Frontiers in Mathematical Science Research Workshop

---Joint workshop with Tohoku University, Japan

Shanghai University

Shanghai, China

September 27 - 29, 2019

Sponsor:

International Office of Shanghai University Global, China

Frontiers in Mathematical Science Research Workshop

—Joint workshop with Tohoku University, Japan

Purpose

Mathematics plays an essential role in almost all areas of science and technology in the modern world. In this workshop, we invite distinguished mathematicians, physicists and information scientists from Tohoku University and Shanghai University to exchange mutual research interests and discuss directions of future research in mathematical sciences. Subjects to be covered include, but not limited to, algebraic combinatorics, discrete geometry, number theory, non-commutative differential geometry, integrable systems, knot theory and complex network from mathematical and information theoretical sides while quantum information, quantum computing, quantum control, quantum biology and topological phase from physics side. Through two days intensive discussions, it is expected that many new collaborations between two universities will start after the workshop.

Organizing Committee

Mikio Nakahara, Shanghai University, China

Motoko Kotani, Tohoku University, Japan

Cheng Zhang, Shanghai University, China

Yan Zhu, Shanghai University, China

Local Organizing Committee

Mikio Nakahara (**Chair**)

Cheng Zhang

Shingo Kukita

Naoki Watamura

Yan Zhu

Lingji Lou

Information for Participants

Accomodation

Building 2, New Lehu Hotel, Shanghai University, 716 Jinqiu Road
上海市宝山区锦秋路 716 号上海大学北大门乐乎新楼 2 号楼

Transportation

1. **Pudong Airport**

   By Taxi: Directly take taxi to 716 Jingqiu Road, Shanghai University (Baoshan Campus, North Gate). (Total price is about 250 RMB.)

   By Metro: Metro Line 2 to Jing'an Temple exchange to Metro Line 7 to Shanghai University. (Total price is 8 RMB.)

2. **Hongqiao Airport & Shanghai Hongqiao Railway Station**

   By Taxi: Directly take taxi to 716 Jingqiu Road, Shanghai University (Baoshan Campus, North Gate). (Total price is about 70 RMB.)

   By Metro: Metro Line Line 2 to Jing'an Temple exchange to Metro Line 7 to Shanghai University (Baoshan Campus). (Total price is 6 RMB.)

3. **Shanghai Railway Station**

   By Taxi: Directly take taxi to 716 Jingqiu Road, Shanghai University (Baoshan Campus, North Gate). (Total price is about 50 RMB.)

   By Metro: Metro Line 3 to Zhenping Road exchange to Metro Line 7 to Shanghai University (Baoshan Campus). (Total price is 4 RMB.)

Contact Us

Prof. Mikio Nakahara `nakahara@shu.edu.cn`

Website:

`http://math.shu.edu.cn/CQIT2019/`
`http://mikio-nakahara.com/workshop/CQIT2019/`

TIME TABLE

September 27, 2019 (Friday)

Time	Venue: Lobby of Lehu Hotel (乐乎楼 1 号楼大厅)
17:00-18:00	Registration
18:00-19:00	Dinner at Lehu hotel restaurant

September 28, 2019 (Suturday)

Time	Venue: Daxue Hall (大学厅) Speaker/Title	Chair
09:00-09:40	Opening talks and Group Photo	Mikio Nakahara
09:40-10:20	**Masayuki Ohzeki** Quantum annealing and its application to new generation of natural computing	
10:20-10:40	Coffee and Tea	
10:40-11:20	**Xi Chen** TBA	Ping Ao
11:20-12:00	**Motoko Kotani** Mathematical challenges for materials design	
12:00-13:00	Lunch at Lehu hotel restaurant	
13:00-13:40	**Yasuo Ohno** Relations among multiple zeta values and Arakawa-Kaneko zeta functions	Benjamin Sheller
13:40-14:20	**Satoshi Watamura** T-duality and Geometry of Effective Theory for String	
14:20-15:00	**Yukinari Sumino** A geometric view of loop integral reduction by IBP recurrence relations	
15:00-15:20	Coffee and Tea	
15:20-16:00	**Kentraro Nomura** Chiral anomaly and spin-electromagnetic responses in topological materials	Wei Ren
16:00-16:40	**Akihiro Munemasa** Equiangular lines in Euclidean spaces	

