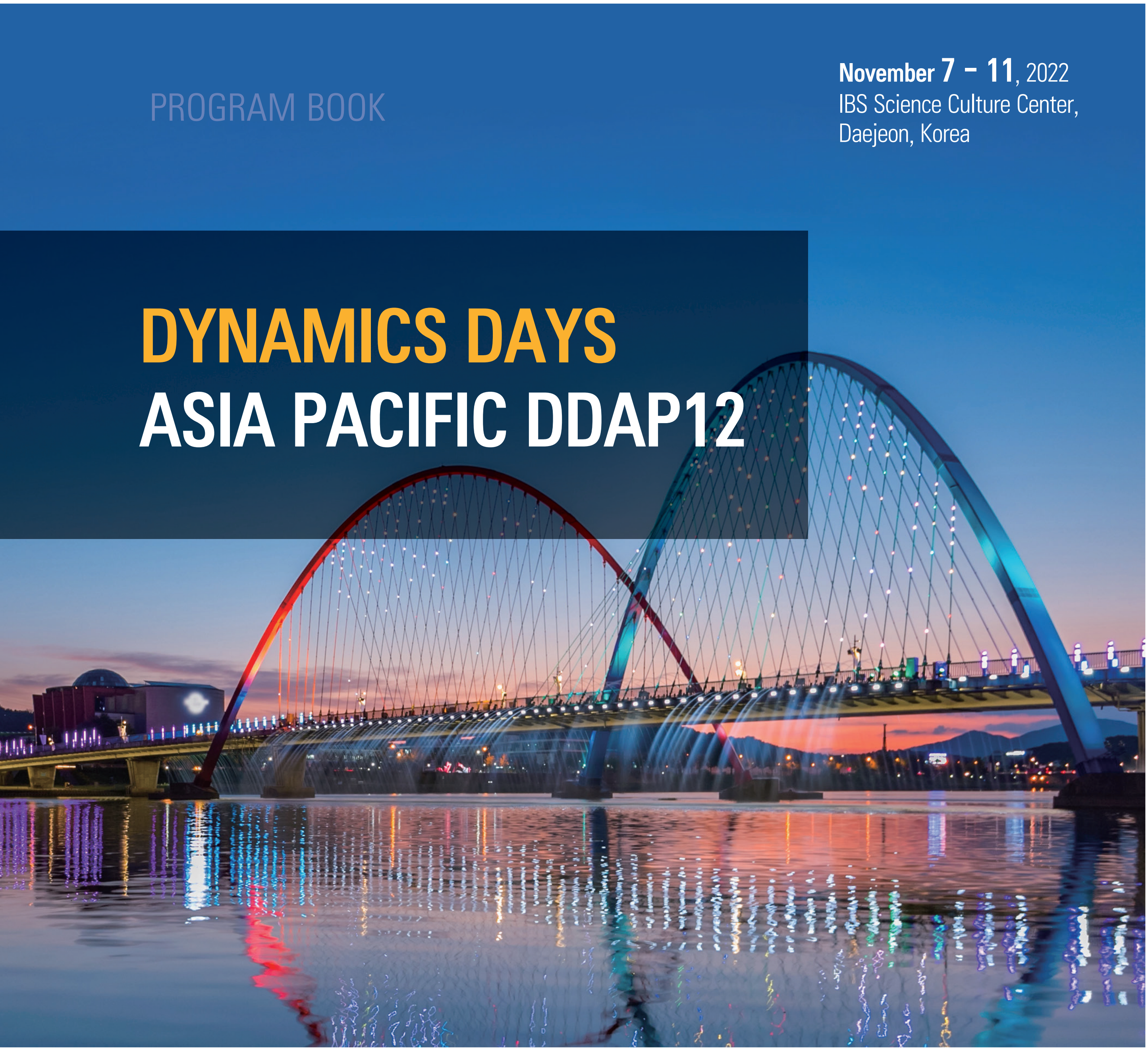
PROGRAM BOOK

November 7 – 11, 2022
IBS Science Culture Center,
Daejeon, Korea

DYNAMICS DAYS
ASIA PACIFIC DDAP12

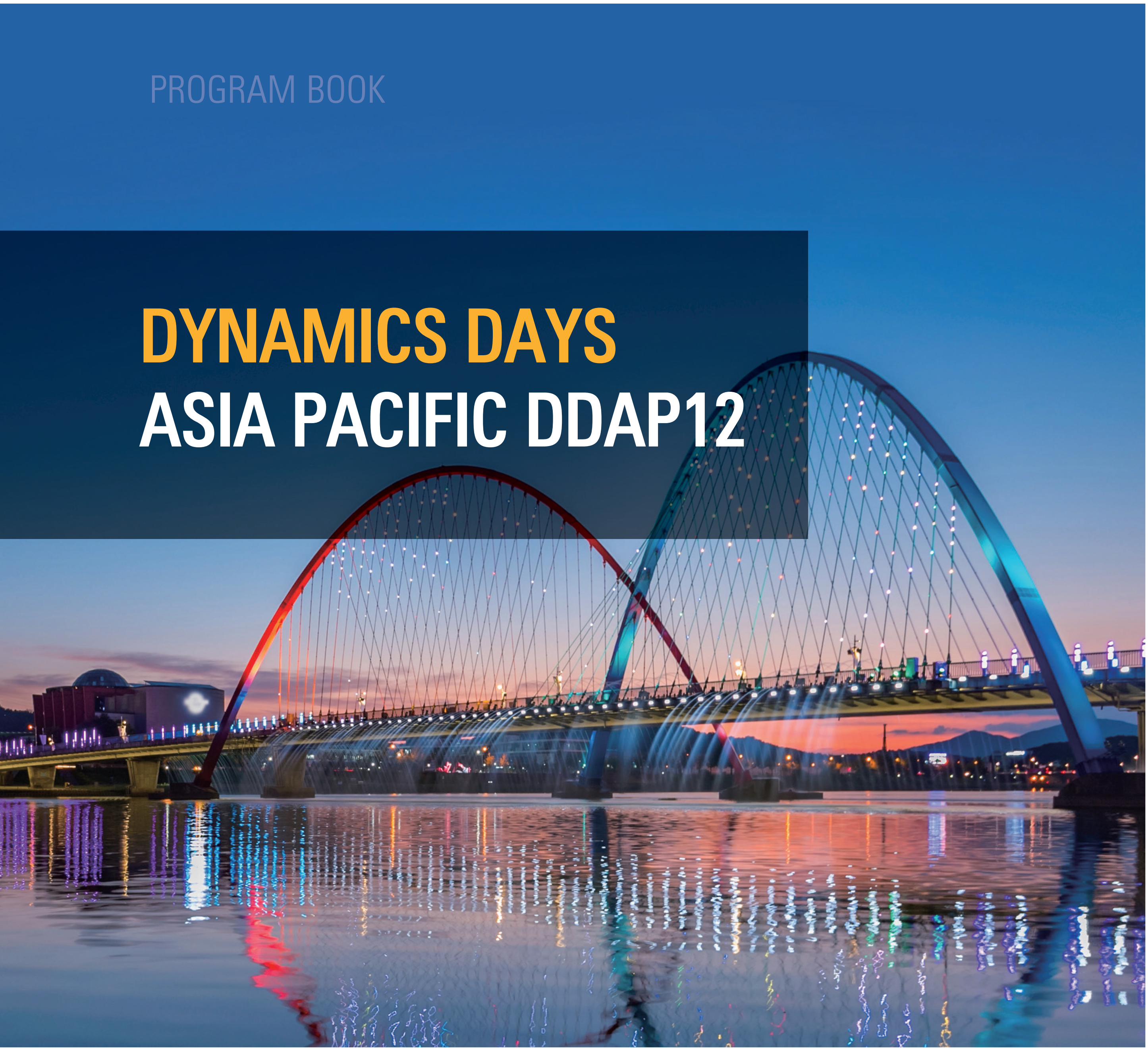


Institute for Basic Science

Center for Theoretical Physics of Complex Systems

PROGRAM BOOK

DYNAMICS DAYS ASIA PACIFIC DDAP12



Institute for Basic Science

Center for Theoretical Physics of Complex Systems

Dynamics Days
Asia Pacific DDAP12

Dynamics Days meetings are international conferences which started in 1980 with original focus on theory and applications of nonlinear dynamics. They have been held regularly in Europe, the US, the Asia-Pacific region, the Latin America and the Carribean, and in Central Asia.

Dynamics Days Asia Pacific started in Hong Kong in 1999, and then moved on to Hangzhou (2002), Singapore (2004), Pohang (2006), Nara (2008), Sydney (2010), Taipei (2012), Chennai (2014), Hong Kong (2016), Xiamen (2018), Singapore (2020), and Daejeon (2022).

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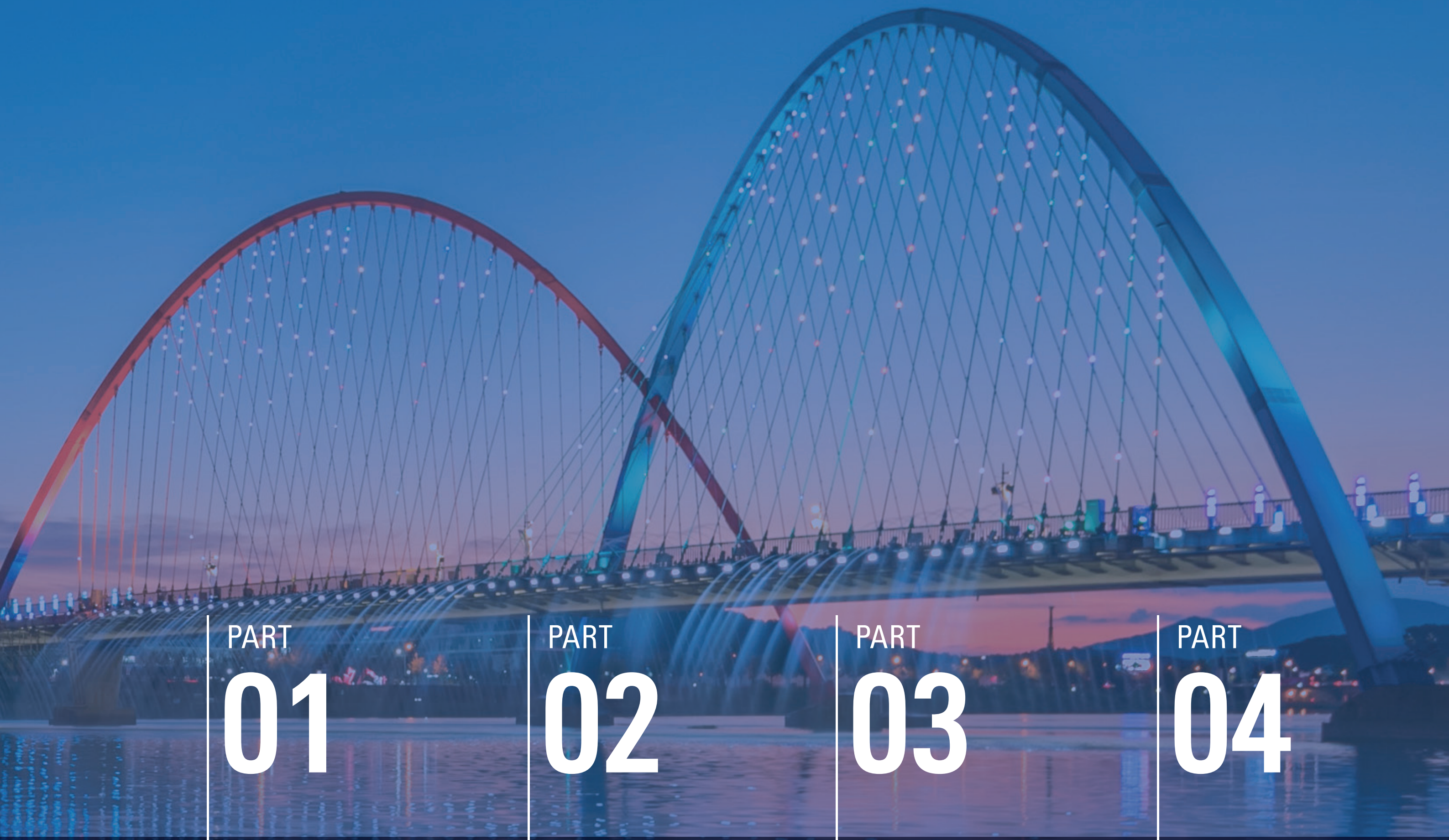

