1,\infty)$ punctured projective line. In our awarded article, we considered iterated integrals on a four-point $(0,1,\infty,z)$ punctured projective line. The main difference between the four-point version and the MZVs is that the former has a free complex variable "z", for which the iterated integrals satisfy a system of differential equations. The confluence relation is the relations constructed via re-integrating the derivatives of iterated integrals using the fundamental theorem of calculus. This simple construction turned out to be a powerful method of studying the relations among MZVs, and we proved that the well-known regularized double shuffle relations and the duality relations are both consequences of the confluence relations. These are the main contents of the awarded article. In the talk, we would also like to discuss some subsequent works after the awarded article. Firstly, the confluence relations can also be reformulated by the language of generating functions and Furusho proved that they are equivalent to the pentagon equation of the KZ-associators. Also, due to the simplicity of the idea, we further generalized the idea of confluence relations to more general iterated integrals, and in particular, gave a complete description of the relations among motivic alternating multiple zeta values.

Frontiers of Science Award Paper: Minoru Hirose and Nobuo Sato. Iterated integrals on $\mathbb{P}^1 \setminus \{0,1,\infty,z\}$ and a class of relations among multiple zeta values. *Adv. Math.*, 348:163–182, 2019

On the low-regularity inextendibility of singular spacetimes: Schwarzschild and beyond

Jan Sbierski (University of Edinburgh)

Date: 7.19 Time: 13:00-13:45 Venue: Lecture Room 2 (A3-1a 2F)

A weak solution to the Einstein equations can be defined if the metric is continuous and the derivatives of the metric are locally square integrable. In order to show that a particular solution cannot be extended as a weak solution it thus suffices to show that it is inextendible as a Lorentzian manifold in this regularity class. In this talk I will review the proof of the C^0-inextendibility of the maximal analytic Schwarzschild spacetime and conclude with more recent developments concerning weak null singularities.

Frontiers of Science Award Paper: Jan Sbierski. The C^0-inextendibility of the Schwarzschild spacetime and the spacelike diameter in Lorentzian geometry. *J. Differential Geom.*, 108(2):319–378, 2018

Complete solution to the most general nonlinear filtering problems with the capability of overcoming the curse of dimensionality

Stephen Yau (Yanqi Lake Beijing Institute of Mathematical Sciences and Applications (BIMSA))

Date: 7.19 Time: 14:00-15:00 Venue: Lecture Room 9 (A6 1F)

The famous filtering problem of estimating the state of a stochastic dynamical system from noisy observations is of central importance in engineering, and high-dimensional nonlinear filtering is still a challenging problem. This problem is reduced to solving the Duncan-Mortensen-Zakai (DMZ) equation which is satisfied by the unnormalized conditional density of the state given the observation history. For general nonlinear filtering problems, we leverage on the representation ability of recurrent neural network and provide a computationally efficient and optimal framework for nonlinear filter design based on Yau-Yau algorithm and recurrent neural network. Theoretically, it can be proved that the size of the neural network required in this algorithm only increases in polynomial (rather than exponentially) with respect to the dimension, which implies that the Yau-Yau algorithm based on recurrent neural network has the capability to overcome the curse of dimensionality. This solves a century old nonlinear filtering problem.

Boundary regularity in optimal transportation

Shibing Chen (University of Science and Technology of China)

Date: 7.19 Time: 14:00-14:45 Venue: Lecture Room 7 (A3-4 1F)

In this talk, we will discuss our recent results on the global regularity of optimal transport maps and the regularity of free boundaries that arise in the optimal partial transport problem. The free boundary marks the interface between the transported and untransported regions, and its regularity is linked to the regularity of optimal transport map nearby. This is based on joint works with Jiakun Liu and Xu-Jia Wang.

Frontiers of Science Award Paper: Shibing Chen, Jiakun Liu, and Xu-Jia Wang. Global regularity for the Monge-Ampère equation with natural boundary condition. *Ann. of Math. (2)*, 194(3):745–793, 2021

BPS cohomology and representation theory

Ben Davison (University of Edinburgh)

Date: 7.19 Time: 14:00-14:45 Venue: Lecture Room 1 (A3-1 3F)

BPS cohomology is a cohomology theory that "categorifies" refined BPS invariants associated to 3-Calabi-Yau categories, in the sense that this cohomology recovers these invariants after passing to the (virtual) Poincaré polynomial of the BPS cohomology. As well as categorifying refined BPS state counts, this cohomology turns out to have a rich algebraic structure, with links to various constructions and central objects in quantum algebra and geometric representation theory. I will survey the construction of BPS cohomology, as well as applications in the above areas and beyond.

Frontiers of Science Award Paper: Ben Davison and Sven Meinhardt. Cohomological Donaldson-Thomas theory of a quiver with potential and quantum enveloping algebras. *Invent. Math.*, 221(3):777–871, 2020

The global non-linear stability of the Kerr-de Sitter family of black holes

Peter Hintz (ETH Zürich)

Date: 7.19 Time: 14:00-14:45 Venue: Lecture Room 2 (A3-1a 2F)

I will describe some of the ideas behind the proof of the global stability of the Kerr-de Sitter family of black holes as solutions of the initial value problem for the Einstein vacuum equations with positive cosmological constant. I will explain the general framework which enables us to deal systematically with the diffeomorphism invariance of Einstein's equations, and thus how our solution scheme finds a suitable gauge, within a carefully chosen finite-dimensional family of gauges, in which we can find the global solution. I will also address the issue of finding the mass and the angular momentum of the final black hole. This talk is based on joint work with András Vasy.

Frontiers of Science Award Paper: Peter Hintz and András Vasy. The global non-linear stability of the Kerr–de Sitter family of black holes. *Acta Math.*, 220(1):1–206, 2018

E-functions and geometry

Peter Jossen (King's College London)

Date: 7.19 Time: 14:00-14:45 Venue: Lecture Room 3 (A3-1a 2F)

Siegel introduced the notion of E-function in a landmark 1929 paper with the goal of generalising the Hermite-Lindemann-Weierstrass theorem on the transcendence of the values of the exponential function at algebraic numbers. E-functions are power series with algebraic coefficients that are solutions of a linear differential equation and satisfy some growth conditions of arithmetic nature. Besides the exponential function, examples include Bessel functions and a rich family of hypergeometric series. Siegel asked whether all E-functions are polynomial expressions in these hypergeometric series. I explain why the answer to Siegel's question is negative, and then try to amend it by describing how E-functions arise from geometry in the form of "exponential period functions" and why it might seem reasonable, in the light of other conjectures, to expect that all E-functions are of this kind.

Frontiers of Science Award Paper: Javier Fresán and Peter Jossen. A non-hypergeometric E-function. *Ann. of Math. (2)*, 194(3):903–942, 2021

Minimal surfaces in negatively curved manifolds

André Neves (University of Chicago)

Date: 7.19 Time: 14:00-15:00 Venue: Lecture Room 8 (A3-4 3F)

We will address several recent progresses in the study of asymptotic growth properties of minimal surfaces in negatively curved manifolds.

Frontiers of Science Award Paper: Danny Calegari, Fernando C. Marques, and André Neves. Counting minimal surfaces in negatively curved 3-manifolds. *Duke Math. J.*, 171(8):1615–1648, 2022

Wednesday, July 19, Afternoon Session III

Advances on the generalized Gorenstein Symmetry Conjecture

Ioannis Emmanouil (National Kapodistrian University of Athens)

Date: 7.19 Time: 15:00-16:00 Venue: Lecture Room 1 (A3-1 3F)

The Gorenstein Symmetry conjecture for an Artin algebras R can be formulated in the form of an equality between certain homological invariants of R, which may be generalized to arbitrary rings. We will present a variety of examples of rings, over which this equality has been actually established.

TBA

Yanyan Li (Rutgers University)

Date: 7.19 Time: 15:00-16:00 Venue: Lecture Room 7 (A3-4 1F)

TBA

On deep learning as a remedy for the curse of dimensionality in nonparametric regression

Benedikt Bauer (Technische Universität Darmstadt)

Date: 7.19 Time: 15:15-16:00 Venue: Lecture Room 9 (A6 1F)

Assuming that a smoothness condition and a suitable restriction on the structure of the regression function hold, least squares estimates based on multilayer feedforward neural networks are able to circumvent the curse of dimensionality in nonparametric regression. The proof is based on approximation results concerning multilayer feedforward neural networks with bounded weights and a bounded number of hidden neurons. Finally, a brief outlook on continuing results is given.

Frontiers of Science Award Paper: Benedikt Bauer and Michael Kohler. On deep learning as a remedy for the curse of dimensionality in nonparametric regression. *Ann. Statist.*, 47(4):2261–2285, 2019

The Möbius disjointness conjecture of Sarnak for ergodic weights

Nikos Frantzikinakis (University of Crete)

Date: 7.19 Time: 15:15-16:00 Venue: Lecture Room 3 (A3-1a 2F)

The Möbius function is a multiplicative function which encodes important information related to distributional properties of the prime numbers. It is widely believed that its non-zero values fluctuate between plus and minus one in such a random way that causes non-correlation with any "reasonable" sequence of complex numbers. One conjecture in this direction, formulated by Sarnak, states that the Möbius function does not correlate with any bounded deterministic sequence, meaning, any sequence that is produced by a continuous function evaluated along the orbit of a point in a zero entropy topological dynamical system. I will give an overview of the proof of a joint result of mine with Bernard Host from 2018, in which we proved the logarithmically averaged variant of this conjecture for a wide class of dynamical systems, which includes all uniquely ergodic ones. Our approach is to study structural properties of measure preserving systems naturally associated with the Möbius function. I will explain how these structural results are obtained using a combination of tools from ergodic theory and analytic number theory, and how we use them for our purposes. Time permitting, I will give a brief overview of other recent exciting developments.

Frontiers of Science Award Paper: Nikos Frantzikinakis and Bernard Host. The logarithmic Sarnak conjecture for ergodic weights. *Ann. of Math. (2)*, 187(3):869–931, 2018

On Kerr Stability Conjecture

Siyuan Ma (Academy of Mathematics and Systems Science, Chinese Academy of Science)

Date: 7.19 Time: 15:15-16:00 Venue: Lecture Room 2 (A3-1a 2F)

Black holes are one of the fundamental predictions in the theory of General Relativity, and the ones of most interest are the Kerr spacetimes, the metrics of which describe a family of rotating, stationary, axisymmetric, asymptotically flat solutions to the vacuum Einstein equations. One of the central problems in Mathematical General Relativity is the Kerr Stability Conjecture, which aims to show that the family of Kerr spacetimes is nonlinearly stable against small perturbations. I will discuss my own work on this conjecture, along with the recent advances made toward it.

Frontiers of Science Award Paper: Siyuan Ma. Uniform energy bound and Morawetz estimate for extreme components of spin fields in the exterior of a slowly rotating Kerr black hole II: Linearized gravity. *Comm. Math. Phys.*, 377(3):2489–2551, 2020

On the Multiplicity One Conjecture in min-max theory

Xin Zhou (Cornell University)

Date: 7.19 Time: 15:15-16:00 Venue: Lecture Room 8 (A3-4 3F)

We will present the proof of the Multiplicity One Conjecture in the min-max theory of minimal hypersurfaces.

Frontiers of Science Award Paper: Xin Zhou. On the multiplicity one conjecture in min-max theory. *Ann. of Math. (2)*, 192(3):767–820, 2020

Wednesday, July 19, Afternoon Session IV

Irrational numbers and where to find them

Simon Kristensen (Aarhus University)

Date: 7.19 Time: 16:00-17:00 Venue: Lecture Room 3 (A3-1a 2F)

While all but countably many real numbers are irrational (and even transcendental), it is preciously difficult to decide whether this is the case for concrete real numbers, unless some special reason is apparent. For instance, we all know that $e = \sum_{n=0}^{\infty} \frac{1}{n!}$ is transcendental, but modify the series slightly and consider the number $\sum_{n=0}^{\infty} \frac{1}{n!+1}$. It is not known whether this number is irrational, let alone transcendental. In my talk, I will give sufficient conditions for classes of numbers given in terms of series expansions, continued fractions, infinite products and combinations thereof to be irrational and is some cases transcendental. I will also discuss the question of algebraic independence between individual numbers with such representations. The work is joint work with S. B. Andersen, J. Hančl and M. L. Laursen in various combinations.

Deep approximation via deep learning

Zuowei Shen (National University of Singapore)

Date: 7.19 Time: 16:00-17:00 Venue: Lecture Room 9 (A6 1F)

The primary objective of many applications is to approximate or estimate a function using samples obtained from a probability distribution on the input space. Deep approximation involves approximating a function by composing numerous layers of simple functions, which can be seen as a sequence of nested feature extractors. The fundamental concept of deep learning networks is to convert these layers of compositions into layers of adjustable parameters that can be fine-tuned through a learning process, ultimately achieving a high-quality approximation based on the input data. In this presentation, we will delve into the mathematical theory behind this innovative approach and explore the approximation rate of deep networks. Additionally, we will highlight the distinctions between this new approach and traditional approximation theory, and demonstrate how this novel theory can be leveraged to comprehend and design deep learning network.

TBA

Richard Bamler (University of California, Berkeley)

Date: 7.19 Time: 16:15-17:00 Venue: Lecture Room 8 (A3-4 3F)

TBA

Frontiers of Science Award Paper: Richard H. Bamler and Bruce Kleiner. Uniqueness and stability of Ricci flow through singularities. *Acta Math.*, 228(1):1–215, 2022

Stable solutions to semilinear elliptic equations are smooth up to dimension 9

Xavier Cabré (Institució Catalana de Recerca i Estudis Avançats (ICREA) & Universitat Politècnica de Catalunya)

Date: 7.19 Time: 16:15-17:00 Venue: Lecture Room 7 (A3-4 1F)

The regularity of stable solutions to semilinear elliptic PDEs has been studied since the 1970's. Our work solves an open problem posed by Brezis in the mid-nineties by proving the regularity of stable solutions up to the optimal dimension 9. I will also describe a more recent paper of mine which provides full quantitative proofs of the corresponding interior and boundary regularity results.

Frontiers of Science Award Paper: Xavier Cabré, Alessio Figalli, Xavier Ros-Oton, and Joaquim Serra. Stable solutions to semilinear elliptic equations are smooth up to dimension 9. *Acta Math.*, 224(2):187–252, 2020

Thursday, July 20, Morning Session I

A_∞ category and Floer homology

Kenji Fukaya (Simons Center for Geometry and Physics)

Date: 7.20 Time: 08:00-09:00 Venue: Lecture Room 9 (A6 1F)

Floer homology is a half infinite dimensional homology theory invented by A. Floer 40 years ago. The further study of the structure in Floer theory shows a kind of higher category theory is useful. I will survey this topic including its application to Symlectic Geometry and Gauge theory.

Multiplicative Jensen's formula, dual Lyapunov exponents, and global theory of one-dimensional analytic quasiperiodic operators

Svetlana Jitomirskaya (University of California, Irvine)

Date: 7.20 Time: 08:00-09:00 Venue: Lecture Room 3 (A3-1a 2F)

We will briefly review the main concepts and fascinating physics background of one-dimensional analytic quasiperiodic operators and related cocycles. We then present the highlights of our joint papers with Lingrui Ge, Jiangong You, Qi Zhou, and Xin Zhao on a non-commutative generalization of the classical Jensen's formula, the explanation of the mysteries of Avila's global theory and various global spectral corollaries.

Helgason-Fourier analysis on hyperbolic spaces and sharp geometric and functional inequalities

Guozhen Lu (University of Connecticut)

Date: 7.20 Time: 08:00-09:00 Venue: Lecture Room 7 (A3-4 1F)

Sharp geometric inequalities play important roles in analysis, geometry, mathematical physics, PDEs and many other branches of modern mathematics. In this talk, we will report progress on using the techniques of Helgason-Fourier analysis on hyperbolic spaces to establish sharp gemetric and functional inequalities we have developed in recent years. These include higher order Poincare and Sobolev inequalities and Hardy-Sobolev-Maz'ya inequalities for GJMS operators on hyperbolic spaces and their best constants, Hardy- Moser-Trudinger and Hardy-Adams inequalities and their best constants, etc. The Helgason-Fourier analysis techniques play a crucial role in our approaches different from tools in the literature.

Thursday, July 20, Morning Session II

On quantum groups and quantum cohomology

Andrei Okounkov (Columbia University)

Date: 7.20 Time: 09:15-10:15 Venue: Lecture Room 9 (A6 1F)

I will revisit several key threads that run through our book "Quantum groups and quantum cohomology" with Davesh Maulik

---

Thursday, July 20, Morning Session III

Mathematics and Machine Learning

Sergei Gukov (California Institute of Technology & Dublin Institute for Advanced Studies)

Date: 7.20 Time: 10:30-11:30 Venue: Lecture Room 9 (A6 1F)

In this talk, intended for a broad audience, I will use concrete examples from combinatorial group theory and low-dimensional topology to illustrate how rapid growth of AI algorithms can change the way we do mathematical research and help us with some of the most difficult mathematical challenges. No prior familiarity with machine learning is required; rather, one of the goals of this talk is to provide a gentle introduction to some of the modern tools in this subject, in part explaining its increasing role in everyday life and in pure mathematics as well.

Some recent extensions of the Weinstein conjecture

Michael Hutchings (University of California, Berkeley)

Date: 7.20 Time: 10:30-11:30 Venue: Lecture Room 10 (A7 1F)

The Weinstein conjecture from the 1970s asserts that every Reeb vector field on a compact odd-dimensional manifold has a periodic orbit. This was proved in the three-dimensional case by Taubes in 2006. We describe some recent extensions in the three-dimensional case proved by various authors. These include existence of two or infinitely many periodic orbits in most cases, generic density of periodic orbits, and quantitative closing lemmas. We give an introduction to the tools (from Seiberg-Witten theory and holomorphic curve theory) used to prove such results.

Emergence of regularity in large graphs

Benjamin Sudakov (ETH Zürich)

Date: 7.20 Time: 10:30-11:30 Venue: Lecture Room 8 (A3-4 3F)

"Every large system, chaotic as it may be, contains a well-organized subsystem". This phenomenon is truly ubiquitous and manifests itself in different mathematical areas. One of the central problems in extremal combinatorics, which was extensively studied in the last hundred years, is to estimate how large a graph/hypergraph needs to be to guarantee the emergence of such well-organized substructures. In the first part of this talk we will give an introduction to this topic, mentioning some classical results as well as a few applications to other areas of mathematics. Then we discuss the recent solution (with Oliver Janzer) of the following fundamental problem, posed by Erdos and Sauer about 50 years ago: "How many edges on n vertices force the existence of an r-regular subgraph ($r > 2$)?" Our proof uses algebraic and probabilistic tools, building on earlier works by Alon, Friedland, Kalai, Pyber, Rödl and Szemerédi.

Thursday, July 20, Afternoon Session I

TBA

Hugo Falconet (Courant Institute, New York University)

Date: 7.20 Time: 13:00-13:45 Venue: Lecture Room 3 (A3-1a 2F)

TBA

Frontiers of Science Award Paper: Jian Ding, Julien Dubédat, Alexander Dunlap, and Hugo Falconet. Tightness of Liouville first passage percolation for $\gamma \in (0,2)$. *Publ. Math. Inst. Hautes Études Sci.*, 132:353–403, 2020

One can hear the shape of nearly circular ellipses

Hamid Hezari (University of California, Irvine)

Date: 7.20 Time: 13:00-13:45 Venue: Lecture Room 7 (A3-4 1F)

This talk is about Kac's inverse problem from 1966: "Can one hear the shape of a drum?" The question asks whether the frequencies of vibration of a bounded domain determine the shape of the domain. First, we present a quick survey on the known results. Then we discuss the key connection between eigenvalues of the Laplacian and the dynamics of the billiard, which is governed by the so-called "Poisson Summation Formula". Finally, we discuss our main theorem that "one can hear the shape of nearly circular ellipses". This is joint work with Steve Zelditch.

Frontiers of Science Award Paper: Hamid Hezari and Steve Zelditch. One can hear the shape of ellipses of small eccentricity. *Ann. of Math. (2)*, 196(3):1083–1134, 2022

Interlacing methods in Extremal Combinatorics

Hao Huang (National University of Singapore)

Date: 7.20 Time: 13:00-13:45 Venue: Lecture Room 2 (A3-1a 2F)

Extremal Combinatorics studies how large or how small a collection of finite objects can be, if it has to satisfy certain restrictions. In this talk, we will discuss how the eigenvalue interlacing method can be used to prove various interesting results in Extremal Combinatorics, including the Erdos-Ko-Rado Theorem and its degree version, an isodiametric inequality for hypercubes, and the resolution of the Sensitivity Conjecture.

Frontiers of Science Award Paper: Hao Huang. Induced subgraphs of hypercubes and a proof of the sensitivity conjecture. *Ann. of Math. (2)*, 190(3):949–955, 2019

Rigidity of lattices in Lie groups

Sebastian Hurtado (Yale University)

Date: 7.20 Time: 13:00-13:45 Venue: Lecture Room 1 (A3-1 3F)

Lattices in Lie groups are objects of importance in Geometry and Topology (providing examples of tilings and manifolds with many symmetries), Number Theory (via arithmetic groups), Dynamics, etc. We will attempt to describe these objects and explain a beautiful phenomenon about the lack of flexibility of these objects in higher dimensions, including famous theorems of Mostow, Margulis among others.

Frontiers of Science Award Paper: Aaron Brown, David Fisher, and Sebastian Hurtado. Zimmer's conjecture: subexponential growth, measure rigidity, and strong property (T). *Ann. of Math. (2)*, 196(3):891–940, 2022

Sharp arithmetic Spectral transition and universal hierarchical structure for supercritical almost mathieu operators

Wencai Liu (Texas A&M University)

Date: 7.20 Time: 13:00-13:45 Venue: Lecture Room 8 (A3-4 3F)

The Harper's model describes Bloch electrons on a 2D lattice under a constant magnetic field. The mathematical study of Harper's model led to the development of spectral theory of the almost Mathieu operator. In this talk, we will discuss recent progress in the study of the sharp arithmetic spectral transition for almost Mathieu operators in the positive Lyapunov exponent regime, distinguishing between singular continuous and pure point spectra. We have also uncovered the universal hierarchical structure for the eigenfunctions in the pure point spectrum regime. The talk is based on several papers, mainly joint with Svetlana Jitomirskaya.

Frontiers of Science Award Paper: Svetlana Jitomirskaya and Wencai Liu. Universal hierarchical structure of quasiperiodic eigenfunctions. *Ann. of Math. (2)*, 187(3):721–776, 2018

Thursday, July 20, Afternoon Session II

Classification of simple $\mathscr{Z}$-stable C^*-algebras

Huaxin Lin (East China Normal University & University of Oregon)

Date: 7.20 Time: 14:00-14:45 Venue: Lecture Room 8 (A3-4 3F)

C^*-algebras are norm closed and $*$-closed subalgebras of bounded linear operators on a Hilbert space. C^*-algebras may come from topological dynamical systems, operator theory, non-commutative geometry as well as number theory. Classification of C^*-algebras is a program to use Elliott invariant, or K-theory related invariant to classify C^*-algebras up to $*$-isomorphisms. We will try to give some description of current status of the program.

Frontiers of Science Award Paper: Guihua Gong, Huaxin Lin, and Zhuang Niu. A classification of finite simple amenable $\mathscr{Z}$-stable C^*-algebras, I: C^*-algebras with generalized tracial rank one. *C. R. Math. Acad. Sci. Soc. R. Can.*, 42(3):63–450, 2020

Hyperbolic manifolds

Bruno Martelli (Università di Pisa)

Date: 7.20 Time: 14:00-14:45 Venue: Lecture Room 1 (A3-1 3F)

A hyperbolic manifold is a Riemannian manifold of constant curvature -1. Compact (more generally, complete finite-volume) hyperbolic manifolds exist in every dimension n, but our understanding of their topology and geometry is still very limited when n¿3. One of the most striking aspects of 3-manifolds is that many of them are total spaces of bundles over the circle, so their topology is determined by the monodromy, which is in turn beautifully described by Thurston's theory of diffeomorphisms of surfaces. We will show here that a similar picture arises for some hyperbolic 5-manifolds. This is joint work with Italiano and Migliorini.

Frontiers of Science Award Paper: Giovanni Italiano, Bruno Martelli, and Matteo Migliorini. Hyperbolic 5-manifolds that fiber over S^1. *Invent. Math.*, 231(1):1–38, 2023

How to build a random surface

Scott Sheffield (Massachusetts Institute of Technology)

Date: 7.20 Time: 14:00-14:45 Venue: Lecture Room 3 (A3-1a 2F)

The theory of "random surfaces" has emerged in recent decades as a significant field of mathematics, lying somehow at the interface between geometry, probability, combinatorics, analysis and mathematical physics. Just as Brownian motion is a special kind of random path, there is a similarly special kind of random surface, which is characterized by special symmetries, and which arises in many different contexts. Random surfaces are often motivated by physics: statistical physics, string theory, quantum field theory, and so forth. They have also been independently studied by mathematicians working in random matrix theory and enumerative graph theory. But even without that motivation, one may be drawn to wonder what a "typical" two-dimensional manifold look likes, or how one can make sense of that question. I will give a broad overview of what this theory is about, including many computer simulations and illustrations. In particular, I will highlight some recent work with Jason Miller in which we proved the equivalence of Liouville quantum gravity and the Brownian sphere — two random surface models that were historically defined in completely different ways.

Frontiers of Science Award Paper: Jason Miller and Scott Sheffield. Liouville quantum gravity and the Brownian map I: the QLE$(8/3,0)$ metric. *Invent. Math.*, 219(1):75–152, 2020

Curvature and harmonic analysis on compact manifolds

Christopher Sogge (Johns Hopkins University)

Date: 7.20 Time: 14:00-14:45 Venue: Lecture Room 7 (A3-4 1F)

We shall explore the role that curvature plays in harmonic analysis on compact manifolds. We shall focus on spectral projection estimates and Strichartz estimates for solutions of the Schrödinger equation. We focus on gains that arise when the sectional curvatures of the manifold are negative.

Frontiers of Science Award Paper: Matthew D. Blair and Christopher D. Sogge. Logarithmic improvements in L^p bounds for eigenfunctions at the critical exponent in the presence of nonpositive curvature. *Invent. Math.*, 217(2):703–748, 2019

Improved sunflower bounds and their applications

Jiapeng Zhang (University of Southern California)

Date: 7.20 Time: 14:00-14:45 Venue: Lecture Room 2 (A3-1a 2F)

The Erdős-Rado sunflower is a very useful structure in both computer science and mathematics. It is a simple notation with deep and amazing connections to many problems. The sunflower conjecture is one of the tantalizing open problems in combinatorics. In this talk, I will review recent progress on studies of sunflower structures, and their applications.

Frontiers of Science Award Paper: Ryan Alweiss, Shachar Lovett, Kewen Wu, and Jiapeng Zhang. Improved bounds for the sunflower lemma. *Ann. of Math. (2)*, 194(3):795–815, 2021

Thursday, July 20, Afternoon Session III

Anomalous random walks and scaling limits: from fractals to random media

Takashi Kumagai (Waseda University)

Date: 7.20 Time: 15:00-16:00 Venue: Lecture Room 3 (A3-1a 2F)

We present results on the behavior of random walks and scaling limits on disordered media. Examples treated include fractals and models of random graphs, such as percolation clusters, uniform spanning trees and random planar maps. We will overview the areas chronologically, and describe how the techniques have developed from those introduced for self-similar fractals to more robust ones required for random graphs.

Constructing SYZ mirror via Maurer-Cartan equation

Nai Chung Leung (Chinese University of Hong Kong)

Date: 07.20 Time: 15:00-16:00 Venue: Lecture Room 10 (A7 1F)

In 2002, Fukaya proposed a remarkable explanation of mirror symmetry detailing the SYZ conjecture by introducing two correspondences: one between the theory of pseudo-holomorphic curves on a Calabi-Yau manifold $\check{X}$ and the multi-valued Morse theory on the base $\check{V}$ of an SYZ fibration $\check{p} : \check{X} \to \check{B}$, and the other between deformation theory of the mirror X and the same multi-valued Morse theory on $\check{B}$. We prove a reformulation of the main conjecture in Fukaya's second correspondence, where multi-valued Morse theory on the base $\check{B}$ is replaced by tropical geometry on the Legendre dual B. This is a joint work with Kwokwai Chan and Ziming Ma.