16:40-17:20	**Hajime Tanaka** The independence number of the orthogonality graph in dimension 2^k	Yan Zhu
17:20-18:00	**Hitoshi Murakami** Introduction to the volume conjecture for knots	
18:10-19:00	Dinner at Lehu hotel restaurant	

September 29, 2019 (Sunday)

Time	Venue: **Daxue Hall (大学厅)** Speaker/Title	Chair
09:00-09:40	**Tuncay Aktosun** Determining the shape of a human vocal tract from speech sounds	Motoko Kotani
09:40-10:20	**Peicheng Zhu** TBA	
10:20-10:40	Coffee and Tea	
10:40-11:20	**Benjamin Sheller** Riemannian geometry and Cartan decompositions	Hitoshi Murakami
11:20-12:00	**Mikio Nakahara** Majorana representation of complex vectors and topological excitations in Bose-Einstein condensates	
12:00-13:00	Lunch at Lehu hotel restaurant	
13:00-13:40	**Yan Zhu** Relative t-designs in Johnson association schemes for P-polynomial structure	Hajime Tanaka
13:40-14:20	**Bing Wang** The application of network approach to the epidemic modelling	
14:20-15:00	**Cheng Zhang** Aspects of boundary-value problems for soliton equations	

15:00-15:20	Coffee and Tea	
15:20-16:00	**Da-jun Zhang** Multidimensional consistency and discrete integrable systems	Kentaro Nomura
16:00:16:40	**Wei Ren** TBA	
16:40-17:20	**Ping Ao** From "Dissipative Landau-Zener Transition" to "Complete Fidelity with Coherence": quantum control in perspective	Satoshi Watamura
17:20-18:00	**Yongcong Chen** Resonant confinement of an excitonic polariton and ultra-efficient light harvest in artificial photosynthesis	
18:10-19:00	Dinner at Lehu hotel restaurant	

Note: Daxue Hall (大学厅) (the 1st floor of New Lehu Hotel)

September 30, 2019 (Monday)

Departure

Abstract (chronological order)

Name: Masayuki Ohzeki, mohzeki@tohoku.ac.jp

Affiliation: Graduate School of Information Sciences, Tohoku University, Japan
Institute of Innovative Research, Tokyo Institute of Technology, Japan
Sigma-i Co. Ltd., Japan

Title: Quantum annealing and its application new generation of natural computing

Abstract: Quantum annealing is a generic solver for optimization problems, which uses fictitious quantum fluctuation. The most groundbreaking progress in the research field of quantum annealing is its hardware implementation, that is, the so-called quantum annealer, by using artificial spins. In this presentation, we demonstrate several application of quantum annealing in real industry after a short introduction.

Name: Xi Chen, xchen@shu.edu.cn
Affiliation: Department of Physics, Shanghai University, P. R. China
Title: TBA
Abstract: TBA

Name: Motoko Kotani, kotani@wpi-aimr.tohoku.ac.jp

Affiliation: Advanced Institute for Materials Research, and Institute of Mathematics, Tohoku University, Japan

Title: Mathematical challenges for materials design

Abstract: I would like to discuss application of discrete geometric analysis to understand the relation between macroscopic properties and microscopic structure of materials. Advanced technology enables us to observe and control atoms and molecules in materials and therefore new mathematical methods to bridge different scales in materials are required. Discrete geometric analysis aims to develop discrete version of geometric analysis and study continuum structures behind discrete objects. Through collaborations with materials scientists in the past few years, we found several interesting connections of mathematics with materials, which I would like to share with you.

Name: Yasuo Ohno, ohno.y@tohoku.ac.jp

Affiliation: Mathematical Institute, Tohoku University, Japan

Title: Relations among multiple zeta values and Arakawa-Kaneko zeta functions.