PART 01

INFORMATION & FREQUENTLY ASKED QUESTIONS

INFORMATION & FREQUENTLY ASKED QUESTIONS

• VISITOR PROGRAM

In case of emergency: +82 10 2743 4200 (Ms. Gileun Lee)

• Wi-Fi

- Please use IBS-LIB (free wifi)

• MEALS, TRAVEL

- IBS cafeteria (IBS Theory Building 1st floor): lunches on Mon. – Fri. / dinner on Thu. (please use the provided coupons)
- Shuttle bus departure times (sharp):
  to the IBS: 8.40 am (Mon.), 8.20 am (Tue. – Fri.)
  to the Good morning residence hotel: 8 pm (Mon.), 8 pm (Tue., Thu,.), 8.30 pm (Wed.), 2 pm (Fri.)

• SOCIAL PROGRAM

- **Welcome reception (Monday, November 7)**
  Time: 6 pm, venue: IBS Science Culture Center, 3F
- **Poster session (Tuesday, November 8)**
  Time: 6 pm, venue: IBS Science Culture Center, 3F
- **Conference picture (Tuesday, November 8 & Thursday, November 10)**
  Time: Tuesday, 12.30 pm, meeting point: IBS Science Culture Center, 2F lounge
  Time: Thursday, 3.30 pm, meeting point: IBS Science Culture Center, 2F lounge
- **Excursion (Wednesday, November 9)**
  Departure: 1.30 pm, venue: Jeonju
  Shuttle bus to the excursion: 1.30 pm (sharp) in front of IBS Science Culture Center
- **Conference banquet (Wednesday, November 9 – final stop of excursion)**
  Time: 7 pm, venue: 쌍촌본가 (Daejeon, Yuseong-gu, Wonchon-dong, 77-4)
  Shuttle bus: Banquet place > IBS > Good morning residence Hotel (8.30 pm)

• ADDITIONAL INFORMATION – please contact pcs@ibs.re.kr

• FEEDBACK FORM

Please scan the QR code with your phone camera to provide feedback on this conference.

PART
02

PROGRAM

PROGRAM

MONDAY			
8:30 - 9:30	Registration		
Place	**2F Auditorium**		
9:30 - 9:45	Opening		
9:45 - 10:30	Steven Strogatz		
10:30 - 11:00	Break		
11:00 - 11:45	Boris Altshuler		
11:45 - 12:30	Ying-Cheng Lai		
12:30 - 14:00	Lunch (IBS Theory Building 1F Cafeteria)		
Place	**2F Auditorium**	**2F Hall**	**3F Hall**
14:00 - 14:30	Emil Yuzbashyan	Hayato Chiba	Christian Franzke
14:30 - 15:00	Dario Rosa	Kazumasa Takeuchi	Yoo-Geun Ham
15:00 - 15:30	Sudhir-Ranjan Jain	Arkady Pikovsky	Laurie Menviel
15:30 - 16:00	Thomas Bilitewski	Daan Crommelin	Malte Stuecker
16:00 - 16:30	Break		
Place	**2F Auditorium**		
16:30 - 17:15	Changsong Zhou		
17:15 - 18:00	Yamir Moreno		
18:00 - 20:00	Welcome reception(3F)		

All times in the program refer to Korean Standard Time (KST).

PROGRAM

<table>
<tr><th colspan="4">TUESDAY</th><th colspan="2">WEDNESDAY</th></tr>
<tr><th>Place</th><th colspan="3">2F Auditorium</th><th>Place</th><th>2F Auditorium</th></tr>
<tr><td>9:00 - 9:45</td><td colspan="3">Takahiro Sagawa</td><td>9:00 - 9:45</td><td>Juergen Kurths</td></tr>
<tr><td>9:45 - 10:30</td><td colspan="3">Wenwei Ho</td><td>9:45 - 10:30</td><td>Yoshiyuki Kabashima</td></tr>
<tr><td>10:30 - 11:00</td><td colspan="5">Break</td></tr>
<tr><th>Place</th><th>2F Auditorium</th><th>2F Hall</th><th>3F Hall</th><td rowspan="2">11:00 - 11:45</td><td rowspan="2">Jiangbin Gong</td></tr>
<tr><td>11:00 - 11:30</td><td>Dario Poletti</td><td>Lock Yue Chew</td><td>Kenta Ishimoto</td></tr>
<tr><td>11:30 - 12:00</td><td>Berge Englert</td><td>Andreas Dechant</td><td>Rui Zhang</td><td rowspan="2">11:45 - 12:30</td><td rowspan="2">Byungnam Kahng</td></tr>
<tr><td>12:00 - 12:30</td><td>Mile Gu</td><td>Jae Sung Lee</td><td>Younghae Do</td></tr>
<tr><td>12:30 - 14:00</td><td colspan="5">Lunch
(IBS Theory Building 1F Cafeteria)</td></tr>
<tr><th>Place</th><th colspan="3">3F Lounge</th><td rowspan="5">13:30 - 19:00</td><td rowspan="5">Excursion
(Jeonju)</td></tr>
<tr><td>14:00 - 16:30</td><td colspan="3">Poster Session(3F)</td></tr>
<tr><th>Place</th><th colspan="3">2F Auditorium</th></tr>
<tr><td>16:30 - 17:15</td><td colspan="3">Henk Dijkstra</td></tr>
<tr><td>17:15 - 18:00</td><td colspan="3">Antonio Politi</td></tr>
<tr><td>18:00 - 20:00</td><td colspan="3">Poster session dinner(3F)</td><td>19:00 - 20:30</td><td>Banquet
(쌍촌본가)</td></tr>
</table>

All times in the program refer to Korean Standard Time (KST).

PROGRAM

THURSDAY

Place	2F Auditorium
9:00 - 9:45	Igor Aronson
9:45 - 10:30	Reka Albert
10:30 - 11:00	Break

Place	2F Auditorium	2F Hall	3F Hall
11:00 - 11:30	Moon Jip Park	Deok-Sun Lee	Antonio Celani
11:30 - 12:00	Yuto Ashida	Yong Woon Kim	Liang Tian
12:00 - 12:30	Ryo Hanai	Seung Ki Baek	Yongjoo Baek
12:30 - 14:00	Lunch (IBS Theory Building 1F Cafeteria)		

Place	2F Auditorium	2F Hall	3F Hall
14:00 - 14:30	Alexei Andreanov	Dong-Hee Kim	Manas Kulkarni
14:30 - 15:00	Arul Lakshminarayan	Chi-Hang Lam	Andrey Kolovsky
15:00 - 15:30	Carlo Danieli	Chang-Hwan Yi	Giuliano Benenti
15:30 - 16:30	Break		

Place	2F Auditorium
16:30 - 17:15	Federico Ricci-Tersenghi
17:15 - 18:00	David Saad
18:00 - 20:00	Dinner (IBS Theory Building 1F Cafeteria)

FRIDAY

Place	2F Auditorium
9:00 - 9:45	Hugues Chate
9:45 - 10:30	Jae Dong Noh
10:30 - 11:00	Break
11:00 - 11:45	Sriram Ramaswamy
11:45 - 12:30	Axel Timmermann
12:30 - 14:00	Closing & Lunch

All times in the program refer to Korean Standard Time (KST).

PART
03

ABSTRACTS

Global Synchronization: New Theorems, New Puzzles

Steven Strogatz
Cornell University, USA

Consider a network of N identical Kuramoto oscillators. Suppose all the coupling strengths are equal and bidirectional, and each oscillator is connected to at least μ(N-1) other oscillators, where $0 \leq \mu \leq 1$. How likely is the network to end up in perfect synchrony, starting from random initial conditions? It's known that all networks with sufficiently large μ will globally synchronize, but how large is large enough? In this Zoom talk, I'll discuss the big gap - and the big unsolved puzzle about what happens - between the best known upper and lower bounds on the critical connectivity μ_c above which all such networks globally synchronize. I'll also mention what is currently known for randomly connected networks. This is joint work with Alex Townsend, Mike Stillman, and Martin Kassabov.

Many-Body Localization

Boris Altshuler
Columbia University, New York, USA

Localization of the eigenfunctions of quantum particles in a random potential was discovered by P.W. Anderson more than 60 years ago. In spite of its respectable maturity and intensive theoretical and experimental studies this field is far from being exhausted.

Later the domain of applicability of the concept of localization was dramatically broadened. It provides an adequate framework for discussing the transition between integrable and chaotic behavior in quantum systems.

The states of non-integrable many-body systems with large number of degrees of freedom is not always completely chaotic. It can be localized in the space of quantum numbers of the underlying integrable system rather than in the real space. This behavior is now known as Many-Body Localization (MBL). We will discuss several examples of the MBL transition and a connected problem of the ergodicity of the extended many-body states.