TBA

Yuhei Suzuki (Hokkaido University)

Date: 7.20 Time: 15:00-15:45 Venue: Lecture Room 8 (A3-4 3F)

TBA

Frontiers of Science Award Paper: Yuhei Suzuki. Complete descriptions of intermediate operator algebras by intermediate extensions of dynamical systems. *Comm. Math. Phys.*, 375(2):1273–1297, 2020

High-dimensional expansion, matroids, and log-concave polynomials

Nima Anari (Stanford University)

Date: 7.20 Time: 15:15-16:00 Venue: Lecture Room 2 (A3-1a 2F)

Matroids are basic combinatorial objects, abstracting the notion of linear independence. Despite the simplicity of their definition, they exhibit mysterious properties, some of which have taken mathematicians decades to prove. I will talk about a new facet of matroid theory that was revealed by thinking of matroids as high-dimensional expanders. This viewpoint revealed surprising connections with geometry of polynomials, the theory of Markov chains, and log-concavity and unimodality conjectures in combinatorics, and helped resolve two long-standing conjectures of Mihail and Vazirani, and Mason. I will also mention how subsequent works have built on this idea to resolve other major conjectures about mixing time of Markov chains.

Frontiers of Science Award Paper: Nima Anari, Shayan Oveis Gharan, and Cynthia Vinzant. Log-concave polynomials, I: entropy and a deterministic approximation algorithm for counting bases of matroids. *Duke Math. J.*, 170(16):3459–3504, 2021

Sums of squares, positivity and property (T) for $\mathrm{Aut}(F_n)$

Marek Kaluba (Karlsruher Institut für Technologie)

Date: 7.20 Time: 15:15-16:00 Venue: Lecture Room 1 (A3-1 3F)

Sums of squares appear naturally as solutions to polynomial positivity problems via famous Kirvine-Stengle Positivstellensatz. The reach of such methods is however much wider and extends to the non-commutative setting of *-algebras. In particular the positivity of a particular element in group C^*-algebra is equivalent to Kazhdan property (T) which is originally defined in the language of unitary group actions on Hilbert spaces. N. Ozawa showed that the positivity truly holds in the group algebra and that property (T) always follows from the existence of a finite sum of squares decomposition. This result was the base of the new computational method for proving property (T). We show that such methods can not only be used for single groups but a well-crafted single computation, through a sequence of embeddings, will establish the property for a whole family of groups. With D. Kielak and P.W. Nowak we applied this technique to $\mathrm{Aut}(F_n)$, the automorphisms of the free group, proving property (T) for $n \geqslant 5$ and hence solving a major problem in geometric group theory. As a byproduct we obtain lower estimates on the Kazhdan constant which are notoriously hard to compute.

Frontiers of Science Award Paper: Marek Kaluba, Dawid Kielak, and Piotr W. Nowak. On property (T) for $\mathrm{Aut}(F_n)$ and $\mathrm{SL}_n(\mathbb{Z})$. *Ann. of Math. (2)*, 193(2):539–562, 2021

Incidence estimates and Fourier analysis

Ruixiang Zhang (University of California, Berkeley)

Date: 7.20 Time: 15:15-16:00 Venue: Lecture Room 7 (A3-4 1F)

We will start by introducing an important class of problems in Fourier analysis known as Fourier restriction type problems. As a modern way to attack them, one can decompose the underlying functions and then use rectangular boxes in Euclidean spaces to approximate each summand. Understanding how those boxes overlap (called an incidence problem) thus naturally play an important role in the original Fourier analytic problems. We will talk about the solutions to two such long-standing problems (Carleson's problem in high dimensions and local smoothing in three dimensions) and highlight the places where incidence estimates show up. Based on joint work with Xiumin Du and joint work with Larry Guth and Hong Wang.

Frontier of Science Award Paper: Xiumin Du and Ruixiang Zhang. Sharp L^2 estimates of the Schrödinger maximal function in higher dimensions. *Ann. of Math. (2)*, 189(3):837–861, 2019
Larry Guth, Hong Wang, and Ruixiang Zhang. A sharp square function estimate for the cone in $\mathbb{R}^3$. *Ann. of Math. (2)*, 192(2):551–581, 2020

Thursday, July 20, Afternoon Session IV

Quantum symmetries in operator algebras and mathematical physics

Yasuyuki Kawahigashi (University of Tokyo)

Date: 7.20 Time: 16:00-17:00 Venue: Lecture Room 8 (A3-4 3F)

A notion of symmetry is fundamental in mathematics and physics. A new type of "quantum" symmetry has emerged in operator algebras, quantum groups, quantum invariants in low dimensional topology, integrable systems, vertex operator algebras, quantum field theory and condensed matter physics since 1980's. I will present recent development in these areas from an operator algebraic viewpoint. Emphasis is given to representation theoretic aspects of the Jones theory of subfactors, chiral conformal field theory and two-dimensional topological order.

Sharp estimates for oscillatory integral operators via polynomial partitioning

Marina Iliopoulou (University of Birmingham)

Date: 7.20 Time: 16:15-17:00 Venue: Lecture Room 7 (A3-4 1F)

Central in harmonic analysis is the study of extension operators: Fourier transforms of functions defined on curved surfaces. Such objects are sums of waves, evolving inside tubes in space-time. The restriction conjecture (Stein, 1960s) claims that these waves in principle interfere with each other destructively, forcing the extension operators to have small p-norms (for low p). The restriction conjecture is intimately connected with geometric measure theory, PDE, number theory and incidence geometry. In 1973, Hörmander asked whether more general oscillatory integral operators have similarly small p-norms. Hörmander's operators can be viewed again as Fourier transforms of functions defined on curved surfaces, with the difference that the surfaces vary as we change the point where we calculate the Fourier transform. In this paper and in subsequent work, we settled Hörmander's question according to the curvature signature of the involved varied surfaces, exploiting the algebraic nature that underlies the problem. In the talk we will discuss Hörmander's question, applications and aspects of the solution.

Frontiers of Science Award Paper: Larry Guth, Jonathan Hickman, and Marina Iliopoulou. Sharp estimates for oscillatory integral operators via polynomial partitioning. *Acta Math.*, 223(2):251–376, 2019

Structures and computations in the motivic stable homotopy categories

Hana Jia Kong (Institute for Advanced Study)

Date: 7.20 Time: 16:15-17:00 Venue: Lecture Room 1 (A3-1 3F)

A fundamental question in classical stable homotopy theory is to understand the stable homotopy groups of the spheres. A relatively new method is via the motivic approach. Motivic stable homotopy theory has an algebro-geometric root and closely connects to questions in number theory. Besides, it relates to classical theory. One example of motivic applications in the classical theory is the Adams spectral sequence computations by Isaksen—Wang—Xu. They base their approach on a theoretical result by Gheorghe—Wang—Xu about a t-structure on the p-complete cellular C-motivic category. I will first talk about a generalization of this result, joint with Tom Bachmann, Guozhen Wang, and Zhouli Xu. The generalization leads to computational applications in the classical and motivic Adams spectral sequences.

Frontiers of Science Award Paper: Tom Bachmann, Hana Jia Kong, Guozhen Wang, and Zhouli Xu. The Chow t-structure on the ∞-category of motivic spectra. *Ann. of Math. (2)*, 195(2):707–773, 2022

Fuglede's conjecture for convex bodies

Máté Matolcsi (Alfréd Rényi Institute of Mathematics & Budapest University of Technology and Economics)

Date: 7.20 Time: 16:15-17:00 Venue: Lecture Room 2 (A3-1a 2F)

A set W of positive measure in $\mathbb{R}^d$ is said to be spectral if the space $L^2(W)$ has an orthogonal basis of exponential functions. A conjecture of Fuglede (1974) stated that W is a spectral set if and only if it can tile the space by translations. While this conjecture was disproved for general sets, it has long been known that for a convex body W the "tiling implies spectral" part of the conjecture is true. In this talk we will sketch the proof of the other direction of Fuglede's conjecture for convex bodies, that is, any spectral convex body tiles the space by translation. Joint work by NIr Lev and Mate Matolcsi.

Frontiers of Science Award Paper: Nir Lev and Máté Matolcsi. The Fuglede conjecture for convex domains is true in all dimensions. *Acta Math.*, 228(2):385–420, 2022

TBA

Aran Raoufi (Citadel Securities)

Date: 7.20 Time: 16:15-17:00 Venue: Lecture Room 3 (A3-1a 2F)

TBA

Frontiers of Science Award Paper: Hugo Duminil-Copin, Aran Raoufi, and Vincent Tassion. Sharp phase transition for the random-cluster and Potts models via decision trees. *Ann. of Math. (2)*, 189(1):75–99, 2019

Friday, July 21, Morning Session I

On local rigidity of linear abelian actions on the torus

Bassam Fayad (University Maryland, College Park)

Date: 7.21 Time: 08:00-09:00 Venue: Lecture Room 3 (A3-1a 2F)

Two famous manifestations of local rigidity for higher rank abelian actions are 1) KAM-rigidity of simultaneously Diophantine torus translations (Moser) and 2) smooth rigidity of hyperbolic or partially hyperbolic higher rank actions (Damjanovic and Katok). To complete the picture of local rigidity for higher rank abelian affine actions on the torus, the case of parabolic actions must be addressed. With D. Damjanovic and M. Saprykina we show that KAM-rigidity of abelian parabolic actions holds when one of the elements of the action is of step 2. With S. Durham, we show that KAM-rigidity does not necessarily hold if the elements of the action are all of step higher than 2.

Definition. We say that a linear map $A \in \mathrm{SL}(d,\mathbb{Z})$ is parabolic of step n if $(A-\mathrm{Id})^n = 0$, and $(A-\mathrm{Id})^{n-1} = 0$. An affine map $a(\cdot) = A(\cdot) + \alpha$ is said to be of step n if A is of step n. We say that a $\mathbb{Z}^2$ affine action by parabolic elements is of step n if all of its elements are of step at most n.

Partial heights and the geometric Bombieri–Lang Conjecture

Junyi Xie (Beijing International Center for Mathematical Research, Peking University)

Date: 7.21 Time: 08:00-09:00 Venue: Lecture Room 9 (A6 1F)

This is a joint work with Xinyi Yuan. Let $K = k(B)$ the function field a variety B over a field k of characteristic 0. Let X be a projective variety over K. Assume that there is a finite morphism from X to an abelian variety A with trivial trace. We show that $X(K)$ is contained in the algebraic special subset. In particular, if further X is of general type, then $X(K)$ is not Zariski dense.

An index theory for manifolds with polyhedral boundary and Gromov's dihedral extremality and rigidity conjectures

Guoliang Yu (Texas A&M University)

Date: 7.21 Time: 08:00-09:00 Venue: Lecture Room 2 (A3-1a 2F)

In this talk, I will give an introduction to an index theorem for manifolds with polyhedral boundary and explain how to use this index theorem to prove Gromov's dihedral extremality conjecture on scalar curvature (joint work with Jinmin Wang and Zhizhang Xie). I will also discuss subsequent work of Jinmin and Zhizhang on Gromov's dihedral rigidity conjecture.

Friday, July 21, Morning Session II

Towards a geometric theory of cohomology functors : the case of degree 0

Laurent Lafforgue (HUAWEI TECHNOLOGIES FRANCE)

Date: 7.21 Time: 09:15-10:15 Venue: Lecture Room 9 (A6 1F)

We will explain how Olivia Caramello's proposed approach for constructing a Galois-type Theory of cohomology functors can be implemented and fully verified in the case of cohomology of degree 0. The models of this Theory - or equivalently the points of the associated Classifying Topos - are exactly cohomology functors of degree 0. As its Classifying Topos is Galois, this Theory is complete, which means that all its models share the same geometric-logic properties. In particular, their components at all different geometric objects all have the same dimensions and the same algebraic structures. These results are already non-trivial and can be considered as toy-models for cohomology in higher degrees, which is the objective of Caramello's proposed approach.

Friday, July 21, Morning Session III

The geometry of polynomial equations

Christopher Hacon (University of Utah)

Date: 7.21 Time: 10:30-11:30 Venue: Lecture Room 9 (A6 1F)

Algebraic varieties are geometric objects defined by polynomial equations. In this lecture we will discuss progress towards understanding their features in arbitrary dimension.

From Hardy to Rellich inequalities on graphs

Matthias Keller (University of Potsdam)

Date: 7.21 Time: 10:30-11:30 Venue: Lecture Room 2 (A3-1a 2F)

Hardy's celebrated original inequality from the 1920's was formulated as a discrete inequality on the natural numbers. Since then it became most relevant in its various continuum versions. For example in mathematical physics it serves as a quantitative version of Heisenberg's uncertainty principle and it is a most powerful tool in partial differential equation. We return to the discrete setting of graphs and discuss how Hardy inequalities can be obtained and explain how optimality can be shown. We illustrate this by various examples. This also leads us to a disparity to the continuum setting namely that Hardy's original inequality can be improved in the discrete setting. Finally, we explain how Hardy inequalities can be used to derive Rellich inequalities control the growth of solutions. (This includes joint work with F. Fischer, M. Lemm, M. Nietschmann, F. Pogorzelski and Y. Pinchover)

Factorization of the Weyl character at special elements

Dipendra Prasad (Indian Institute of Technology)

Date: 7.21 Time: 10:30-11:30 Venue: Lecture Room 3 (A3-1a 2F)

The character of a finite-dimensional irreducible representation of a compact connected Lie group is given by the Weyl character formula. The Weyl character formula expressed at special elements of the ambient group factorises nicely in terms of the Weyl character formulae for smaller groups. We discuss some results obtained by the speaker and others.

Friday, July 21, Afternoon Session I

Curvature of graphs and local discrepancy

Paul Horn (University of Denver)

Date: 7.21 Time: 13:00-14:00 Venue: Lecture Room 8 (A3-4 3F)

Spectral graph theory, the use of eigenvalues to study graphs, gives an important window into many properties of graphs. One of the reasons for this is that the eigenvalues can be used to certify the 'pseudo-randomness' of the edge set of a graph. In recent years, several notions of discrete curvature have been introduced that gives a 'local' way (depending on the neighborhood structure of vertices) to study some of the same properties that eigenvalues can capture. In this talk, we'll introduce some of the notions of curvature of graphs and, in particular, introduce some newly developed 'discrepency inequalities.' These (like eigenvalues) certify pseudo-randomness of an edge set but, in the case of curvature establish a 'local pseudo-randomness' of edges within the first few neighborhoods of a vertex.

Hausdorff measures and co-analytics sets

Theodore Slaman (University of California, Berkeley)

Date: 7.21 Time: 13:00-14:00 Venue: Lecture Room 1 (A3-1 3F)

In the 1950s and 1960s, it was shown that many of the regularity properties of Lebesgue measure transfer to Hausdorff measures, but only for analytic sets. We will describe how the definability-theoretic structure theory for co-analytic sets applies to show that these regularity properties can fail there. We will also indicate the results of further metamathematical investigations.

Moduli space of Fano varieties

Yuchen Liu (Northwestern University)

Date: 7.21 Time: 13:00-13:45 Venue: Lecture Room 2 (A3-1a 2F)

Fano varieties are complex algebraic varieties admitting positive Ricci curvature metrics. They form one of the three fundamental building blocks of algebraic varieties, thus their classification problem is important. However, it is known that moduli spaces of all Fano varieties have pathological behaviors. In this talk, I will explain that if we impose K-stability on Fano varieties, an algebraic condition arising from the study of Kähler-Einstein metrics, then we indeed get a compact moduli space. Based on joint works with H. Blum, D. Halpern-Leistner, C. Xu, and Z. Zhuang.

Frontiers of Science Award Paper: Yuchen Liu, Chenyang Xu, and Ziquan Zhuang. Finite generation for valuations computing stability thresholds and applications to K-stability. *Ann. of Math. (2)*, 196(2):507–566, 2022

Journey to the center of the earth

Gunther Uhlmann (University of Washington & Hong Kong University of Science and Technology)

Date: 7.21 Time: 13:00-14:00 Venue: Lecture Room 7 (A3-4 1F)

We consider the inverse problem of travel time tomography: Can one determine the sound speed or index of refraction of a medium by measuring the travel times of waves going through the medium? This problem arises in global seismology, medical imaging, oceanography and many others. This inverse problem can be recast as a geometric problem: can one determine the Riemannian metric of a compact Riemannian manifold with boundary by measuring the distance function or the scattering relation?

Frontiers of Science Award Paper: Plamen Stefanov, Gunther Uhlmann, and András Vasy. Local and global boundary rigidity and the geodesic X-ray transform in the normal gauge. *Ann. of Math. (2)*, 194(1):1–95, 2021

Counting ℓ-adic local systems over a curve

Hongjie Yu (Weizmann Institute of Science)

Date: 7.21 Time: 13:00-13:45 Venue: Lecture Room 3 (A3-1a 2F)

TBA

Frontiers of Science Award Paper: Hongjie Yu. Comptage des systèmes locaux ℓ-adiques sur une courbe. *Ann. of Math. (2)*, 197(2):423–531, 2023

Friday, July 21, Afternoon Session II

The null-categories of noncommutative resolutions

Alexey Bondal (Steklov Mathematical Institute)

Date: 7.21 Time: 14:00-15:00 Venue: Lecture Room 2 (A3-1a 2F)

Various constructions for noncommutative resolutions and their properties will be discussed. In particular, the Knoerrer periodicity for the null-categories of Auslander resolutions will be explained.

Phase transitions for Gödel incompleteness

Andreas Weiermann (Ghent University)

Date: 7.21 Time: 14:00-15:00 Venue: Lecture Room 1 (A3-1 3F)

We start with surveying phase transitions results regarding natural independent statements for fragments of arithmetic. Afterwards we will cover our recent findings regarding problems posed by Harvey M. Friedman.

Ancient solutions to the Mean Curvature Flow and applications

Or Hershkovits (Hebrew University of Jerusalem)

Date: 7.21 Time: 14:15-15:00 Venue: Lecture Room 7 (A3-4 1F)

In the last 35 years, geometric flows have proven to be a powerful tool in geometry and topology. The Mean Curvature Flow is, in many ways, the most natural flow for surfaces in Euclidean space. In this talk, which will assume no prior knowledge, I will present recent progress in classifying ancient solutions to the mean curvature flow (including joints work with Kyeongsu Choi, Robert Haslhofer and Brian White). I will also explain how this classification assists in answering fundamental questions regarding the singularity formation of the flow, and describe what are the remaining challenges in converting the mean curvature flow into the powerful tool we hope it can become.

Frontiers of Science Award Paper: Kyeongsu Choi, Robert Haslhofer, and Or Hershkovits. Ancient low-entropy flows, mean-convex neighborhoods, and uniqueness. *Acta Math.*, 228(2):217–301, 2022

Friday, July 21, Afternoon Session III

Berry-Esseen bounds for design-based causal inference with possibly diverging treatment levels and varying group sizes

Peng Ding (University of California Berkeley)

Date: 7.21 Time: 15:00-16:00 Venue: Lecture Room 8 (A3-4 3F)

Neyman (1923/1990) introduced the randomization model, which contains the notation of potential outcomes to define causal effects and a framework for large-sample inference based on the design of the experiment. However, the existing theory for this framework is far from complete especially when the number of treatment levels diverges and the group sizes vary a lot across treatment levels. We provide a unified discussion of statistical inference under the randomization model with general group sizes across treatment levels. We formulate the estimator in terms of a linear permutational statistic and use results based on Stein's method to derive various Berry–Esseen bounds on the linear and quadratic functions of the estimator. These new Berry–Esseen bounds serve as basis for design-based causal inference with possibly diverging treatment levels and diverging dimension of causal effects. We also fill an important gap by proposing novel variance estimators for experiments with possibly many treatment levels without replications. Equipped with the newly developed results, design-based causal inference in general settings becomes more convenient with stronger theoretical guarantees.

Geometry of Laplacian eigenfunctions

Nikolai Nadirashvili (Centre National de la Recherche Scientifique (CNRS))

Date: 7.21 Time: 15:15-16:00 Venue: Lecture Room 7 (A3-4 1F)

For the Laplace operator in bounded Euclidean domains with Dirichlet or Neumann boundary conditions we discuss the geometrical structure of eigenfunctions.

Frontiers of Science Award Paper: A. Logunov, E. Malinnikova, N. Nadirashvili, and F. Nazarov. The sharp upper bound for the area of the nodal sets of Dirichlet Laplace eigenfunctions. *Geom. Funct. Anal.*, 31(5):1219–1244, 2021

Birational types

Yuri Tschinkel (New York University)

Date: 7.21 Time: 15:15-16:00 Venue: Lecture Room 2 (A3-1a 2F)

I will discuss new invariants in equivariant birational geometry inspired by ideas of motivic integration.

Frontiers of Science Award Paper: Maxim Kontsevich and Yuri Tschinkel. Specialization of birational types. *Invent. Math.*, 217(2):415–432, 2019

Friday, July 21, Afternoon Session IV

Complements

Vyacheslav V Shokurov (Johns Hopkins University)

Date: 7.21 Time: 16:00-17:00 Venue: Lecture Room 2 (A3-1a 2F)

A survey of theory of complements with applications will be presented.

An integrative framework for two-sample sparse inference

Tony Cai (University of Pennsylvania)

Date: 7.21 Time: 16:15-17:00 Venue: Lecture Room 8 (A3-4 3F)

The conventional approach to two-sample multiple testing is to first reduce the data matrix to a single vector of test statistics such as p-values and then choose a cutoff along the rankings to adjust for multiplicity. However, this inference framework often leads to suboptimal multiple testing procedures due to the loss of information in the data reduction step. We introduce a new framework for two-sample multiple testing by incorporating a carefully constructed auxiliary variable in inference to improve the power. A data-driven multiple testing procedure is developed by employing a covariate-assisted ranking and screening (CARS) approach that optimally combines the information from both the primary and auxiliary variables. This integrative framework is then extended to handle a range of dependence structures such as those arise in multiple testing for high-dimensional linear regression, differential correlation analysis, and differential networks.

Frontiers of Science Award Paper: T. Tony Cai, Wenguang Sun, and Weinan Wang. Covariate-Assisted Ranking and Screening for Large-Scale Two-Sample Inference. *Journal of the Royal Statistical Society Series B: Statistical Methodology*, 81(2):187–234, 03 2019

Zeroes of harmonic functions and growth

Aleksandr Logunov (University of Geneva & Massachusetts Institute of Technology & Princeton University)

Date: 7.21 Time: 16:15-17:00 Venue: Lecture Room 7 (A3-4 1F)

Nadirashvili's conjecture states that a non-constant harmonic function in the three-dimensional Euclidean space has a zero set of infinite area. The recent proof (2018) of Nadirashvili's conjecture implied the lower bound in Yau's conjecture for zero sets of Laplace eigenfunctions. We will discuss an open folklore conjecture relating the growth of harmonic functions and the area of their zero sets and its applications.

Frontiers of Science Award Paper: Alexander Logunov. Nodal sets of Laplace eigenfunctions: proof of Nadirashvili's conjecture and of the lower bound in Yau's conjecture. *Ann. of Math. (2)*, 187(1):241–262, 2018

Monday, July 24, Morning Session I

Logical analysis of Ramsey type theorems

Chi Tat Chong (National University of Singapore)

Date: 7.24 Time: 08:00-09:00 Venue: Lecture Room 10 (A7 1F)

This lecture is concerned with the reverse mathematics of Ramsey type combinatorial theorems, focusing on their proof-theoretic complexity and strength using the tools of subsystems of second order arithmetic.

Recent developments of augmented Hessian equations

Feida Jiang (Southeast University)

Date: 7.24 Time: 08:00-09:00 Venue: Lecture Room 7 (A3-4 1F)

In recent years, there has been growing interest in augmented Hessian equations due to their connections with optimal transport, geometric optics, and conformal geometry. These equations have attracted significant research attention. In this talk, we focus on discussing the existence, uniqueness, and regularity results for the boundary value problems associated with augmented Hessian equations. Additionally, we will present some of the latest advancements and progress made in this particular field.

Quantum invariants of colored 3-manifolds

Zhengwei Liu (Tsinghua University & Yanqi Lake Beijing Institute of Mathematical Sciences and Applications (BIMSA))

Date: 7.24 Time: 08:00-09:00 Venue: Lecture Room 8 (A3-4 3F)

In this talk, we introduce the bi-colored 3-manifold decorated by a spherical fusion category and obtain quantum invariants on bi-colored 3-manifold. We show that the quantum invariants produce topological invariants for embedded surfaces, knot invariants, 3-manifold invariant including the Reshetikhin-Turaev invariants and the Turaev-Viro invariants (also for pseudo-manifolds). We also introduce the tube category topologizing Drinfeld center and categorifing the Ocneanu's tube algebra. By the duality of bi-colored 3-manifold, we obtain the equality of the Reshetikhin-Turaev invariants and the Turaev-Viro invariants directly. By the topologized framework, we obtain an elegant topological and computational interpretation of the generalized Frobenius-Schur indicators. Moreover, the equivariance of generalized Frobenius-Schur indicators immediately follows from the homemorphism invariance of the quantum invariants.

Regularity of free boundary problems on metric spaces

Xi-Ping Zhu (Sun Yat-sen University)

Date: 7.24 Time: 08:00-09:00 Venue: Lecture Room 9 (A6 1F)

In this talk, we consider free boundary problems on metric measure spaces. We show the existence and the local Lipschitz regularity of the solutions. We further prove that for each solution, the free boundary is a differential manifold away from a relatively closed subset of codimension at least 2.

Monday, July 24, Morning Session II

Coupling Learning with Classical Computational Inversion

Kui Ren (Columbia University)

Date: 7.24 Time: 09:15-10:15 Venue: Lecture Room 10 (A7 1F)

In the absence of analytical inversion formulas, reconstructions in inverse problems are traditionally achieved through costly computational methods (such as those based on the classical least-squares inversion). In recent years, various machine learning methods have been proposed as new computational tools to solve inverse problems. In this talk, we will discuss some of our recent understandings of how to couple machine learning methods and classical inversion techniques for inverse coefficient problems for PDEs. While most of the results are computational, we do attempt to provide some theoretical justifications when possible.

On varieties of general type with extremal invariants

Jungkai Chen (National Taiwan University)

Date: 7.24 Time: 09:15-10:15 Venue: Lecture Room 9 (A6 1F)

In this talk, we will describe varieties of general type with extremel invariants by providing several examples and describing their special features. We will work on threefolds and higher dimensional varieties.

Diff-ResNet: Integrating diffusion mechanism in residual neural network

Zuoqiang Shi (Tsinghua University)

Date: 7.24 Time: 09:15-10:15 Venue: Lecture Room 7 (A3-4 1F)

Diffusion is a fundamental internal mechanism emerging in many physical processes, describes the interaction among different objects. In many learning tasks with limited training samples, the diffusion connects the labeled and unlabeled data points and is a critical component for achieving high classification accuracy. Many existing deep learning approaches directly impose the fusion loss when training neural networks. In this talk, inspired by the convection-diffusion equations, we propose a novel diffusion residual network (Diff-ResNet), internally introduces diffusion into the architectures of neural networks. Under the structured data assumption, it is proved that the proposed diffusion block can increase the distance-diameter ratio that improves the separability of inter-class points and reduces the distance among local intra-class points. Moreover, this property can be easily adopted by the residual networks for constructing the separable hyperplanes. Extensive experiments of synthetic binary classification, semi-supervised graph node classification and few-shot image classification in various datasets validate the effectiveness of the proposed method.