Abstract: The "multiple zeta values" is an infinite set of real numbers originally studied by Euler, and its connection with research subjects in various fields has been pointed out. In this talk, we review the basic properties of multiple zeta values of Euler-Zagier type and related zeta functions. We focus on families of relations among them and their proofs in terms of the generating functions.

Name: Satoshi Watamura, watamura@tuhep.phys.tohoku.ac.jp

Affiliation: Department of Physics, Faculty of Science, Tohoku University, Japan

Title: T-duality and Geometry of Effective Theory for String

Abstract: We present a T-duality invariant formulation of an effective theory of string. We explain the role of T-duality in string theory and the use of the so-called doubled geometry which is a generalization of Hitchin's generalized geometry based on the Courant algebroid structure. Then, the recent developments in DFT (Double Field Theory), the effective theory based on the doubled geometry, is presented.

Co-author(s): Noriaki Ikeda and Ursula Carow-Watamura

Name: Yukinari Sumino, sumino@tuhep.phys.tohoku.ac.jp

Affiliation: Department of Physics, Tohoku University, Japan

Title: A geometric view of loop integral reduction by IBP recurrence relations

Abstract: During the last decades, there have been remarkable developments in the technology of analytical calculations for high energy processes in particle physics. The technology is tightly connected to different areas of mathematics. I will first review the key ingredients in the technology, which are based on reduction of complicated multiloop integrals to a small set of basis integrals by using a class of recursion relations. Then I will introduce a new idea to re-interpret the reduction procedure by developing a geometric view in terms of a generating function in a multi-dimensional space and a successive dimensional reduction algorithm.

Name: Kentaro Nomura, nomura@imr.tohoku.ac.jp

Affiliation: Institute for Materials Research, Tohoku University, Japan

Title: Chiral anomaly and spin-electromagnetic responses in topological materials

Abstract: A Weyl semimetal is a topologically protected gapless quantum state, with either time-reversal or spatial inversion symmetries broken in three dimensions. Weyl semimetals with broken time-reversal symmetry are more interesting from basic science and mathematical points of view and reward applications for spintronics devices. In Weyl semimetals, the chiral charge is not conserved in the presence of external nonorthogonal magnetic and electric fields; this chiral anomaly is physical manifestation of the index theorem. In this talk we discuss some related phenomena occur in magnetic Weyl semimetals. We derive an effective free energy functional of magnetization which describes electromagnetic responses of a Weyl semimetal with ferromagnetic order. We demonstrate that Weyl electrons in a magnetic Weyl semimetal exert a spin torque on the local magnetization, without a flowing current, when the chemical potential is modulated in a magnetic field. The spin torque is proportional to the anomalous Hall conductivity, and its effective field strength may overcome the Zeeman field. Using this effect, the direction of the local magnetization is switched by gate control in a thin film.

Co-author(s): Daichi Kurebayashi, Yasufumi Araki

Name: Akihiro Munemasa, munemasa@math.is.tohoku.ac.jp

Affiliation: Graduate School of Information Sciences, Tohoku University, Japan

Title: Equiangular lines in Euclidean spaces

Abstract: We survey the problem of maximizing the size of an equiangular set of lines through the origin in a real Euclidean space. After normalization, the problem becomes a combinatorial one in which linear algebraic technique is useful. More specifically, the problem can be formulated in terms of a *Seidel matrix*, which is a symmetric matrix with zero diagonals and all other entries in $\{\pm 1\}$. We highlight peculiar phenomena in dimensions $7, 8, \ldots, 13$ and 14, mentioning an open problem in dimension 14.

Co-author(s): Gary Greaves, Jack Koolen, and Ferenc Szöllősi.

Name: Hajime Tanaka, htanaka@tohoku.ac.jp

Affiliation: Research Center for Pure and Applied Mathematics, Graduate School of Information Sciences, Tohoku University, Japan

Title: The independence number of the orthogonality graph in dimension 2^k

Abstract: We determine the independence number of the orthogonality graph on 2^k-dimensional hypercubes. This answers a question by Galliard from 2001 which is motivated by a problem in quantum information theory. Our method is a modification of a rank argument due to Frankl who showed the analogous result for $4p^k$-dimensional hypercubes, where p is an odd prime.