Finding the Equations and Structures of Complex Systems from Data

Ying-Cheng Lai
Arizona State University, USA

In applications of nonlinear and complex dynamical systems, a common situation is that the system can be measured, but its structure and the detailed rules of the dynamical evolution are unknown. The inverse problem is to determine the system equations and structures from time series data. Sparse optimization was articulated in 2011 to find the equations of dynamical systems from data. The basic idea is to expand the system equations into a power series or a Fourier series of a finite number of terms and then to determine the vector of the expansion coefficients based solely on data through sparse optimization. In this talk, the history of this area of research will be reviewed and recent progress will be presented. Issues discussed include discovering the equations of stationary or nonstationary chaotic systems to enable the prediction of critical transition and system collapse, inferring the full topology of complex oscillator networks and social networks hosting evolutionary game dynamics, and identifying partial differential equations for spatiotemporal dynamical systems. Situations where sparse optimization works or fails will be pointed out. The relation with the traditional delay-coordinate embedding method and the recent development of a model-free, data-driven prediction framework based on machine learning will be discussed.

Cost-Efficient Neural Dynamics: Reconciling Multilevel Spontaneous and Evoked Activity in E-I Balanced Neural Networks at Criticality

Changsong Zhou
Hong Kong Baptist University, Hong Kong

The brain is highly energy consuming, therefore is under strong selective pressure to achieve cost-efficiency in both cortical connectivity and activity. Cortical neural circuits display highly irregular spiking in individual neurons but variably sized collective firing, oscillations and critical avalanches at the population level, all of which have functional importance. It is not clear how cost-efficiency is related to ubiquitously observed multi-level properties of irregular firing, oscillations and neuronal avalanches. In this talk, I will introduce a series of our work demonstrating that prominent multilevel neural dynamics properties can be simultaneously reconciled in a generic, biologically plausible neural circuit model that captures excitation-inhibition balance and realistic dynamics of synaptic conductance. Their co-emergence achieves minimal energy cost as well as maximal energy efficiency on information capacity, when neuronal firings are maintained in the form of critical neuronal avalanches. We propose a semi-analytical mean-field theory to derive the field equations governing the network macroscopic dynamics. It reveals that the critical state E-I balanced state of the network manifesting irregular individual spiking is characterized by a macroscopic stable state, which can be either a fixed point or a periodic motion and the transition is predicted by a Hopf bifurcation in the macroscopic field. An analysis of the impact of network topology from random to modular networks shows that local dense connectivity under E-I balanced dynamics appears to be the key "less-is-more" solutions to achieve cost-efficiency organization in neural systems. In the presence of external stimuli, the model at criticality can simultaneously account for various reliable neural response features observed in experiments. The modeling framework offers opportunities for study complex neural dynamics in neural information processing, as well as in cost-efficient brain-inspired artificial intelligence.

Contagion Dynamics on Single, Multilayer, and Higher-Order Networks

Yamir Moreno
University of Zaragoza, Spain

Modern network science has greatly contributed to our understanding of many processes in diverse fields of science. Arguably, contagion dynamics -including network epidemiology- is the area in which network concepts have had a bigger practical impact. Nowadays, we are able to model how diseases unfold and spread with unprecedented precision, which also makes it possible to analyze other spreading-like processes, such as social contagion. In this talk, we revise this area of research by discussing how the modeling of spreading processes has evolved in the last two decades. We start by analyzing contagion dynamics in single populations that are described by different network topologies. Next, we discuss cases in which a multilayer approach is needed. Finally, we introduce contagion dynamics in higher-order networks, which shows a much rich phase space for the dynamics of the system. We round off the talk by discussing what are the challenges that remain for the future.

Quantum Fluctuation Theorems under Measurement and Feedback

Takahiro Sagawa
University of Tokyo, Japan

The fluctuation theorem characterizes the universal properties of the entropy production far from equilibrium. In the presence of measurement and feedback by "Maxwell's demon", the fluctuation theorem is generalized by incorporating information contents such as mutual information, elucidating the link between thermodynamics and information [1]. While the fluctuation theorem in classical systems has been thoroughly generalized under various feedback control setups, the role of information in thermodynamics in the quantum regime has not been fully revealed, despite its significance in quantum feedback control. In this talk, starting from a brief review of thermodynamics of information, I will focus on the generalized fluctuation theorem under continuous quantum measurement and feedback [2]. The relevant information content is the quantum-classical-transfer (QC-transfer) entropy, which can be naturally interpreted as the quantum counterpart of transfer entropy that is commonly used in classical time series analysis. I will also demonstrate our theoretical result by numerical simulation based on an experiment-numerics hybrid verification method. These results reveal a fundamental connection between quantum thermodynamics and quantum information.

[1] J. M. R. Parrondo, J. M. Horowitz, and T. Sagawa, Nature Phys.11, 131–139 (2015).
[2] T. Yada, N. Yoshioka, T. Sagawa, Phys. Rev. Lett. 128, 170601 (2022).

Quantum Many-Body Dynamics in the Age of Noisy, Intermediate-Scale Quantum (NISQ) Devices

Wenwei Ho
National University of Singapore, Singapore

There is currently a tremendous global effort invested into building quantum computing technologies. While today's devices are still far from having the fault-tolerance required to perform reliable large-scale computation, they are nevertheless exceptional platforms ideal for the investigation of quantum many-body physics in regimes that go beyond conventional material experiments, especially collective phenomena far-from-equilibrium. This stems from their unprecedented capabilities for control and measurement. In this talk I will demonstrate how such capabilities allow for the probing of a novel phenomenon in dynamics, namely a deeper form of quantum thermalization (the process by which systems settle down over time), in which not just local observables relax to universal values but also conditional post-measurement wave-functions acquire a universally random distribution. Quantum information theoretic concepts are used to characterize this, showing the importance of the union of many-body and quantum information frameworks to yield new insights into fundamental phenomena. Time-permitting, I will sketch how such universal randomness can in fact be used as a resource for applications in quantum information science, like quantum state learning.

Tipping of the Atlantic Ocean Circulation

Henk Dijkstra
Utrecht University, Netherlands

The Atlantic Ocean Circulation, in particular its zonally averaged component called the Atlantic Meridional Overturning Circulation (AMOC), is one of the tipping elements in the climate system. The AMOC is sensitive to freshwater perturbations and may undergo a transition to a climate disrupting state within a few decades under continuing greenhouse gas emissions. The potential climate impacts of such a collapse are enormous and hence reliable estimates of the probability of its occurrence before the year 2100 are crucial information for policy makers. In his talk, an overview will be given of current approaches to determine AMOC transition probabilities in a hierarchy of ocean-climate models.

A New Interpretation of Laser Instabilities

Antonio Politi
University of Aberdeen, UK

An accurate mathematical model to describe laser instabilities is available since more than 50 years. However, a detailed comprehension of the resulting dynamical behaviour is still missing.

In particular, the reason why atomic polarization cannot be adiabatically eliminated even in the presence of very fast relaxation processes is puzzling.

I revisit the dynamical equations by first transforming the original model into an equation with delay much easier to simulate numerically and then implementing a multi-scale perturbative approach, which reintroduced a space-time representation.

As a result, I am able to show that the laser dynamics is unexpectedly nearly Hamiltonian, the underlying equation being nonlinear wave equation of Klein-Gordon type in the presence of a Toda potential.

The closeness to a Hamiltonian dynamics explains a posteriori the singularity of the original model, including the difficulty of adiabatically eliminating the polarization.

Climate Meets Complex Systems: Exploring Predictability of Extreme Climate Events via a Complex Network Approach

Juergen Kurths
Potsdam Institute for Climate Impact Research, Germany

The Earth system is a very complex and dynamical one basing on various feedbacks. This makes predictions and risk analysis even of very strong (sometime extreme) events as floods, landslides, and heatwaves etc. a challenging task. Additionally, there is a strongly increasing number of extreme events due to climate change.

After introducing physical models for weather forecast already in 1922 by L.F. Richardson, a fundamental open problem has been the understanding of basic physical mechanisms and exploring anthropogenic influences on climate. In 2021 Hasselmann and Manabe got the Physics Nobel Price for their pioneering works on this. I will shortly review their main seminal contributions.

Next, I will present a recently developed innovative approach via complex networks mainly to analyze strong climate events. This leads to an inverse problem: Is there a backbone-like structure underlying the climate system? To treat this problem, we have proposed a method to reconstruct and analyze a complex network from spatio-temporal data. This approach enables us to uncover relations to global and regional circulation patterns in oceans and atmosphere, which leads to construct substantially better predictions, in particular for the onset of the Indian Summer Monsoon, extreme rainfall in South America, the Indian Ocean Dipole and tropical cyclones but also to understand phase transition in the past climate.

References

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J. Runge, …, J. Kurths, Nature Comm. 6, 8502 (2015)

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Z. Su, H. Meyerhenke, J. Kurths, CHAOS 32, 043126 (2022).

Assessing Transfer Entropy from Biochemical Data

Yoshiyuki Kabashima
University of Tokyo, Japan

We develop a method for evaluating the transfer entropy (TE) produced by biochemical reactions from experimentally measured data. The usefulness of the developed method is examined by applying it to real biological data experimentally measured from the ERBB-RAS-MAPK system that superintends diverse cell fate decisions.
A comparison between cells containing wild-type and mutant proteins exhibits a distinct difference in the time evolution of TE while any apparent difference is hardly found in average profiles of the raw signals. Such a comparison may help in unveiling important pathways of biochemical reactions.

Nonequilibrium Topological Phases and Floquet Quantum Computation

Jiangbin Gong
National University of Singapore, Singapore

Nonequilibrium topological phases of matter induced by time-periodic modulation are unusually rich, exotic and highly tuneable. This line of research at both the single-particle and many-body levels has attracted considerable experimental and theoretical interests during the past decade. After covering some background information, I wish to cover a few important results from my own research group at NUS, including the generation of an arbitrary number of robust chiral edge channels or many topological 0 and pi modes on demand. I shall then showcase intriguing subharmonic responses in Floquet topological matter and the possibility of using Floquet topological edge modes for braiding operations and measurement-based quantum computation.

References:

1. W.W. Zhu, J. Gong, R.W. Bomantara, Topological pi modes and beyond, A “Perspective” article for Science Bulletin (2022) (in press).
2. W. W. Zhu, H. R. Xue, J. Gong, Y. D. Chong, B. L. Zhang, Time-periodic corner states from Floquet higher-order topology, Nature Communications 13, 11 (2022).
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8. L. W. Zhou and J. Gong, Recipe for creating an arbitrary number of Floquet chiral edge states, Phys. Rev. B 97, 245430 (2018).

Universal Microscopic Mechanism of Hybrid Percolation Transitions

Byungnam Kahng
Korea Institute of Energy Technology, Korea

A hybrid percolation transition (HPT) exhibits both discontinuity of the order parameter and critical behavior at the transition point. Such dynamic transitions can occur in two ways: by cluster pruning with suppression of loop formation of cut links or by cluster merging with suppression of the creation of large clusters. While the microscopic mechanism of the former is understood in detail, a similar framework is missing for the latter. By studying cluster merging models, we uncover the universal mechanism of the features of HPT-s of the two models at a microscopic level. We find that these features occur in three steps: (i) medium-sized clusters are accumulated due to the suppression rule hindering the growth of large clusters, (ii) those clusters are merged and a giant cluster increases rapidly, and (iii) the suppression effect disappears and the kinetics is governed by the Erdős-Rényi type of dynamics. We characterize the critical behavior by two sets of critical exponents associated with the order parameter and cluster size distribution, which are related to each other by a scaling relation. Extensive numerical simulations are carried out to support the theory where a specific method is applied for finite-size scaling analysis to enable handling the large fluctuations of the transition point. Our results provide a unified theoretical framework of the HP.