TBA

Wen-An Yong (Tsinghua University)

Date: 7.24 Time: 09:15-10:15 Venue: Lecture Room 8 (A3-4 3F)

TBA

Monday, July 24, Morning Session III

Positive mass theorem for asymptotically locally hyperbolic manifolds

Lan-Hsuan Huang (University of Connecticut)

Date: 7.24 Time: 10:30-11:30 Venue: Lecture Room 10 (A7 1F)

The asymptotically (locally) hyperbolic manifold appears in a fundamental role in the AdS/CFT correspondence. It motivates further study on the properties of global invariants defined at conformal infinity, such as the energy-momentum vector. We will give a partial survey on positivity of the energy-momentum vector and the equality case.

Arbitrarily high order finite element methods for arbitrarily shaped domains with automatic mesh generation

Zhiming Chen (Academy of Mathematics and Systems Science, Chinese Academy of Sciences)

Date: 7.24 Time: 10:30-11:30 Venue: Lecture Room 7 (A3-4 1F)

Partial different equations with discontinuous coefficients having complex interface geometry are of great interests in practical applications. The design of body-fitted high-order finite element methods requires the construction of shape regular body-fitted meshes for complex geometry and also nonlinear element transforms from the reference element to the elements with curved boundary. In practical applications, it may be challenging to satisfy the

conditions imposed on the nonlinear element transforms in the literature which depend on the geometry of the interface. In this talk we study high-order unfitted finite element methods on Cartesian meshes with hanging nodes for elliptic interface problems, which release the work of body-fitted mesh generation and provide a natural way to design high-order methods without resorting to nonlinear element transforms. We introduce new concepts of large element and interface deviation to solve the small cut cell problem of unfitted finite element methods. We construct a reliable algorithm to merge small interface elements with their surrounding elements to automatically generate the finite element mesh whose elements are large with respect to both domains. We show novel hp-domain inverse estimates which allow us to prove the stability of the finite element method under practical interface resolving mesh conditions and prove hp a priori and a posteriori error estimates. We propose new basis functions for the interface elements to control the growth of the condition number of the stiffness matrix in terms of the finite element approximation order, the number of elements of the mesh, and the interface deviation. Numerical examples are presented to illustrate the competitive performance of the method. This talk is based on joint works with Ke Li, Yong Liu and Xueshuang Xiang.

Monodromy of a generalized Lame equation of third order and applications

Zhijie Chen (Tsinghua University)

Date: 7.24 Time: 10:30-11:30 Venue: Lecture Room 8 (A3-4 3F)

In this lecture, I will talk about a generalized Lame equation of third order. We say that the monodromy is unitary if the monodromy group is conjugate to a subgroup of the unitary group. We study the problem when the monodromy is unitary. Some applications to the Toda system on torus will also be given.

Hyperbolic p-sum and horospherical p-Brunn-Minkowski theory in hyperbolic space

Haizhong Li (Tsinghua University)

Date: 7.24 Time: 10:30-11:30 Venue: Lecture Room 9 (A6 1F)

The classical Brunn-Minkowski theory studies the geometry of convex bodies in Euclidean space by use of the Minkowski sum. It originated from H. Brunn's thesis in 1887 and H. Minkowski's paper in 1903. Since there is no universally acknowledged definition of the sum of two sets in hyperbolic space, there has been no Brunn-Minkowski theory in hyperbolic space since 1903. In this talk, for any $p > 0$ we introduce a sum of two sets in hyperbolic space, and we call it the hyperbolic p-sum. Then we develop a Brunn-Minkowski theory in hyperbolic space by use of our hyperbolic p-sum, and we call it the horospherical p-Brunn-Minkowski theory. This is joint work with Botong Xu.

Monday, July 24, Afternoon Session I

The mathematics of general relativity

Piotr Chrusciel (University of Vienna)

Date: 7.24 Time: 13:00-14:00 Venue: Lecture Room 10 (A7 1F)

I will report on recent progress in mathematical general relativity.

Structure-preserving parametric finite element methods for geometric PDEs

Weizhu Bao (National University of Singapore)

Date: 7.24 Time: 13:00-14:00 Venue: Lecture Room 7 (A3-4 1F)

In this talk, I begin with a review of different geometric flows (PDEs) including mean curvature (curve shortening) flow, surface diffusion flow, Willmore flow, etc., which arise from materials science, interface dynamics in multi-phase flows, biology membrane, computer graphics, geometry, etc. Different mathematical formulations and numerical methods for mean curvature flow are then discussed. In particular, an energy-stable linearly implicit parametric finite element method (PFEM) is presented in detail. Then the PFEM is extended to surface diffusion flow and anisotropic surface diffusion flow, and a structure-preserving implicit PFEM is proposed. Finally, sharp interface models and their PFEM approximations are presented for solid-state dewetting. This talk is based on joint works with Harald Garcke, Wei Jiang, Yifei Li, Robert Nuernberg, Yan Wang and Quan Zhao.

On local regularity of space times

Bing-Long Chen (Sun Yat-sen University)

Date: 7.24 Time: 13:00-14:00 Venue: Lecture Room 9 (A6 1F)

We derive the first order regularity for any space time, in terms of the bounds of Ricci curvature and Lie derivative of the Lorentzian metric relative to an arbitrary timelike vector field.

Free interface problems and stabilizing effects of transversal magnetic fields

Zhouping Xin (The Institute of Mathematical Sciences, The Chinese University of Hong Kong)

Date: 7.24 Time: 13:00-14:00 Venue: Lecture Room 8 (A3-4 3F)

Dynamical interface motions are important flow patterns and fundamental free boundary problems in fluid mechanics, and have attracted huge attentions in the mathematical community. Such waves for purely inviscid fluids are subject to various instabilities such as Kelvin-Helmholtz and Rayleigh-Taylor instabilities unless other stabilizing effects such as surface tension, Taylor-sign conditions or dissipations are imposed. However, in the presence of magnetic fields, it has been known that tangential magnetic fields may have stabilizing effects for free surface waves such as plasma-vacuum or plasma-plasma interfaces (at least locally in time), yet whether transversal magnetic fields (which occurs often for interfacial waves for astrophysical plasmas) can stabilize typical free interfacial waves remains to be some open problems. In this talk I will show the stabilizing effects of the transversal magnetic fields for some interfacial waves for both compressible and incompressible multi-dimensional magnetohydrodynamics (MHD). First, I will present the local (in time) well-posedness in Sobolev space of multi-dimensional compressible MHD contact discontinuities, which are most typical interfacial waves for astrophysical plasma and prototypical fundamental waves for systems of hyperbolic conservations. Such waves are characteristic discontinuities for which there is no flow across the discontinuity surface while the magnetic field crosses transversally, which lead to a two-phase free boundary problem that may have nonlinear Rayleigh-Taylor instability and whose front symbols have no ellipticity. We overcome such difficulties by exploiting full the transversality of the magnetic fields and designing a nonlinear approximate problem, which yield the local well-posed without loss of derivatives and without any other conditions such as Rayleigh-Taylor sign conditions or surface tension. Second, I will discuss some results on the global well-posedness of free interface problems for the incompressible inviscid resistive MHD with transversal magnetic fields. Both plasma-vacuum and plasma-plasma interfaces are studied. The global in time well-posedness of both interface problems in a horizontally periodic slab impressed by a uniform non-horizontal magnetic field near an equilibrium are established, which reveal the strong stabilizing effect of the transversal field as the global well-posedness of the free boundary incompressible Euler equations (without the irrotational assumptions) around an equilibrium is unknown. This talk is based on joint works with Professor Yanjin Wang. The research works reported here are partially supported by Hong Kong RGC Earmarked Research Grants: CUHK14301421, CUHK14300819, CUHK14302819, CUHK14300917, and CUHK14302917.

The stability of charged black holes

Elena Giorgi (Columbia University)

Date: 7.24 Time: 14:15-15:00 Venue: Lecture Room 10 (A7 1F)

Black hole solutions in General Relativity are parametrized by their mass, spin and charge. In this talk, I will present recent results on the stability properties of charged black holes and explain how the charge adds interesting dynamics to solutions of the Einstein equation thanks to the interaction between gravitational and electromagnetic radiation.

Encoding orbits via best approximation

Yitwah Cheung (Tsinghua University)

Date: 7.24 Time: 14:15-15:15 Venue: Lecture Room 8 (A3-4 3F)

It is well-known that geodesics on the modular surface are encoded by the theory of continued fractions. By a classical theorem of Lagrange, convergents of the continued fraction are precisely best approximants of the second kind. In this talk, we present generalizations of the theory of continued fractions from the perspective of best approximation that preserves the interplay between number theory and dynamics.

Data- and Model-Driven Approach for Computational Imaging

Bin Dong (Peking University)

Date: 7.24 Time: 14:15-15:15 Venue: Lecture Room 7 (A3-4 1F)

Computational imaging constitutes a pivotal pathway for our observation and comprehension of the natural world. It encompasses three key components: image sensing, image reconstruction, and image analysis. These components have historically evolved separately, with a limited degree of integration among them. However, this situation is gradually changing in light of significant advancements in machine learning, particularly deep learning. The primary focus of this talk lies in exploring the opportunities and challenges brought about by deep learning for computational imaging. It presents an overview of the integration of traditional image reconstruction algorithms with deep learning methodologies, thereby designing data-driven and task-driven imaging algorithms that enable organic fusion of the three components of computational imaging. The final section of the report discusses the significance of computational imaging from a broader perspective in cutting-edge research in life sciences and medicine, as well as its future development trajectories.

Symmetry of hypersurfaces with symmetric boundary

Hui Ma (Tsinghua University)

Date: 7.24 Time: 14:15-15:15 Venue: Lecture Room 9 (A6 1F)

We obtain the interior symmetry of embedded C^1 minimal hypersurfaces and hypersurfaces of constant mean curvature in $\mathbb{R}^{n+1}$ with G-invariant boundary and G-invariant contact angle, where G is a compact connected Lie subgroup of $SO(n+1)$. This extends the result for spherical boundaries where $G = SO(n)$. The main idea is to build a real analytic solution of a Cauchy problem based on infinitesimal Lie group actions and Morrey's regularity theory. It allows us to apply Cauchy-Kovalevskaya theorem. By the same argument, we also investigate the symmetry inheritance from boundaries for hypersurfaces of constant higher order mean curvature and Helfrich-type hypersurfaces in $\mathbb{R}^{n+1}$. This talk is based on the recent joint work with Chao Qian, Jing Wu and Yongsheng Zhang.

The AdS instability conjecture in general relativity

Georgios Moschidis (École Polytechnique Fédérale de Lausanne (EPFL))

Date: 7.24 Time: 15:15-16:00 Venue: Lecture Room 10 (A7 1F)

In the presence of confinement, the Einstein field equations are expected to exhibit turbulent dynamics. In this context, the AdS instability conjecture claims the existence of arbitrarily small perturbations to the initial data of Anti-de Sitter spacetime which, under evolution by the vacuum Einstein equations with reflecting boundary conditions at conformal infinity, lead to the formation of black holes after sufficiently long time. In this talk, I will present a proof of this conjecture in the setting of the spherically symmetric Einstein-massless Vlasov system, and also discuss some more recent results regarding other related problems.

Converse L^2 theory for d-bar and positivity of direct image bundles

Fusheng Deng (University of Chinese Academy of Sciences)

Date: 7.24 Time: 15:30-16:30 Venue: Lecture Room 9 (A6 1F)

We give a survey on the converses of L^2 theory of d-bar (L^2 extension of holomorphic objects and L^2 estimate of the d-bar operator) that developed in recent years, and present some applications to the study of curvature positivity of holomorphic vector bundles and their direct images.

Traceability of water pollution: An inversion scheme via dynamic CGO solutions

Lingyun Qiu (Tsinghua University)

Date: 7.24 Time: 15:30-16:30 Venue: Lecture Room 7 (A3-4 1F)

We aim to find the time-dependent source term in the diffusion equation from the boundary measurement, which allows for the possibility of tracing back the source of pollutants in the environment. Based on the idea of dynamic complex geometrical optics (CGO) solutions, we analyze a variational formulation of the inverse source problem and prove the uniqueness and stability result. A two-step reconstruction algorithm is proposed, which first recovers the locations of the point sources, and then the Fourier components of the emission concentration functions are reconstructed. Numerical experiments on simulated data are conducted. The results demonstrate that our proposed two-step reconstruction algorithm can reliably reconstruct multiple point sources and accurately reconstruct the emission concentration functions. In addition, we decompose the algorithm into two parts: online and offline computation, with most of the work done offline. This paves the way towards real-time traceability of pollution. The proposed method can be used in many fields, particularly those related to water pollution, to identify the source of a contaminant in the environment and can be a valuable tool in protecting the environment.

Reverse mathematics and models of weak Koenig's lemma

Kazuyuki Tanaka (Yanqi Lake Beijing Institute of Mathematical Sciences and Applications (BIMSA))

Date: 7.24 Time: 15:30-16:30 Venue: Lecture Room 8 (A3-4 3F)

Reverse mathematics is a research program on foundations of mathematics, whose aim is to isolate axioms or assumptions needed to prove a theorem of ordinary mathematics. Among others, weak Koenig's lemma, which asserts that every infinite binary tree has an infinite path, is a crucial assumption often used to prove theorems that rely on some form of compactness, such as the maximum principle or Goedel's completeness theorem. In this talk, we overview basic results and recent improvements on models of weak Koenig's lemma.

Supertranslation invariance of angular momentum

Po-Ning Chen (University of California, Riverside)

Date: 7.24 Time: 16:15-17:00 Venue: Lecture Room 10 (A7 1F)

The notion of angular momentum in general relativity has been a subtle issue since the 1960's, due to the discovery of "supertranslation ambiguity": the angular momentums recorded by two distant observers of the same system may not be the same. In this talk, we shall show how mathematical theory identifies a correction term and leads to a new definition of angular momentum that is free of any supertranslation ambiguity.

Memory-efficient Anderson mixing methods and beyond

Chenglong Bao (Tsinghua university)

Date: 7.24 Time: 16:45-17:45 Venue: Lecture Room 7 (A3-4 1F)

Anderson mixing (AM) is a useful method that can accelerate fixed-point iterations by exploring the information from historical iterations. Despite its numerical success in various applications, the memory requirement in AM remains a bottleneck when solving large-scale optimization problems in a resource-limited machine. In this talk, I will discuss our work on a short-term recurrent AM method that significantly reduces the computational burden. Various experiments on network training will validate the effectiveness of the proposed method. Finally, I will introduce the extension of AM to minimization problems on Riemannian manifolds.

A Quantum Algorithm for Analyzing Single-Cell Omics Data

Ping Ma (University of Georgia)

Date: 7.24 Time: 16:45-17:45 Venue: Lecture Room 8 (A3-4 3F)

With the rapid development of quantum computers, researchers have shown quantum advantages in physics-oriented problems. Quantum algorithms tackling computational biology problems are still lacking. In this talk, I will demonstrate the quantum advantage in analyzing single-cell omics data. I will present a quantum algorithm that takes advantage of quantum parallelism by integrating binary search and Grover's algorithm to enable fast computation. Theoretical results are provided to show the privilege of the algorithm in the estimation error and computational complexity. The empirical performance of the algorithm is demonstrated on both the IBM quantum computer and simulator.

The Lp Minkowski problem for the electrostatic capacity

Ge Xiong (Tongji University)

Date: 7.24 Time: 16:45-17:45 Venue: Lecture Room 9 (A6 1F)

1 and 1 Existence and uniqueness of the solution to the Lp Minkowski problem for the electrostatic $\wp$-capacity are proved when p ¿ 1 and 1 ¡ $\wp$ ¡ n. These results are nonlinear extensions of the solution to the Lp Minkowski problem for $\wp$-capacity when p = 1 and 1 ¡ $\wp$ ¡ n by Colesanti et al. and Akman et al., and the classical solution to the Minkowski problem for electrostatic capacity when p = 1 and $\wp$ = 2 by Jerison.

Tuesday, July 25, Morning Session I

Superintegrability and stratified symplectic spaces

Nicolai Reshetikhin (Yau Mathematical Sciences Center, Tsinghua University & Yanqi Lake Beijing Institute of Mathematical Sciences and Applications (BIMSA))

Date: 7.25 Time: 08:00-09:00 Venue: Lecture Room 8 (A3-4 3F)

The talk will start with an introduction of superintegrability in Hamiltonian mechanics. Then I will focus on examples of superintegrable systems on stratified symplectic spaces related to the Hamiltonian reduction of the cotangent bundle to a simple Lie group.

On the global stability of large Fourier mode for 3-D Navier-Stokes equation

Ping Zhang (Academy of Mathematics and Systems Science, Chinese Academy of Sciences)

Date: 7.25 Time: 08:00-09:00 Venue: Lecture Room 7 (A3-4 1F)

We will show that algebraic groups with Frobenius maps have many interesting infinite dimensioanl irreducible rerpesentations,such as an infinite dimensioanl Steinberg representation is irreducible.

Tuesday, July 25, Morning Session II

Variational bihamiltonian cohomologies and integrable evolutionary PDEs

Youjin Zhang (Tsinghua University)

Date: 7.25 Time: 09:15-10:15 Venue: Lecture Room 8 (A3-4 3F)

We introduce the notion of variational bihamiltonian cohomology to study properties of a class of integrable evolutionary PDEs, which are associated to semisimple Frobenius manifolds and have close relations with the study of 2d topological field theory and the Gromov-Witten theory. We show the existence of Virasoro symmetries of such integrable systems by computing the associated variational bihamiltonian cohomology groups, and prove the polynomiality property of their bihamiltonian structures.

Hermitian manifolds: when Chern connection is Ambrose-Singer

Fangyang Zheng (Chongqing Normal University)

Date: 7.25 Time: 09:15-10:15 Venue: Lecture Room 7 (A3-4 1F)

This talk is based on joint work with Prof. Lei Ni of UCSD. We will discuss the geometry of a special type of locally homogeneous Hermitian manifolds: those whose Chern connection is Ambrose-Singer, namely with parallel torsion and curvature. We will show that the universal covering spaces of such manifolds are always the product of Hermitian symmetric spaces and complex Lie groups.

Tuesday, July 25, Morning Session III

Automorphisms of the quantum cohomology of the Springer resolution and applications

Changzheng Li (Sun Yat-sen University)

Date: 7.25 Time: 10:30-11:30 Venue: Lecture Room 8 (A3-4 3F)

In this talk, we will introduce quantum Demazure–Lusztig operators acting by ring automorphisms on the equivariant quantum cohomology of the Springer resolution. Our main application is a presentation of the torus-equivariant quantum cohomology in terms of generators and relations. We will discuss explicit descriptions for the classical types. We also recover Kim's earlier results for the complete flag varieties by taking the Toda limit. This is based on my joint work with Changjian Su and Rui Xiong.

Tuesday, July 25, Afternoon Session I

Resurgent structure in topological strings

Jie Gu (Southeast University)

Date: 7.25 Time: 13:00-14:00 Venue: Lecture Room 8 (A3-4 3F)

Topological string theory has (spacetime) instanton sectors, which the resurgence theory predicts to be completely controlled by the perturbative free energy via Stokes transformations. Recent results also suggest the Stokes constants are related to BPS/DT invariants. To make this picture concrete, one needs to first solve the instanton amplitudes and then calculate the Stokes constants. We demonstrate that the first problem can be solved exactly and completely through a trans-series extension of the BCOV holomorphic anomaly equations. We also show that valuable information on BPS invariants can be obtained through the calculation of Stokes constants. We will demonstrate our results with the example of the famous quintic manifold.

TBA

Hongwei Xu (Zhejiang University)

Date: 7.25 Time: 13:00-14:00 Venue: Lecture Room 7 (A3-4 1F)

TBA

Tuesday, July 25, Afternoon Session II

$N = 2^*$ Schur indices and line defect correlators

Tadashi Okazaki (Shing-Tung Yau Center of Southeast University)

Date: 7.25 Time: 14:15-15:15 Venue: Lecture Room 8 (A3-4 3F)

The closed-form expressions of the Schur indices and line defect correlation functions of four-dimensional $N = 2^*$ $U(N)$ gauge theory are obtained by using the Fermi-gas method. These functions can be expressed in terms of the twisted Weierstrass functions as well as several generating functions for combinatorial objects, including the overpartitions, plane partition diamonds.

Spectral geometry of Kähler manifolds

Hao Xu (Zhejiang University)

Date: 7.25 Time: 14:15-15:15 Venue: Lecture Room 7 (A3-4 1F)

First we survey known results on spectral geometry of Kähler manifolds. Then we study the question of the spectral characterization of $\mathbb{CP}^n$. Namely for each fixed nonnegative integers p, if a compact Kähler manifold M of complex dimension n has the same p-spectra as $\mathbb{CP}^n$ equipped withthe Fubini-Study metric, we give explicit range of n such that this Kähler manifold is holomorphically isometric to $\mathbb{CP}^n$. This extends previous works of Tanno, Chen-Vanhecke, Goldberg for $p \leq 2$ and Ping Li for even p. This is joint work with K. Liu, X. Huang and Y. Zhi.

Tuesday, July 25, Afternoon Session III

New minimal Lagrangian surfaces in $\mathbb{CP}^2$

Sebastian Heller (BIMSA)

Date: 7.25 Time: 15:30-16:30 Venue: Lecture Room 7 (A3-4 1F)

An immersion $f : \Sigma \to \mathbb{CP}^2$ is called a minimal Lagrangian surface if it is minimal with respect to the Fubini study metric and Lagrangian with respect to the Kähler form. Besides the real projective plane and minimal Lagrangian tori, which can all be constructed via integrable systems methods, the only known compact examples have been obtained by Haskins and Kapouleas for odd genera. In this talk, we explain the construction of new compact minimal Lagrangian surfaces of genus $g = \frac{(k-2)(k-1)}{2}$ for large $k \in \mathbb{N}$ using gauge theoretic and loop group factorization methods. These surfaces are analogous to Lawson's minimal surfaces in the 3-sphere and coincide with the projective plane and the Clifford torus for $k = 2, 3$, respectively. We determine their symmetry groups and show that the underlying Riemann surfaces are the Fermat curves. We also discuss further geometric properties such as their area and Willmore energy. This talked is based on joint work with Charles Ouyang and Franz Pedit.

Global quantum many-body theory

Liang Kong (Southern University of Science and Technology)

Date: 7.25 Time: 15:30-16:30 Venue: Lecture Room 8 (A3-4 3F)

I will give a bird's-eye view on the so-called "global quantum many-body theory", which is devoted to the study of the categories of all quantum liquids. The possibility of such a global theory is due to the emergence of a unified mathematical description of all quantum liquids, including topological orders, SPT/SET orders and spontaneous symmetry-breaking orders and certain gapless quantum phases.

Tuesday, July 25, Afternoon Session IV

Magnetic quivers for theories with 8 supercharges

Sperling Marcus (Southeast University)

Date: 7.25 Time: 16:45-17:45 Venue: Lecture Room 8 (A3-4 3F)

Supersymmetric theories with 8 supercharges in dimensions 3 through 6 have a large moduli space of vacua, and the Higgs branches are one of the most significant parts of this space. These (singular) hyper-Kahler spaces can be characterised by a combinatorial object known as the magnetic quiver. By using this technique, we can fully encode the Higgs branch geometry for both the low energy effective description and the strongly coupled conformal fixed point. A simple algorithm on the magnetic quiver allows us to access the stratification of the Higgs branch, which physically corresponds to the generalised Higgs mechanism. In this talk, I will discuss this construction in the context of 5d and 6d theories.

TBA

Entao Zhao (Zhejiang University)

Date: 7.25 Time: 16:45-17:45 Venue: Lecture Room 7 (A3-4 1F)

TBA

Wednesday, July 26, Morning Session I

Hypergeometric systems on reductive groups

Lei Fu (Yau Mathematical Sciences Center, Tsinghua University)

Date: 7.26 Time: 08:00-09:00 Venue: Lecture Room 7 (A3-4 1F)

Hypergeometric differential systems on reductive groups are introduced by Kapranov. We study the arithmetic counterpart, that is, the l-adic hypergeometric geometric sheaves and the p-adic hypergeometric arithmetic D-modules on reductive groups, and discuss their application to the study of exponential sums on reductive groups.

Gromov-Witten invariants of Calabi-Yau quintics via mixed-spring-P-field theory

Weiping Li (Hong Kong University of Science and Technology)

Date: 7.26 Time: 08:00-09:00 Venue: Lecture Room 8 (A3-4 3F)

I will discuss the higher genus Gromov-Witten invariants of the Calabi-Yau quintic threefolds. I will concentrate on the geometric aspect of the method used, which is called N-mixed spin P-fields. The method and its variations are developed by Huai-Liang Li, Guo Shui, Jun Li, Melissa Liu, Wei-Ping LI and Zhou Yang.

Wednesday, July 26, Morning Session II

Cohomological rank functions and surfaces with $p = q = 2$

Zhi Jiang (Shanghai Center for Mathematical Sciences, Fudan University)

Date: 7.26 Time: 09:15-10:15 Venue: Lecture Room 7 (A3-4 1F)

Surfaces of general type with $p = q = 2$ has been studied extensively in the past decade. A full classification is still out of reach. We will report some progress in this topic by applying cohomological rank functions on abelian varieties.

From probability theory to noncompact Calabi-Yau 3-folds

Jian Zhou (Tsinghua University)

Date: 7.26 Time: 09:15-10:15 Venue: Lecture Room 8 (A3-4 3F)

Noncompact Calabi-Yau 3-folds play an important role in the study of local mirror symmetry. The latter provides connections among supersymmetric gauge theories, conformal field theories, matrix models, and integrable hierarchies. In this talk we explain some constructions that associate a noncompact Calabi-Yau 3-fold to a one-dimensional probability distribution.

Wednesday, July 26, Morning Session III

Hodge-Riemann relations for Schur classes

Weizhe Zheng (Academy of Mathematics and Systems Science, Chinese Academy of Sciences)

Date: 7.26 Time: 10:30-11:30 Venue: Lecture Room 7 (A3-4 1F)

The Hard Lefschetz Theorem and the Hodge-Riemann bilinear relations for ample line bundles are important consequences of Hodge Theory on projective varieties. I will give an overview of extensions of these properties to Chern and Schur classes of ample vector bundles

Regularized integrals on configuration spaces of Riemann surfaces and cohomological pairings

Jie Zhou (Tsinghua University)

Date: 7.26 Time: 10:30-11:30 Venue: Lecture Room 8 (A3-4 3F)

Regularizing divergent integrals is a key step in the mathematical understanding of quantum field theories via their correlation functions. An analytic notion of regularization was introduced and developed by Li-Zhou that aims to assign finite values to divergent integrals on configuration spaces of Riemann surfaces. This notion provides a satisfying regularization scheme that meets various expectations from two dimensional chiral conformal field theories. In this talk, I will explain an extended notion of regularized integrals, and more importantly provide cohomological formulations using the tools of current cohomology and mixed Hodge structures. I will also explain practical ways of constructing representatives of the corresponding cohomology classes in terms of smooth differential forms.

Wednesday, July 26, Afternoon Session I

Rozansky-Witten theory and KZ-equations

Babak Haghighat (Tsinghua University)

Date: 7.26 Time: 13:00-14:00 Venue: Lecture Room 8 (A3-4 3F)

Rozansky-Witten theory is a 3d TQFT which is formulated in terms of a sigma model with a hyperkähler target space. We focus on the case where the Hyperkähler manifold is a K3 surface and analyze the corresponding TQFT with regard to a braided tensor category structure. To this end we formulate KZ-equations from which we extract the associator of the tensor category. This then leads to a representation of the braid group which we discuss.

Motivic local systems on projective line removing 4-points

Kang Zuo (Wuhan University)

Date: 7.26 Time: 13:00-14:00 Venue: Lecture Room 7 (A3-4 1F)

This is a joint work with Jinbang Yang. We construct infinitely many abelian schemes of GL_2-type on the projective line with bad reductions on given 4-punctures of type-$(1/2)_\infty$. The method relies on p-adic Hodge theory and Langlands correspondence over function field of characteristic p. Recently Lin-Sheng-Wang solved a conjecture by Sun-Yang-Zuo on torsionness of zeros of Kodaira-Spencer maps of those type abelian schemes. Based on their solution of this conjecture we give a complete classification of those abelian schemes.