Co-author: Ferdinand Ihringer

Name: Hitoshi Murakami, hitoshi@tohoku.ac.jp

Affiliation: Division of Mathematics, Graduate School of Information Sciences, Tohoku University, Japan

Title: Introduction to the volume conjecture for knots

Abstract: The volume conjecture states that the asymptotic behavior of the colored Jones polynomial of a knot in the three-sphere would determine the volume of the knot complement. In this talk, I would like to give an introduction to this conjecture and its various generalizations.

Name: Tuncay Aktosun, aktosun@uta.edu

Affiliation: Department of Mathematics, University of Texas at Arlington, Arlington, TX, USA

Title: Determining the shape of a human vocal tract from speech sounds

Abstract: The elementary units for human speech are called phonemes, and the utterance of each phoneme by a person is governed by a particular shape of that person's vocal tract. A mathematical description is presented for the shape of the vocal tract during the creation of each phoneme, which corresponds to a direct problem. A corresponding inverse problem is analyzed to determine the shape of the human vocal tract from the sound pressure measurements at the lips associated with an uttered phoneme. The talk is based on joint work with P. Sacks of Iowa State University.

Name: Peicheng Zhu, pczhu@shu.edu.cn

Affiliation: Department of Mathematics, Shanghai University, P. R. China

Title: TBA

Abstract: TBA

Name: Benjamin Sheller, shellerba@yahoo.com

Affiliation: Department of Mathematics, Shanghai University, P. R. China

Title: Riemannian geometry and Cartan decompositions

Abstract: In this talk I will briefly introduce Cartan decompositions of semisimple Lie groups/algebras with some applications to quantum systems. I will also discuss how Riemannian geometry can be used to study the cut locus of control systems arising from these decompositions and also how the Riemannian geodesics in symmetric spaces give information on the KAK decomposition of Lie groups.

Name: Mikio Nakahara, nakahara@shu.edu.cn

Affiliation: Department of Mathematics, Shanghai University, P. R. China

Title: Majorana representation of complex vectors and topological excitations in Bose-Einstein condensates

Abstract: It is well known that a vector $|\psi\rangle \in \mathbb{C}^2$ in quantum physics (more precisely an element of $\mathbb{C}P^1$) is visualized by a point $a \in S^2$. Then it is natural to consider how to visualize a vector $|\Psi\rangle \in \mathbb{C}^d$ with $d \geq 3$. The Majorana representation visualizes $|\Psi\rangle$ in terms of $d-1$ points, called the Majorana vectors, in S^2. The Majorana vectors rotate as a rigid body when a d-dimensional representation $U \in \mathrm{U}(2)$ acts on $|\Psi\rangle$ while they change the shape in general when the fundamental representation $U \in \mathrm{U}(d)$ acts.

When alkali metal atoms are cooled down to ultra low temperature, they undergo a phase transition to form a single entity called the Bose-Einstein condensate. The condensate is described by a complex vector whose dimension is identified with that of the representation of SU(2). In my talk, I concentrate on the spin-2 condensate whose complex vector space is $\mathbb{C}^5$ and is expressed in terms of 4 Majorana vectors. We consider two stable phases of the condensate, whose Majorana vectors form a tetrahedron (the cyclic (C) state) and a square (the biaxial nematic (BN) state). The "orientation" of the vectors in these states is specified by an element of $G_C = \mathrm{U}(1) \times \mathrm{SO}(3)/T$ (C state) and $G_{BN} = \mathrm{U}(1) \times \mathrm{SO}(3)/D_4$ (BN state), where T and D_4 are the tetrahedral group and the dihedral group of order 4, respectively.