Self-Organization of Signaling Active Matter

Igor Aronson
Pennsylvania State University, USA

In this talk, we will consider active matter endowed with an ability to communicate via chemical waves and make simple decisions. We have shown that this decision-making capacity dramatically expands their ability to form complex structures, allowing them to self-organize through a series of collective dynamical states at multiple hierarchical levels. Our findings provide insights into the role of self-sustained signal processing for self-organization in biological systems and open routes to applications using chemically driven colloids or microrobots.

Identifying Decisions in Biological Systems: Toward Understanding and Control

Reka Albert
Pennsylvania State University, USA

My group is using network science and dynamic modeling to understand the emergent properties of biological systems. As an example, we think of cell types as attractors of a dynamical system of interacting (macro)molecules, and we aim to find the network patterns that determine these attractors. We collaborate with wet-bench biologists to develop and validate predictive dynamic models of specific systems. Over the years we found that network-based discrete dynamic modeling is very useful in synthesizing causal interaction information into a predictive, mechanistic model. We use the accumulated knowledge gained from specific models to draw general conclusions that connect a network's structure and dynamics. An example of such a general connection is our identification of stable motifs, which are self-sustaining cyclic structures that determine trap spaces of the system. We have elucidated the system's decision-making as a choice between two mutually exclusive stable motifs and have shown that the control of stable motifs can guide the system into a desired attractor. We have translated the concept of stable motif to a broad class of continuous (ODE-based) models. We have recently developed the software library pystablemotifs, which implements efficient algorithms to determine and control any Boolean system's attractor repertoire. Stable motif - based attractor control can form the foundation of therapeutic strategies on a wide application domain.

Representative references:

1. JGT Zañudo, SN Steinway, R Albert, Discrete dynamic network modeling of oncogenic signaling: Mechanistic insights for personalized treatment of cancer, Current Opinion in Systems Biology 9, 1-10 (2018).
2. JC Rozum, R Albert, Identifying (un)controllable dynamical behavior in complex networks, PLOS Computational Biology 14, e1006630 (2018).
3. JC Rozum, JGT Zañudo, X. Gan, D. Deritei, R. Albert, Parity and time reversal elucidate both decision-making in empirical models and attractor scaling in critical Boolean networks, Science Advances 7, eabf8124 (2021).

Rejuvenation and Memory: Amazing Effects in the Spin Glass Dynamics, Involving Several Growing Length Scales

Federico Ricci-Tersenghi
Sapienza University of Rome, Italy

Spin glasses are disordered magnets whose relaxation times are so large that never reach equilibrium at low temperatures, even on experimental time scales. In their out-of-equilibrium dynamics, experimental spin glasses show amazing effects, called rejuvenation and memory, whose explanation has remained elusive for decades, given the inability of reproducing such effects in numerical simulations.

I will present the results of the first large-scale numerical simulation which has been able to reproduce such effects, exploiting the computational power of the Janus 2 dedicated computer.

The microscopic explanation of these effects requires the measurement of more than a single growing length scale, something that currently can be achieved only in numerical simulations.

Pandemics, Marketing and Opinion Formation – The Power of Spreading Processes

David Saad
Aston university, UK

The modern world comprises interlinked networks of contacts between individuals, computing devices and social groups, where infectious diseases, information and opinions propagate through their edges in a probabilistic or deterministic manner via interactions between individual constituents. The spread of information, opinions and marketing material can be modelled and analysed in a similar manner to that of epidemic spreading among humans or animals.

To contain and mitigate the spread of infectious diseases one would like to model the spread accurately, implement effective prevention and mitigation policies and deploy vaccines in a way that minimises the spread. This is a difficult problem and becomes even harder in the presence of infectious but asymptomatic individual states. In the world of marketing and opinion setting, winners are those who maximise the impact by deploying resource to the most influential available nodes at the right time, occasionally in competition (or collaboration) with adversarial (supportive) spreading processes. These can represent opinion formation by political parties (competitive) or diseases that increase the susceptibility to mutual infections (collaborative).

I will explain the modelling of epidemic spreading processes and present the probabilistic analytical framework for impact maximisation/minimisation we have developed, addressing the questions of vaccine (budget) deployment and spreading maximisation in single and competitive/collaborative processes. I will also present the analysis for epidemic spreading processes with infectious but asymptomatic states and the effectiveness of containment and mitigation steps in this case.

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B. Li and D. Saad, Phys. Rev. E 103, 052303 (2021).

A Synchronization Viewpoint on Some Active Matter Results

Hugues Chaté
CEA - Saclay, France

After a brief update on our current understanding of simple active matter models, I will discuss some recent results on 2D dry aligning active matter from a synchronization viewpoint, taking the polarity of the self-propelled particles involved as the phase of an oscillator.
I will focus on the simple case of polar particles aligning ferromagnetically, like in the Vicsek model, well-known to exhibit true long-range orientational order, i.e. phase synchronization in the presence of noise. I will in particular discuss the effect of chirality or Kuramoto-type disorder, and that of quenched spatial disorder, both of which have been found recently to be able destroy synchronization even if they are arbitrarily weak.

References:

[1] H. Chaté, Ann. Rev. Cond. Mat. Phys. 11, 189 (2020)
[2] B. Ventejou, et al., Phys. Rev. Lett. 127, 238001 (2021)
[3] D. Yu, et al., Phys. Rev. Lett. 126, 178001 (2021)

Do Quantum Systems Thermalize?

Jae Dong Noh
University of Seoul, Korea

Recent advances in experimental techniques allow us to observe static and dynamic properties of isolated quantum systems under the unitary time evolution. These achievements trigger huge amounts of research activities to find an answer to the fundamental question of statistical mechanics: Can an isolated quantum mechanical system relax to the thermal equilibrium state? The eigenstate thermalization hypothesis is believed to explain the mechanism for the thermalization of a quantum system with a nonintegrable Hamiltonian. In this talk, we present a review on the recent progress in our understanding of the quantum thermalization. We also discuss promising but unresolved topics for future works.

Directions in the Hydrodynamics of Active Matter

Sriram Ramaswamy
Indian Institute of Science, Bangalore, India

Active systems, by definition, are made of constituents endowed with a steady free-energy supply which they convert into systematic movement, i.e., work. These self-driven materials break the rules of equilibrium matter in intriguing, instructive and possibly useful ways. My talk will present recent results from our work on the collective properties of active systems, with emphasis on the roles of inertia, chirality and non-reciprocality.

Reconstructing, Simulating and Understanding Abrupt Climate Change

Axel Timmermann
IBS Center for Climate Physics & Pusan National University, Korea

As our planet is experiencing unprecedented anthropogenic warming, sea level rise and ocean acidification the question arises whether the continuation of any of these trends could lead to threshold behavior either in physical or biological systems. Earth system computer models used to project future planetary warming still have difficulties in capturing the extremely variable climate during the last glacial period (~80-15 thousand years ago), which was characterized by abrupt warming transitions, unpredictable ice-sheet instabilities, and large-scale centennial to millennial shifts in ocean circulation. To elucidate the underlying physical processes and improve earth system models' capabilities to simulate spontaneous climatic transitions, climate scientists rely on accurate reconstructions and an improved physical understanding of abrupt past climate changes on regional to global scales.

In this presentation I will take you take you on a journey that begins in the caves of Gangwon-do in the northeastern part of South Korea, and ends in the discovery of a remarkable abrupt climate transition that occurred around 16 thousand years. This event was characterized by one of the most abrupt large-scale coolings recorded to date. Within 5-10 years the entire northern hemisphere plunged into a cold state, which lasted for about 100 years. To identify the causes of this event, we combined new geochemical and isotopic proxies from Korean stalagmites with isotope-enabled climate model simulations. The most likely explanation, which is consistent with the global fingerprint of the recorded event, is that a huge glacial meltwater lake burst into the northern North Atlantic, leading to increased ocean stratification, massive sea ice formation and large-scale reorganizations of the atmospheric circulation, which impacted even remote regions such as the Korean Peninsula and Australia.

Such events are not explicitly resolved in the current generation of climate models, which lack ice-sheet dynamics and complex hydrology. In the last part of my presentation, I will report on our center's progress in coupling dynamical ice-sheet models with a state-of-the-art earth system model. The new modeling system is capable of simulating glacial/interglacial cycles realistically and some level of millennial-scale variability. Future concerted modeling efforts need to be launched to improve the representation of abrupt and internally generated low-frequency climate transitions.

Is Nonequilibrium Superconductivity a Quantum or a Classical Phenomenon?

Emil Yuzbashyan
Rutgers University, USA

I will show that the classical (mean-field) description of nonequilibrium superconductivity is exact in the thermodynamic limit for local observables but breaks down for global quantities, such as the entanglement entropy or Loschmidt echo. I will do this by solving for and comparing exact quantum and exact classical long-time dynamics of a BCS superconductor with interaction strength inversely proportional to time and evaluating local observables explicitly.

The long-time steady state of the system is a gapless superconductor whose superfluid properties are only accessible through energy resolved measurements. This state is nonthermal but conforms to an emergent generalized Gibbs ensemble

Delocalization and Scrambling of Operators in Quantum Networks

Dario Rosa
IBS PCS

I will introduce the notion of operator delocalization, to be contrasted with the more conventional notion of operator growth. I will show that even free quantum mechanical systems, once defined on sufficiently connected networks, can exhibit non-trivial delocalization properties. The connection with the notion of operator scrambling and quantum chaos will be also uncovered.

Qubit Control and Protection: Ideas from Nonlinear Science

Sudhir-Ranjan Jain
Bhabha Atomic Research Centre, India

We employ the stochastic path-integral formalism and action principle for continuous quantum measurements to understand the stages in which quantum Zeno effect helps control the states of a simple quantum system. The detailed dynamics of a driven two-level system subjected to repeated measurements unravels a myriad of phases, so to say. When the detection frequency is smaller than the Rabi frequency, the oscillations slow down, eventually coming to a halt at an interesting resonance when measurements are spaced exactly by the time of transition between the two states. On the other hand, in the limit of large number of repeated measurements, the dynamics organizes itself in a rather interesting way about two hyperbolic points in phase space whose stable and unstable directions are reversed. Thus, the phase space flow occurs from one hyperbolic point to another, in different ways organized around the separatrices. We believe that the systematic treatment presented here paves the way for a better and clearer understanding of quantum Zeno effect in the context of quantum error correction.