Wednesday, July 26, Afternoon Session II

Towards non-perturbative QFT's and strings

Sen Hu (University of Science and Technology of China)

Date: 7.26 Time: 14:15-15:15 Venue: Lecture Room 8 (A3-4 3F)

Construction of non-perturbative QFT and strings is the key to understand many outstanding problems in current physics. We propose to use A_infinity structures to model spaces. It unifies spaces appeared in regularizations of QFT and in string field theories. There are natural effective theories over such spaces like matrix models. They are governed by gauge symmetries. Large N limit exists in some cases. It gives non-perturbative formulation of some QFT's and strings.

Commensurabilities among lattices in $\mathrm{PU}(1,n)$

Chenglong Yu (Yau Mathematical Sciences Center, Tsinghua University)

Date: 7.26 Time: 14:15-15:15 Venue: Lecture Room 7 (A3-4 1F)

In simple Lie groups, except the series $\mathrm{PU}(1,n)$ with $n>1$, either lattices are all arithmetic, or mathematicians constructed infinitely many nonarithmetic lattices. So far there are only finitely many nonarithmetic lattices constructed for $\mathrm{PU}(1,2)$ and $\mathrm{PU}(1,3)$ and no examples for $n>3$. One important construction is via monodromy of hypergeometric functions. The discreteness and arithmeticity of those groups are classified by Deligne and Mostow. Thurston also obtained similar results via flat conic metrics. However, the classification of those lattices up to conjugation and finite index (commensurability) is not completed. When $n=1$, it is the commensurabilities of hyperbolic triangles. The cases of $n=2$ are almost resolved by Deligne-Mostow and Sauter's commensurability pairs, and commensurability invariants by Kappes-Möller and McMullen. Our approach relies on the study of some higher dimensional Calabi-Yau type varieties instead of complex reflection groups. We obtain some relations and commensurability indices for higher n and also give new proofs for existing pairs in $n=2$. This is based on joint work with Zhiwei Zheng.

Wednesday, July 26, Afternoon Session III

Finite subgroups of derived automorphisms of generic $K3$ surfaces

Yu-Wei Fan (Tsinghua University)

Date: 7.26 Time: 15:30-16:30 Venue: Lecture Room 7 (A3-4 1F)

We show that all nontrivial finite subgroups of derived automorphisms of K3 surfaces of Picard number one have order two, and give explicit formulas for the numbers of their conjugacy classes. We also obtain a similar result for the subgroups which are finite up to shifts. This in turn shows that such a K3 surface admits an associated cubic fourfold if and only if it has a derived automorphism of order three up to shifts. These results are achieved by proving that such a subgroup fixes a Bridgeland stability condition. Joint work with Kuan-Wen Lai.

Physics and mathematics of higher genus Gromov-Witten invariants of the quintic threefolds

Shuai Guo (Peking University)

Date: 7.26 Time: 15:30-16:30 Venue: Lecture Room 8 (A3-4 3F)

In this talk, we will first introduce several conjectural structures for the Gromov-Witten invariants of Calabi-Yau threefolds at higher genus. We will then discuss some of the recent mathematical advances on this topic and outline possible directions for future research.

Wednesday, July 26, Afternoon Session IV

Quantum current

Tian Lan (The Chinese University of Hong Kong)

Date: 7.26 Time: 16:45-17:45 Venue: Lecture Room 8 (A3-4 3F)

We establish the formulation for quantum current. Given a symmetry group G, let $\mathscr{C} := \mathrm{Rep}\, G$ be its representation category. Physically, symmetry charges are objects of $\mathscr{C}$ and symmetric operators are morphisms in $\mathscr{C}$. The addition of charges is given by the tensor product of representations. For any symmetric operator O crossing two subsystems, the exact symmetry charge transported by O can be extracted. The quantum current is defined as symmetric operators that can transport symmetry charges over an arbitrary long distance. A quantum current exactly corresponds to an object in the Drinfeld center $Z_1(\mathscr{C})$. The condition for quantum currents to be condensed is also specified. It is proved that in the 1+1D fixed-point models, condensed quantum currents form a Lagrangian algebra in $Z_1(\mathscr{C})$. Overall, the quantum current provides a natural physical interpretation to the categorical symmetry.

Thursday, July 27, Morning Session I

Profinite properties of finite-volume hyperbolic 3-manifolds

Yi Liu (Peking University)

Date: 7.27 Time: 08:00-09:00 Venue: Lecture Room 8 (A3-4 3F)

In this talk, I will discuss recent progress on profinite properties of 3-manifold groups. In particular, I will show that fundamental groups of finite-volume hyperbolic 3-manifolds are profinitely unique up to finite ambiguity.

Infinite dimensional representations of algebraic groups with Frobenius maps

Nanhua Xi (Academy of Mathematics and Systems Science, Chinese Academy of Sciences)

Date: 7.27 Time: 08:00-09:00 Venue: Lecture Room 7 (A3-4 1F)

We will show that algebraic groups with Frobenius maps have many interesting infinite dimensioanl irreducible rerpesentations,such as an infinite dimensioanl Steinberg representation is irreducible.

Thursday, July 27, Morning Session II

Gravitational instantons and special geometry

Lars Andersson (Yanqi Lake Beijing Institute of Mathematical Sciences and Applications (BIMSA))

Date: 7.27 Time: 09:15-10:15 Venue: Lecture Room 7 (A3-4 1F)

Gravitational instantons are Ricci flat complete Riemannian 4-manifolds with at least quadratic curvature decay. Classical examples include the Taub-NUT and the Euclidean Kerr instanton. A classification of half-flat instantons is known but the uniqueness problem remains open in general. In this talk I will present some recent results the classification of S^1-symmetric instantons obtained using an identity of Israel-Robinson type and the G-signature theorem, together with recent results on instantons with special geometry.

Redefining Kontsevich's characteristic classes using formal smooth structures

Jianfeng Lin (Yau Mathematical Sciences Center, Tsinghua University)

Date: 7.27 Time: 09:15-10:15 Venue: Lecture Room 8 (A3-4 3F)

In 2018, Watanabe disproved the 4-dimensional Smale conjecture by showing that the diffeomorphism group of a 4-dimensional disk relative to its boundary is noncontractible. A central tool in Watanabe's argument is a version of Kontsevich's characteristic classes for smooth families of disk bundles. One may wonder what's the role played by the smooth structure. In a recent project, we show that Kontsevich's characteristic class can be redefined just using a formal smooth structure (i.e., vector bundle structure on the tangent microbundle). As an application, we show that for arbitrary compact 4-manifold (with or without boundary), the space of smooth structure is noncontractible. And we show that the homeomorphism group of the 4-dimensional Euclidean space has infinitely many nontrivial rational homotopy groups. (This is a joint work with Yi Xie.)

Thursday, July 27, Morning Session III

On the instability of naked singularities in general relativity

Junbin Li (Sun Yat-sen University)

Date: 7.27 Time: 10:30-11:30 Venue: Lecture Room 7 (A3-4 1F)

The weak cosmic censorship in general relativity states that naked singularities cannot appear in gravitational collapse generically. In this talk, I will introduce some research progress on the instability of naked singularities.

Topology and complex network

Jie Wu (Yanqi Lake Beijing Institute of Mathematical Sciences and Applications (BIMSA))

Date: 7.27 Time: 10:30-11:30 Venue: Lecture Room 8 (A3-4 3F)

In this lecture, guided by the applications to higher-order network, we will discuss some topological approaches to graphs and hypergraphs beyond topological data analysis (TDA), including GLMY homology introduced by S. T. Yau et al, and it generalizations. We will start to explain the motivations of mathematical explorations on the subject from the views of scientific challenges in high-order complex network. After reviewing some topological approaches on the subject, we will report some of our recent progress on the applications of GLMY theory in biology and materials. Finally, we will discuss the homotopy theory of digraphs and its connections to the fundamental higher-order structures of complex network.

Thursday, July 27, Afternoon Session I

Spectral rigidity of complex projective spaces

Kefeng Liu (University of California, Los Angeles)

Date: 7.27 Time: 13:00-14:00 Venue: Lecture Room 7 (A3-4 1F)

I will discuss recent joint work with X. Huang, H. Xu and Y. Zhi on certain new geometric characterizations of complex projective space using p-form spectra and Bergman kernel.

Modularity for W-algebras and affine Springer fiber

Peng Shan (Tsinghua University)

Date: 7.27 Time: 13:00-14:00 Venue: Lecture Room 8 (A3-4 3F)

We will explain a bijection between admissible representations of affine Kac-Moody algebras and fixed points in affine Springer fibers. We will also explain how to match the modular group action on the characters with the one defined by Cherednik in terms of double affine Hecke algebras, and extensions of these relations to representations of W-algebras. This is based on joint work with Dan Xie and Wenbin Yan.

Thursday, July 27, Afternoon Session II

Recent progress on p-adic Jacquet-Langlands correspondence for $\mathrm{GL}(2,\mathbb{Q}_p)$

Yongquan Hu (Academy of Mathematics and Systems Science & Morningside Center of Mathematics, Chinese Academy of Sciences)

Date: 7.27 Time: 14:15-15:15 Venue: Lecture Room 8 (A3-4 3F)

The classical Jacquet-Langlands (J-L) correspondence relates complex representations of $\mathrm{GL}(n)$ and that of its inner forms. It was proved in 1970's and provides one of the first examples of the functoriality conjecture in Langlands program. However, when we consider representations with p-adic or mod p coefficients, the analogue of J-L correspondence is still poorly understood, even in the simplest case of $\mathrm{GL}(2,\mathbb{Q}_p)$. In this talk, we will report some recent progress on the p-adic and mod p J-L correspondence for$\mathrm{GL}(2,\mathbb{Q}_p)$. This is joint work with Haoran Wang.

On Kähler Ricci shrinker surfaces

Bing Wang (University of Science and Technology of China)

Date: 7.27 Time: 14:15-15:15 Venue: Lecture Room 7 (A3-4 1F)

We shall survey the recent progresses on Kähler Ricci shrinker surfaces. Combining the efforts of many authors and of our own, we shall provide a complete classification of all Kähler Ricci shrinker surfaces. This is joint work with Yu Li.

Thursday, July 27, Afternoon Session III

Recent progress on G_2 flows

Yi Li (Southeast University)

Date: 7.27 Time: 15:30-16:30 Venue: Lecture Room 7 (A3-4 1F)

In this talk, I will report several recent results, including the long time existence, parabolic frequency, and solitons, on G_2 flows.

Robba site and Robba cohomology

Koji Shimizu (Yau Mathematical Sciences Center, Tsinghua University)

Date: 7.27 Time: 15:30-16:30 Venue: Lecture Room 8 (A3-4 3F)

We will discuss a p-adic cohomology theory for rigid analytic varieties with overconvergent structure (dagger spaces) over a local field of characteristic p.

Thursday, July 27, Afternoon Session IV

The area of Lawson surfaces and multiple zeta values

Lynn Heller (Yanqi Lake Beijing Institute of Mathematical Sciences and Applications (BIMSA))

Date: 7.27 Time: 16:45-17:45 Venue: Lecture Room 7 (A3-4 1F)

In this talk I will report on joint work with Sebastian Heller and Martin Traizet about recent progress in constructing higher genus harmonic maps using integrable systems methods. By taking the genus as parameter, we obtain a Taylor expansion for the area of the Lawson surfaces (ξ_1, g) with an iterative algorithms to compute all coefficients. Remarkably, these coefficients turns out to be Multiple Zeta Values. Moreover, the Taylor series is shown to converge for genus > 2 which also yields monotonicity of the area for $g > 3$.

Splitting models and Galois representations

Xu Shen (Academy of Mathematics and Systems Science & Morningside Center of Mathematics, Chinese Academy of Sciences)

Date: 7.27 Time: 16:45-17:45 Venue: Lecture Room 8 (A3-4 3F)

We explain certain geometric constructions on the Pappas-Rapoport splitting models of Shimura varieties. These integral models are resolutions of singularities for the corresponding canonical models in the ramified setting. We will also discuss applications to coherent cohomology and Galois representations. This is a joint work with Y. Zheng.

Friday, July 28, Morning Session I

Nonlinear Partial Differential Equations of Mixed Type: From the Riemann Problem to the Isometric Embedding Problem

Guiqiang Chen (University of Oxford)

Date: 7.28 Time: 08:00-09:00 Venue: Lecture Room 8 (A3-4 3F)

Three of the basic types of partial differential equations (PDEs) are elliptic, hyperbolic, and parabolic, following the standard classification for linear PDEs. Linear theories of PDEs of these types have been considerably better developed. On the other hand, many nonlinear PDEs arising in Mathematics and Science naturally are of mixed type. The solution of several longstanding fundamental problems greatly requires a deep understanding of such nonlinear PDEs of mixed type, especially mixed elliptic-hyperbolic type. Important examples include the multi-dimensional Riemann problem (formulated by Riemann in 1860 for the one-dimensional case) and related shock reflection/diffraction problems in fluid dynamics (the compressible Euler equations), and the isometric embedding problem in differential geometry (the Gauss-Codazzi-Ricci equations), among many others. In this talk, we will present some old and new underlying connections of nonlinear PDEs of mixed type with the longstanding fundamental problems from the Riemann problem to the isometric embedding problem and will then discuss some recent developments in the analysis of these nonlinear PDEs through the examples with emphasis on developing/identifying unified approaches, ideas, and techniques for dealing with the mixed-type problems. Some most recent developments, further perspectives, and open problems in this direction will also be addressed.

Normalized discrete Ricci flow and community detection

Yong Lin (Tsinghua University)

Date: 7.28 Time: 08:00-09:00 Venue: Lecture Room 7 (A3-4 1F)

We prove the existence and uniqueness of solution of normalized discrete Ricci flow on graph. We also use the discrete Ricci flow on the graph cut problems. These are the joint works with Bai, Lai, Lu, Wang and Yau.

Friday, July 28, Morning Session II

Cheeger type constants and spectral theory of signed graphs

Shiping Liu (University of Science and Technology)

Date: 7.28 Time: 09:15-10:15 Venue: Lecture Room 7 (A3-4 1F)

A signed graph is a graph whose edges are labelled by a signature. It serves as a simple model of discrete vector bundle. We will introduce various Cheeger type constants based on vertex or edge boundaries and frustration indices, the latter of which measures how far the signature is from being balanced. Applications to the spectral theory of p-Laplacian on signed graphs and spectral theory of non-bipartite Cayley graphs will be discussed. This talk is based on joint works with Fatihcan Atay, Chuanyuan Ge, Chunyang Hu and Dong Zhang.

Connection probabilities for Ising model and their relation to Dyson's circular ensemble

Hao Wu (Tsinghua University)

Date: 7.28 Time: 09:15-10:15 Venue: Lecture Room 8 (A3-4 3F)

Conformal invariance of critical lattice models in two-dimensional has been vigorously studied for decades. In this talk, we focus on connection probabilities for Ising model. This talk has two parts. In the first part, we consider critical Ising model and give the connection probabilities of multiple interfaces. Such probabilities are related to solutions to BPZ equations in conformal field theory. In the second part, we explain a relation between multiple Ising interfaces and Dyson's circular ensemble.

Friday, July 28, Morning Session III

Asynchronous opinion Dynamics

Yuval Peres (Yanqi Lake Beijing Institute of Mathematical Sciences and Applications (BIMSA))

Date: 7.28 Time: 10:30-11:30 Venue: Lecture Room 8 (A3-4 3F)

We analyze the asynchronous averaging dynamics: In a connected graph G with n nodes, each node has an initial opinion. and an independent Poisson clock. When a clock at a node v rings, the opinion at v is replaced by the average opinion of its neighbors. It is well known that the opinions converge to a consensus. We show that the expected time to reach a near consensus is poly(n) in undirected graphs and in Eulerian digraphs, but for some digraphs of bounded degree it is exponential. Our main result is that in undirected graphs and Eulerian digraphs, if the degrees are uniformly bounded and the initial opinions are i.i.d., then E the convergence time is polylog(n). We give sharp estimates for the variance of the limiting consensus opinion, which measures the ability to aggregate information ("wisdom of the crowd"). We also prove generalizations to non-reversible Markov chains and infinite graphs. New results of independent interest on fragmentation processes and coupled random walks are crucial to our analysis. Joint work with D. Elboim and R. Peretz

Orientations of graphs with forbidden out-degree lists

Hehui Wu (Fudan University)

Date: 7.28 Time: 10:30-11:30 Venue: Lecture Room 7 (A3-4 1F)

Let G be a graph and $F : V(G) \mapsto 2^{\mathbb{N}}$ be a mapping. The graph G is said to be F- avoidable if there exists an orientation D of G such that for each vertex v, the out-degree $d_D^+(v) \notin F(v)$. It was conjectured by Akbari, Dalirrooyfard, Ehsani,Ozeki and Sherkati that if $|F(v)| \leq (d(v)-1)/2$ for each vertex v, then G is F-avoiding , and they showed that $|F(v)| \leq d(v)/4$ suffices. By using Combinatorial Nullestellensatz theorem, we improve the bound to $|F(v)| \leq [d(v)/3]$. Furthermore, if the maximum degree is sub-exponentail of the minimum degree δ, then if $|F(v)| \leq (\sqrt{2}-1-o(1))d(v) \approx (0.41+o(1))d(v)$ for each vertex v, then G is F-avaidable. This is joint work with Peter Bradshaw, Bojan Mohar in Simon Fraser University, and my students Yaobin Chen, Hao Ma in Fudan University.

Friday, July 28, Afternoon Session I

Interface motion from non-gradient Glauber-Kawasaki dynamics

Tadahisa Funaki (Yanqi Lake Beijing Institute of Mathematical Sciences and Applications (BIMSA))

Date: 7.28 Time: 13:00-14:00 Venue: Lecture Room 8 (A3-4 3F)

Glauber-Kawasaki dynamics is a large-scale interacting particle system, in which particles make random walks under hard core exclusion rule with the effect of creation and annihilation. We recently derived mean curvature flow or Huygens' principle from Glauber-Kawasaki dynamics under gradient condition. Our goal is to extend these results to general non-gradient cases.

Extremal graph theory and conjectures of Erdos-Simonovits

Jie Ma (University of Science and Technology of China)

Date: 7.28 Time: 13:00-14:00 Venue: Lecture Room 7 (A3-4 1F)

In Extremal Graph Theory one is interested in relations between various graph invariants. Given a property P and an invariant u for a family $\mathscr{F}$ of graphs, we wish to determine the maximum value of $u(G)$ among all graphs G in $\mathscr{F}$ satisfying the property P. The optimal value $u(G)$ is called the *extremal number* and the graphs attaining this value are called *extremal graphs*. A principal example of such an extremal problem is the so-called Turan type problem, initiated by Hungarian mathematicians Turan and Erdős in 1940s. In this talk, we will discuss recent results on several prominent conjectures of Erdős-Simonovits on extremal graphs.

Friday, July 28, Afternoon Session II

Spectral extremal graphs for disjoint cliques

Liying Kang (Shanghai University)

Date: 7.28 Time: 14:15-15:15 Venue: Lecture Room 7 (A3-4 1F)

Let kK_{r+1} be the graph consisting of k vertex-disjoint copies of the complete graph K_{r+1}. Moon [Canad. J. Math. 20 (1968) 95–102] and Simonovits [Theory of Graphs (Proc. colloq., Tihany, 1996)] independently showed that if n is sufficiently large, then the join of a complete graph K_{k-1} and an r-partite Turán graph $T_{n-k+1,r}$ is the unique extremal graph for kK_{r+1}. In this talk we consider the graph which has the maximum spectral radius among all graphs without k disjoint cliques. We show that if G attains the maximum spectral radius over all n-vertex kK_{r+1}-free graphs for sufficiently large n, then G is isomorphic to the join of a complete graph K_{k-1} and an r-partite Turán graph $T_{n-k+1,r}$. This is a joint work with Zhenyu Ni, Jing Wang.

The hypernetwork model of complex systems

Rongling Wu (Yanqi Lake Beijing Institute of Mathematical Sciences and Applications (BIMSA))

Date: 7.28 Time: 14:15-15:15 Venue: Lecture Room 8 (A3-4 3F)

Network models have been widely used as a powerful tool to study complex systems. Existing approaches reconstruct pairwise networks whose interacting pairs of nodes are connected by edges, failing to characterize the high-order architecture of complex systems. In this talk, I will be presenting a statistical physics model that marries evolutionary game theory and ecology theory to leverage the definition and estimation of high-order interactions (HOI). This model can quantitatively reveal both patterns of how a node shapes interactions between pairs of other nodes (active HOI) and how a pairwise interaction influences the third nodes (passive HOI). We coalesce active and passive HOI into hypernetworks, shedding light on the mechanistic understanding of emergent properties of complex systems.

Friday, July 28, Afternoon Session III

Orientations of graphs avoiding non-consecutive integers on out-degrees

Hongliang Lu (Xi'an Jiaotong University)

Date: 7.28 Time: 15:30-16:30 Venue: Lecture Room 7 (A3-4 1F)

Let G be a graph and $F : V(G) \to 2^N$ be a set function. The graph G is said to be *F-avoiding* if there exists an orientation O of G such that $d_O^+(v) \notin F(v)$ for every $v \in V(G)$, where $d_O^+(v)$ denotes the out-degree of v in the directed graph G with respect to O. In this paper, we obtain the following result: if the set $F(v)$ satisfies $|F(v)| \leq \frac{1}{2}(d_G(v) - 1)$ and $F(v)$ contains no two consecutive integers, then G is *F-avoiding*. In fact, we give a Gallai-Edmonds type characterization if the set $F(v)$ satisfies $|F(v)| \leq \lceil \frac{1}{2} d_G(v) \rceil$ and $F(v)$ contains no two consecutive integers.

Wave motion in topological materials

Yi Zhu (Tsinghua University)

Date: 7.28 Time: 15:30-16:30 Venue: Lecture Room 8 (A3-4 3F)

In the past decade, a revolution in materials sciences has been brought about by the recognition of topology in characterizing the physical properties. These materials which support nontrivial topological phases are termed as topological materials. The related research is now beyond the electric system and the phenomena have been realized in other systems such as photonics, acoustics and mechanics. In this talk, I will introduce some results on these materials from the applied analysis and numerics aspects. Especially, I will focus on photonic topological materials, including existence of Dirac points, topological edge states and topologically protected wave motions and corresponding numerical methods.

Friday, July 28, Afternoon Session IV

Hypergraphs with irrational Turán density and many extremal configurations

Jianfeng Hou (Fuzhou University)

Date: 7.28 Time: 16:45-17:45 Venue: Lecture Room 7 (A3-4 1F)

Unlike graphs, determining the Turán density of hypergraphs is known to be notoriously hard in general. The essential reason is that for many classical families of r-uniform hypergraphs $\mathscr{F}$, there are perhaps many near-extremal configurations with very different structure. Such a phenomenon is called not stable, and Liu and Mubayi gave the first example that is not stable. Another perhaps reason is that little is known about the set consisting of all possible Turán densities which has cardinality of the continuum. Let $t \geq 2$ be an integer. In this paper, we

construct an finite family of $\mathscr{M}$ of 3-uniform hypergraphs such that the Turán density of $\mathscr{M}$ is irrational, and there are t near-extremal $\mathscr{M}$-free configurations that are far from each other in edit-distance. This is the first example that has an irrational Turán density and is not stable. We also prove its Andrásfai-Erdős-Sós type stability theorem.

Mediation analysis with the mediator and outcome missing not at random

Fan Yang (Tsinghua University)

Date: 7.28 Time: 16:45-17:45 Venue: Lecture Room 8 (A3-4 3F)

Mediation analysis is widely used for investigating direct and indirect causal pathways through which an effect arises. However, many mediation analysis studies are challenged by missingness in the mediator and outcome. In general, when the mediator and outcome are missing not at random, the direct and indirect effects are not identifiable without further assumptions. In this work, we study the identifiability of the direct and indirect effects under some interpretable missing not at random mechanisms. We evaluate the performance of statistical inference under those assumptions through simulation studies and illustrate the proposed methods via the National Job Corps Study.

Theoretical Physics

Titles and Abstracts

Monday, July 17, Afternoon Session I

The Swampland distance conjecture

Irene Valenzuela (CERN Institute of Theoretical Physics (IFT) UAM/CSIC)

Date: 7.17 Time: 13:15-14:00 Venue: Lecture Room 4 (A3-2 1F)

The Distance Conjecture plays a key role in the Swampland program, which aims to determine the constraints that effective field theories must satisfy to be consistent with quantum gravity. The conjecture implies the existence of an infinite tower of states becoming exponentially light at every infinite distance limit of the field space. I will review past and recent progress checking this conjecture in string theory, as well as its relation to the Emergence proposal.

Frontiers of Science Award Paper: Thomas W. Grimm, Eran Palti, and Irene Valenzuela. Infinite distances in field space and massless towers of states. *J. High Energy Phys.*, (8):143, front matter+71, 2018

Monday, July 17, Afternoon Session II

Emergence and the Swampland Distance Conjecture

Thomas Rudelius (University of California, Berkeley)

Date: 7.17 Time: 14:00-14:45 Venue: Lecture Room 4 (A3-2 1F)

The Ooguri-Vafa Swampland Distance Conjecture claims that in any consistent theory of quantum gravity, when venturing to large distances in scalar field space, a tower of particles will become light at a rate that is exponential in the field space distance. In this talk, I provide a bottom-up viewpoint on this claim: if we assume that a tower of states becomes light near a particular point in field space, and we further demand that loop corrections drive both gravity and the scalar to strong coupling at a common energy scale, then the requirement that the particles become light exponentially fast in the field-space distance in Planck units follows automatically.

Frontiers of Science Award Paper: Ben Heidenreich, Matthew Reece, and Tom Rudelius. Emergence of weak coupling at large distance in quantum gravity. *Phys. Rev. Lett.*, 121:051601, Aug 2018

Monday, July 17, Afternoon Session III

Geometry of Higher Form Symmetries

Mirjam Cvetic (University of Pennsylvania)

Date: 7.17 Time: 15:45-16:45 Venue: Lecture Room 4 (A3-2 1F)

By studying M-theory on singular non-compact special holonomy spaces X we demonstrate, via a process of cutting and gluing of singularities that extend to the boundary of X, the appearance of 0-form, 1-form and 2-group symmetries in the resulting supersymmetric quantum field theory. We study the fate of these symmetries when these spaces become compact by employing sophisticated gluing techniques. We highlight prototype examples with spaces X being elliptically fibered Calabi-Yau manifolds, which are dual to F-theory constructions. There we can compare obtained results to previous studies, encoded in the arithmetic structure of elliptic fibration.

Measuring randomness of an evaporating black hole

Ahmed Eid Khamis Thani Almheiri (New York University Abu Dhabi)

Date: 7.17 Time: 15:00-15:45 Venue: Lecture Room 4 (A3-2 1F)

The black hole information paradox arises due to the large amount of randomness in the Hawking radiation emitted by black holes. I will discuss how this paradox is resolved by effects coming from wormholes: connections between distant parts of spacetime.

Frontiers of Science Award Paper: Ahmed Almheiri, Netta Engelhardt, Donald Marolf, and Henry Maxfield. The entropy of bulk quantum fields and the entanglement wedge of an evaporating black hole. *J. High Energy Phys.*, (12):063, 46, 2019

Tuesday, July 18, Morning Session I

Holographic entanglement and beyond

Tadashi Takayanagi (Yukawa Institute for Theoretical Physics, Kyoto University)

Date: 7.18 Time: 08:00-09:00 Venue: Lecture Room 4 (A3-2 1F)

The idea of holography in string theory provides a simple geometric computation of entanglement entropy. This generalizes the well-known Bekenstein-Hawking formula of black hole entropy and strongly suggests that a gravitational spacetime consists of many bits of quantum entanglement. After we give a brief review of this field, I will explain progresses on a recently introduced quantity called pseudo entropy, which generalizes the entanglement entropy and has a manifest gravity dual. We will also discuss an extension of this idea to holography for de Sitter spaces.