Consider Bose-Einstein condensate in $\mathbb{R}^3$ and suppose $|\Psi(x)\rangle$ ($x \in \mathbb{R}^3$) approaches a fixed vector $|\Psi_0\rangle$ as $|x| \to \infty$. Then $\mathbb{R}^3$ is compactified to form S^3 and the topological structure of the condensate is classified by the third homotopy group $\pi_3(G)$, where $G = G_C, G_{BN}$. It is know that $\pi_3(G_C) = \pi_3(G_{BN}) = \mathbb{Z}$ showing there are non-trivial configurations of the complex vector field, which cannot be made uniform by homotopic deformation. These structures are visualized by plotting the spatial dependence of the tetrahedron or the square, which is shown in the talk.

Reference: Konstantin Tiurev, Tuomas Ollikainen, Pekko Kuopanportti, Mikio Nakahara, David S Hall, and Mikko Möttönen, *Three-dimensional skyrmions in spin-2 Bose-Einstein condensates*, New J. Phys. **20** (2018) 055011.

Co-author(s): David S Hall, Mikko Möttönen, Tuomas Ollikainen, and Konstantin Tiurev.

Name: Yan Zhu, zhu_yan@shu.edu.cn

Affiliation: Department of Mathematics, Shanghai University, P. R. China

Title: Relative t-designs in Johnson association schemes for P-polynomial structure

Abstract: Relative t-designs are defined in both P- and Q-polynomial association schemes. In this talk, we will discuss our recent work on relative t-designs in Johnson association schemes $J(v,k)$ for P-polynomial structure. It is known that each nontrivial shell X_r of $J(v,k)$ is identified with the product of two smaller Johnson association schemes. We prove that relative t-designs in $J(v,k)$ supported by one shell X_r are equivalent to weighted $\mathcal{T}$-designs in X_r for $\mathcal{T} = \{(t_1,t_2) \mid 0 \le t_1, t_2 \le t\}$. We consider the existence problem of tight relative t-designs for $t = 2, 3$ and make an algorithm to construct tight relative 2-designs.

Co-author(s): Naoki Watamura (Shanghai University).

Name: Bing Wang, bingbignwang@shu.edu.cn

Affiliation: School of Computer Engineering and Science, Shanghai University, P. R. China

Title: The application of network approach to the epidemic modelling

Abstract: The application of network approach to describe real systems, such as social, economic, and information systems has provided novel insights into various real problems, such as identification of super-spreaders, the suppression of infectious disease spreading. Among them, the infectious disease epidemiology provides quantitative analyses in support of policy-making processes. In this talk, I will review the epidemic modelling with network approach. Firstly, I will introduce epidemic modelling of diseases that are closely related with the ones that spread along contacts, such as sexual disease. The basic mathematical modelling approach will be introduced. Secondly, I will introduce the epidemic modelling of diseases that are usually affected by human mobility, such as airborne influenza. I will discuss factors that may influence the epidemic spreading such as network structure of human contact, information propagation, human behaviour of mobility, and I will give insightful guidance for the suppression of infectious diseases. Finally, I will briefly summarize my talk and provide possible applications and key issues in epidemic modelling.

Co-authors: Kazuyuki Aihara, Hideyuki Suzuki

Name: Cheng Zhang, ch.zhang.maths@gmail.com

Affiliation: Department of Mathematics, Shanghai University, P. R. China

Title: Aspects of boundary-value problems for soliton equations

Abstract: I will give an overview of the integrable approach to dealing with nonlinear boundary-value problems. The central object is the so-called reflection equation, which is an algebraic equation and appears in the context of open-boundary problems in quantum spin chains. A "classical version" of the reflection equation arises when dealing with integrable field theories. As applications, I will show some how to applied the theory to solve integrable PDEs on the half-line. The technique is named as "dressing the boundary", and can be in theory applied to a wide range of integrable PDEs. Here I will focus on the nonlinear-Schrödinger equation and the sine-Gordon equation. Some possible connection to physics will also be discussed.