From KPZ Scaling to Long-Lived Solitons in the Classical Heisenberg Chain

Thomas Bilitewski
Oklahoma State University, USA

We investigate the origin of the recently discovered KPZ scaling [1] in the classical Heisenberg chain. We find that this -- arguably maximally simple spin chain -- surprisingly supports long-lived solitons whose existence had so far escaped notice [2].

We are able to relate these solitons to those known to exist in the integrable Ishimori chain by constructing an interpolating model between the (non-integrable) Heisenberg with $S_i\cdot S_j$ and the integrable Ishimori chain with $\log(1+ S_i\cdot S_j)$ interactions. This further allows us to adiabatically transform Ishimori solitons into Heisenberg solitons.
We provide an explicit construction for stable (infinitely long-lived) stationary solitons in the Heisenberg chain, as well as adiabatically constructed moving soliton solutions.
We map out the existence regions of single soliton solutions in the Heisenberg chain, and determine the renormalisation of the properties of HB solitons compared to their Ishimori counterparts. We further study two-soliton scattering in the HB chain, finding these solitons to survive multiple (hundreds of) scattering events, and determine the renormalisation of the scattering phase shifts.

Finally, we demonstrate their presence in thermal states of the Heisenberg chain.

Refs: [1] Phys. Rev. B 105 L100403 (2022)
[2] arxiv 2207.08866 (2022)

A Bifurcation in the Kuramoto Model on Networks

Hayato Chiba
Tohoku University, Japan

For the mean-field limit of a system of globally coupled phase oscillators defined on networks, a bifurcation from the incoherent state to the partially locked state at the critical coupling strength is investigated based on the generalized spectral theory. This reveals that a network topology affects the dynamics through the eigenvalue problem of a certain Fredholm integral operator which defines the structure of a network.

Scaling and Spontaneous Symmetry Restoring of Topological Defect Dynamics in Liquid Crystal

Kazumasa A. Takeuchi
The University of Tokyo, Japan

Topological defects are a universal concept playing important roles in diverse systems studied in physics and beyond, including the universe, various condensed matter systems, and recently, even life phenomena. Among these, liquid crystal has been a platform for studying topological defects via visualization, yet it has been a challenge to resolve three-dimensional structures of dynamically evolving singular topological defects. Here, we report a direct confocal observation of nematic liquid crystalline defect lines, called disclinations, relaxing from an electrically driven turbulent state. We focus in particular on reconnections, characteristic of such line defects. We find a scaling law for in-plane reconnection events, by which the distance between reconnecting disclinations decreases by the square root of time to the reconnection. Moreover, we show that apparently asymmetric dynamics of reconnecting disclinations is actually symmetric in a comoving frame, in marked contrast to the two-dimensional counterpart whose asymmetry is established. We argue, with experimental supports, that this is because of energetically favorable symmetric twist configurations that disclinations take spontaneously, thanks to the topology that allows for rotation of the winding axis. Our work illustrates a general mechanism of such spontaneous symmetry restoring that may apply beyond liquid crystal, which can take place if topologically distinct asymmetric defects in lower dimensions become homeomorphic in higher dimensions and if the symmetric intermediate is energetically favorable.

This is a joint work with Yohei Zushi (Univ. Tokyo).

Reference:

Y. Zushi and K. A. Takeuchi, Proc. Natl. Acad. Sci. USA 119, e2207349119 (2022). https://doi.org/10.1073/pnas.2207349119

Dynamics of Oscillator Populations: Exact Finite-Dimensional Reduction and Beyond

Arkady Pikovsky
University of Potsdam, Germany

Large ensembles of globally coupled oscillators can be described by means of kinetic equations for the evolution of the distribution densities. These equations take the simplest form if the oscillators are described by their phases only, and have a remarkable property first discovered by Ott and Antonsen in 2008: there exists an invariant manifold on which the dynamics reduces to just one complex equation. In this talk I extend this result [Ros Cestnik and Arkady Pikovsky, to appear in Chaos] by showing, that for arbitrary initial conditions the dynamics reduces to that of three complex variables.

In the noise-free case of identical oscillators, our equations are equivalent to the system derived by Watanabe and Strogatz in 1993. The finite-dimensional reduction allows for following transients to attracting Ott-Antonsen states, by solving a simple six-dimensional system of equations. I also discuss two appoaches beyond validity of the Ott-Antonsen theory. The first one, based on the circular cumulants technique, allows for an approximate description of noisy systems close to the Ott-Antonsen manifold. The second one, based on the transfer matrix method, allows for a complete description of possible stationary states in oscillator populations whith coupling in several harmonics.

Machine Learning and Resampling for Stochastic Parameterization with Memory

Daan Crommelin
CWI Amsterdam & University of Amsterdam, Netherlands

For parameterization of unresolved processes in multiscale dynamical systems (e.g. the climate system), data-based methods relying on machine learning (ML) techniques are rapidly gaining ground. Ususally the ML-based parameterization is deterministic and ignores uncertainty in the feedback from the small-scale (unresolved) to the large-scale processes. By considering stochastic rather than deterministic parameterization, this uncertainty can be taken into account. In this talk I will discuss recent work constructing data-based stochastic parametrizations with memory, using resampling. A straightforward approach to implement resampling is by binning. In case of long memory, resampling by binning is hampered by curse of dimension. To overcome this, a neural network for probabilistic classification can be used in combination with resampling. I will discuss both approaches and show their performance on several test problems.

Causality Detection and Multi-Scale Decomposition of the Climate System using Machine Learning

Christian Franzke
IBS Center for Climate Physics & Pusan National University, Korea

Detecting causal relationships and physically meaningful patterns from the complex climate system is an important but challenging problem. In my presentation I will show recent progress for both problems using Machine Learning approaches. First, I will show that Reservoir Computing is able to systematically identify causal relationships between variables. I will show evidence that Reservoir Computing is able to systematically identify the causal direction, coupling delay, and causal chain relations from time series. Reservoir Computing Causality has three advantages: (i) robustness to noisy time series; (ii) computational efficiency; and (iii) seamless causal inference from high-dimensional data. Second, I will demonstrate that Multi-Resolution Dynamic Mode Decomposition can systematically identify physically meaningful patterns in high-dimensional climate data. In particular, Multi-resolution Dynamic Mode Decomposition is able to extract the changing annual cycle.

Deep Learning for Detecting Anthropogenic Global Warming Signal in Daily Precipitation

Yoo-Geun Ham
Chonnam National University, Korea

In this talk, I demonstrate that deep learning successfully detects the emerging climate change signals in daily precipitation fields during the observed record. Accordingly, we trained a convolutional neural network with daily precipitation variability and annual mean global mean surface air temperature data obtained from an ensemble of present-day and future climate model simulations. After applying the algorithm to the observational record, we found that the daily precipitation data represented an excellent predictor for the observed planetary warming, as they have showed a clear deviation from natural variability since the mid-2010s. Furthermore, we probed the machine learning model with an interpretability framework and observed that daily precipitation variability over the tropical eastern Pacific and mid-latitude storm track regions was most sensitive to anthropogenic warming. Our results highlight that, although the long-term shifts in annual mean precipitation were non-emergent above the natural background variability, the daily hydrological fluctuations already carry a detectable example of human interference.

Drivers of the Evolution and Amplitude of African Humid Periods

Laurie Menviel

The University of New South Wales, Australia

During orbital precession minima, the Sahara was humid and more vegetated. Uncertainties remain over the climatic processes controlling the initiation, demise and amplitude of these African Humid Periods (AHPs). Here we study these processes using a series of transient simulations of the penultimate deglaciation and Last Interglacial period performed with an Earth system model of intermediate complexity (LOVECLIM). These results are compared to a transient simulation of the last deglaciation and Holocene. We find that the strengthening of the Atlantic Meridional Overturning Circulation (AMOC) at the end of deglacial millennial-scale events exerts a dominant control on the abrupt initiation of AHPs, as the AMOC modulates the position of the Intertropical Convergence Zone. In addition, residual Northern Hemispheric ice-sheets can delay the peak of the AHPs. Through its impact on Northern Hemispheric ice-sheets disintegration and thus AMOC, the larger rate of insolation increase during the penultimate compared to the last deglaciation can explain the earlier and more abrupt onset of the AHP during the Last Interglacial period. Finally, we show that the mean climate state modulates precipitation variability, with higher variability under wetter background conditions.

The Climate Trio: Stochastic Climate Variability, Seasonal Cycle, and El Niño

Malte Stuecker
University of Hawaii at Manoa, USA

The far-reaching impacts of the El Niño-Southern Oscillation (ENSO) on the global climate system have been long recognized since the pioneering work of Walker and Bjerknes. However, due to ENSO's intricate interplay with the climatological seasonal cycle and the ocean mixed layer thermal inertia, many more of ENSO's imprints on global climate are just emerging or have yet to be discovered. Moreover, some of ENSO's relationships with other modes of climate variability have been previously misinterpreted due to the limitations of commonly employed linear statistical methods. Here, we develop a hierarchy of conceptual models that allows us to delineate ENSO's ubiquitous climate impacts and revisit ENSO's observed statistical relationships with other spatio-temporal coherent patterns of climate variability. We demonstrate the importance of correctly accounting for different seasonal phasing in the linear growth/damping rates of different climate phenomena as well as the seasonal phasing of ENSO teleconnections and of atmospheric noise forcings. This conceptual model hierarchy allows us to trace the impacts of the aforementioned seasonal processes on the covariance functions and power spectra of observed and simulated climate variability. Finally, we argue that these advancements in our theoretical understanding of ENSO's complexity have already led to advancements in seasonal predictions and might even help constrain future climate projections of the tropical Pacific.

Typicality of Nonequilibrium (Quasi-)Steady Currents

Dario Poletti
Singapore University of Technology and Design, Singapore

The understanding of the emergence of equilibrium statistical mechanics has progressed significantly thanks to developments from typicality, canonical and dynamical, and from the eigenstate thermalization hypothesis. Here we focus on a nonequilibrium scenario in which two nonintegrable systems prepared in different states are locally and non-extensively coupled to each other. Using both perturbative analysis and numerical exact simulations of up to 28 spin systems, we demonstrate the typical emergence of nonequilibrium (quasi-)steady current for weak coupling between the subsystems. We also identify that these currents originate from a prethermalization mechanism, which is the weak and local breaking of the conservation of the energy for each subsystem.

Highly Accurate Numerical Solutions of the Time-Dependent Schrödinger Equation

Berge Englert
National University of Singapore, Singapore

The unitary evolution operator for nonrelativistic quantum dynamics can be approximated with a fifth-order error by a five-factor expression of Suzuki-Trotter type, whereas the standard Suzuki-Trotter approximation with the same accuracy has eleven factors. The five-factor approximation has been benchmarked successfully and then employed for a full-blown numerical study of a Stern-Gerlach interferometer with a realistic magnetic field.

References:

New J. Phys. 20, 073003 (2018), arXiv:1709.01719;
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Symmetry 13, 1660 (2021), arXiv:2106.00205.

