2013 NCTS March Workshop on Critical Phenomena and Complex Systems

Date: March 11-12, 2013

Place: Institute of Physics, Academia Sinica

March 11: Place: The auditorium at first floor

Time	Speaker	Talk Title
15:10-16:00	Prof. Fa-Hsuan Lin Institute of Biomedical Engineering National Taiwan University E-mail: fhlin@ntu.edu.tw	Functional connectivity of human brain revealed by noninvasive neuroimaging methods
16:00-16:20	*Tea break*	
16:20-17:10	Prof. Plamen Ch. Ivanov Department of Physics, Boston University and Division of Sleep Medicine, Harvard Medical School; E-mail: plamen@buphy.bu.edu	From 1/f noise to multifractal complexity and self-organization in physiologic dynamics

March 12: Place: The auditorium at first floor (morning) / The first meeting room at fifth floor (afternoon)

Time	Speaker	Talk Title
10:10-11:00	Prof. Plamen Ch. Ivanov Department of Physics, Boston University and Division of Sleep Medicine, Harvard Medical School; E-mail: plamen@buphy.bu.edu	Critical Transitions and Self-Organization in Sleep
11:00-11:20	*Tea break*	
11:20-12:10	Dr. Chi-Keung Chan Institute of Physics, Academia Sinica; E-mail: ckchan@gate.sinica.edu.tw	Suppression of cardiac alternans by chaotic attractors
12:10-14:00	*Lunch break*	
14:00-14:50	Prof. Plamen Ch. Ivanov Department of Physics, Boston University and Division of Sleep Medicine, Harvard Medical School; E-mail: plamen@buphy.bu.edu	Network Physiology: Mapping interactions between complex physiological systems
14:50-15:10	*Tea break*	
15:10-16:00	Dr. Chun-Chung Chen Institute of Physics, Academia Sinica; E-mail: cjj@phys.sinica.edu.tw	Dynamic structures in a plastic spiking network
16:00-16:20	*Tea break*	
16:20-17:10	Prof. Alexander S. Mikhailov Department of Physical Chemistry, Fritz Haber Institute of the Max Planck Society; E-mail: mikhailov@fhi-berlin.mpg.de	Stationary and Oscillatory Turing Patterns in Networks

Organizers：National Center for Theoretical Sciences (Critical Phenomena and Complex Systems focus group) and Institute of Physics of Academia Sinica (Taipei)

Website: http://proj1.sinica.edu.tw/~statphys/

Abstract

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Prof. Plamen Ch. Ivanov (Department of Physics, Boston University; E-mail: plamen@buphy.bu.edu)

Talk-1:
Title: From 1/f noise to multifractal complexity and self-organization in physiologic dynamics
Abstract:

Physiological systems under neural regulation exhibit erratic fluctuations, which traditionally have been considered as noise and thus, often neglected. However, recent findings indicate that physiologic fluctuations exhibit a temporal cale-invariant structure spanning time scales from seconds to hours, resembling the behavior of non-equilibrium physical systems characterized by power-law long-range correlations, fractal and multi-fractal behavior. We will briefly review scale-invariance as a fundamental concept in modern physics, and we will demonstrate its usefulness in studying physiologic dynamics on examples of physiologic systems under integrated neural control -- cardiac dynamics and locomotion.

Talk-2:
Title: Critical Transitions and Self-Organization in Sleep
Abstract:

Humans and animals exhibit brief awakenings from sleep (arousals), which are traditionally viewed as random disruptions of sleep caused by external stimuli or pathological perturbations. However, our findings show that arousals represent previously unrecognized intrinsic aspects of sleep, and exhibit complex temporal organization and scale-invariant behavior characterized by a power-law probability distribution for their durations. In contrast, sleep-stage durations exhibit exponential behavior. The co-existence of these two very different processes in the sleep regulatory mechanism has not been observed in any other physiological system, and resembles a special class of non-equilibrium physical systems exhibiting self-organized criticality (SOC). Such organization of arousals makes it unlikely that they are merely a response to random stimuli. We show that these SOC-type dynamics persist throughout the sleep period in humans and across several mammalian species with different sleep architecture, raising the hypothesis that arousals are an integral part of healthy sleep and relate to basic neuronal interactions.

Talk-3:
Title: Network Physiology: Mapping interactions between complex physiological systems
Abstract:

The human organism is an integrated network where complex physiological systems, each with its own regulatory mechanisms, continuously interact, and where failure of one system can trigger a breakdown of the entire network. Identifying and quantifying dynamical networks of diverse systems with different types of interactions is a challenge. We propose a framework to probe interactions among diverse systems, and we identify a physiological network. We find that each physiological state is characterized by a specific network structure, demonstrating a robust interplay between network topology and function. Across physiological states, the network undergoes topological transitions associated with fast reorganization of physiological interactions on time scales of a few minutes, indicating high network flexibility in response to perturbations. The proposed system-wide integrative approach facilitates the development of a new field, Network Physiology.

Prof. Alexander S. Mikhailov (Department of Physical Chemistry, Fritz Haber Institute of the Max Planck Society, Germany; E-mail: mikhailov@fhi-berlin.mpg.de)

Talk title: Stationary and Oscillatory Turing Patterns in Networks

Abstract:
The diffusion-induced instability, discovered in 1952 by Alan Turing, has played a paradigmatic role in the subsequent research on self-organization phenomena far from equilibrium. Originally proposed as a mechanism for biological morphogenesis, it has been experimentally investigated both for biological and chemical systems. Together with prof. H. Nakao from the Kyoto University (now in Tokyo Institute of Technology), we have considered analogs of this bifurcation in network-organized systems. As examples, ecological networks have been chosen, although the results are general and can be as well applied to networks formed by biological cells or chemical reactors. Our analysis has revealed [1] that the instability leads to spontaneous differentiation on a subset of network nodes, if mobility of the inhibitor species (the predator in our model) is gradually increased. Thus, a self-organized stationary pattern develops in a network. As we have shown [2], such patterns can be efficiently controlled by introduction of global feedback. Recently, oscillatory network Turing patterns, corresponding to the so-called wave bifurcation in reaction-diffusion media, have been investigated [3]. Such patterns spontaneously develop in metapopulations with the food webs comprising at least three species when the mobility of one of the species is raised. They lead to the emergence of oscillations and may eventually result in global destabilization of an ecosystem and the extinction of its species.

[1] H. Nakao and A. S. Mikhailov, Turing patterns in network-organized activator-inhibitor systems, Nature Physics 6, 544 (2010).
[2] S. Hata, H. Nakao, and A. S. Mikhailov, Global feedback control of Turing patterns in network-organized activator-inhibitor systems, Europhys. Lett. 98, 64004 (2012)
[3] S. Hata, H. Nakao, and A. S. Mikhailov, Dispersal-induced destabilization of metapopulations and oscillatory Turing patterns in ecological networks, in preparation (2013).