Name: Da-jun Zhang, djzhang@staff.shu.edu.cn

Affiliation: Department of Mathematics, Shanghai University, P. R. China

Title: Multidimensional consistency and discrete integrable systems

Abstract: 3D consistency can be considered as a kind of integrability of 2D quadrilateral lattice equations. In this talk I will introduce such a property and applications in constructing Lax pairs, Bäcklund transformations and solutions. I will also introduce some recent developments in discrete integrable systems.

Name: Wei Ren, renwei@shu.edu.cn

Affiliation: Department of Physics, Shanghai University, P. R. China

Title: TBA

Abstract: TBA

Name: Ping Ao, aoping@shu.edu.cn

Affiliation: Shanghai Center for Quantitative Life Sciences and Physics Department, Shanghai University, P. R. China

Title: From "Dissipative Landau-Zener Transition" to "Complete Fidelity with Coherence": quantum control in perspective

Abstract: Adiabatic transformation can achieve 100% fidelity in a quantum processes, but it is not useful for practical applications, such as quantum computing. We need a way to achieve such goal within a finite time. Exact formulation of the problem was studied long again by Landau, Zener and others. Within the dissipative quantum dynamics of Feynman-Vernon-Caldeira-Leggett, it was studied again and rich dynamical behaviors were found but, unfortunately, complete fidelity remained elusive. From a control theory perspective, it was later found to be possible. Then the main results have been found by numerous other authors. Recently it has been shown that such control can be realized experimentally. A review of this great progress and a few possible directions will be discussed.

Reference: **1**. Influence of Dissipation on the Landau-Zener Transition. Ao, Rammer, Phys Rev Lett 62, 3004 (1989); **2**. Quantum Dynamics of a Two-State System in a Dissipative Environment. Ao, Rammer, Phys Rev B43, 5397 (1991); **3**. Steering an Eigenstate to Destination, Emmanouilidou, Zhao, Ao, Niu, Phys Rev Lett 85, 1626 (2000); **4**. Emerging of Stochastic Dynamical Equalities and Steady State Thermodynamics from Darwinian Dynamics. Ao, Commun Theor Phys 49, 1073 (2008); **5**. SDE Decomposition and A-Type Stochastic Interpretation in Nonequilibrium Processes. Yuan, Tang, Ao. Front Phys 12, 120201 (2017)

Co-author(s)::YC Chen and XG Zhao

Name: Yong-Cong Chen, chenyongcong@shu.edu.cn

Affiliation: Shanghai Center for Quantitative Life Sciences & Physics Department, Shanghai University, P. R. China

Title: Resonant confinement of an excitonic polariton and ultra-efficient light harvest in artificial photosynthesis

Abstract: We uncover a novel phenomenon from a recent artificial light-harvesting experiment [Angewandte Chemie Intl. Ed. 55, 2759 (2016)] on organic nanocrystals of self-assembled difluoroboron chromophores.

A resonant confinement of polariton under strong photon-exciton coupling is predicted to exist within the microcavity of the crystals own natural boundaries. Moreover, the radiative energy of a localized exciton falls into the spectrum of the confinement.

The spontaneous emission of an excited pigment would undergo a two-step process. It should first decay to an excitonic polariton trapped by the cavity resonance. The captive intermediate could then funnel the energy directly to doped acceptors, leading to the observed over 90% transfer efficiency at less than 1/1000 acceptor-donor ratio.