Can Quantum Machines Execute Complex Adaptive Strategies more Efficiently?

Mile Gu
Nanyang Technological University, Singapore

Predators chasing prey, investors trading stocks, a patron playing blackjack: all can be thought of as agents that are required to make real-time decisions based on a combination of present observations and experience. As the tasks they seek to achieve become ever more complex, executing strategies that maintain consistency over ever-greater timescales and ever-greater awareness of their environment. Success thus requires such agents to maintain more complex models, tracking ever-growing amounts of data that incur additional computational or energetic resource costs.

Could such an agent gain an operational advantage by processing quantum information?

Here, I introduce a framework to describe quantum-enhanced agents - automated machines capable of processing data quantum mechanically. I show that such agents can leverage quantum information to track a less complex model of reality without necessary loss in adaptive function. I then outline the potential resource cost savings, enabling a fundamental reduction in energetic costs for quantum machines to respond to environmental stimuli in real time.

Thermodynamics of Information Ratchet with Finite Tape: Second Law and Correlation Effects

Lock Yue Chew
Nanyang Technological University, Singapore

Maxwell demon is an important paradigm in the thermodynamics of information processing with information ratchet being an explicit example. Here, we demonstrate a version of an information ratchet that interacts with information in a finite tape and shows that it supports the operational regime of an engine or eraser. These thermodynamic functionalities of engine or eraser, however, cannot be sustained due to eventual equilibration resulting from the finite information capacity of the tape. Nonetheless, cumulative work can be accrued or expended through successive tape scans, and we prove that at all times the ratchet obeys the Information Processing Second Law (IPSL). Unlike the IPSL for the infinite-tape ratchet which was shown to apply at the stationary state, the IPSL here is applicable also at the transient phase of the ratchet operation. We explore two ratchet designs where we uncovered that a ratchet with memory harnesses correlation to accumulate more work by having a larger time constant to reach steady state relative to one without memory. Furthermore, we found that correlation typically induces the information ratchet to approach a nonequilibrium regime in the stationary state.

Geometric Decomposition of Entropy Production

Andreas Dechant
Kyoto University, Japan

A nonvanishing entropy production is the defining feature of out-of-equilibrium systems. However, in contrast to the rather narrow class of equilibrium systems, there are typically many ways in which a system can be driven out of equilibrium. For example, a system may posses an equilibrium state, but be driven out of equilibrium by a time-dependent change of its parameters. Other systems, by contrast, do not relax to a thermal equilibrium at all, but rather remain in a nonequilibrium steady state even for constant parameters. A classical result of nonequilibrium thermodynamics states that these different types of driving can be attributed to different contributions to the entropy production, called excess (or nonadiabatic) and housekeeping (or adiabatic) entropy production. Somewhat surprisingly, however, this decomposition is not unique, with at least two different proposals existing in the literature. Here, we address this issue based on a geometric decomposition of the flows in the system into orthogonal components. As a result, we obtain a general relation between the different decompositions, as well as a new decomposition into three positive contributions, which can be attributed to time-dependent driving, persistent flows, and the interaction between the two, respectively. We also derive variational expressions for the excess and housekeeping contributions, which can be used to independently compute them from experimental or numerical data.

Speed Limit for a Highly Irreversible Process and Tight Finite-Time Landauer's Bound

Jae Sung Lee
KIAS, Korea

Landauer's bound is the minimum thermodynamic cost for erasing one bit of information. As this bound is achievable only for quasistatic processes, finite-time operation incurs additional energetic costs. We find a “tight” finite-time Landauer's bound by establishing a general form of the classical speed limit. This tight bound well captures the divergent behavior associated with the additional cost of a highly irreversible process, which scales differently from a nearly irreversible process. We demonstrate the validity of this bound via discrete one-bit and coarse-grained bit systems. Our work implies that more heat dissipation than expected occurs during high-speed irreversible computation. (ref: arxiv:2204.07388)

Swimming in Flows: Beyond Jeffery's Orbits

Kenta Ishimoto
Kyoto University, Japan

A microscopic object immersed in fluid rotates following Jeffery's orbits, non-linear periodic orbits for an arbitrary body-of-revolution. In this talk, we discuss theoretical extensions to chiral and deforming objects. Considering symmetries based on invariance in resistance tensor, we can define "hydrodynamic" axisymmetric objects and these naturally include chirality of an object. When a self-propelled object deforms rapidly, by using multi-scale analysis one can capture an effective shape parameter for a shape-changing object. The talk is based on collaborations with M. P. Dalwadi (UCL), E. A. Gaffney (Oxford), C. Moreau (RIMS, Kyoto) and B. J. Walker (UCL).

Dynamic Features of Topological Defects in Active Liquid Crystals

Rui Zhang
Hong Kong University of Science and Technology, Hong Kong

Topological defects are ubiquitous across different physical systems. In liquid crystals (LCs), these topological defects can segregate impurities, and are therefore potentially useful for directing self-assembly and serving as micro reactors. A particular interesting system is active LCs; examples include bacteria-LC composites, certain tissues, and dense biopolymer suspensions. In active LCs, certain topological defects can self-propel, which shows its promise in material transport. However, defect dynamics and hydrodynamic flows in these systems are often-times difficult to control, limiting their further applications. In this talk, I will discuss our current understanding of the dynamical features of these active defects and how we can manipulate their nucleation and trajectories. Specifically, I will discuss how topological confinement, activity patterning, and temperature gradient can control defect dynamics and rectify hydrodynamic flows in the system. I will further show how the highly controlled defect motion and spontaneous flows can be used to transmit information and perform logic operations, paving the way towards the design of LC-based autonomous materials systems.

Complexity Dynamics of Atopic Dermatitis System

Younghae Do
Kyungpook National University, Korea

In this talk, we present our current results of Atopic dermatitis (AD)which has been known as the most common allergic inflammatory skin disease and its immunopathogenetic network is very complex.
To investigate the complexity of AD, we study a in silico AD model based on the mechanisms of AD disease pathogenesis, which is described by a nonsmooth system with three switches, and uncover a new oscillating behavior Os called Serious Oscillation, which can make a clear distinction between oscillating behaviors. It thus makes possible to classify AD attractors, which is very similar to AD clinical symptoms used in SCORAD index. A striking finding is that by investigating the existence and the stability of all found attractors on the parameter space for Barrier permeability and Immune responses, there exist many different types of bi- and multistability: four and five different types of bistability and multistability, respectively. By characterizing these different types of bi- and multistability, we finally conclude that the complexity of AD is caused by multistability detected in too much wide parameter ranges. In addition, we show a peculiar bifurcation phenomenon occurred in nonsmooth dynamical system. Our results suggest that the existence of multistability will make it possible to better understand the complexity of AD, which can be applicable in the development of new therapy strategies.

Non-Hermitian Hopf-bundle Matter

Moon Jip Park
IBS PCS

Line excitations in topological phases are a subject of particular interest as their mutual linking structures encode robust topological information of matter. Recently, it has been shown that the linking and winding of complex eigenenergy strings classify one-dimensional non-Hermitian topological matters. Yet, in higher dimensions, the bundles of the linked strings can emerge such that every string is mutually linked by all the other strings. As such an unconventional topological structure, we propose the topological phases of matter characterized by non-Hermitian Hopf bundle. Furthermore, we show the concomitant bulk-boundary correspondence of the Hopf bundle in momentum space and the emergence of higher-order skin effect in real space.

Dissipative Quantum Phase Transition and Cavity QED

Yuto Ashida
University of Tokyo, Japan

Strong coupling between matter and quantized electromagnetic modes may offer yet another approach of controlling equilibrium phases or dynamics of quantum many-body systems. Recent developments have realized such strong light-matter interaction in genuinely nonperturbative regimes, where conventional theoretical methods often fail. I will talk about how one can analyze strongly coupled quantum light-matter systems at arbitrary interaction strengths on the basis of an asymptotically disentangling unitary transformation [1,2]. I discuss its application to construction of tight-binding Hamiltonians, dynamics of bound states in the continuum, and revisiting dissipative quantum phase transition in resistively shunted Josephson junctions [3,4].

[1] YA, Imamoglu and Demler, PRL 126, 153603 (2021).
[2] YA, Yokota, Imamoglu and Demler, PRR 4, 023194 (2022).
[3] Masuki, Sudo, Oshikawa and YA, PRL 129, 087001 (2022).
[4] Yokota, Masuki and YA, arXiv:2208.14107 (2022)

Non-Reciprocal Frustration: Time Crystalline Order-by-Disorder Phenomenon and a Spin-Glass-Like State

Ryo Hanai
YITP, Japan & APCTP, Korea

Having conflicting goals often leads to frustration. The conflict occurs, for example, in systems that cannot simultaneously minimize all interaction energy between the objects, a situation known as geometrical frustration. A typical feature of these systems is the presence of accidental ground state degeneracy that gives rise to a rich variety of unusual phenomena such as order-by-disorder and spin glasses. In this article, we show that a dynamical counterpart of these phenomena may arise from a fundamentally different, non-equilibrium source of conflict: non-reciprocal interactions. We show that non-reciprocal systems with anti-symmetric coupling generically generate marginal orbits that can be regarded as a dynamical counterpart of accidental degeneracy, due to the emerging Liouville-type theorem. These ``accidental degeneracies'' of orbits are shown to often get ``lifted'' by stochastic noise or weak random disorder to give rise to order-by-disorder phenomena with the peculiarity that the emerging state usually has a time crystalline order. We further report numerical evidence of a non-reciprocity-induced spin-glass-like state that exhibits aging and a power-law temporal relaxation associated with a short-ranged spatial correlation. Our work provides an unexpected link between the physics of complex magnetic materials and non-reciprocal matter.

Flatbands: Construction and Perturbation

Alexei Andreanov
IBS PCS

Flatbands are dispersionless bands in translationally invariant systems resulting from either fine-tuning or symmetry protection.

They typically, but not always, feature compact localised states -- strictly compact eigenstates. The study of flatbands is motivated by their extreme sensitivity to perturbations which makes them either a perfect host for unconventional phases of matter due to disorder, interactions, nonlinearities or enhance the already known phases, like superconductivity/superfluidity. The fine-tuning at the origin of flatband Hamiltonians makes it hard to find and identify flatbands.

I will review our recent progress in constructing flatbands in various settings, including in the presence of a d.c. field, and how systematic construction of flatbands allows to understand their response to perturbations -- disorder and interactions -- leading to the emergence of nonergodic phases.

Dual Unitary Circuits as Models of Many-Body Quantum Chaos

Arul Lakshminarayanan
IIT Madras, India

Dual-unitary circuits are being studied as models of many-body quantum systems that can span a range of dynamical features. We discuss how a quantum ergodic hierarchy can be identified in such systems wherein the peak is occupied by quantum Bernoulli like systems constructed of perfect tensors. The talk will also discuss algorithms to construct dual-unitary and multi-unitary or perfect tensors.