Tuesday, July 18, Morning Session II

Semiclassical fluctuations around black holes

Mukund Rangamani (University of California, Davis)

Date: 7.18 Time: 09:15-10:15 Venue: Lecture Room 4 (A3-2 1F)

TBA

Tuesday, July 18, Morning Session III

Exotic hadronic states and hadron structure

Bingsong Zou (Institute of Theoretical Physics, Chinese Academy of Sciences)

Date: 7.18 Time: 10:30-11:30 Venue: Lecture Room 4 (A3-2 1F)

Hadrons, including mesons and baryons, are the smallest units that can be separated from matter and have been observed to have internal structures. Searching for new hadronic states and exploring their internal quark gluon structure is a cross cutting frontier topic of common concern in particle physics and medium to high energy nuclear physics. In recent years, more and more exotic hadronic states beyond the expectation of the classical Quark model have been observed experimentally. Although there are various explanations for their nature, these exotic hadron states can basically be explained as multi-quark hadronic molecular states. For hadrons that met the expectations of the Quark model in the past, such as protons, there are also some new experimental observations that cannot be explained by the classical Quark model, and the multi-quark component caused by the unquenching dynamics must be considered. Therefore, in order to truly understand the hadron spectrum and hadron structure, it is necessary to study multi-quark exotic hadron states.

Tuesday, July 18, Afternoon Session I

The count of instantons

Nikita Nekrasov (Simons Center for Geometry and Physics)

Date: 7.18 Time: 13:00-14:00 Venue: Lecture Room 4 (A3-2 1F)

Exploration of integrals over moduli spaces motivated by quantum field theory and string theory have been an extremely fruitful endeavour in both Physics and Mathematics of the last 50 years. Old and new problems will be reviewed.

Tuesday, July 18, Afternoon Session II

An exact AdS/CFT duality

Matthias Gaberdiel (ETH Zürich)

Date: 7.18 Time: 14:00-14:45 Venue: Lecture Room 4 (A3-2 1F)

I will review an exact AdS_3/CFT_2 duality, relating the tensionless string on $AdS_3 \times S^3 \times \mathbb{T}^4$ with minimal ($k = 1$) NS-NS flux to the symmetric orbifold of $\mathbb{T}^4$. I will also explain how a similar description seems to exist for the string dual of free $N = 4$ SYM in $D = 4$.

Frontiers of Science Award Paper: Lorenz Eberhardt, Matthias R. Gaberdiel, and Rajesh Gopakumar. The worldsheet dual of the symmetric product CFT. *J. High Energy Phys.*, (4):103, 46, 2019

Tuesday, July 18, Afternoon Session III

Particle Physics and Its Future — and Opportunities for China

Yifang Wang (Institute of High Energy Physics, Chinese Academy of Sciences)

Date: 7.18 Time: 15:15-16:15 Venue: Lecture Room 4 (A3-2 1F)

Particle physics is now at the turning point. On the one hand, Standard Model seems so successful with no obvious way towards the future. On the other hand, experimental evidence and theoretical analysis shows that physics beyond the Standard Model do exist. This talk will analysis possible future of particle physics and suggest a roadmap for China.

Wednesday, July 19, Morning Session I

Formation of merging compact binaries

Dong Lai (Cornell University)

Date: 7.19 Time: 08:00-09:00 Venue: Lecture Room 4 (A3-2 1F)

The recent breakthrough in the detection of gravitational waves (GWs) from merging black hole (BH) and neutron star (NS) binaries by advanced LIGO/Virgo has generated renewed interest in understanding the formation mechanisms of merging compact binaries, from the evolution of massive stellar binaries and triples in the galactic fields, dynamical interactions in dense star clusters to binary mergers in AGN disks. I will review these different formation channels, and discuss how observations of spin-orbit misalignments, eccentricities, masses and mass ratios in a sample of merging binaries by aLIGO can constrain various formation channels. The important roles of space-borne gravitational wave detectors will also be discussed.

Wednesday, July 19, Morning Session II

On Corrollian conformal field theory

Bin Chen (Peking University)

Date: 7.19 Time: 09:15-10:15 Venue: Lecture Room 4 (A3-2 1F)

In recent years, it turns out that the Corrollian conformal field theory has important implications in celestial holography, flat space holography and black hole physics. In this work, I will report our recent work on Corrollian conformal field theories in various spacetime dimensions.

Wednesday, July 19, Morning Session III

The interior structure of hairy black holes

Rong-Gen Cai (Institute of Theoretical Physics, Chinese Academy of Scieces)

Date: 7.19 Time: 10:30-11:30 Venue: Lecture Room 4 (A3-2 1F)

We prove that there exists no inner Cauchy horizon for both spherical and planar black holes with scalar hair. The hairy black holes approach to a spacelike singularity at late interior time. The geometry near the singularity takes a universal Kasner form when the kinetic term of the scalar hair dominates, while novel behaviors different from the Kasner form are uncovered when the scalar potential become important to the background. For the hyperbolic horizon case, we show that hairy black hole can only has at most one inner horizon, and a concrete example with an inner horizon is presented. For the charged vector field case, we present a general proof of no inner horizon of the black holes. Before reaching the singularity,in addition to the Einstein-Rosen bridge contracting towards the singularity, the instability triggered by the vector hair results in the oscillations of vector condensate and the anisotropy of spatial geometry. Due to the effects from vector condensate and $U(1)$ gauge potential, there is generically a never-ending alternation of Kasner epochs towards the singularity. The character of evolution on approaching the singularity is found to be described by the Kasner epoch alternation with flipping of powers of the Belinskii-Khalatnikov-Lifshitz type.

Wednesday, July 19, Afternoon Session I

The measurement-induced entanglement phase transition

Brian Skinner (Ohio State University)

Date: 7.19 Time: 13:00-13:45 Venue: Lecture Room 4 (A3-2 1F)

What a quantum many-body system undergoes unitary evolution punctuated by sporadic measurements, its dynamics can fall into one of two broad classes: (1) "entangling" dynamics, in which the quantum entanglement between two subregions grows linearly in time and ultimately saturates at a value proportional to the subregion volume; and (2) "disentangling" dynamics, in which the entanglement growth rate vanishes and the final entanglement depends only on the area of the subregion boundary. I will discuss our efforts to understand the phase transition between these two classes, including the intuition behind our original prediction of its existence and our later efforts to find a situation where the transition can be solved exactly.

Frontiers of Science Award Paper: Brian Skinner, Jonathan Ruhman, and Adam Nahum. Measurement-Induced Phase Transitions in the Dynamics of Entanglement. *Phys. Rev. X*, 9:031009, Jul 2019

Wednesday, July 19, Afternoon Session II

Field theoretic approach to Eliashberg theory with repulsive interactions

Jonathan Ruhman (Bar Ilan University)

Date: 7.19 Time: 14:00-14:45 Venue: Lecture Room 4 (A3-2 1F)

Superconductors are characterized by the formation of an electronic condensate of pairs, which form in spite of their Coulombic repulsion. The Eliashberg theory deals with this apparent contradiction by considering the dynamical properties of the interactions. The pairing instability arises from pair correlations that exploit the interaction's frequency dependence to extract attractive "channels" while avoiding repulsive ones. However, the role of Coulomb repulsion in the properties of the resulting superconducting state remains uncertain, in part because deriving the phenomenological Ginzburg-Landau theory for such a superconductor from a microscopic model that incorporates repulsion remains elusive. We present a formalism that addresses this challenge by applying the standard Hubbard-Stratonivich transformation to an interaction that we first decompose into attractive and repulsive channels. This leads to a complex action governed by a saddle point that is shifted from the original field-integration manifold into a generalized complex one. Using a gradient-descent method, we obtain a numerical solver that finds the solution to Eliashberg equations efficiently and impartially. We then describe how we account for fluctuations around this complex saddle point and apply it to compute the upper critical field near the superconducting transition temperature.

Wednesday, July 19, Afternoon Session III

Marginal triviality of the 4D Ising model

Hugo Duminil-Copin (Université de Genève)

Date: 7.19 Time: 15:15-16:15 Venue: Lecture Room 4 (A3-2 1F)

In this talk, we discuss the fact that the scaling limit of spin fluctuations in four-dimensional Ising-type models with nearest-neighbor ferromagnetic interaction at or near the critical point is Gaussian and its implications from the point of view of Euclidean Field Theory. Similar statements will be proven for the $\lambda\varphi^4$ fields over $\mathbb{R}^4$ with a lattice ultraviolet cutoff, in the limit of infinite volume and vanishing lattice spacing. The proofs are enabled by the models' random current representation, in which the correlation functions' deviation from Wick's law is expressed in terms of intersection probabilities of random currents with sources at distances which are large on the model's lattice scale. Guided by the analogy with random walk intersection amplitudes, the analysis focuses on the improvement of the so-called tree diagram bound by a logarithmic correction term, which is derived here through multi-scale analysis.

Frontiers of Science Award Paper: Michael Aizenman and Hugo Duminil-Copin. Marginal triviality of the scaling limits of critical 4D Ising and ϕ^4_4 models. *Ann. of Math. (2)*, 194(1):163–235, 2021

Wednesday, July 19, Afternoon Session IV

TBA

Geoffrey Penington (University of California, Berkeley)

Date: 7.19 Time: 16:15-17:00 Venue: Lecture Room 4 (A3-2 1F)

TBA

Frontiers of Science Award Paper: Geoffrey Penington. Entanglement wedge reconstruction and the information paradox. *J. High Energy Phys.*, (9):002, 83, 2020

Thursday, July 20, Morning Session I

Astrophysical probes to new physics beyond the standard model

Yue Zhao (University of Utah)

Date: 7.20 Time: 08:00-09:00 Venue: Lecture Room 4 (A3-2 1F)

Particle physics research can significantly deepen people's understanding about the elementary building blocks and fundamental laws of nature. The Standard Model of particle physics provides the foundation of modern high energy physics. However, the Standard Model fails miserably in several aspects. First, it has no dark matter candidate. Further, there are a few super tiny parameters, such as the strong CP phase, which remains to be explained. Both aspects point to the existence of new physics beyond the Standard Model. In this talk, I will present two novel ways utilizing astrophysical observations to probe the existence of new physics. I will first talk about how to use the Gravitational Wave experiments, such as LIGO and LISA, to search for ultra-light dark photon dark matter. Then I will demonstrate that, with high spatial resolution, polarimetric imaging of a supermassive black hole by the Event Horizon Telescope can be used to probe the existence of axions. Through these two example, we show that a nice bridge can be built between astrophysics and particle physics, and interesting particle physics questions can be answered by powerful astrophysical probes.

Thursday, July 20, Morning Session II

Geometric phases old and new

Michael Berry (University of Bristol)

Date: 7.20 Time: 09:15-10:15 Venue: Lecture Room 4 (A3-2 1F)

The waves that describe systems in quantum physics can carry information about how their environment has been altered, for example by forces acting on them. This effect is the geometric phase. It occurs in the optics of polarised light, where it goes back to the 1830s, possibly earlier. It influences wave interference; and it provides insight into the spin-statistics relation for identical quantum particles. The underlying mathematics is geometric: parallel transport, explaining how falling cats turn upright, and how to park a car. Recent results describe the typical behaviour of the geometric phase curvature and the related quantum metric. Incorporating the back-reaction of the geometric phase on the dynamics of the changing environment exposes an unsolved problem: how can a system be separated from its slowly-varying environment? The concept has a tangled history.

Thursday, July 20, Morning Session III

Density-matrix and tensor-network renormalization

Tao Xiang (Institute of Physics, Chinese Academy of Sciences)

Date: 7.20 Time: 10:30-11:30 Venue: Lecture Room 4 (A3-2 1F)

The concept and methodology of the renormalization group is a cornerstone in physics, with far-reaching implications for the study of quantum field theory and critical phenomena. Its impact on the field cannot be overstated. One important direction in the research of many-body quantum theory is the renormalization group study of the so-called tensor-network states. The ultimate goal is to provide a powerful tool for solving correlated quantum problems, such as the mechanism behind high-temperature superconductivity. In this talk, I will delve into the physical background and fundamental ideas that underlie the development of this field. Additionally, I will discuss the latest progress and explore directions for future research. Through this exploration, we hope to gain a deeper understanding of the renormalization group and its potential for further advancing our understanding of the complex phenomena that arise in quantum many-body systems.

Thursday, July 20, Afternoon Session I

Emergent phenomena in monitored quantum systems

Xiao Chen (Boston College)

Date: 7.20 Time: 13:00-13:45 Venue: Lecture Room 4 (A3-2 1F)

Recent research has revealed that monitoring a quantum system can induce an entanglement phase transition. This talk will provide an overview of this entanglement phase and discuss a few important applications of this phase transition. In addition, it will discuss a range of emergent quantum phases that arise in the context of monitored quantum dynamics.

Frontiers of Science Award Paper: Yaodong Li, Xiao Chen, and Matthew P. A. Fisher. Quantum Zeno effect and the many-body entanglement transition. *Phys. Rev. B*, 98:205136, Nov 2018

Thursday, July 20, Afternoon Session II

Landscape of quantum phases in quantum materials

Liujun Zou (Perimeter Institute for Theoretical Physics)

Date: 7.20 Time: 14:00-14:45 Venue: Lecture Room 4 (A3-2 1F)

A major goal of condensed matter physics is to explore the full landscape of quantum phases of matter via quantum materials. I will first introduce the vast landscape of quantum phases of matter that have been theoretically studied, and then discuss how moire materials are great platforms to explore the landscape of different quantum phases. Next, I will discuss the notion of quantum anomaly, which determines the landscape of quantum phases of matter in specific quantum materials.

Frontiers of Science Award Paper: Hoi Chun Po, Liujun Zou, Ashvin Vishwanath, and T. Senthil. Origin of Mott Insulating Behavior and Superconductivity in Twisted Bilayer Graphene. *Phys. Rev. X*, 8:031089, Sep 2018

Thursday, July 20, Afternoon Session III

Light-ray operators and Regge trajectories in CFTs

Petr Kravchuk (King's College London)

Date: 7.20 Time: 15:15-16:00 Venue: Lecture Room 4 (A3-2 1F)

Analyticity in spin, manifested in the Regge trajectories and the associated light-ray operators is perhaps the most rigid structure that we know of in the spectrum of higher-dimensional conformal field theories. In this talk I will review the progress achieved in understanding this structure and applying it to concrete problems, as well as discuss the future directions.

Frontiers of Science Award Paper: Petr Kravchuk and David Simmons-Duffin. Light-ray operators in conformal field theory. *J. High Energy Phys.*, (11):102, front matter+108, 2018

Thursday, July 20, Afternoon Session IV

Scattering amplitudes and gravitational wave physics

Mao Zeng (University of Edinburgh)

Date: 7.20 Time: 16:15-17:00 Venue: Lecture Room 4 (A3-2 1F)

The detection of gravitational waves by LIGO/VIRGO in 2015 opened up a new era for multi-messenger astronomy. Precision theoretical predictions for gravitational wave signals require a combination of numerical and analytic perturbative calculations. We present a new framework for perturbative calculations, based on scattering amplitudes in quantum field theory and their classical limits. We use a wide range of tools in theoretical high-energy physics, including on-shell methods, the double copy, effective field theory, and advanced loop integration techniques. In our paper, the conservative dynamics of non-spinning black holes in a binary system is obtained at the third order in the gravitational constant for the first time. The result shows improved agreement with numerical relativity simulations compared with lower-order results. Since our breakthrough, a flurry of publications have extended our results to include the effect of spin, finite sizes, dissipation, and higher orders in perturbation theory.

Frontiers of Science Award Paper: Zvi Bern, Clifford Cheung, Radu Roiban, Chia-Hsien Shen, Mikhail P. Solon, and Mao Zeng. Scattering Amplitudes and the Conservative Hamiltonian for Binary Systems at Third Post-Minkowskian Order. *Phys. Rev. Lett.*, 122:201603, May 2019

Friday, July 21, Morning Session I

How Effective is the Standard Model of Particle Physics?

John Ellis (King's College London)

Date: 7.21 Time: 08:00-09:00 Venue: Lecture Room 4 (A3-2 1F)

The Standard Model of particle remains consistent with (most) data, despite the best efforts of experiments, and the abundance of open problems including the identity of dark matter, the origin of the matter in the Universe and the nature of the mysterious Higgs boson, not to mention the unification of the Standard Model with gravity. The Standard Model should be regarded as an effective field theory that is a low-energy approximation to a more complete theory of fundamental physics. The latter may reveal itself through higher-order interactions between Standard Model particles that are being sought at the Large Hadron Collider and elsewhere. Any luck yet?

Friday, July 21, Morning Session II

Long lived particles and the future of particle physics

Jonathan Feng (University of California, Irvine)

Date: 7.21 Time: 09:15-10:15 Venue: Lecture Room 4 (A3-2 1F)

The gold standard for progress in particle physics is the discovery of new elementary particles. For decades the search for new particles focused on heavy particles with short lifetimes. More recently, however, there has been a paradigm shift, with a new focus on long-lived particles that can be either heavy or light. Such particles appear in many theories designed to address the outstanding questions of neutrino mass and dark matter, and the possibility that they exist has led to an explosion of new, creative ideas for particle searches. This talk will place the paradigm shift toward long-lived particles in its historical context, highlight some of the ongoing experiments that are already yielding interesting results, and provide an outlook for the future.

Friday, July 21, Morning Session III

Cosmological late-time attractors and string theory

Gary Shiu (University of Wisconsin-Madison)

Date: 7.21 Time: 10:30-11:30 Venue: Lecture Room 4 (A3-2 1F)

We investigate whether an accelerating universe can be realized as an asymptotic late-time solution of Friedmann–Lemaître–Robertson–Walker (FLRW) cosmology with multi-field multi-exponential potentials. Such potentials are commonly considered in phenomenological models of dark energy, and at the same time describe the asymptotic regions of the moduli space of string theory. Late-time cosmological solutions exhibit a universal behavior which enables us to bound the rate of time variation of the Hubble parameter. We prove the conditions under which scaling cosmologies are inevitable late-time cosmological attractors of this general class of potentials, independently of initial conditions. As scaling solutions are known analytically, we can characterize late-time observables exactly. Our analysis is general as it does not rely on any approximation nor assumptions on the microscopic origin of the potential. When applied to string-theory, our analytic knowledge of late-time cosmological solutions enables us to single out potentials that can describe an accelerating universe from those which cannot and to quantitatively test several conjectured Swampland criteria.

Friday, July 21, Afternoon Session I

Solving quantum field theory

Francesco Sannino (University of Southern Denmark)

Date: 7.21 Time: 13:00-14:00 Venue: Lecture Room 4 (A3-2 1F)

Quantum Field Theory offers the only known way to reconcile quantum mechanics and special relativity. It has allowed mankind to achieve the most profound understanding of the laws of the Universe, from the Standard Model to cosmology and condensed matter physics. Yet much is still left to be understood about QFTs, especially in regimes where theories are strongly interacting and standard calculations methods fail. Quantum chromodynamics, the theory responsible for the existence of protons and neutrons, is the most celebrated example of a strongly interacting QFT. Quantum gravity itself becomes strongly coupled at the Planck scale. Similar strongly coupled systems are encountered in condensed matter, particle physics and string theory. The ambitious goal of this talk is to show how to tackle Quantum Field Theory dynamics by exploiting different regimes that allow for controlled investigations and precise results. The talk is organized around the following themes: Quantum Field Theory landscape: Here I will show how to map the QFTs landscape and identify scale-invariant theories acting as signposts among possible QFTs. I will then show how to construct effective descriptions of quantum black holes thereby mapping the landscape of quantum gravity theories. Quantum Field Theory on the blackboard: BY employing and extending semiclassical approaches, from the large quantum number limits to resurgence, we will learn how to compute physical quantities to all orders in the coupling strengths. Quantum Field Theory on supercomputers: When analytical methods fail we must use first-principle numerical simulations on larger supercomputers to determine the critical behavior of QCD and QCD-like theories at high temperatures and/or density, including quantum phase transitions. A major strength of our way to address unsolved issues in Quantum Field Theory is the combined use of complementary approaches from the renormalization group to semiclassical and numerical simulations.

Friday, July 21, Afternoon Session II

Geometries, particles and strings

Song He (Institute of Theoretical Physics, Chinese Academy of Sciences)

Date: 7.21 Time: 14:00-14:45 Venue: Lecture Room 4 (A3-2 1F)

Recent progress on positive geometries for scattering of particles and strings

Friday, July 21, Afternoon Session III

On 6-dimensional SCFTs and little string theories

Kimyeong Lee (Korea Institute for Advanced Study)

Date: 7.21 Time: 15:15-16:15 Venue: Lecture Room 4 (A3-2 1F)

We explore the twisting of maximally symmetric 6-dimensional conformal field theories and little string theories. We also discuss the characteristics of partition function on the Omega deformed background.

Friday, July 21, Afternoon Session IV

Non-invertible symmetries in two dimensions

Chi-Ming Chang (Tsinghua University)

Date: 7.21 Time: 16:15-17:00 Venue: Lecture Room 4 (A3-2 1F)

Frontiers of Science Award Paper: Chi-Ming Chang, Ying-Hsuan Lin, Shu-Heng Shao, Yifan Wang, and Xi Yin. Topological defect lines and renormalization group flows in two dimensions. *J. High Energy Phys.*, (1):026, front matter+83, 2019

Monday, July 24, Morning Session I

Inflationary cosmology: Theory and observations

Andrei Linde (Stanford University)

Date: 7.24 Time: 08:00-09:00 Venue: Online

Inflationary theory was proposed about 40 years ago as a bold attempt to solve numerous problems of the Big Bang theory. Gradually it became the leading cosmological paradigm describing the origin of the universe and formation of its large scale structure. Many of its predictions are already confirmed by cosmological observations. I will briefly describe the development of inflationary cosmology and its present status with an account taken of the latest observational data.

Monday, July 24, Morning Session II

Will LHC create baryons?

Henry S Tye (Cornell University & Hong Kong University of Science & Technology)

Date: 7.24 Time: 09:15-10:15 Venue: Lecture Room 4 (A3-2 1F)

Review the possibility that baryon number violation can be observed at proton-proton colliders.

Monday, July 24, Morning Session III

The Nature of Spacetime and Gravity in Hyperunified Field Theory

Yue-Liang Wu (Institute of Theoretical Physics, Chinese Academy of Sciences)

Date: 7.24 Time: 10:30-11:30 Venue: Lecture Room 4 (A3-2 1F)

In this talk, I will show how the general relativity and quantum mechanics can be combined consistently to establish the gravitational quantum field theory (GQFT), which motivates us to build the hyperunified field theory (HUFT) based on the maximum entangled-qubits motion principle as well as gauge and scaling invariance principle. Such a HUFT enables us to understand the nature of spacetime and gravity, and make issues on the basic questions: what is the fundamental building block of nature? what brings about the fundamental symmetry of nature? what is the fundamental interaction of nature? how does the fundamental symmetry govern basic forces? what is the basic structure of spacetime? how many dimensions does spacetime have? why is there only a single temporal dimension? why do we live in a universe with only four-dimensional spacetime? why are there leptons and quarks beyond one family? how does early universe get inflationary expansion? what is a dark matter candidate? what is the nature of dark energy? It is expected that the gravitational wave detections will provide a new window in probing the gravitational universe and exploring the nature of spacetime and gravity.

Monday, July 24, Afternoon Session I

On high dimension operators, gauge/gravity correspondence and emergent spacetime

Hai Lin (Shing-Tung Yau Center of Southeast University)

Date: 7.24 Time: 13:00-13:45 Venue: Lecture Room 4 (A3-2 1F)

Gauge/gravity correspondence or dualities are useful nonperturbative methods for string theory and quantum gravity, and vice versa for strongly coupled quantum systems and quantum field theories. It manifests relation between quantum theory with gravity in higher dimensions and dual quantum system in lower dimensions. We discuss coherent state operators describing various giant gravitons, wrapped branes, and other excitations on spacetime. There are various emergent phenomena, including the emergence of the bulk spacetimes and excitations thereof. We construct also coherent states in the $SL(2)$ sectors and their cousin $PSU(1,1|2)$ sectors. The coherent state amplitudes are further packaged into supermatrix, which encode information of giants and dual giants. We add strings onto the coherent state operators. The string-added coherent states capture near-BPS states. The coherent state representations, auxiliary integrals, as well as auxiliary susy integrals, facilitate the computations efficiently. We generate correlation functions of integrated operators from correlation functions of un-integrated operators. Various other new techniques including new saddle point method, localization, analytic combinatorics, permutations are also briefly overviewed.

Monday, July 24, Afternoon Session II

From conformal collider to the LHC and beyond

HuaXing Zhu (Peking University)

Date: 7.24 Time: 14:00-14:45 Venue: Lecture Room 4 (A3-2 1F)

Conformal symmetry has recently been found to have unexpected applications in quantum chromodynamics (QCD) at high energy, particularly in the calculation of energy flow correlations at the Large Hadron Collider (LHC) and other collider experiments. This builds on previous studies of using collider observables to constrain conformal field theory, known as conformal collider physics. This talk provides a comprehensive review of the progress made in this field, highlighting the power of symmetry in interpreting experimental results and the implications for our understanding of QCD at high energies. The insights gained from these findings have led to the discovery of new experimental phenomena, which demand a deeper understanding of QCD in Minkowski spacetime.

Monday, July 24, Afternoon Session III

Studies on cosmic ray origin and propagation with DAMPE and LHAASO

Qiang Yuan (Purple Mountain Observatory, Chinese Academy of Sciences)

Date: 7.24 Time: 15:15-16:00 Venue: Lecture Room 4 (A3-2 1F)

After more than 110 years of the discovery of cosmic rays, their origin and propagation remains one of the most important unresolved questions of the cosmos. Precise measurements of the spectra, composition, and anisotropies of cosmic rays are the key to understand such problems. In recent years, China launched the space satellite, the Dark Matter Particle Explorer (DAMPE), and built the Large High Altitude Air Shower Observatory (LHAASO), which are dedicated to uncovering the origin of cosmic rays. The progresses of these two projects will be presented.

Monday, July 24, Afternoon Session IV

Operator size distribution and its dynamical transition

Pengfei Zhang (Fudan University)

Date: 7.24 Time: 16:15-17:00 Venue: Lecture Room 4 (A3-2 1F)

Information scrambling emerges as a cornerstone in understanding thermalization in most closed quantum systems. In such systems, the initial information, though fully preserved under the unitary evolution, is scrambled from local physical objects into those highly non-local objects. The operator size distribution provides a quantitative description of the information scrambling dynamics. In this talk, I will present two recent works on operator size distribution. In the first work, we derive the full time evolution of the size distribution in large N quantum mechanics using the scramblon effective theory. In the second work, we study the dynamics of operator size in open systems, revealing novel dynamical phase transitions driven by the competition between scrambling and dissipation.

Tuesday, July 25, Morning Session I

The open string pair production, its enhancement and more

Jianxin Lu (University of Science and Technology of China)

Date: 7.25 Time: 08:00-09:00 Venue: Lecture Room 4 (A3-2 1F)

In this talk, I will discuss the open string pair production of two D-branes placed parallel at a separation when either or both carry electric plus possible magnetic fluxes in Type II superstring theories. I will also discuss the enhancement of this pair production with the presence of a particular magnetic flux in addition to the applied electric one. However, for the system of D0/Dp, one in general does not expect such a pair production to occur. I will explore the case for which a finite non-vanishing open string pair production rate can indeed be produced when a certain worldvolume flux is applied to the Dp brane.

Tuesday, July 25, Morning Session II

Exploring Particle Physics Frontiers with Perturbative Quantum Field Theories

Lilin Yang (Zhejiang University)

Date: 7.25 Time: 09:15-10:15 Venue: Lecture Room 4 (A3-2 1F)

Our current understanding of physics at the smallest scale is based on the Standard Model of Particle Physics. However, that is not the end of the story, and we need to scrutinize this theory at various frontiers in order to push its limits. In this lecture, I will describe some mathematical tools in perturbative quantum field theories, and the applications in our exploration of the properties of fundamental particles.

Tuesday, July 25, Morning Session III

Did LIGO detect primordial black holes?