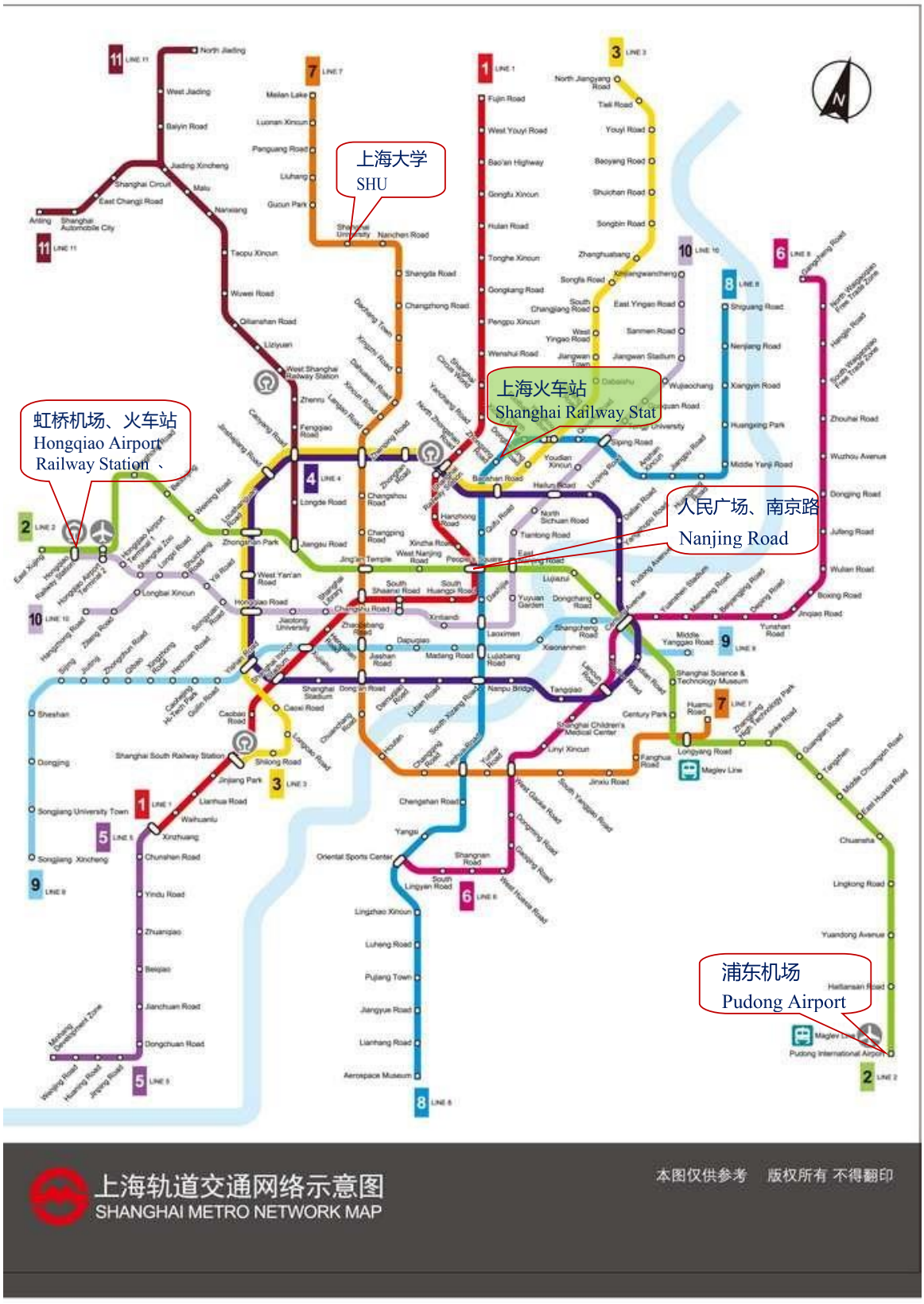
The proposed mechanism is supported by parameter-free analyses entirely based on experiment data. Our finding may imply possible polariton-mediated pathways for energy transfers in biological photosynthesis.

Reference: Work published in Phys. Rev. Lett. 122, 257402 (2019):
https://journals.aps.org/prl/pdf/10.1103/PhysRevLett.122.257402

Co-author(s): Prof. Ping Ao, Xiaomei ZHU, Shanghai Center for Quantitative Life Sciences & Physics Department, Shanghai University; Prof. Bo Song, Shanghai Key Lab of Modern Optical System, University of Shanghai for Science and Technology; Prof. A. J. Leggett, Shanghai Center for Complex Physics, Shanghai Jiao Tong University Department of Physics, University of Illinois at Urbana-Champaign

Shanghai University Map (Baoshan Campus)

Metro Map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Pudong Airport
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SHANGHAI METRO NETWORK MAP
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