Localization Phenomena in Interacting Flatband Systems

Carlo Danieli
Sapienza University, Italy

Linear wave equations on translationally invariant flatband networks exhibit at least one dispersionless band in their Bloch spectrum, and host compact localized eigenstates (CLS) with nonzero amplitudes restricted to a finite volume. Flatbands and the associated CLS are typically highly sensitive to perturbations – e.g. disorder, interaction.
However, the impact of such perturbations strongly depends on the chosen flatband network. In this talk, we focus on the case of interacting flatband networks, and overview diverse localization features that emerge from applying finetuning protocols to the network geometry and to the interaction terms. We discuss such protocols for classical nonlinear and quantum many-body interactions. In particular, we show that in both cases finetuning may result in the existence of exact spatially compact solutions in flatband lattices, as well as in the complete suppression of transport in the case of lattices lacking dispersion (i.e. lattices where all Bloch bands are flat).

Emergence and Robustness of Wealth Inequality in the Generalized Yard-Sale Model on Graphs

Deok-Sun Lee
KIAS, Korea

The yard-sale model allows every pair of individuals to exchange a given portion of the smaller of their wealth, which results in one individual possessing nearly all of the wealth. The remaining wealth is then distributed among others according to a power law with exponent one, which illustrates a possible origin of the universal power-law wealth distributions in the real world. Here, we investigate how robust such strongly heterogeneous wealth distribution is against changes in wealth exchange and limits on individuals' interaction. We find a crossover from a log-normal distribution to an inverse gamma distribution of wealth with a finite variance as we permit wealth redistribution, in which the amount of transferred wealth is proportional to the sender's wealth. If individuals are allowed to interact only with the nearest neighbors on a one-dimensional lattice or on sparse scale-free graphs, the wealth variance saturates quite early in the original yard-sale model because the system enters a frozen state in which each rich individual is surrounded by poor ones and thus their wealth cannot be changed any longer. The redistribution-type wealth exchange can enable the system to escape from the frozen state and the wealth variance to grow again with time. The dynamic scaling of wealth variance and the functional form of the wealth distribution that we obtain analytically and numerically for this generalized yard-sale model defined on complete and sparse graphs are presented in this talk.

Random Target Searches by Multiple Particles

Yong Woon Kim
KAIST, Korea

The random target search problem, also called the first-passage problem, concerns the question, how long does it take to find a target through random processes? This problem has been spotlighted in the physics community as the first-passage process is ubiquitous in many natural and man-made systems, with the examples transcend the conventional boundary of physics, such as animal foraging and triggering of stock options. Most previous studies in this field focused on the target search by a single particle. In reality, however, a group of particles is usually involved. In this talk, I will present recent advances related to the first-passage problems by many Brownian particles. In the presence of multiple particles, the problem becomes complicated because the smallest value among first-passage times recorded by respective particles is only meaningful in the context of the first-passage dynamics. I will also discuss how the first-passage dynamics is reformulated when there are competing multiple searching agents and what is the optimal initial searcher distribution to minimize the first-passage time. If time allows, the effects of interactions among search agents are briefly mentioned.

Local Stability of Cooperation in a Continuous Model of Indirect Reciprocity

Seung Ki Baek
Pukyong National University, Korea

Reputation is a powerful mechanism to enforce cooperation among unrelated individuals through indirect reciprocity, but it suffers from disagreement originating from private assessment, noise, and incomplete information. In this work, we investigate stability of cooperation in the donation game by regarding each player's reputation and behaviour as continuous variables. First, we carry out the stability analysis in the presence of erroneous assessment by expanding the dynamics of reputation to the second order of perturbation under the assumption that everyone initially cooperates with good reputation. This approach clarifies the difference between Image Scoring and Simple Standing in the sense that punishment for defection against a well-reputed player should be regarded as good for maintaining cooperation. Second, through perturbative calculation, we derive a condition that a social norm should satisfy to give penalties to its close variants, provided that everyone initially cooperates with a good reputation, and this result is supported by numerical simulation. A crucial factor of the condition is whether a well-reputed player's donation to an ill-reputed co-player is appreciated by other members of the society, and the condition can be reduced to a threshold for the benefit-cost ratio of cooperation which depends on the reputational sensitivity to a donor's behaviour as well as on the behavioural sensitivity to a recipient's reputation. Our continuum formulation suggests how indirect reciprocity can work beyond the dichotomy between good and bad even in the presence of inhomogeneity, noise, and incomplete information.

Bounds of Information Scrambling in the Strongly Disordered XXZ Model

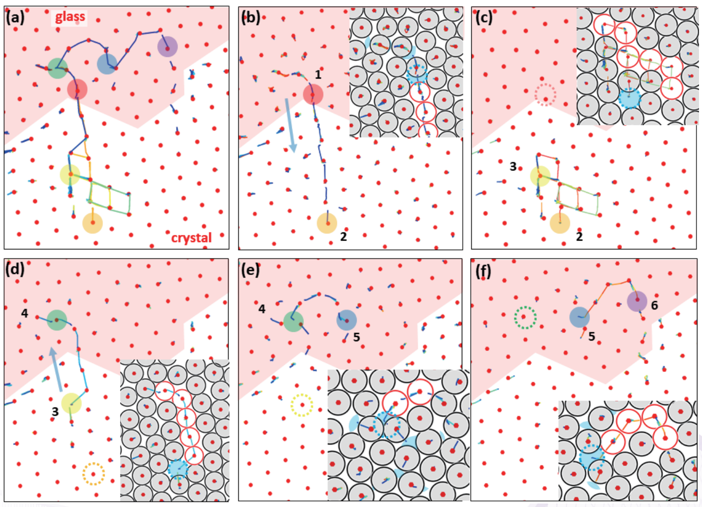
Dong-Hee Kim
Gwangju Institute of Science and Technology, Korea

We present the perturbative calculation of the out-of-time-ordered correlator (OTOC) in the deep many-body localized regime of the disordered Heisenberg XXZ model. We find that the OTOC measured in the Fock space indicates the lower and upper bounds of information propagation speed, constructing a highly structured light cone confined in strictly logarithmic bounds. We obtain the analytic expression of OTOC associated with the slowest scrambling along the upper logarithmic light cone. For the lower light cone of the fastest scrambling, we provide an effective Hamiltonian with a reduced Hilbert space for the lowest order perturbation calculation of OTOC. Our method is applied to 2D as well as 1D lattices, providing evidence that the logarithmic bounds of information scrambling may be valid in higher dimensions in the strong disorder and weak hopping limit.

Quasivoid: A Quasi-Particle Approach for the Dynamics of Structural Glass

Chi-Hang Lam
Hong Kong Polytechnic University, Hong Kong

Particle dynamics in glass and the nature of the glass transition are long-standing controversial problems. By performing days-long experiments on glassy colloidal systems [1], we show that fluid-like behaviors diminish at very deep supercooling. Motions are instead dominated by sequences of activated particle hops. We suggest that they are induced by defects called quasivoids, each consisting of a few localized free volume fragments with a combined volume comparable to that of a particle. Their relevance is evidenced by the observation of the reversible conversion of a quasivoid into a vacancy when diffusing across a glass-crystal interface. The dynamics of glass can then be described based on motions of these quasiparticles. An additional feature is that quasivoid motion is not only dictated by the system disorder but it also perturbs the disorder. These mechanisms are incorporated into a distinguishable-particle lattice model (DPLM). It has successfully reproduced a wide range of glassy phenomena, including very non-trivial ones such as Kovacs paradox [2] and diffusion coefficient power-laws under partial-swap [3]. In this picture, glassy dynamics is analytically tractable using a local random configuration-tree theory [4].



Particle dynamics in 2D colloidal system. (a) Coarse-grained particle trajectories and (b-f) the same trajectories split up over consecutive time sub-intervals. Red dots show initial particle positions. (b) A void moves from the glass to the crystal and (d) moves back to the glass. Insets: Particle configurations revealing the void as a vacancy (blue solid circles) in the crystal (c-d) and a quasivoid (blue areas) in the glass (b,e.f) [1].

1. C.T. Yip, M. Isobe, C.H. Chan, S.M. Ren, K.P. Wong, Q.X. Huo, C.S. Lee, Y.H. Tsang, Y.L. Han, and C.H. Lam, Phy. Rev. Lett. 125, 258001 (2020).
2. M. Lulli, C.S. Lee, H.Y. Deng, C.T. Yip, and C.H. Lam, Phy. Rev. Lett. 124, 095501 (2020).
3. G. Gopinath, C.S. Lee, X.Y. Gao, X.D. An, C.H. Chan, C.T. Yip, H.Y. Deng, and C.H. Lam, Phy. Rev. Lett. 129, 168002 (2022).
4. http://apricot.polyu.edu.hk/treetheory

Bloch Theorem Dictated Wave Chaos in Microcavity Crystals

Chang-Hwan Yi
IBS PCS

Chaotic microcavity has been the primary testing ground for studying quantum chaos. In this work, we generalize the wave chaos theory to cavity lattice systems. We discover the intrinsic coupling of the crystal momentum to the internal cavity dynamics, which substitutes the role of the deformed boundary shape in the ordinary microcavity problem. This provides a new platform enabling the in-situ study of microcavity light dynamics. A momentum coupling leads to the dynamical localization transition, where the degenerate scar-mode pairs hybridize and non-trivially localize around regular islands in phase space. A the Brillouin zone boundary, we find that the intercavity chaotic modes coupling and wave confinement are significantly altered.

Learning to Fly High: Reinforcement Learning for Soaring and Airborne Wind Energy

Antonio Celani
ICTP, Italy

Soaring is a flying strategy adopted by birds and sailplane pilots that exploits thermals for long-distance navigation. Airborne Wind Energy is a lightweight technology that allows power extraction from the wind using kites. The dynamical complexity and unpredictability of aerodynamics in the turbulent atmosphere makes these control problems especially hard to solve. Here we propose to search for near-optimal control strategies by means of Reinforcement Learning.

Pharmacological Principle of Traditional Chinese Medicine: A Big-Data and AI Perspective

Liang Tian
Hong Kong Baptist University, Hong Kong

Traditional Chinese Medicine (TCM), which originated in ancient China with a history of thousands of years, characterizes and addresses human physiology, pathology, and diseases diagnosis and prevention using TCM theories and Chinese herbal products. However, the pharmacological principles in TCM theory, the core treasure house of TCM, have rarely been systematically investigated in a top-down manner, which hinders the modernization and standardization of TCM. In this work, we proposed a novel TCM-based network pharmacology framework to discern general patterns and principles of human disease and predict herb-diseases associations. Specifically, we constructed an integrative database and a pharmacological network of TCM through extensively collecting and cleaning large-scale TCM prescription data from ancient books, modern literature, and existing TCM data resources. Various topological and structural properties of the TCM pharmacological network were systematically characterized to decipher the pharmacological principles of TCM theory. Based on the TCM pharmacological network, we uncovered the human disease-disease relationship and build an in-silico network-based pipeline for the prediction of drug-disease associations. Our work promotes the quantitative underpinning of TCM pharmacological principles, provides a basis for the objectification of the diagnosis and treatment process of Chinese medicine, and paves the way for the knowledge fusion of TCM evidence-based medicine and modern biology.

