The 4th Asia-Pacific Regional Workshop for Complex Non-Equilibrium Systems

June 28-30, 2018

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Institute of Natural Sciences, Shanghai Jiao Tong University

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1 General Information

Brief Introduction

Over the past decades, the field of complex non-equilibrium systems is experiencing a fast and significant advance. The 4th Asia-Pacific Regional Workshop for Complex Non-Equilibrium Systems is intended to provide a broad perspective on the contemporary researches in soft matter science, non-equilibrium systems, and statistical physics for researchers in Asia-Pacific area.

Date

June 28-30, 2018

Venue

601 Pao Yue-Kong Library

Organizers

- Shi Jin, Shanghai Jiao Tong University
- Jie Zhang, Shanghai Jiao Tong University

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3 Abstract

3.1 Day 1, 29 Jun

Dynamics of Coherent Structures in Turbulent Thermal Convection

Ke-Qing Xia, The Chinese University of Hong Kong
09:00 - 09:45

A hallmark of fluid turbulence is the existence of an extremely large number of degrees of freedom. The formation of large-scale flow structures, or coherent structures, may simplify the description of turbulent flows. Instead of taking into account all the high-dimensional space, one can capture the essential coherent structure dynamics by considering only a few relevant flow modes and model the others stochastically. In this talk I will present two examples using such dynamical systems or statistical mechanics approach. The first one is turbulent annulus Rayleigh-Bénard convection (RBC), in which a flow topology transition from a high-symmetry high-heat-transport efficiency quadrupole state to a low-symmetry low-heat-transport efficiency dipole state is observed as the turbulence level increases. This transition is accompanied by a global bifurcation of the mean flow, which is reminiscent of the spontaneous symmetry breaking that usually results in phase transitions in condensed matter physics. The second one is the motion of vortices, or convective Taylor columns (CTCs), in rotating RBC, in which the horizontal motions of the CTCs show Brownian type behavior, i.e. their short time behavior is ballistic and crosses over to diffusive in long time. Very interestingly, although the motions of the vortices are random in time, they exhibit ordering in space. The present findings should stimulate more studies of turbulent flows from the dynamical systems point of view, which should also have implications beyond fluid dynamics.

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Liquid Crystals with Designer 2D and 3D Molecular Orientations

Qihuo Wei, Liquid Crystal Institute, Kent State University, Kent, OH 44242, USA
09:45 - 10:30

Liquid crystals (LCs) are a state of matter between liquid and solid and are characterized by the long-range orientation ordering of the constituent molecules. One particular phase of the LCs is the nematic phase where all molecules align approximately along one common direction. Most current flat panel displays are made of the nematic LCs, and designed and manufactured with all molecules aligned uniformly at the confining surfaces. In this talk, I will show our recent work in controlling spatially variant molecular orientations of the LCs in both 2D and 3D in a designable fashion, and their emerging applications in directed assembly of colloidal particles, stimuli-responsive liquid crystal elastomers, and micro-optical devices.

Biological Locomotion and Fluid Resistance

Jun Zhang, New York University and NYU Shanghai
10:50 - 11:35

Whenever an object moves inside a fluid, either in water or in air, a resistive force is felt immediately. Even though it sounds quite negative as if it would oppose the tendency of motion, the resistive force is often the much-needed driving force for animal locomotion. And indeed, it does very often reduce the speed of bio-locomotion when it plays as an opposing force to thrust. In this talk, we will discuss how resistive force affects the motion of some biomimetic systems in fluids, when such force comes to determine the moving speed, the scaling relationship (between force and speed), and the dynamic stability.

The Cheerios effect of floating droplets

Tuan Tran, Nanyang Technological University
11:35 - 12:20

Droplets partially submersed in an miscible liquid pool attract each other. We experimentally study the interaction of floating droplets containing aqueous solution of a volatile liquid. A droplet affects its neighbors by generating a vapor gradient to the surrounding and responds by evaporating asymmetrically over its exposed cap. We show that the induced asymmetric temperature distribution causes a surface tension gradient driving the droplets. We highlight that the attracting motion always consists of an accelerating and a decelerating stages. We finally provide a theoretical model that quantitatively captures the interactive forces between droplets and predicts essential features of the attracting motion.