Qing-Guo Huang (Institute of Theoretical Physics, Chinese Academy of Sciences)

Date: 7.25 Time: 10:30-11:30 Venue: Lecture Room 4 (A3-2 1F)

After the detection of coalescence of binary black holes by LIGO, a key question reads what the origin of these black holes is. Recently, we realize that primordial black holes may provide an explanation of these merger events, and can consist of all of the dark matter in our Universe. We will explore how to probe primordial black holes with multi-band gravitational waves.

Tuesday, July 25, Afternoon Session I

From the smallest to the largest: Understanding particles through the universe

Yi Wang (Hong Kong University of Science and Technology)

Date: 7.25 Time: 13:00-13:45 Venue: Lecture Room 4 (A3-2 1F)

The universe works as a particle collider: In the primordial universe, the nature of elementary particles, such as mass, spin, decay width and CP, are imprinted on the density distribution of the universe, and can be measured by studying galaxy correlations today. This talk is an overview on how this "cosmological collider" works.

Tuesday, July 25, Afternoon Session II

3D integrability in supersymmetric gauge theories and M-theory

Junya Yagi (Tsinghua University)

Date: 7.25 Time: 14:00-14:45 Venue: Lecture Room 4 (A3-2 1F)

The Zamolodchikov tetrahedron equation is a fundamental relation for the integrability of 3D lattice models in statistical mechanics, playing a role similar to the Yang-Baxter equation in 2D lattice models. I will discuss recent developments in which new solutions of the tetrahedron equation were constructed with use of quantum cluster algebras and related to 3D supersymmetric gauge theories, and a well-known solution was argued to arise from a brane system in M-theory.

Tuesday, July 25, Afternoon Session III

Neutrino masses and new physics beyond the standard model

Shun Zhou (Institute of High Energy Physics, Chinese Academy of Sciences)

Date: 7.25 Time: 15:15-16:00 Venue: Lecture Room 4 (A3-2 1F)

The discovery of neutrino oscillations indicates that neutrinos are massive, calling for new physics beyond the Standard Model of elementary particles. In this lecture, we introduce the simplest and most natural extensions of the Standard Model to account for neutrino masses and explain how to explore the related new physics in the future experiments.

Tuesday, July 25, Afternoon Session IV

A quantum information perspective on entanglement islands

Qiang Wen (Southeast University)

Date: 7.25 Time: 16:15-17:00 Venue: Lecture Room 4 (A3-2 1F)

I will give a purely quantum information perspective for the Island formula. In a quantum system when the state of a subset is totally encoded in the state of another subset, the way we compute the reduced density matrix and related entropy quantities will change essentially, which result in a new island formula in quantum systems, which we conjecture to be the same island formula in gravity recently proposed to rescue the unitarity for black hole evaporation. The new perspective help us better understand the entanglement wedge cross-section in island phases in the context of partial entanglement entropy.

Wednesday, July 26, Morning Session I

Parton Distributions and Progresses in Lattice Gauge Field Theory

Wei Wang (Shanghai Jiaotong University)

Date: 7.24 Time: 16:45-17:45 Venue: Lecture Room 8 (A3-4 3F)

Parton distributions on the lightcone are mandatory inputs in high energy scattering and play an important role in searching for new physics at high energy. In this lecture, I will review fundamental properties on patron distributions, and recent progresses, in particular on the lattice QCD stimulation based on the large momentum effective theory.

Wednesday, July 26, Morning Session II

The TsT/$T\bar{T}$ correspondence

Wei Song (Tsinghua University)

Date: 7.26 Time: 09:15-10:00 Venue: Lecture Room 4 (A3-2 1F)

IIB string theory on AdS3 with NS-NS flux admits two CFT descriptions, a WZW model on the string worldsheet, and a holographic dual CFT at the asymptotic boundary. This example of AdS3/CFT2 correspondence allows us to build a class of toy models of holographic dualities beyond the AdS/CFT correspondence by deforming the two CFTs. On the string theory side, we can perform a TsT transformations(T-duality, shift, and T-duality), leading to a new string background that interpolates locally AdS3 in the IR and linear dilaton background in the UV. On the boundary, the holographic dual is conjectured to be a single trace version of TTbar deformation. As supporting evidence, we find a matching of the deformed spectrum, the thermodynamics of black holes, and correlation functions.

Wednesday, July 26, Morning Session III

RG fixed point tensors and factorisation of 2d CFT

Ling Yan Hung (Tsinghua University)

Date: 7.26 Time: 10:15-11:00 Venue: Lecture Room 4 (A3-2 1F)

We will review the construction of an RG operator that explicitly preserves a given categorical symmetry. We discuss exact fixed points of these RG operators describing 2D CFTs, and their relationship with factorising closed string into open string degrees freedom, and the relation to the entanglement boundary condition discussed in the literature.

Wednesday, July 26, Afternoon Session I

Searching for physics beyond the Standard Model with astrophysical and cosmological phenomena

Haipeng An (Tsinghua University)

Date: 7.26 Time: 13:00-13:45 Venue: Lecture Room 4 (A3-2 1F)

Focusing on dark matter and gravitational waves, I will discuss recent development in looking for new physics beyond the Standard Model of Particle Physics in astrophysical and cosmological observations.

Wednesday, July 26, Afternoon Session II

Probing new physics through gravitational wave observations

Jing Ren (Institute of High Energy Physics, Chinese Academy of Sciences)

Date: 7.26 Time: 14:00-14:45 Venue: Lecture Room 4 (A3-2 1F)

Despite the great success of the standard model of particle physics and general relativity, there is compelling evidence for the existence of new physics. Meanwhile, gravitational wave astronomy has rapidly advanced in recent years, providing a wealth of observational data that can be used to expand our search for new physics. The detection of compact binary coalescences by ground-based interferometers provide a unique opportunity to explore physics in the immediate vicinity of black holes. Quantum gravity corrections may be detected through gravitational wave echoes, representing a promising avenue for new physics research. Pulsar timing arrays, acting as galactic-scale interferometers, can detect stochastic gravitational waves as well as wave dark matter. By further incorporating polarization information, the collected data can be used to probe non-gravitational interaction of dark matter to confirm its nature. High-frequency gravitational waves carry a wealth of information on the early Universe. They can be detected through GW-to-photon conversion in laboratory, galactic and cosmic magnetic fields, as well as planet and neutron star magnetospheres. Overall, the intersection of high energy physics and astronomy presents a rapidly growing field with exciting new opportunities, and the use of gravitational wave observations has a vast potential to shed light on the mysteries of the Universe.

Wednesday, July 26, Afternoon Session III

Integrable boundary states: from quench dynamics to AdS/CFT

Yunfeng Jiang (Shing-Tung Yau Center of Southeast University)

Date: 7.26 Time: 15:15-16:00 Venue: Lecture Room 4 (A3-2 1F)

Integrable boundary states are fascinating quantum states which can be defined for a wide range of integrable models. In the first part of the talk, I will give the definition of integrable boundary states in QFT and then discuss the generalizations to spin chains and 1D Bose gas. I will then discuss their important properties. As an example, I will discuss an intriguing state called crosscap state, which can be defined universally for all the aforementioned models. In the second part of the talk, I will present applications of integrable boundary states. These include quench dynamics in statistical mechanics and the computation of certain correlation functions in AdS/CFT correspondence.

Wednesday, July 26, Afternoon Session IV

Geometric engineering of QFTs and generalized symmetries

Yinan Wang (Peking University)

Date: 7.26 Time: 16:15-17:00 Venue: Lecture Room 4 (A3-2 1F)

The superstring/M-theory framework is a powerful tool to construct a large class of supersymmetric quantum field theories, especially SCFTs. In this talk, I will introduce my recent works on the subject, with a particular emphasis on their generalized global symmetries. In particular, I will present the computation of higher-form symmetries and non-invertible symmetries for non-Lagrangian QFTs, using the geometric engineering approach.

Thursday, July 27, Morning Session I

TBA

Qikun Xue (Southern University of Science and Technology)

Date: 7.27 Time: 08:00-09:00 Venue: Lecture Room 4 (A3-2 1F)

TBA

Thursday, July 27, Morning Session II

Theory for High Tc Superconducting Cuprates

Fuchun Zhang (University of Chinese Academy of Sciences)

Date: 7.27 Time: 09:15-10:15 Venue: Lecture Room 4 (A3-2 1F)

Theoretical progress will be reviewed in mechanism for high Tc cuprates from the viewpoint of doped Mott insulator. The pros and cons of Anderson's RVB theory will be discussed in connection with most recent experimental and simulation results.

Thursday, July 27, Morning Session III

Spin superconductor and electric dipole superconductor

Xin-Cheng Xie (Peking University & Fudan University)

Date: 7.27 Time: 10:30-11:30 Venue: Lecture Room 4 (A3-2 1F)

We propose the concept of the spin superconductor (SSC), a counterpart to the charge superconductor. We carry out theoretical study to show the existence of a spin superconductor in a ferromagnetic graphene, in which the spin-polarized electron-hole excitons play the roles of the 'Cooper' pairs. We present a BCS-type theory and the Laudau-Ginzburg theory for the SSC. With the "London-type equations" of the super-spin-current density, we show the existence of an electric "Meissner effect" against a spatial varying electric field. We further study a SSC/normal conductor/SSC junction and predict a spin-current Josephson effect. Recent experimental results showing the possible sign of a spin superconductor will also be reported. Some aspect of the electric dipole superconductor will also be discussed.

Thursday, July 27, Afternoon Session I

Theory of a strange metal at the breakdown of a heavy Fermi liquid

Erik Aldape (University of California, Berkeley)

Date: 7.27 Time: 13:00-13:45 Venue: Lecture Room 4 (A3-2 1F)

We introduce an effective theory for quantum critical points (QCPs) in heavy-fermion systems, involving a change in carrier density without symmetry breaking. Our theory captures a strongly coupled metallic QCP, leading to robust marginal Fermi-liquid transport phenomenology, and associated linear in temperature "strange metal" resistivity, all within a controlled large-N limit. This is contrasted with the conventional so-called "slave boson" theory of the Kondo breakdown, where the large-N limit describes a weak coupling fixed point and nontrivial transport behavior may only be obtained through uncontrolled 1/N corrections. We compute the weak field Hall coefficient within the effective model as the system is tuned across the transition. We find that between the two plateaus, reflecting the different carrier densities in the two Fermi liquid phases, the Hall coefficient can develop a peak in the critical crossover regime, consistent with recent experimental findings. In the parameter regime of strong damping of emergent bosonic excitations, the QCP also displays a near-universal "Planckian" transport lifetime determined only by the temperature, the Boltzmann constant and the Planck constant.

Thursday, July 27, Afternoon Session II

Global phase diagram of twisted Bilayer graphene

Glenn Wagner (University of Zürich)

Date: 7.27 Time: 14:00-14:45 Venue: Lecture Room 4 (A3-2 1F)

We investigate the full doping and strain-dependent phase diagram of the normal state of magic-angle twisted bilayer graphene. Using comprehensive Hartree-Fock calculations, we show that at temperatures where superconductivity is absent the global phase structure can be understood based on the competition and coexistence between three types of intertwined orders: a fully symmetric phase, spatially uniform flavor-symmetry-breaking states, and an incommensurate Kekulé spiral (IKS) order.

Thursday, July 27, Afternoon Session III

The rise of intrinsic magnetic topological insulators

Mikhail Otrokov (Ikerbasque Materials Physics Center (MPC))

Date: 7.27 Time: 15:15-16:00 Venue: Lecture Room 4 (A3-2 1F)

In this talk, I will tell the story of the discovery of the intrinsic magnetic topological insulators (MTIs) of the MnBi2Te4 family attracting a great deal of attention nowadays. To describe the context in which the intrinsic MTIs appeared in the research arena, I will briefly discuss the magnetic doping and magnetic proximity effect approaches of introducing magnetism into TIs, whose limitations triggered the rise of materials of the MnBi2Te4 family. Then, the two types of novel topological heterostructures involving the MnBi2Te4 thin films will be discussed, which anticipated the appearance of the intrinsic MTIs. Finally, I will present our theoretical prediction and immediate experimental confirmation of the first antiferromagnetic TI, MnBi2Te4 [1]. This discovery raised a huge interest and many groups around the world instantly joined the topic that has now consolidated itself as a standalone and rapidly growing field. As a result, MnBi2Te4-based systems have been predicted or observed to show 11 different types of Hall effect. Some of them are fundamentally new, such as layer Hall effect. Besides, MnBi2Te4 is predicted to be a platform for realizing high-Chern number phases, high-order topological insulator

and superconductor states, Weyl semimetal phase, axion electrodynamics, Majorana fermions, and many others. Novel device proposals specific to the MnBi2Te4 family have already been put forward, such as transistors, rectifiers, spin filters,to name a few. Quantum computing and sensing applications have also been envisioned recently.
[1] M.M. Otrokov, I.I. Klimovskikh, H. Bentmann, et al. Prediction and observation of an antiferromagnetic topological insulator. Nature 576, 416 (2019).

Thursday, July 27, Afternoon Session IV

Non-Hermitian parent hamiltonian and composite quantum phases

Shuo Yang (Tsinghua University)

Date: 7.27 Time: 16:15-17:00 Venue: Lecture Room 4 (A3-2 1F)

Non-Hermitian systems provide a rich playground to explore novel many-body phenomena not present in Hermitian settings. However, directly constructing interacting non-Hermitian models that exhibit unique features remains challenging. In this talk, we introduce a new method to systematically construct non-Hermitian many-body Hamiltonians by generalizing the parent Hamiltonian approach to non-Hermitian regimes. Applying this method, we construct a non-Hermitian spin-1 model which preserves both chiral order and symmetry-protected topological order. Our approach opens up new avenues to design non-Hermitian many-body systems and study their properties. In addition, we present a precise definition of quantum phases for non-Hermitian systems and propose a new class of phases dubbed composite quantum phases. We demonstrate the existence of these phases in our spin-1 model and show their robustness. Our work establishes a framework to explore quantum phases and phenomena in interacting non-Hermitian systems.
[1] Ruohan Shen, Yuchen Guo, Shuo Yang, Construction of Non-Hermitian Parent Hamiltonian from Matrix Product States, Phys. Rev. Lett. 130, 220401 (2023).
[2] Yuchen Guo, Ruohan Shen, Shuo Yang, Composite Quantum Phases in Non-Hermitian Systems, arXiv:2304.04588.

Friday, July 28, Morning Session I

TBA

Philip Candelas (University of Oxford)

Date: 7.28 Time: 08:00-09:00 Venue: Lecture Room 4 (A3-2 1F)

TBA

Friday, July 28, Morning Session II

From linear algebra to Feynman integrals

Yan-Qing Ma (Peking University)

Date: 7.28 Time: 09:15-10:15 Venue: Lecture Room 4 (A3-2 1F)

Feynman integrals play a crucial role in quantum field theory, yet they are extremely hard to compute. I will show that all Feynman integrals, to any loop orders and including all types of propagators, are completely determined by linear algebra between Feynman integrals. This observation results in a very powerful method to calculate arbitrary Feynman integrals to high precision.

Friday, July 28, Morning Session III

TBA

Hong Yao (Tsinghua University)

Date: 7.28 Time: 10:30-11:30 Venue: Lecture Room 4 (A3-2 1F)

TBA

Friday, July 28, Afternoon Session I

Amoeba formulation of non-Hermitian band theory

Zhong Wang (Tsinghua University)

Date: 7.28 Time: 13:00-13:45 Venue: Lecture Room 4 (A3-2 1F)

Many aspects of non-Hermitian systems are not well described in the framework of Bloch band theory. The non-Bloch band theory, in which the concept of Brillouin zone is generalized, has been widely applied to study non-Hermitian systems in one spatial dimension. However, its generalization to higher dimensions has been challenging. Here, we introduce a formulation of non-Hermitian band theory in arbitrary spatial dimensions, which is based on a natural geometrical object known as the amoeba. This theory provides a general framework for studying non-Hermitian bands beyond one dimension. Key quantities of non-Hermitian bands, including the energy spectrum, eigenstates profiles, and the generalized Brillouin zone, can be efficiently obtained from this approach. Reference: H.-Y. Wang, F. Song, Z. Wang, arXiv:2212.11743

Friday, July 28, Afternoon Session II

Analytical methods for QFT amplitudes in dS spacetime

Zhong-Zhi Xianyu (Tsinghua University)

Date: 7.28 Time: 14:00-14:45 Venue: Lecture Room 4 (A3-2 1F)

Inflation correlators encode ultra-high-energy physics at the inflation scale and are promising targets for future cosmological observations. Theory-wise, these objects are boundary correlators of bulk dS quantum fields, which play crucial roles in our understanding of QFT in dS. However, the analytical computation of dS correlators is notoriously difficult, and significant progress has been made only in recent years. In this talk, I shall introduce our recent efforts in understanding and computing inflation correlators. I shall describe new analytical tools we have developed, including the partial Mellin-Barnes representation, the bootstrap equations, and the spectral decomposition. I shall also present new results and insights we obtained with these techniques, including exact and analytical expressions for a wide range of inflation correlators at both tree and 1-loop levels, a 1-loop factorization theorem, the cutting rule, and the boundary OPE.

Friday, July 28, Afternoon Session III

TBA

Hossein Yavartanoo (Yanqi Lake Beijing Institute of Mathematical Sciences and Applications (BIMSA))

Date: 7.28 Time: 15:15-16:00 Venue: Lecture Room 4 (A3-2 1F)

TBA

Theoretical Computer and Information Sciences

Titles and Abstracts

Monday, July 17, Afternoon Session I

An alternative view on AI: Collaborative learning, incentives, and social welfare

Michael Jordan (University of California, Berkeley)

Date: 7.17 Time: 13:30-14:30 Venue: Lecture Room 12 (A7 3F)

Artificial intelligence (AI) has focused on a paradigm in which intelligence inheres in a single, autonomous agent. Social issues are entirely secondary in this paradigm. When AI systems are deployed in social contexts, however, the overall design of such systems is often naive—a centralized entity provides services to passive agents and reaps the rewards. Such a paradigm need not be the dominant paradigm for information technology. In a broader framing, agents are active, they are cooperative, and they wish to obtain value from their participation in learning-based systems. Agents may supply data and other resources to the system, only if it is in their interest to do so. Critically, intelligence inheres as much in the overall system as it does in individual agents, be they humans or computers. This is a perspective familiar in the social sciences, and a first goal in this line of work is to bring economics into contact with the computing and data sciences. The long-term goal is two-fold—to provide a broader conceptual foundation for emerging real-world AI systems, and to upend received wisdom in the computational, economic, and inferential disciplines.

Quantum-inspired computational imaging

Vivek Goyal (Boston University)

Date: 7.17 Time: 13:30-14:15 Venue: Lecture Room 13 (A7 3F)

Computational imaging is the fusion of computational methods and imaging techniques with the aim of producing better images, including examples where it is potentially surprising that any image can be formed at all. The development of new imaging sensors and, in particular, instruments with single-photon sensitivity has resulted in a surge of activity in this field. This talk will present a sampling of recent results that highlight the gains that have been made from physics-driven probabilistic modeling at the level of single-photon detection.

Frontiers of Science Award Paper: Yoann Altmann, Stephen McLaughlin, Miles J. Padgett, Vivek K. Goyal, Alfred O. Hero, and Daniele Faccio. Quantum-inspired computational imaging. *Science*, 361(6403):660+, Aug 17 2018

Monday, July 17, Afternoon Session II

An integrated imaging sensor for aberration-corrected 3D photography

Lu Fang (Tsinghua University)

Date: 7.17 Time: 14:30-15:45 Venue: Lecture Room 13 (A7 3F)

Planar digital image sensors facilitate broad applications in a wide range of areas and the number of pixels has scaled up rapidly in recent years. However, the practical performance of imaging systems is fundamentally limited by spatially nonuniform optical aberrations originating from imperfect lenses or environmental disturbances. We propose an integrated scanning light-field imaging sensor, termed unstructured meta-imaging sensor, to achieve high-performance photography up to a gigapixel with a single spherical lens without a data prior, leading to orders-of-magnitude reductions in system capacity and costs for optical imaging. Moreover, high-density accurate depth maps can be retrieved simultaneously, facilitating diverse applications from autonomous driving to industrial inspections.

Frontiers of Science Award Paper: Jiamin Wu, Yuduo Guo, Chao Deng, Anke Zhang, Hui Qiao, Zhi Lu, Jiachen Xie, Lu Fang, and Qionghai Dai. An integrated imaging sensor for aberration-corrected 3D photography. *Nature*, 612(7938):62–71, December 2022

Monday, July 17, Afternoon Session III

Statistical methods for estimating cell-type-specific gene co-expressions using single cell and bulk RNA-seq data

Hongyu Zhao (Yale University)

Date: 7.17 Time: 15:15-16:15 Venue: Lecture Room 12 (A7 3F)

The inference of gene co-expressions from microarray and RNA-sequencing data has motivated many methodology developments for high-dimensional data and led to rich insights on biological processes and disease mechanisms. However, the bulk samples analyzed in most studies are a mixture of different cell types. As a result, the inferred co-expressions are confounded by varying cell type compositions across samples and only offer an aggregated view of gene regulations that may be distinct across different cell types. In this talk, we introduce two complementary statistical methods for inferring cell-type-specific co-expression networks based on two distinct sources of RNA sequencing (RNA-seq) data. First, to address the unique opportunity and challenge from the recently developed single cell RNA-seq (scRNA-seq) technology, we developed a method, named CS-CORE, that explicitly addresses the high sequencing depth variations and measurement errors present in single cell data for estimating and testing cell-type-specific co-expression. When applied to analyze multiple scRNA-seq datasets including those on Alzheimer's disease, CS-CORE identified cell-type-specific co-expressions and differential co-expressions that were more reproducible and/or more enriched for relevant biological pathways than those inferred from the existing methods. Moreover, to leverage the rich collection of bulk RNA-seq data, we also developed CSNet, a flexible framework to estimate cell-type-specific gene co-expression networks from bulk sample data. We show that the proposed sparse least squares estimator is efficient to implement and enjoys good theoretical properties. When applied to analyze bulk RNA-seq data from Alzheimer's disease, CSNet identified previously unknown cell-type-specific co-expressions among Alzheimer's disease risk genes, suggesting cell-type-specific disease pathology for Alzheimer's disease. This is joint work with Chang Su, Jingfei Zhang, Zichun Xu, Xinning Shan, and Biao Cai.

Monday, July 17, Afternoon Session IV

Artificial intelligence for 6G mobile communications

Jiangzhou Wang (University of Kent)

Date: 7.17 Time: 16:30-17:30 Venue: Lecture Room 12 (A7 3F)

Because there are many vertical industry applications, mobile communication has been developed very rapidly. This lecture will discuss the application of artificial intelligence/reinforcement learning in 6G mobile communications. The lecture will explain why mobile communication requires artificial intelligence/reinforcement learning and how it works, and finally give application examples.

Information metasurface – simultaneous modulations of waves and digital information in electromagnetic space

Tie Jun Cui (Southeast University)

Date: 7.17 Time: 16:00-16:45 Venue: Lecture Room 13 (A7 3F)

We proposed the concepts of digital coding metamaterial and metasurface, in which the meta-atoms are represented by using digital states of phases. The digital representation of metamaterial and metasurface makes it possible to manipulate the electromagnetic waves and modulate the digital information simultaneously on the same platform, evolving a new direction of information metamaterial and metasurface. The information metasurfaces set up a bridge between the physical world and the digital world. Integrated with field programmable gate array (FPGA), the information metasurfaces can control the electromagnetic waves and process the digital information in real time and programmable way. Based on the information metasurfaces, new-architecture microwave imaging and wireless communication systems have been designed and realized, showing great potentials in the next-generation wireless applications.

Frontiers of Science Award Paper: Xin Ge Zhang, Wei Xiang Jiang, Hao Lin Jiang, Qiang Wang, Han Wei Tian, Lin Bai, Zhang Jie Luo, Shang Sun, Yu Luo, Cheng-Wei Qiu, and Tie Jun Cui. An optically driven digital metasurface for programming electromagnetic functions. *Nature Electronics*, 3(3):165–171, Mar 2020

Tuesday, July 18, Morning Session I

Robotics, AI, and real-world challenges

Kazuhiro Kosuge (University of Hong Kong)

Date: 7.18 Time: 08:00-09:00 Venue: Lecture Room 12 (A7 3F)

Current AI cannot provide a complete solution for real-world robotics challenges. Still, AI is a valuable tool for robotic applications for real-world challenges that traditional methods cannot solve. This talk will discuss how robotics and AI can solve real-world problems, such as collaborative robots and the manipulation of soft materials.

Brain activity , numbers in the brain and reading your thoughts

Mina Teicher (Bar-Ilan University)

Date: 7.18 Time: 08:00-09:00 Venue: Lecture Room 13 (A7 3F)

In the lecture , I'll briefly mention what is currently known about the Brain, will mention the main models for Brain activity , will present and review our proof of the synchronization conjecture (in behaving animals), and how it reflects on the synfire chain model. I'll explain my conjecture on numeration in the brain and it's (partial) proof , and how we can read from your Brain activity what numbers you currently think on .

Tuesday, July 18, Morning Session II

Nano science of universe

Ningsheng Xu (Fudan University)

Date: 7.18 Time: 09:15-10:15 Venue: Lecture Room 13 (A7 3F)

To raise issues of nano science of the universe. Currently studies have been focused on smaller and smaller scale nanomaterials around ourselves, and such scheme should be changed, and new research strategy will be proposed. Key issues to include the followings and beyond: i) nanomaterials exist in the universe and their synthesis mechanisms. ii) nanomaterials may lead to lives in the universe. iii) complex processes occurring in nano space of the universe.

On recommendations via large multi-modal models

Philip S. Yu (University of Illinois Chicago)

Date: 7.18 Time: 09:15-10:15 Venue: Lecture Room 12 (A7 3F)

As the variety of products and services continues to increase, recommender systems play a critical role in assisting customers by presenting products or services that are likely to be of interest to them. In the era of big data, there is an abundance of data available from various sources, encompassing different modalities. In addition to user rating information on products, other relevant data sources can include social networks, knowledge bases, product descriptions and reviews, as well as contextual and temporal information. Even cross-domain and cross-site information can prove useful. In this talk, our focus is on utilizing large multi-modal models through broad learning to fuse multiple information sources of diverse modalities and perform synergistic deep recommendation tasks across these fused sources in a unified manner. We examine the various heterogeneous information sources and explore ways to enhance the effectiveness of recommendation systems by leveraging large multimodal models to harness the power of deep and broad learning.

Tuesday, July 18, Morning Session III

Classification program of counting problems

Jin-Yi Cai (University of Wisconsin, Madison)

Date: 7.18 Time: 10:30-11:30 Venue: Lecture Room 13 (A7 3F)

I will describe advances in the complexity classification of counting problems: graph homomorphisms, counting constraint satisfaction problems, and Holant problems.

Mapping and predicting protein dynamics in living cells

Bo Huang (University of California, San Francisco)

Date: 7.18 Time: 10:30-11:30 Venue: Lecture Room 12 (A7 3F)

Cellular processes are orchestrated by a large number of biomolecules in a spatially and temporally coordinated manner within a tiny volume. To uncover the underlying organizational principles and their functional relevance, we take microscopy visualization as the primary approach to systematically map their spatial localization, temporal dynamics and activity profiles. By combining small tags engineered from split fluorescence proteins and CRISPR/Cas9-mediated gene editing, we have enabled large-scale tagging of endogenous proteins in human cell lines for both microscopy visualization and biochemical analysis. We have further developed the deep-learning framework to connect cellular images of proteins to their amino acid sequences.