Negative Drag and Symmetry-Breaking Motility in a Dilute Active Fluid

Yongjoo Baek
Seoul National University, Korea

A symmetric object in an active fluid may gain motility due to a ‘negative drag’ which applies in the direction of the object’s velocity. In previous studies, the phenomenon presupposed the presence of polar or nematic order in the active fluid. In this study, we show by a mean-field argument that such symmetry-breaking motility can generally emerge even in dilute and disordered active funds. The phenomenon manifests itself as both continuous and discontinuous transitions associated with the bifurcation of the steady-state velocity of the object. We also numerically show that the critical phenomena accounting for the continuous transition belong to the mean-field Ising universality class regardless of the shape of the object.

Anomalous Transport at Band Edges

Manas Kulkarni
ICTS - TIFR, India

Understanding symmetries and transitions in non-Hermitian matrices and their physical consequences is of tremendous interest in the context of open quantum systems. The spectrum of a one dimensional tight-binding chain with periodic on-site potential can be obtained by casting the problem in terms of transfer matrices. We find that these non-Hermitian matrices have a symmetry akin to parity-time symmetry, and hence show transitions across exceptional points. The exceptional points of the transfer matrix of a unit cell correspond to the band edges of the spectrum. When connected to two zero temperature baths at two ends, this consequently leads to subdiffusive scaling of conductance with system size if the chemical potential of the baths are equal to the band edges. We further demonstrate the existence of a dissipative quantum phase transition as the chemical potential is tuned across any band edge. This behavior is universal, irrespective of the details of the periodic potential and the number of bands of the underlying lattice. It, however, has no analog in absence of the baths.

Bistability and Chaos-Assisted Tunneling in Dissipative Quantum Systems

Andrey Kolovksy
Kirensky Institute of Physics SB RAN, Russia

We revisit the problem of quantum bi- and multistability by considering the dissipative double resonance model. For a large driving frequency, this system has a simpler phase structure than the driven dissipative nonlinear oscillator, the paradigm model for classical and quantum bistability. This allows us to obtain an analytical estimate for the lifetime of quantum limit cycles. On the other hand, for a small driving frequency, the system is much richer than the nonlinear oscillator. This allows us to address a novel phenomenon of dissipation- and chaos-assisted tunneling between quantum limits cycles.

Micromasers as Quantum Batteries

Giuliano Benenti
University of Insubria, Italy

Quantum technologies, i.e. technological devices obtained by building and manipulating quantum mechanical systems, are becoming a reality in recent days. Since they need energy to operate, the concept of quantum batteries, which are quantum mechanical systems used as energy storage devices, has been developed.

It is therefore of uttermost importance to find suitable quantum platforms which could be used as quantum batteries. It is shown [1] that a micromaser, where a beam of qubits is used to charge the electromagnetic field in a cavity, is an excellent model of quantum battery. Indeed, a highly excited, pure, and effectively steady state of the cavity mode, charged by coherent qubits, can be achieved, also in the ultra-strong coupling regime of field-matter interaction. Stability of these appealing features against loss of coherence of the qubits and the effect of counter-rotating terms in the interaction Hamiltonian are also discussed.

Ref.: V. Shaghaghi, V. Singh, G. Benenti and D. Rosa, Micromasers as quantum batteries, Quantum Sci. Technol. 7, 04LT01 (2022).

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PART
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POSTERS

POSTERS

1. **Aamna Ahmed** | IISER Bhopal, India
   Flat-Band-Based Multifractality in the All-Bands-Flat Diamond Chain
2. **Samuel Begg** | APCTP, Korea
   Liouvillian Skin Effect in an Interacting System
3. **Tilen Cadez** | IBS PCS
   Ergodicity Breaking in the Rosenzweig-Porter Model
4. **Xingye Cheng** | Hong Kong Baptist University, Hong Kong
   Cleaning and Standardization of Traditional Chinese Medicine Data
5. **Hoyun Choi** | Seoul National University, Korea
   Universal Microscopic Mechanism of Hybrid Percolation Transition
6. **Adam Craig** | Hong Kong Baptist University, Hong Kong
   Comparison of Ability of Machine Learning Methods to Learn Functional Connectivity from fMRI Data
7. **Pragna Das** | IISER Bhopal, India
   Phase Transitions of the Anisotropic Dicke Model
8. **Mi Feng** | Hong Kong Baptist University, Hong Kong
   Criterion for Markovian and Non-Markovian Frameworks in Epidemic Modeling, Forecasting, and Prevention Evaluation
9. **Leonardo Garibaldi Rigon** | Seoul National University, Korea
   Collective Boundary Motion of Self-Propelled Particles in Vibrated Granular Media
10. **Jeehye Choi** | Chungbuk National University, Korea
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11. **Bukyoung Jhun** | Seoul National University, Korea
    Effective Control of Nonlocal Cascading Failures in Complex Networks Using Graph Neural Networks
12. **Takuya Kamijima** | University of Tokyo, Japan
    Extensions and Applications of the Thermodynamic Uncertainty Relation
13. **Sakkaravarthi Karuppaiya** | APCTP, Korea
    Dynamics of Optical Soliton Molecules with Mixed-type Temporally-varying Coherently- and Incoherently-Coupled Nonlinearities
14. **Cook Hyun Kim** | Korea Institute of Energy Technology
    The “Hub” Structure of Complex Network Profoundly Change the Phase Diagram of the AT Model
15. **Yeongjun Kim** | IBS PCS & UST, Korea
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16. **Andrey Kolovsky** | Kirensky Institute of Physics SB RAN, Russia
    Resonant Transport of Bosonic Carriers through a Quantum Device

POSTERS

17. **Sergei Koniakhin** | IBS PCS
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18. **Jongshin Lee** | Korea Institute of Energy Technology
(K,Q)-Core Pruning Process of Hypergraphs

19. **Sanghoon Lee** | IBS PCS & UST, Korea
Critical-to-Insulator Transition and Fractality Edges in Perturbed Flatbands

20. **Haoran Li** | Hong Kong Baptist University, Hong Kong
Uncovering Pharmacological Principles of Traditional Chinese Medicine (TCM) with Machine Learning and Network Medicine

21. **Dillip Kumar Nandy** | IBS PCS
Probing Many-Body Localization Using Adiabatic Gauge Potential

22. **Jung-Wan Ryu** | IBS PCS & UST, Korea
Oscillation Death in Coupled Counter-Rotating Nonlinear Oscillators

23. **Saptarshi Saha** | IISER Kolkata, India
Effects of Dipolar Coupling on an Entanglement Storage Device

24. **Vahid Shaghaghi** | IBS PCS & Insubria University, Italy
Extracting Work from Random Collisions: A Model of a Quantum Heat Engine

25. **Varinder Singh** | IBS PCS
Thermodynamic Uncertainty Relation in Degenerate and Nondegenerate Maser Heat Engines

26. **Gangmin Son** | KAIST, Korea
Multiscale Nature of Geometric Correlations in Multiplex Networks

27. **Kabyashree Sonowal** | IBS PCS & UST, Korea
Valley Spin-Acoustic Resonance in Monolayer MoS_2

28. **Kumar Utkarsh** | Northwestern University, USA
Pain Begets More Pain: A Self-Exciting Model for Pain Caused by Sickle Cell Disease

29. **Sonu Verma** | IBS PCS
Exceptional Phase Transitions in Chiral Kuramoto Lattices

30. **Toshihiro Yada** | University of Tokyo, Japan
Quantum Fluctuation Theorem Under Quantum Jumps with Continuous Measurement and Feedback

31. **Weihua Zhang** | IBS PCS & Lanzhou University, China
Lyapunov SpectrumTransition in Disordered Unitary Circuits with Nonlinearity

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PROGRAM BOOK

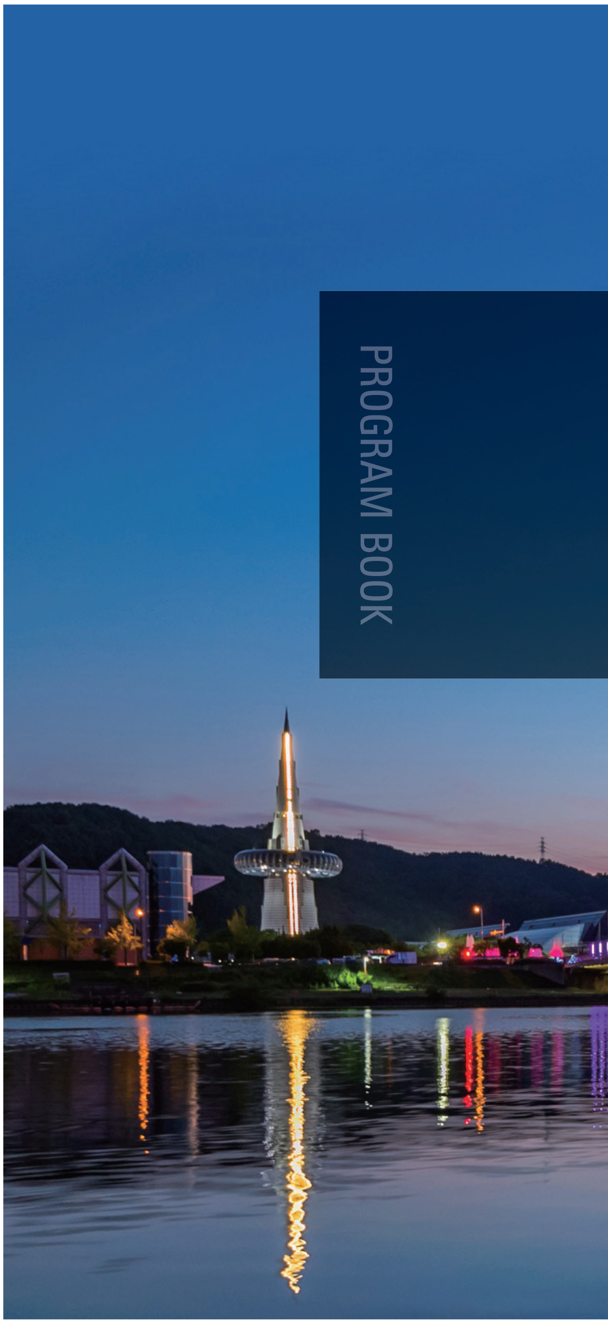
DYNAMICS DAYS
ASIA PACIFIC DDAP12

Institute for Basic Science

Center for Theoretical Physics of Complex Systems

DYNAMICS DAYS
ASIA PACIFIC DDAP12

November 7 – 11, 2022
IBS Science Culture Center, Daejeon, Korea



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