Dynamic heterogeneity and non-Gaussian statistics for protein diffusion on live cell membrane

Penger Tong, Department of Physics, Hong Kong University of Science and Technology
14:30 - 15:15

The Brownian motion of molecules at thermal equilibrium usually has a finite correlation time and will eventually be randomized after a long delay time, so that their displacement follows the Gaussian statistics. This is true even when the molecules have experienced a complex environment with a finite correlation time. It is commonly believed that the equilibrium Gaussian statistics, as dictated by the central limit theorem, also applies to the motion of biomolecules, such as membrane-bound proteins and lipids in a living cell, as was originally envisioned by Saffman and Delbruck. Although our general view of molecular motion in living cells has evolved with recent discoveries of the slow active remodeling of the cytoskeletal network due to the activity of molecular motors and other non-equilibrium cellular processes, up to now we still do not have a quantitative answer about how and to what extend the active dynamics in the living cells affect the statistics of membrane diffusion. In this talk, I will present our recent experimental study of diffusion dynamics of acetylcholine receptors (AChRs) on live muscle cell membrane [1]. The AChRs are linked to fluorescent quantum dots and their trajectories are tracked with nanometer accuracy over a broad range of times. From a careful analysis of a large volume of the protein trajectories obtained over a wide range of sampling rates and long durations, we find that the normalized histogram of the protein displacements shows a consistent exponential tail, which is robust and universal for cells under different conditions. The experiment indicates that the observed non-Gaussian statistics and dynamic heterogeneity are inherently linked to the slow active remodeling of the underlying cortical actin network.

This work was done in collaboration with Wei He, Hao Song, Yun Su, Lin Geng, B. J. Ackerson, and Ben Peng and was supported by the Research Grants Council of Hong Kong SAR.

[1] W. He, H. Song, Y. Su, L. Geng, B. J. Ackerson, H. B. Peng, and P. Tong, Nature Communications, 7:11701 (2016).

Network Reconstruction from Noisy time-series Dynamical data

Pik-Yin Lai, Dept. of Physics, National Central University
15:15 - 16:00

I will discuss our recent work on the challenging inverse problem of network reconstruction solely from the measurement of noisy time-series data. We derived general mathematical results relating the undirected[1,2] or directed[3,4] network connections to the time-lag correlation functions for continuous[1-3] and discrete[4] time network dynamics, under temporally uncorrelated or correlated noises[5]. Based on these results, we have developed a method that reconstructs both the links and their relative coupling strength using only the time-series measurements of node dynamics as input. We demonstrated that our method give accurate results for various kinds of networks with linear and nonlinear dynamics and coupling functions. Using our theoretical results, one can further explain the shortcomings of the common practice of inferring links for undirected networks using Pearson correlation coefficients or partial correlation coefficient. Furthermore, our results give the fluctuation-dissipation relations for network dynamics and enable one to compute the network response functions upon different network parameter changes.

1. E.S.C. Ching, Pik-Yin Lai, and C. Y. Leung, Phys. Rev. E 88, 042817 (2013).

2. E.S.C. Ching, Pik-Yin Lai, and C. Y. Leung, Phys. Rev. E (Rapid Comm.) 91, 030801 (2015).

3. E.S.C. Ching and H .C. Tam, Phys. Rev. E (Rapid Comm.) 95, 010301 (2017).

4. Pik-Yin Lai, Phys. Rev. E 95, 022311 (2017).

5. H.C. Tam E.S.C. Ching, and Pik-Yin Lai, Physica A 502,106 (2018).

Efficiency, reversibility, and power of a heat engine

Hyunggyu Park, Korea Institute for Advanced Study
16:20 - 17:05

Efficiency of an engine is usually expected to deteriorate with increasing irreversibility.

In this talk, I present an engine against this conventional wisdom and discuss its generality and applicability.