Tuesday, July 18, Afternoon Session I

Intelligent image-activated cell sorting

Keisuke Goda (University of Tokyo)

Date: 7.18 Time: 13:00-13:45 Venue: Lecture Room 13 (A7 3F)

Deciphering the immense heterogeneity of cells - particularly the relationship between their spatial architecture and physiological function - remains a central challenge in biology. Regrettably, conventional methodologies such as fluorescence-activated cell sorting and the Coulter counter fall short in revealing these connections and tapping into their potential biomedical applications. In this presentation, I will unveil Intelligent Image-Activated Cell Sorting, a breakthrough technology designed to execute real-time, intelligent, image-based cell sorting at an unparalleled rate of over 1000 cells per second (Nitta et al, Cell 2018; Isozaki et al, Nat. Protoc. 2019; Nitta et al, Nat. Commun. 2020; Mikami et al, Nat. Commun. 2020). This novel technology amalgamates

high-throughput optical imaging, cell focusing, cell sorting, and deep learning within a hybrid software-hardware data-management infrastructure. This integration allows for real-time automated operations encompassing data acquisition, processing, intelligent decision-making, and actuation. Furthermore, I will explore an innovative class of applications in fields such as immunology, cancer biology, infectious disease, microbiology, and food science, all enabled by this groundbreaking technology.

Frontiers of Science Award Paper: Nao Nitta, Takeaki Sugimura, Akihiro Isozaki, Hideharu Mikami, Kei Hiraki, Shinya Sakuma, Takanori Iino, Fumihito Arai, Taichiro Endo, Yasuhiro Fujiwaki, Hideya Fukuzawa, Misa Hase, Takeshi Hayakawa, Kotaro Hiramatsu, Yu Hoshino, Mary Inaba, Takuro Ito, Hiroshi Karakawa, Yusuke Kasai, Kenichi Koizumi, SangWook Lee, Cheng Lei, Ming Li, Takanori Maeno, Satoshi Matsusaka, Daichi Murakami, Atsuhiro Nakagawa, Yusuke Oguchi, Minoru Oikawa, Tadataka Ota, Kiyotaka Shiba, Hirofumi Shintaku, Yoshitaka Shirasaki, Kanako Suga, Yuta Suzuki, Nobutake Suzuki, Yo Tanaka, Hiroshi Tezuka, Chihana Toyokawa, Yaxiaer Yalikun, Makoto Yamada, Mai Yamagishi, Takashi Yamano, Atsushi Yasumoto, Yutaka Yatomi, Masayuki Yazawa, Dino Di Carlo, Yoichiroh Hosokawa, Sotaro Uemura, Yasuyuki Ozeki, and Keisuke Goda. Intelligent image-activated cell sorting. *Cell*, 175(1):266+, Sep 20 2018

Bone-inspired infill optimization for additive manufacturing

Jun Wu (Delft University of Technology)

Date: 7.18 Time: 13:00-13:45 Venue: Lecture Room 12 (A7 3F)

Nature is a great source of inspiration for creating structures that efficiently utilize materials and energy. An excellent example is trabecular bone, which is not only lightweight but also capable of supporting mechanical loads effectively during our daily activities. In this talk, I will present computational approaches to design bone-like porous structures for engineering purposes. The basic principle involves selectively placing material where it is necessary and eliminating material where it is less crucial. The formulation of porous structures is driven by a novel geometric criterion that regularizes the material distribution. Additionally, I will discuss numerical and geometric methods to reduce the involved computation. I will also establish connections between this computational design approach and advances in additive manufacturing (also known as 3D printing), which enable the physical realization of optimized porous structures. Throughout the talk, I will showcase various applications that benefit from this approach, including customized orthopedic implants and lightweight components for future mobility solutions.

Frontiers of Science Award Paper: Jun Wu, Niels Aage, Ruediger Westermann, and Ole Sigmund. Infill optimization for additive manufacturing-approaching bone-like porous structures. *IEEE Transactions on Visualization and Computer Graphics*, 24(2):1127–1140, Feb 2018

Tuesday, July 18, Afternoon Session II

Need for speed: high-performance algorithms in genomics

Heng Li (Dana-Farber Cancer Institute & Harvard Univeristy)

Date: 7.18 Time: 14:00-14:45 Venue: Lecture Room 13 (A7 3F)

TBA

Frontiers of Science Award Paper: Heng Li. Minimap2: pairwise alignment for nucleotide sequences. *Bioinformatics*, 34(18):3094–3100, Sep 15 2018

What makes a good 3D representation?

Yue Wang (University of Southern California)

Date: 7.18 Time: 14:00-14:45 Venue: Lecture Room 12 (A7 3F)

Deep learning has demonstrated considerable success embedding images and more general 2D representations into compact feature spaces for downstream tasks like recognition, registration, and generation. Learning from 3D data, however, is the missing piece needed for embodied agents to perceive their surrounding environments. To bridge the gap between 3D perception and robotic intelligence, my present efforts focus on learning 3D representations with minimal supervision. In this talk, I will discuss my opinions and experiences towards building 3D representations for autonomous driving and robotics. First, I will cover my PhD works that mainly target learning 3D representations from point clouds. Then, I will discuss our recent efforts using neural fields as representations for robotics and autonomous driving. I will cover both benefits and barriers of neural fields. Finally, the talk will conclude with a discussion about future inquiries to design complete and active 3D learning systems.

Frontiers of Science Award Paper: Yue Wang, Yongbin Sun, Ziwei Liu, Sanjay E. Sarma, Michael M. Bronstein, and Justin M. Solomon. Dynamic graph CNN for learning on point clouds. *ACM Transactions on Graphics*, 38(5), Nov 2019

Tuesday, July 18, Afternoon Session III

Contrastive learning of visual representations

Ting Chen (Google)

Date: 7.18 Time: 15:15-16:00 Venue: Lecture Room 13 (A7 3F)

Contrastive learning, exemplified by SimCLR, CLIP and many others, has achieved impressive results for learning visual representations from images and image-text pairs. In this talk, I will cover topics on contrastive self-supervised learning, including an overview of a few basic contrastive methods, important factors in contrastive learning, simple approaches for semi-supervised learning (with lots of unlabeled images and a few labeled images), some intriguing properties and open challenges of existing contrastive learning methods.

Frontiers of Science Award Paper: Ting Chen, Simon Kornblith, Mohammad Norouzi, and Geoffrey Hinton. A Simple Framework for Contrastive Learning of Visual Representations. In Hal Daumé III and Aarti Singh, editors, *Proceedings of the 37th International Conference on Machine Learning*, volume 119 of *Proceedings of Machine Learning Research*, pages 1597–1607. PMLR, 13–18 Jul 2020

Neural radiance fields for view synthesis and beyond

Ravi Ramamoorthi (University of California, San Diego)

Date: 7.18 Time: 15:15-16:00 Venue: Lecture Room 12 (A7 3F)

Neural Radiance Fields have emerged as a new paradigm, not only for the original goal of view synthesis from input images, but as a novel volumetric representation of object geometry in a range of applications in computer vision, graphics, robotics and beyond. This talk will first describe our journey in finding the correct representation for deep learning-based view synthesis, culminating in the original NeRF paper, then discuss some of the exciting practical extensions today to nearly instant training and rendering, text-based editing, real-time radiance fields from portraits and many others, including practical adoption in the metaverse, for digital twins and streetview.

Frontiers of Science Award Paper: Ben Mildenhall, Pratul P. Srinivasan, Matthew Tancik, Jonathan T. Barron, Ravi Ramamoorthi, and Ren Ng. NeRF: Representing scenes as neural radiance fields for view synthesis. *Communications of the ACM*, 65(1):99–106, Jan 2022

Towards scalable and automatic neural network training

Cho-Jui Hsieh (University of California, Los Angeles)

Date: 7.18 Time: 16:15-17:00 Venue: Lecture Room 13 (A7 3F)

In this talk, I will discuss how to design a scalable neural network optimizer, from human-based design to AI-based automatic design. The first part of the talk will center around my journey in developing scalable optimizers, including Cluster-GCN, LAMB, and various second-order optimizers. The second part of the talk will introduce some of our initial efforts in automating the optimizer design, including an efficient optimizer search framework and automatically discovered algorithms that surpass Adam's performance on several large-scale training tasks.

Frontiers of Science Award Paper: Wei-Lin Chiang, Xuanqing Liu, Si Si, Yang Li, Samy Bengio, and Cho-Jui Hsieh. Cluster-GCN: An Efficient Algorithm for Training Deep and Large Graph Convolutional Networks. In *Proceedings of the 25th ACM SIGKDD International Conference on Knowledge Discovery & Data Mining*, KDD '19, pages 257–266. Assoc Comp Machinery; Assoc Comp Machinery SIGKDD; Assoc Comp Machinery SIGMOD, 2019. 25th ACM SIGKDD International Conference on Knowledge Discovery & Data Mining (KDD), Anchorage, AK, AUG 04-08, 2019

Robot active perception and motion generation for deformable object manipulation using multimodal deep learning

Namiko Saito (University of Edinburgh)

Date: 7.18 Time: 16:15-17:00 Venue: Lecture Room 12 (A7 3F)

Robots which work and support daily tasks are increasingly demanded. We aim realization of an AI-robot that autonomously learn, adapt to their environment, evolve in intelligence and act alongside human beings. The robot needs to recognize demanded goal, perceive the current situations and generate motions automatically by itself. Especially, in cooking scenario, humans daily use ingredients with complicated and fragile characteristics, which change and deform continuously by heat and force. We tackle on the question and realize a robot which can perceive target object characteristics in real time and generate a motion accordingly, which have not been achieved in previous research. We focus on active perception using multimodal sensorimotor data while a robot interacts with objects, and allow the robot to recognize their extrinsic and intrinsic characteristics. We construct a deep neural networks (DNN) model that learns to recognize object characteristics, acquires object–action relations, and generates motions. As examples, the robot performs an ingredients transfer task, using a turner or ladle to transfer an ingredient from a pot to a bowl. The results confirm that the robot recognizes object characteristics and servings even when the target ingredients are unknown. We also examine the contributions of images, force, and tactile data and show that learning a variety of multimodal information results in rich perception.

Frontiers of Science Award Paper: Namiko Saito, Tetsuya Ogata, Satoshi Funabashi, Hiroki Mori, and Shigeki Sugano. How to select and use tools? : Active perception of target objects using multimodal deep learning. *IEEE Robotics and Automation Letters*, 6(2):2517–2524, Apr 2021

Wednesday, July 19, Morning Session I

DM & TCS

Noga Alon (Princeton University)

Date: 7.19 Time: 08:00-09:00 Venue: Lecture Room 12 (A7 3F)

The tight connections between Discrete Mathematics and Theoretical Computer Science has been fruitful in the development of both areas in the recent decades. I will describe several examples illustrating this fact.

Wednesday, July 19, Morning Session II

On computation of Markov perfect equilibrium

Xiaotie Deng (Peking University)

Date: 7.19 Time: 09:15-10:15 Venue: Lecture Room 13 (A7 3F)

Multi-Agent Reinforcement Learning (MARL) has been gaining popularity in stochastic applications. As a result, Markov Perfect Equilibrium (MPE), a fundamental solution concept in Stochastic Games, has received substantial attention and effort in its computational forefront. We present an approximate algorithmic approach for solving MPE and proves its PPAD-completeness. This approach has the potential to enhance the computational efficiency of MPE and enable its application in a wider range of stochastic games.

Medical robotics for cell surgery

Yu Sun (University of Toronto)

Date: 7.19 Time: 09:15-10:15 Venue: Lecture Room 12 (A7 3F)

The capability of manipulating micro and nanometer-sized objects, such as cells and nanomaterials opens new frontiers in robotic surgery, disease diagnostics, industrial applications and enables new discoveries in many disciplines such as biology, medicine, and materials science. The field of micro-nanorobotics involves the design and construction of robotic agents that are micro-nanometer sized and robotic manipulation of objects with dimensions in the micrometer and nanometer ranges. The past decades have witnessed spurred development of micro-nanorobotic systems and technologies with common hallmarks of precision instrumentation, sensing, actuation, and control. This talk will begin with a brief review of the evolution of the robotic micromanipulation field, followed by an overview of challenges, opportunities, and recent advances made in this field. Examples of robotic cell manipulation systems for clinical surgery and drug screen will be given; sub-micrometer position control and sub-nano Newton force control for realizing 3D intracellular and intra-tissue manipulation and measurement will be introduced; and mechanical nanosurgery of chemoresistant tumors will be discussed.

Wednesday, July 19, Morning Session III

Robotics and wearable technology (exoskeletons) for better health

Darwin G Caldwell (Italian Institute of Technology)

Date: 7.19 Time: 10:30-11:30 Venue: Lecture Room 12 (A7 3F)

Aging and rapidly increasing populations are placing more demands on global health systems. Yet, even in the midst of these unprecedented population growths, many countries are also experiencing shortfalls in qualified staff. The competing demands of increasing healthcare provision in a shrinking personnel market are now, and

will increasingly in the future, have an enormous impact across all areas of medical provision including training, rehabilitation, social care, prosthetics, surgery, diagnosis, physical and social assistance, and disabled and elderly care. It is therefore not surprising that robotics is increasingly seen as a key (and perhaps the key) to address this looming healthcare crisis. This presentation will consider how robotics and wearable technology can help provide sustainable health provision across all areas of medical support. Initially it will consider the global aspects of the crisis before focusing on some specific medical technologies, particularly those developed at the Italian Institute of Technology (IIT) including; surgical assistive and intervention technologies such as: CALM (Computer Assisted Laser Microsurgery) the world's most advanced throat surgery system, the world's first 5G Telesurgery procedure, unique Smart Probes for detection and characterization of tissue type including malignancy of the throat, pioneering pediatric interventions for neurosurgery and Twin-to-Twin Transfusion Syndrome (TTTS), Smart Cannulisation (CathBot and CathBot Pro), Magnetically driven Fibre Optic Lasers for enhanced endoscopic surgery, and Endoscopic Tissue Analysis to support and improve cancer diagnosis and treatment. The presentation will conclude with an analysis of where, and how, this technology can be applied and it will suggest how this can lead to better outcomes for patients, physicians, healthcare systems/providers and society.

Post-quantum cryptography, a new era

Jintai Ding (Tsinghua University)

Date: 7.19 Time: 10:30-11:30 Venue: Lecture Room 13 (A7 3F)

Public key cryptosystems (PKC) are the security foundation of modern communication systems, in particular, the Internet. However Shor's algorithm shows that the existing PKC like Diffie-Hellmann key exchange, RSA and ECC can be broken by a quantum computer. To prepare for the coming age of quantum computing, we need to build new public key cryptosystems that could resist quantum computer attacks. In this lecture, we will give an introduction to post-quantum cryptography and its recent developments, in particular, the NIST standardization process and its impact. Then we will present a practical and provably secure (authenticated) key exchange protocol based on the learning with errors problems, which is conceptually simple and has strong provable security properties. This new construction was established in 2011-2012. We will explain that all the existing LWE-based key exchanges are variants of this fundamental design. In addition, we will explain how to use the signal function invented for KE for authentication schemes. Then we will discuss key reuse attacks on those key exchanges.

Wednesday, July 19, Afternoon Session I

Convergence of computer vision and natural language processing

Han Hu (Microsoft Research Asia)

Date: 7.19 Time: 13:00-13:45 Venue: Lecture Room 12 (A7 3F)

As mankind, we can accomplish various intelligence capabilities, such as vision, language, and science, simply by using a single neuron organ called the cerebral cortex. The pre-training of cortical neurons for different capabilities also relies heavily on a similar mechanism of predictive learning. These unified biological mechanisms have enabled human beings to adapt quickly and effectively to new environments and acquire new capabilities without millions of years' biological evolution. In artificial intelligence, architectures and learning methods in various domains are also converging. Transformer, which emerges in the field of NLP, is now taking over previous domain-specific architectures in several fields, such as computer vision, speech, science, etc. Generative pre-training such as GPT has also been shown to be very effective in all of NLP, vision, and speech. This talk will introduce the journey towards these convergences, as well as the representative works that have driven this trend. The talk will also present several representative research efforts by the speaker's team, including Swin Transformer V1/V2, SimMIM, etc.

Frontiers of Science Award Paper: Ze Liu, Yutong Lin, Yue Cao, Han Hu, Yixuan Wei, Zheng Zhang, Stephen Lin, and Baining Guo. Swin Transformer: Hierarchical Vision Transformer using Shifted Windows. In *2021 IEEE/CVF International Conference on Computer Vision (ICCV)*, pages 9992–10002, 2021

The 2-to-1 Games Theorem

Muli Safra (Tel Aviv University)

Date: 7.19 Time: 13:00-13:45 Venue: Lecture Room 13 (A7 3F)

The Unique Games Conjecture is a central open problem in Theoretical Computer Science, which if true, would imply a wide plethora of tight hardness of approximation results. In this talk, I'll discuss the recent proof of a "close sibling" of this conjecture, namely the 2-to-1 Games Theorem. The 2-to-1 Games result goes "half of the way" towards a positive resolution of the Unique Games Conjecture.

Frontiers of Science Award Paper: Khot Subhash, Dor Minzer, and Muli Safra. Pseudorandom Sets in Grassmann Graph Have Near-Perfect Expansion. In *2018 IEEE 59th Annual Symposium on Foundations of Computer Science (FOCS)*, pages 592–601, 2018

QSYM: Practical concolic execution and hybrid fuzzing

Meng Xu (University of Waterloo)

Date: 7.19 Time: 13:00-13:45 Venue: Lecture Room 11 (A7 2F)

Hybrid fuzzing has been extremely successful in bug vulnerabilities. This lecture will briefly 1) overview the concept of hybrid fuzzing, 2) showcase how it addresses the limitations of fuzzing and concolic execution by combining both approaches, 3) highlight both its strengths and weaknesses, and 4) present how QSYM, a fast concolic execution engine, addresses some of the limitations, especially on integrating the symbolic emulation with the native execution using dynamic binary translation. We will also cover some of the follow-up works of QSYM and in the area of hybrid fuzzing in general.

Frontiers of Science Award Paper: Insu Yun, Sangho Lee, Meng Xu, Yeongjin Jang, and Taesoo Kim. QSYM: A Practical Concolic Execution Engine Tailored for Hybrid Fuzzing. In *Proceedings of the 27th USENIX Conference on Security Symposium*, SEC'18, page 745–761, USA, 2018. USENIX Association

---

Wednesday, July 19, Afternoon Session II

Tetrahedral meshing in the wild

Yixin Hu (Tencent America)

Date: 7.19 Time: 14:00-14:45 Venue: Lecture Room 12 (A7 3F)

We propose a novel tetrahedral meshing technique that is unconditionally robust, requires no user interaction, and can directly convert a triangle soup into an analysis-ready volumetric mesh. The approach is based on several core principles: (1) initial mesh construction based on a fully robust, yet efficient, filtered exact computation (2) explicit (automatic or user-defined) tolerancing of the mesh relative to the surface input (3) iterative mesh improvement with guarantees, at every step, of the output validity. The quality of the resulting mesh is a direct function of the target mesh size and allowed tolerance: increasing allowed deviation from the initial mesh and decreasing the target edge length both lead to higher mesh quality. Our approach enables "black-box" analysis, i.e. it allows to automatically solve partial differential equations on geometrical models available in the wild, offering robustness and reliability comparable to, e.g., image processing algorithms, opening the door to automatic, large-scale processing of real-world geometric data.

Frontiers of Science Award Paper: Yixin Hu, Qingnan Zhou, Xifeng Gao, Alec Jacobson, Denis Zorin, and Daniele Panozzo. Tetrahedral meshing in the wild. *ACM Transactions on Graphics*, 37(4), Aug 2018

Off-path TCP exploits of the mixed IPID assignment

Ke Xu (Tsinghua University)

Date: 7.19 Time: 14:00-14:45 Venue: Lecture Room 11 (A7 2F)

TBA

Frontiers of Science Award Paper: Xuewei Feng, Chuanpu Fu, Qi Li, Kun Sun, and Ke Xu. Off-path TCP exploits of the mixed IPID assignment. In *Proceedings of the 2020 ACM SIGSAC Conference on Computer and Communications Security*, pages 1323–1335, 2020

Wednesday, July 19, Afternoon Session III

Locally testable codes with constant rate, distance, and locality

Shai Evra (Hebrew University of Jerusalem, Israel)

Date: 7.19 Time: 15:15-16:00 Venue: Lecture Room 13 (A7 3F)

An outstanding open problem in the theory of error correcting codes has been whether there exist locally testable codes with constant rate, constant distance, and constant locality. In this talk this I will describe a recent construction of such codes based on a new two-dimensional complex which we call a left-right Cayley complex. This is based on a joint work with Irit Dinur, Ron Liven, Alex Lubotzky and Shahar Mozes.

Frontiers of Science Award Paper: Irit Dinur, Shai Evra, Ron Livne, Alexander Lubotzky, and Shahar Mozes. Locally Testable Codes with Constant Rate, Distance, and Locality. In *Proceedings of the 54th Annual ACM SIGACT Symposium on Theory of Computing*, STOC 2022, page 357–374, New York, NY, USA, 2022. Association for Computing Machinery

Agile robot autonomy

Antonio Loquercio (University of California, Berkeley)

Date: 7.19 Time: 15:15-16:00 Venue: Lecture Room 12 (A7 3F)

Quadcopters are among the most agile and dynamic machines ever created. In this talk, I'll show how data-driven sensorimotor controllers can push quadcopters with only onboard sensing and computation to their physical limits. Such controllers enable quadcopters to fly faster and more agile than what was possible before in unstructured environments like cities, forests, and disaster scenarios. The insights acquired from quadcopter flight transfer to other domains, including legged locomotion and bio-inspired vision. However, fundamental research questions still need to be addressed to make agile robots adaptable, robust, and safe, and enable their wider application in homes, search and surveillance, and inspection. Teaser videos of the results I will present are Deep Drone Acrobatics (https://youtu.be/2N_wKXQ6MXA) and Agile Autonomy (https://youtu.be/m89bNn6RFoQ).

Frontiers of Science Award Paper: Antonio Loquercio, Elia Kaufmann, René Ranftl, Matthias Müller, Vladlen Koltun, and Davide Scaramuzza. Learning high-speed flight in the wild. *Science Robotics*, 6(59):eabg5810, 2021

The unlimited sensing framework: Digitization via modulo non-linearities

Ayush Bhandari (Imperial College London)

Date: 7.19 Time: 16:15-17:00 Venue: Lecture Room 13 (A7 3F)

Digital data capture is the backbone of all modern-day systems, and "Digital Revolution" has been aptly termed as the Third Industrial Revolution. Underpinning the digital representation is the Shannon-Nyquist sampling theorem and newer developments such as compressive sensing approaches. The fact that there is a physical limit to which sensors can measure amplitudes poses a fundamental bottleneck when it comes to leveraging the performance guaranteed by recovery algorithms. In practice, whenever a physical signal exceeds the maximum recordable range, the sensor saturates, resulting in permanent information loss. Examples include (a) dosimeter saturation during the Chernobyl reactor accident, reporting radiation levels far lower than the true value, and (b) loss of visual cues in self-driving cars coming out of a tunnel (due to sudden exposure to light). In the last decades, recovery strategies have become increasingly non-linear but for most part, the acquisition has remained linear, limiting truly high-dynamic-range (HDR) sensing. To reconcile the gap between theory and practice, we introduce a computational sensing approach—the Unlimited Sensing framework (USF)—that is based on a co-design of hardware and algorithms. On the hardware front, our work is based on non-linear analog-to-digital converters that produce modulo or folded samples. On the algorithms front, we develop new, mathematically guaranteed recovery strategies. In the first part of this talk, we prove a sampling theorem akin to the Shannon-Nyquist criterion. Despite the non-linearity in the sensing pipeline, the sampling rate only depends on the signal's bandwidth. Our theory is complemented with a stable recovery algorithm. Beyond the theoretical results, we also present a hardware demo that shows the modulo ADC in action. Building on the basic sampling theory result, we consider certain variations on the theme. This includes different signal classes (e.g. smooth, sparse and parametric functions) as well as sampling architectures, such as One-Bit and Event-Triggered sampling. Moving further, we reinterpret the USF as a generalized linear model that motivates a new class of inverse problems. We conclude this talk by presenting a research overview in the context of single-shot HDR imaging, sensor array processing, radar sensing and HDR computed tomography based on the modulo Radon transform.

Frontiers of Science Award Paper: Ayush Bhandari, Felix Krahmer, and Ramesh Raskar. On unlimited sampling and reconstruction. *IEEE Transactions on Signal Processing*, 69:3827–3839, 2021

Intelligent microrobots and their potential impact on healthcare

Bradley Nelson (ETH Zürich)

Date: 7.19 Time: 16:15-17:00 Venue: Lecture Room 12 (A7 3F)

Micro and nano robots have made great strides since becoming a focused research topic over two decades ago. Much of the progress has been in material selection, processing, and fabrication, and paths forward in developing clinically relevant biocompatible and biodegradable micro and nano robots are becoming clear. Our group, as well as others, maintain that using biocompatible magnetic composites with externally generated magnetic fields and field gradients is perhaps closest to clinical application. One of the most challenging aspects of the field is in the development of the magnetic navigation system (MNS) that generates the fields and field gradients needed for microrobot locomotion. In this talk, I will present an overview of MNSs and show how these systems are fundamentally robotic in the way they must be designed and controlled. Decades of work in robotic manipulation can be brought to bear on this problem as we move forward in bringing MNS technology to the clinic. I will also look at recent efforts in creating more intelligent micro and nano robots that exhibit increasingly complex behaviors, some of which can even be programmed in situ. The field appears to be on the cusp of realizing the fantastic voyage.

Frontiers of Science Award Paper: H. W. Huang, F. E. Uslu, P. Katsamba, E. Lauga, M. S. Sakar, and B. J. Nelson. Adaptive locomotion of artificial microswimmers. *Science Advances*, 5(1), Jan 2019

Thursday, July 20, Morning Session I

A geometric understanding of generative model in deep learning

Xianfeng Gu (Stony Brook University)

Date: 7.20 Time: 08:00-09:00 Venue: Lecture Room 12 (A7 3F)

Deep learning (DL) has achieved great successes, but understanding of DL remains primitive. In this talk, we try to answer some fundamental questions about DL through a geometric perspective: what does a DL system really learn ? How does the system learn? Does it really learn or just memorize the training data sets? How to improve the learning process? Natural datasets have intrinsic patterns, which can be summarized as the manifold distribution principle: the distribution of a class of data is close to a low-dimensional manifold. DL systems mainly accomplish two tasks: manifold learning and probability distribution transformation. The latter can be carried out based on optimal transportation (OT) theory. This work introduces a geometric view of optimal transportation, which bridges statistics and differential geometry and is applied for generative adversarial networks (GANs) and diffusion models. From the OT perspective, in a GAN model, the generator computes the OT map, while the discriminator computes the Wasserstein distance between the real data distribution and the counterfeit; both can be reduced to a convex geometric optimization process. The diffusion model computes a transportation map from the data distribution to the Gaussian distribution by a heat diffusion, and focuses on the inverse flow. Furthermore, the regularity theory of the Monge-Ampere equation discovers the fundamental reason for mode collapse. In order to eliminate the mode collapses, a novel generative model based on the geometric OT theory is proposed, which improves the theoretical rigor and interpretability, as well as the computational stability and efficiency. The experimental results validate our hypothesis, and demonstrate the advantages of our proposed model.

Thursday, July 20, Morning Session II

TBA

Song-Chun Zhu (Beijing Institute for General Artificial Intelligence)

Date: 7.20 Time: 09:15-10:15 Venue: Lecture Room 12 (A7 3F)

TBA

Thursday, July 20, Morning Session III

The COVID-19 pandemic: What social media and machine learning can inform us at scale and in real-time

Jiebo Luo (University of Rochester)

Date: 7.20 Time: 10:30-11:30 Venue: Lecture Room 12 (A7 3F)

The COVID-19 pandemic has severely affected people's daily lives and caused tremendous economic losses worldwide. AI technologies have been employed to fight the disease and predict the disease spread. However, its impact on human behaviors, e.g., public opinion and mental health, has not received as much attention to inform the policy and decision makers. Traditionally, the studies in these fields have primarily relied on interviews or surveys, largely limited to small-scale and not-up-to-date observations. In contrast, the rise of social media provides an opportunity to study many aspects of a pandemic at scale and in real-time. Meanwhile, the recent advances in machine learning and data mining allow us to perform automated data processing and analysis. We

will introduce several case studies, including 1) nuanced opinions on COVID-19 vaccines, 2) depression trends, 3) attitudes towards work from home, 4) consumer hoarding behaviors, 5) personal face mask usage, and 6) what to blame for inflation,

---

Thursday, July 20, Afternoon Session I

Microscopy image restoration and artifact removal - from the onset of DL-based methods to most recent improvements

Florian Jug (Fondazione Human Technopole)

Date: 7.20 Time: 13:00-13:45 Venue: Lecture Room 13 (A7 3F)

The necessity to analyze scientific images is as old as the ability to acquire such data. While this analysis did initially happen by observation only, modern microscopy techniques now enable us to image at unprecedented spatial and temporal resolutions, through the 'eyes' of many and very diverse imaging modalities. The unfathomable amounts of data acquired in the context of biomedical research cannot any longer be analyzed by manual observation alone. Instead, algorithmic solutions are helping researchers to study and quantify large image data. In the past years, our abilities to use artificial neural networks (ANNs) for the automated analysis of scientific image data gained significant traction, and many important analysis problems have now much improved solutions based on ANNs. At the same time, we start being aware of limitations that come with this new set of machine learning approaches. In my lecture I would like to update you on some of the latest algorithmic developments from our and other labs. I will also talk about efforts of our community to store, share, and run ANN based analysis methods via the BioImage Model Zoo – a new infrastructure currently being established. Finally, I will carefully attempt to look into the future and share my predictions about how artificial intelligence will help us to elevate the rate of scientific discovery.

Frontiers of Science Award Paper: Martin Weigert, Uwe Schmidt, Tobias Boothe, Andreas Müeller, Alexandr Dibrov, Akanksha Jain, Benjamin Wilhelm, Deborah Schmidt, Coleman Broaddus, Siân Culley, Mauricio Rocha-Martins, Fabián Segovia-Miranda, Caren Norden, Ricardo Henriques, Marino Zerial, Michele Solimena, Jochen Rink, Pavel Tomancak, Loic Royer, Florian Jug, and Eugene W. Myers. Content-aware image restoration: pushing the limits of fluorescence microscopy. *Nature Methods*, 15(12):1090+, Dec 2018

Almost linear time algorithms for all flows

Sushant Sachdeva (University of Toronto)

Date: 7.20 Time: 13:00-13:45 Venue: Lecture Room 12 (A7 3F)

Over the last decade or so, combining methods from continuous optimization and analysis with graph theoretic-insights has led to a revolution in algorithms for classic problems on graphs such as maximum flow. In this talk, I will present some of our key ideas behind our recent work that gives almost-linear time algorithms for solving all convex flow problems on graphs. This implies almost linear time algorithms for max-flow, minimum-cost flow, bipartite matching, optimal transport, matrix scaling, isotonic regression, and several other well-studied problems. Our algorithm is designed using a new Interior Point Method (IPM) that builds the flow as a sequence of almost-linear number of approximate undirected minimum-ratio cycles, each of which is computed and processed very efficiently using a new dynamic data structure. Joint work with Li Chen, Rasmus Kyng, Yang Liu, Richard Peng, and, Maximilian Probst Gutenberg.

Frontiers of Science Award Paper: Li Chen, Rasmus Kyng, Yang P. Liu, Richard Peng, Maximilian Probst Gutenberg, and Sushant Sachdeva. Maximum Flow and Minimum-Cost Flow in Almost-Linear Time. In *2022 IEEE 63rd Annual Symposium on Foundations of Computer Science (FOCS)*, pages 612–623, 2022

Analysis of animal behavior with deep learning

Alexander Mathis (École Polytechnique Fédérale de Lausanne (EPFL))

Date: 7.20 Time: 14:00-14:45 Venue: Lecture Room 13 (A7 3F)

Quantifying behavior is crucial for many applications across the life sciences and engineering. Videography provides easy methods for the observation and recording of animal behavior in diverse settings, yet extracting particular aspects of a behavior for further analysis can be highly time consuming and computationally challenging. I will present an efficient method for markerless pose estimation based on transfer learning with deep neural networks that achieves excellent results with minimal training data (DeepLabCut). I will show that for both pretrained and networks trained from random initializations, better ImageNet-performing architectures perform better for pose estimation, with a substantial improvement on out-of-domain data when pretrained on ImageNet. Subsequently, I will present methods that enable robust zero-shot performance. Overall, I will illustrate the versatility of this framework by tracking various body parts in multiple species across a broad collection of behaviors from egg-laying flies to 3D pose estimation on cheetahs.

Frontiers of Science Award Paper: Alexander Mathis, Pranav Mamidanna, Kevin M. Cury, Taiga Abe, Venkatesh N. Murthy, Mackenzie Weygandt Mathis, and Matthias Bethge. DeepLabCut: markerless pose estimation of user-defined body parts with deep learning. *Nature Neuroscience*, 21(9):1281+, Sep 2018

Approximation algorithms for the asymmetric traveling salesman problem

László Végh (London School of Economics and Political Science)

Date: 7.20 Time: 14:00-14:45 Venue: Lecture Room 12 (A7 3F)

The talk will give an overview on recent developments on the asymmetric traveling salesman problem (ATSP). In contrast to the symmetric problem variant, where the Christofides-Serdyukov algorithm gives a simple 3/2-approximation, no constant-factor approximation algorithm has been known for a long time. The talk will give an overview of the different approaches that have lead to improved approximation guarantees over the last decade. I will present the approach of our paper with Svensson and Tarnawski that led to the first constant factor approximation guarantee in 2017, and a subsequent improvement by Traub and Vygen.

Frontiers of Science Award Paper: Ola Svensson, Jakub Tarnawski, and László A. Végh. A Constant-Factor Approximation Algorithm for the Asymmetric Traveling Salesman Problem. In *Proceedings of the 50th Annual ACM SIGACT Symposium on Theory of Computing*, STOC 2018, page 204–213, New York, NY, USA, 2018. Association for Computing Machinery

Thursday, July 20, Afternoon Session III

Practical network intrusion detection with deep learning

Yisroel Mirsky (Ben-Gurion University of the Negev)

Date: 7.20 Time: 15:15-16:00 Venue: Lecture Room 12 (A7 3F)

Deep learning is a common tool used to detect cyberattacks. Models trained with this technology can identify complex patterns which is ideal for distinguishing between benign and malicious behaviors. However, a drawback of using these models is that they require a massive amount of data to train them. Moreover, to perform classification, the data must be labeled by an expert which can be prohibitively expensive or simply impractical to accomplish at scale. In this talk we will take a look at how one kind of architecture, the autoencoder, has revolutionized the way we can detect cyber threats in computer networks. First, we will cover the basics of how these models work and how they are used to perform anomaly detection. Then we will explore how they can be used as practical solutions for detecting malicious network traffic. Finally, we will discuss how we can use them to identify man-in-the-middle and supply-chain attacks through echo analysis.

Frontiers of Science Award Paper: Yisroel Mirsky, Tomer Doitshman, Yuval Elovici, and Asaf Shabtai. Kitsune: An ensemble of autoencoders for online network intrusion detection. In *Proceedings 2018 Network and Distributed System Security Symposium*, 2018. 25th Annual Network and Distributed System Security Symposium (NDSS), San Diego, CA, FEB 18-21, 2018

Adversarial robustness of graph neural networks

Daniel Zügner (Microsoft Research)

Date: 7.20 Time: 15:15-16:00 Venue: Lecture Room 13 (A7 3F)

Graph neural networks (GNNs) have rapidly taken over the field of graph mining and have found many applications in domains such as recommender systems, molecular simulation, and computer vision. This raises questions of how safe GNNs are for real-world applications. This talk discusses the reliability of GNNs, specifically their robustness with respect to adversarial attacks. We show how to obtain robustness certificates for perturbations of the node attributes as well as changes to the graph structure, and how to train up to 4x more robust GNNs.

Frontiers of Science Award Paper: Daniel Zügner, Amir Akbarnejad, and Stephan Günnemann. Adversarial Attacks on Neural Networks for Graph Data. In Yike Guo and Faisal Farooq, editors, *Proceedings of the 24th ACM SIGKDD International Conference on Knowledge Discovery & Data Mining, KDD 2018, London, UK, August 19-23, 2018*, pages 2847–2856. ACM, 2018

Thursday, July 20, Afternoon Session IV

Functional bayesian filter

Kan Li (University of Florida)

Date: 7.20 Time: 16:15-17:00 Venue: Lecture Room 12 (A7 3F)

We present a general nonlinear Bayesian filter for high-dimensional state estimation using the theory of reproducing kernel Hilbert space (RKHS). By applying the kernel method and the representer theorem to perform linear quadratic estimation in a functional space, we derive a Bayesian recursive state estimator for a general nonlinear dynamical system in the original input space. Unlike existing nonlinear extensions of the Kalman filter where the system dynamics are assumed known, the state-space representation for the Functional Bayesian Filter (FBF)

is completely learned online from measurement data in the form of an infinite impulse response (IIR) filter or recurrent network in the RKHS, with universal approximation property. Using a positive definite kernel function satisfying Mercer's conditions to compute and evolve information quantities, the FBF exploits both the statistical and time-domain information about the signal, extracts higher-order moments, and preserves the properties of covariances without the ill effects due to conventional arithmetic operations. We apply this novel kernel adaptive filtering (KAF) to recurrent network training, chaotic time-series estimation and cooperative filtering using Gaussian and non-Gaussian noises, and inverse kinematics modeling. Simulation results show FBF outperforms existing Kalman-based algorithms.

Frontiers of Science Award Paper: Kan Li and José C. Príncipe. Functional bayesian filter. *Trans. Sig. Proc.*, 70:57–71, Jan 2022

Knowledge graphs empower AI applications: recommendation and beyond

Xiang Wang (University of Science and Technology of China)

Date: 7.20 Time: 16:15-17:00 Venue: Lecture Room 13 (A7 3F)

Knowledge graphs are powerful tools that organize and connect information in a structured manner, enabling AI models to reason, infer, and generate insights with increased accuracy and efficiency. We have conducted extensive studies to explore the power of knowledge graphs in empowering AI applications, with a specific focus on recommendation systems and their broader implications. Specifically, knowledge graphs enable the integration of multiple AI techniques (e.g., information generation, retrieval, and recommendation), by providing a unified representation and facilitating knowledge-driven decision-making processes. We highlight real-world use cases where knowledge graphs have empowered diverse applications, including personalized recommendation in AI4E-commerce, and system analysis in AI4Security. Furthermore, we discuss how knowledge graphs empower AIGC.

Frontiers of Science Award Paper: Xiang Wang, Xiangnan He, Yixin Cao, Meng Liu, and Tat-Seng Chua. KGAT: Knowledge Graph Attention Network for Recommendation. In *Proceedings of the 25th ACM SIGKDD International Conference on Knowledge Discovery & Data Mining*, KDD '19, pages 950–958. Assoc Comp Machinery; Assoc Comp Machinery SIGKDD; Assoc Comp Machinery SIGMOD, 2019. 25th ACM SIGKDD International Conference on Knowledge Discovery & Data Mining (KDD), Anchorage, AK, AUG 04-08, 2019

Friday, July 21, Morning Session I

The physical nature of digital images

David Brady (University of Arizona)

Date: 7.21 Time: 08:00-09:00 Venue: Lecture Room 12 (A7 3F)

Nonlinear neural representations fundamentally change the digital structure of measured data. As phyical sampling adapts to this new structure, gigapixel images measuring ultrafast hyperspectral phenomena become possible.

Friday, July 21, Morning Session II

Continual learning: Theory and algorithms

Bing Liu (University of Illinois Chicago)

Date: 7.21 Time: 09:15-10:15 Venue: Lecture Room 12 (A7 3F)

The ability to learn continuously to become more and more knowledgeable is one of the hallmarks of human intelligence. This ability is also necessary for AI agents. However, existing machine learning algorithms are still unable to do that. This talk is about the topic of continual learning, which aims to learn a sequence of tasks incrementally. A challenging setting of continual learning is class incremental learning (CIL). This talk first motivates this research and then presents a theoretical study on (1) the learnability of CIL and (2) how to solve the CIL problem in a principled manner. The key theoretical results are: (1) CIL is learnable and (2) the necessary and sufficient conditions for solving CIL are good within-task prediction and good out-of-distribution (OOD) detection. Based on the theory, several CIL methods have been designed, which have produced state-of-the-art results.

Friday, July 21, Morning Session III

Digital communications and mathematics

Xiang-Gen Xia (University of Delaware)

Date: 7.21 Time: 10:30-11:30 Venue: Lecture Room 12 (A7 3F)

In this talk, I will briefly discuss the importance of mathematics in signal processing in electrical engineering. From my experience in USA over the past decades, I see that the most significant change in human daily life is telecommunications, such as smart phones, where mathematics plays an important role. I will briefly introduce some of the key components of math in communications: some elementary math and some more advanced math, such as, finite fields and orthogonal designs (or compositions of quadratic forms) etc. I will finally briefly show some of our results on orthogonal designs.

Friday, July 21, Afternoon Session I

Next-generation holographic displays incorporating optics and machine intelligence

Yifan Peng (University of Hong Kong)

Date: 7.21 Time: 13:00-13:45 Venue: Lecture Room 13 (A7 3F)

From cameras to displays, visual computing systems are becoming ubiquitous in our daily life. In particular, holographic near-eye displays promise unprecedented capabilities for virtual and augmented reality (VR/AR) systems. However, their underlying design principles have stagnated after decades of evolution. The image quality achieved by traditional holographic displays is limited, and algorithms for computer-generated holography (CGH) are slow. This shortcoming is due to a lack of co-design between hardware and software, importantly, impeding the delivery of vivid 3D visual experience. This talk covers a family of Neural Holography advances that apply the unique combination of machine intelligence and physics to solve long-standing problems of computer-generated holography (CGH). With leveraging the advantages of camera-based optimization and neural-network model representation, we are able to deliver full-color, high-fidelity, 3D holographic images. Driven by trending machine intelligence, these hardware-software jointly optimized holography techniques can unlock the full potential of VR/AR/MR applications.

Frontiers of Science Award Paper: Yifan Peng, Suyeon Choi, Nitish Padmanaban, and Gordon Wetzstein. Neural holography with camera-in-the-loop training. *ACM Transactions on Graphics*, 39(6), Dec 2020

High precision wireless positioning technology: Past, present and future

Zheng Yao (Tsinghua University)

Date: 7.21 Time: 13:00-13:45 Venue: Lecture Room 12 (A7 3F)

In the past decades, the Global Navigation Satellite Systems (GNSS), represented by GPS and BeiDou, which have been developed rapidly, have become the most dominant space-time information service infrastructure worldwide and are the absolutely dominant means of positioning, navigation and timing (PNT) services in the world nowadays. However, while GNSS is widely used in various fields of daily life and has shown great benefits, its inherent limitations are also gradually highlighted, mainly in the vulnerability of the system structure, sensitivity of the electromagnetic environment, and the availability of limited coverage areas. As the requirements for positioning scenarios expand, and the demand for positioning in emergent, temporary and unmanned environments increases, a growing number of missions require high-precision navigation, positioning and timing in scenarios where GNSS is not available. In addition, there are more and more missions to perform rapid sensing of unknown areas and to rapidly establish regional positioning systems to provide positioning and navigation services to the users therein. Such requirements place higher demands on the autonomy, mobility and flexibility of the PNT system. However, the contradiction between the limited bandwidth, concurrency, power consumption, computing power and other resources with the growing performance requirements such as accuracy, deployment speed, environmental adaptability, autonomy, and coverage has become prominent. How to realize the deployment and operation of high-precision wireless positioning system under the conditions of harsh environment and limited resources has become one of the main technical challenges in the PNT architecture construction. The combination of location sensors and mobile intelligences provides the possibility of rapid and autonomous construction of spatio-temporal references in unknown environments. Multi-sensor signal collaboration, multi-node information collaborative, and multi-task locating-explorating-control coordination are powerful solutions for the simultaneous exploration and positioning node deployment in unknown complex environments. This presentation will start from the evolution of wireless positioning system and introduce the development trend and the state of the art of high-precision wireless positioning technology, as well as the technical challenges faced.

Frontiers of Science Award Paper: Tengfei Wang, Zheng Yao, and Mingquan Lu. Combined difference square observation-based ambiguity determination for ground-based positioning system. *Journal of Geodesy*, 93(10):1867–1880, Oct 2019

Friday, July 21, Afternoon Session II

Micro/Nano robotic swarms: Science and applications

Junhui Law (University of Toronto)

Date: 7.21 Time: 14:00-14:45 Venue: Lecture Room 12 (A7 3F)

Inspired by natural swarms, micro/nano-scaled agents have been controlled to form micro/nano robotic swarms for biomedical applications. This talk will start with an introduction of the underlying principles of forming and controlling micro/nano swarms, followed by examples of clinical applications. To address clinical demands, we developed micro/nano swarm actuation techniques and functionalization, and validated their therapeutic efficacies in mouse models and large animals. Present embolization techniques are prone to cause unintentional blockage of non-targeted blood vessels due to the lack of selectivity. We proposed a swarm actuation strategy, using thrombin-coated magnetic particles, to realize selective embolization, where the swarms accurately blocked the blood flow inside a targeted region in vivo. Moreover, using magnetic carbon nanotubes (mCNTs), we reported a mechanical

nanosurgery approach for treating chemoresistant glioblastoma (GBM), the most common and aggressive primary brain cancer. We functionalized mCNTs with tumor-targeting antibodies to increase their recognition of GBM cells and prolong their enrichment and retention within the tumor. By tailoring tumor-focused magnetic fields, we showed that spatiotemporally controlled mobilization of mCNTs, which functioned as swarms of nano-scalpels, generated mechanical work and induced GBM cell death in vivo.

Frontiers of Science Award Paper: Junhui Law, Xian Wang, Mengxi Luo, Liming Xin, Xingzhou Du, Wenkun Dou, Tiancong Wang, Guanqiao Shan, Yibin Wang, Peng Song, Xi Huang, Jiangfan Yu, and Yu Sun. Microrobotic swarms for selective embolization. *Science Advances*, 8(29), Jul 22 2022

Neural nano-optics for high-quality thin lens imaging

Ethan Tseng (Princeton University)

Date: 7.21 Time: 14:00-14:45 Venue: Lecture Room 13 (A7 3F)

Nano-optic imagers that modulate light at sub-wavelength scales could enable new applications in diverse domains ranging from robotics to medicine. Although metasurface optics offer a path to such ultra-small imagers, existing methods have achieved image quality far worse than bulky refractive alternatives, fundamentally limited by aberrations at large apertures and low f-numbers. In this work, we close this performance gap by introducing a neural nano-optics imager. We devise a fully differentiable learning framework that learns a metasurface physical structure in conjunction with a neural feature-based image reconstruction algorithm. Experimentally validating the proposed method, we achieve an order of magnitude lower reconstruction error than existing approaches. As such, we present a high-quality, nano-optic imager that combines the widest field-of-view for full-color metasurface operation while simultaneously achieving the largest demonstrated aperture of 0.5 mm at an f-number of 2.

Frontiers of Science Award Paper: Ethan Tseng, Shane Colburn, James Whitehead, Luocheng Huang, Seung-Hwan Baek, Arka Majumdar, and Felix Heide. Neural nano-optics for high-quality thin lens imaging. *Nature Communications*, 12(1):6493, 2021

Friday, July 21, Afternoon Session III

Recent progress on protein study by AI

Jinbo Xu (MoleculeMind Inc. & Toyota Technological Institute at Chicago)

Date: 7.21 Time: 15:15-16:00 Venue: Lecture Room 13 (A7 3F)

This lecture will present the recent progress on protein study by AI including protein structure and function prediction, protein optimization and de novo design.

Frontiers of Science Award Paper: Jinbo Xu. Distance-based protein folding powered by deep learning. *Proceedings of the National Academy of Sciences*, 116(34):16856–16865, Aug 20 2019

Monday, July 24, Morning Session I

Reflecting on a 75-year Journey of Signal and Data Science

Min Wu (University Maryland, College Park)

Date: 7.24 Time: 08:00-09:00 Venue: Lecture Room 12 (A7 3F)

Think about smartphone, HDTV, video conferencing, CT medical imaging, remote sensing, ... Can you name one technology that underpins all of them? Signal processing (SP) is considered by many as a set of ubiquitous technologies yet often hidden from plain sight, which have transformed the digital world and changed our lives in numerous ways. SP as a field is supported by mathematical theories and coupled with physical, engineering, and other domain-specific insights. The digital SP (DSP) took off in the mid-1960s, aided by the advancement of integrated circuit and digital computers, and has since then made profound impacts on society. With its root traced back to 75 years ago, the IEEE Signal Processing Society (SPS) is the world's premier professional society for SP scientists and professionals. Through its high-quality publications, conferences, and technical and educational activities, the SPS has played a pivotal role in advancing the theory and applications of SP, and in building the global SP community.

This talk will reflect on the 75-year journey of signal and data science. After a general overview, I will zoom in on a few examples from information forensics and security (IFS), an interdisciplinary area that SPS took the leadership in fostering the advancement and community building in the new millennium.

Monday, July 24, Morning Session II

Fundamental differences between natural and artificial intelligence

Michael Zhang (The University of Texas at Dallas)

Date: 7.24 Time: 09:15-10:15 Venue: Lecture Room 12 (A7 3F)

Witnessing rapid development in Artificial Intelligence and Machine Learning, especially, in their powerful applications in helping to discover scientific laws or to prove mathematical theories, many people expect Artificial Intelligence will soon be surpassing Human Intelligence. At the same time, with AlphaGo and ChatGPT mania, many people tend to get confused between facts and fictions, I saw heated debates and anxieties in the public media, worrying future job (including IT job) markets or even humanity disaster if humans should lose the control over robots. I feel obligated to offer my own (biological) view over the AI vs. NI question (material is based on "DIALOG BETWEEN AI & NI" to appear in Quantitative Biology, 2023).

Monday, July 24, Morning Session III

Generative AI for graphs

Michail Vazirgiannis (École polytechnique)

Date: 7.24 Time: 10:30-11:30 Venue: Lecture Room 12 (A7 3F)

Graph generative models are gaining significant interest in different application domains. They are commonly used to model social networks, knowledge graphs, medical data and bio/chemical networks. In this talk we will present the main methods for graph generative models and our recent relevant efforts in the biomedical domain. More specifically we present a novel architecture that generates medical records as graphs with privacy guarantees. We capitalize and modify the Graph Variational autoencoders (GVAEs) architecture. We train the generative model with the well known MIMIC medical database and achieve credible generated data. We also develop new GNNs for predicting antibiotic resistance and other protein related downstream tasks such as enzymes classifications and Gene Ontology classification. We achieve there as well promising results with potential for future application in broader biomedical related tasks. Finally we present interesting research directions for multi modal generative models involving graphs with applications in diverse domains.

Tuesday, July 25, Morning Session I

A Novel High-fidelity Image Compression Framework Based on Optimal Transport Mapping

Min Zhang (Zhejiang University)

Date: 7.25 Time: 08:00-09:00 Venue: Lecture Room 12 (A7 3F)

In this talk, I will propose a new high-fidelity image compression method using optimal transport (OT) mapping to obtain high compression ratio while still preserving fine details about the image. First, I will briefly introduce the theory of OT mapping and how to combine generative adversarial network (GAN) with it to build a compression system. Then I will describe our proposed method. Experimental results show that our method has better performance under objective criteria than other GAN-based methods.

Tuesday, July 25, Morning Session II

ChatGLM: Run your own "ChatGPT" on a laptop

Jie Tang (Tsinghua University)

Date: 7.25 Time: 09:15-10:15 Venue: Lecture Room 12 (A7 3F)

Large language models have substantially advanced the state of the art in various AI tasks, such as natural language understanding and text generation, and image processing, multimodal modeling. In this talk, I am going to talk about how we build GLM-130B, a bilingual (English and Chinese) pre-trained language model with 130 billion parameters. It is an attempt to open-source a 100B-scale model at least as good as GPT-3 and unveil how models of such a scale can be successfully pre-trained. Based on GLM-130B, we have developed ChatGLM, an alternative to ChatGPT. A small version, ChatGLM-6B, is opened with weights and codes. It can be deployed with one RTX 2080 Ti (11G) GPU, which makes it possible for everyone to deploy a ChatGPT! It has attracted over 1,000,000 downloads on Hugging Face in one month, and won the trending #1 model for two weeks.
GLM-130B: https://github.com/THUDM/GLM-130B
ChatGLM: https://github.com/THUDM/ChatGLM-6B

Tuesday, July 25, Morning Session III

Facets of entropy

Raymond Yeung (The Chinese University of Hong Kong)

Date: 7.25 Time: 10:30-11:30 Venue: Lecture Room 12 (A7 3F)

Constraints on the entropy function are sometimes referred to as the laws of information theory. For a long time, the submodular inequalities, or equiva- lently the nonnegativity of the Shannon information measures, are the only known constraints. Inequalities that are implied by the submodular inequality are categorically referred to as Shannon-type inequalities. If the number of random variables is fixed, a Shannon-type inequality can in principle be verified by a linear program known as ITIP. A non-Shannon-type inequality is a constraint on the entropy function which is not implied by the submodular inequality. In the late 1990's, the discovery of a few such inequalities revealed that Shannon-type inequalities alone do not constitute a complete set of constraints on the entropy function. Subsequently, connections between the entropy function and a number of fields in the science of information, mathematics, and physics have been established. These fields include probability theory, network coding, combinatorics, group theory, Kolmogorov complexity, matrix theory, and quantum mechanics. This talk presents a picture for the many facets of the entropy function.

Tuesday, July 25, Afternoon Session I

Quantum artificial intelligence

Dong-Ling Deng (Tsinghua University)

Date: 7.25 Time: 13:00-13:45 Venue: Lecture Room 12 (A7 3F)

Quantum artificial intelligence (Quantum AI) is an emergent interdisciplinary field that explores the interplay between artificial intelligence and quantum physics. On the one hand, judiciously designed quantum algorithms may exhibit exponential advantages in solving certain AI problems; on the other hand, ideas and techniques from AI can also be exploited to tackle challenging problems in the quantum domain. In this talk, I will first make a brief introduction to this field and review some recent progress. I will talk about several concrete examples to illustrate how AI and quantum physics can promote studies in both fields.

Tuesday, July 25, Afternoon Session II

An integrated mathematical framework for opinion dynamics and its applications

Xiaoming Zhang (Yanqi Lake Beijing Institute of Mathematical Sciences and Applications (BIMSA))

Date: 7.25 Time: 14:00-14:45 Venue: Lecture Room 12 (A7 3F)

We propose an integrated framework for the mathematical modeling of opinion dynamics based on notable social psychology theories and previous analytical models. The framework introduces a continuous measure of total social distance, which incorporates non-affective components such as geographical separation, social network connectedness, and status homophily in terms of social similarity, and an affective component for value homophily between the agents. A governing equation is derived for the solution of opinion dynamics problems. Eight examples are provided to illustrate the application of the framework such as the interactions among individuals within an isolated group, interactions of two groups, the effects of different components of social distance, the roles of opinion leader, the effects of different social norms, and the interaction of multiple opinion topics.

Some Basic Problems in Systems and Control

Lei Guo (Academy of Mathematics and Systems Science, Chinese Academy of Sciences)

Date: 7.27 Time: 09:15-10:15 Venue: Lecture Room 12 (A7 3F)

In this lecture, a survey of some theoretical progresses on several basic problems in systems and control science will be presented. We will begin by discussing the following two problems that are related to the emergence of complex systems: When flocks with large population will be synchronized? Can a general theory for distributed adaptive filtering be established? Then we will focus on the understanding of the feedback mechanism for regulating uncertain dynamical systems and to answer the following questions: What are the main features of adaptive control systems where online estimators are combined with real-time controllers in the same feedback loop? Can we establish the global stability and optimality of the well-known self-tuning regulators? What is the rationale behind the widespread use of the classical proportional-integral-derivative (PID) control? How about the maximum capability and fundamental limitations of the feedback mechanism in dealing with nonlinear uncertain systems? Finally, we will discuss how a theory may be established for game-based control systems, where some "intelligent" behaviors including dynamical games may exist in the systems to be regulated.

Speaker Index

In this index, you will find the names of the ICBS speakers sorted alphabetically by last name in English.