Minimal model of stratified epithelium

Hsuan-Yi Chen, National Central University
17:05 - 17:50

A minimal model which includes spatial and cell lineage dynamics for stratified epithelia is presented. The dependence of tissue steady state on cell-differentiation models, cell proliferation rate, cell differentiation rate, and other parameters are studied numerically and analytically. Our minimal model shows some important features. First, we find that morphogen or mechanical stress mediated interaction is necessary to maintain a healthy stratified epithelium. Furthermore, comparing with tissues in which cell differentiation can take place only during cell division, tissues in which cell division and cell differentiation are decoupled can achieve relatively higher degree of stratification. Finally, our model also shows that in the presence of short-range interactions, it is possible for a tissue to have multiple steady states. The relation between our results and tissue morphogenesis or lesion is discussed.

3.2 Day 2, 30 Jun

Converting nearly all available information into work by a nearly error-free Brownian information engine

Hyuk Kyu Pak, UNIST/IBS Center for Soft and Living Matter
09:00 - 09:45

We report on a lossless information engine that converts nearly all available information from an error-free feedback protocol into mechanical work. Combining high-precision detection at resolution of 1 nm with ultrafast feedback control, the engine is tuned to extract the maximum work from information on the position of a Brownian particle. We show that the work produced by the engine achieves a bound set by a generalized second law of thermodynamics, demonstrating for the first time the sharpness of this bound. We validate a generalized Jarzynski equality for error-free feedback-controlled information engines.

Biased Brownian Motion in Narrow Channels with Asymmetry and Anisotropy

Kiwing To, Institute of Physics, Academia Sinica, Taipei
09:45 - 10:30

Recently experiments [Zheng Peng and Kiwing To, PRE 94, 022902 (2016)] showed that a Brownian particle in a narrow channel with asymmetric walls maybe biased to drift uni-directionally by the presence of anisotropy in the longitudinal and transverse directions. Here we perform Brownian dynamics simulations of the experiments to study the physics behind the phenomenon. We verify that the driving force of the drift is indeed originated by the anisotropy the channel walls. Furthermore, the drift velocity is proportional to the mean-square velocity in the transverse direction.

Non-ergodic granular statistical mechanics: Bridging between statics and dynamics

Raphael Blumenfeld, Imperial College London, UK
10:50 - 11:35

The formulation of statistical mechanics for a-thermal particulate systems jump-started the field as a rigorous branch of soft matter physics. I review briefly the Edwards formalism, which we extended to cellular and porous materials, I point out a problem with the original formulation, and how it was overcome.

Using the improved formulation, I show that there are contributions to the entropy from several structural sources. This also clarifies a current raging debate in the field regarding the extensivity of the entropy in these systems. I then present a derivation of an equation of state, relating the volume, the boundary stress and the equivalent of temperatures in these systems.

Time permitting I' ll discuss the extension of this formalism to slow dynamics of dense particulate systems, thus bridging for the first time between static and dynamic systems.

Relevant references:

R. Blumenfeld et al., Phys. Rev. Lett. 116, 148001 (2016).

S. Amitai and R. Blumenfeld, Phys. Rev. E 95, 052905 (2017).

D. Asenjo et al., Phys. Rev. Lett. 112, 098002 (2014).

R. Blumenfeld et al., Phys. Rev. Lett., 119, 039802 (2017).

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Study of an athermal quasi static plastic deformation in a 2D granular material

Jie Zhang, Shanghai Jiao Tong University
11:35 - 12:20

In crystalline materials, the plasticity has been well understood in terms of dynamics of dislocation, i.e. flow defects in the crystals where the flow defects can be directly visualized under a microscope. In a contrast, the plasticity in amorphous materials, i.e. glass, is still poorly understood due to the disordered nature of the materials. In this talk, I will discuss the recent results we have obtained in our ongoing research of the plasticity of a 2D glass in the athermal quasi static limit where the 2D glass is made of bi-disperse granular disks with very low friction. Starting from a densely packed homogeneous and isotropic initial state, we apply pure shear deformation to the system. For a sufficiently small strain, the response of the system is linear and elastic like; when the strain is large enough, the plasticity of the system gradually develops and eventually the shear bands are fully developed. In this study, we are particularly interested in how to relate the local plastic deformation to the macroscopic response of the system and also in the development of the shear bands.