2015 随机过程理论及其在物理和生物中的应用会议

北京大学

2015 年 12 月 12-13 日

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会议地点：

北京国际数学研究中心，镜春园82甲乙丙楼二楼报告厅，北京大学

会议学术委员会：

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- 章复熹，北京大学
- 葛颢，北京大学

会议邀请报告人：

1. 陈振庆，University of Washington
2. 陈娴，北京大学
3. 陈增敬，山东大学
4. 董昭，中科院
5. 冯建峰，复旦大学和英国 Warwick 大学
6. 高付清，武汉大学
7. 葛颢，北京大学
8. 郭先平，中山大学
9. 嵇少林，山东大学
10. 蒋达权，北京大学
11. 李增沪，北京师范大学
12. 骆顺龙，中国科学院
13. 王凤雨，北京师范大学
14. 吴臻，山东大学
15. 向开南，南开大学
16. 谢晓亮，哈佛大学和北京大学
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20. 张兴安，华中师范大学
21. 周达，厦门大学
22. 朱天琪, 中科院

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　　　北京大学数学与生物交叉实验室

会议网址：

　　　http://bicmr.pku.edu.cn/content/show/17-1595.html

日程安排

12 月 12 日上午

主持人：陈大岳		
8:45-9:00		开幕式，合影
9:00-9:30	谢晓亮	Life at single-molecule level
9:30-10:00	冯建峰	Stochastic processes in neuroscience
10:00-10:30	蒋达权	Cycle renewals and circulation fluctuations of some Markov processes
10:30-11:00		茶歇
主持人：冯建峰		

11:00-11:30	骆顺龙	量子非 Markov 过程
11:30-12:00	张希承	L^p-maximal hypoelliptic regularity of nonlocal kinetic Fokker-Planck operators
12:00-13:30		午餐 畅春园

12 月 12 日下午

主持人：巩馥洲		
14:00-14:30	李增沪	Branching processes, trees and stochastic equations
14:30-15:00	高付清	Moderate deviations for stochastic lattice gas models
15:00-15:30	章复熹	Is discrete Liouville quantum gravity metric universal for log-correlated Gaussian fields?
15:30-16:00		茶歇
主持人：刘勇		
16:00-16:30	向开南	Finite Approximation for Unimodular Random Networks
16:30-17:00	嵇少林	Stochastic maximum principle for stochastic recursive optimal control problem under volatility ambiguity
17:00-17:30	张兴安	Mathematical modeling the pathway of human breast cancer
17:30-18:00	葛颢	Fluctuating-rate model and associated rate formula for phenotype transition in single-cell biology
18:30-20:30		晚宴 勺园 (全体报告人)

12 月 13 日上午

主持人：任艳霞		
8:30-9:00	陈振庆	Obliquely reflected Brownian motion
9:00-9:30	王凤雨	Poincare Inequality for Dirichlet Distributions and Infinite-Dimensional Generalizations
9:30-10:00	郭先平	Semi-Markov decision processes with a risk probability criterion
10:00-10:30		茶歇
主持人：向开南		

10:30-11:00	陈增敬	A Stochastic Competing Species Model: Existence and Ergodic Behavior
11:00-11:30	董昭	Exponential Convergence for 3D Stochastic Primitive Equations of the Large Scale Ocean
11:30-12:00	吴臻	Optimal switching under a regime-switching model with two-time-scale Markov chains
12:00-13:30	午餐 畅春园	

12 月 13 日下午

主持人：蒋达权		
14:00-14:30	朱天琪	A maximum likelihood implementation of an isolation-with-migration model for three species
14:30-15:00	周达	Some quantitative methods for characterizing reversible cell lineage
15:00-15:30	陈娴	Continuous states q-processes and applications in the study of coalescent with recombination
15:30-16:00	张蕊	Limit Theorems for Some Critical Superprocesses
16:00-16:15	闭幕式	

题目和摘要

题目：Obliquely reflected Brownian motion

报告人：陈振庆(University of Washington)

摘要：In this talk, we will be concerned with the construction and characterization of obliquely reflected Brownian motions in all bounded simply connected planar domains, including non-smooth domains, with general reflection vector field on the boundary. We show that the family of all obliquely reflected Brownian motions in a given domain can be characterized in two different ways, either by the field of angles of oblique reflection on the boundary or by the stationary distribution and the rate of rotation of the process about a reference point in the domain. We further show that Brownian motion with darning and excursion reflected Brownian motion can be obtained as a limit of obliquely reflected Brownian motions. Based on joint work with K. Burdzy, D. Marshall and K. Ramanan.

题目：Continuous states q-processes and applications in the study of coalescent with recombination

报告人：陈娴(北京大学)

摘要：In this talk I will present some new results on the transformation of Markov jump process and their applications in the study of coalescent with recombination. More specifically, we provide a verifiable necessary and sufficient condition for a regular q-process to be again a regular q-process under a transform of state space. Applying this result as well as some other results on continuous states q-processes, we rigorously prove that the statistical properties of the two classes of simulation models widely used in the study of coalescent with recombination are identical. That is, they share the same probability distribution on the space of ancestral recombination graphs (ARGs). As a consequence, our study provides a unified interpretation for the algorithms of simulating coalescent with recombination, and will facilitate the study of statistical inference on recombination. The results presented here are joint with Professor Zhi-Ming Ma and Dr. Ying Wang.

题目：A Stochastic Competing Species Model: Existence and Ergodic Behavior

报告人：陈增敬(山东大学)

摘要：Mao and Renshaw considered a deterministic population dynamics ordinary differential equations model with Gaussian noise added to the rate function. They showed that quite different behavior can occur with the deterministic versus the stochastic versions of the model. In particular they showed that (i) explosion can be suppressed in a logistic model of population dynamics and (ii) for a Lotka-Volterra model with n interacting species and noise for the i-th population proportional to $x_i(t)$, then the process is finite for all time, that is it lives in R_n^+. However their proof will not work for smaller noise, for example noise proportional to $x_i(t)$. In this paper we consider cases of such smaller noise, proportional to $x_i(t)$ and for competing species models. We show that if the noise is less than a certain threshold then solution is in R_n^+. In addition if the noise is less than a certain threshold, that we calculate, we show the solution is also ergodic. For the exposition we concentrate on the case of n = 3 species, with one predator and two prey. We indicate how the proof carries over to a general n species model. The necessary and sufficient condition for ergodicity

is a nice geometric property of whether a ellipsoid obtained from the rate function is a proper subset of R3+. (with Reg Kulperger)

题目：Exponential Convergence for 3D Stochastic Primitive Equations of the Large Scale Ocean

报告人：董昭(中科院)

摘要：In this paper, we consider the ergodicity for the three-dimensional stochastic primitive equations of the large scale oceanic motion. We proved that if the noise is at the same time sufficiently smooth and non-degenerate, then the weak solutions converge exponentially fast to equilibrium. Moreover, uniqueness of invariant measures are stated.

题目：Stochastic processes in neuroscience

报告人：冯建峰(复旦大学和英国 Warwick 大学)

摘要：From a single channel activity (a q process) to a single neuron activity (a point process), to the local field potential (a stochastic process), neuroscience is essentially a subject of stochastic processes. Collectively a brain activity is a random field. To understand the brain is equivalent to understand or decode the random field. In my talk, i will concentrate on modelling, from subcellular, to cellular, to the whole brain. In particular, I will talk about open issues and our ongoing projects in our area.

题目：Moderate deviations for stochastic lattice gas models

报告人：高付清(武汉大学)

摘要：We introduce some results on moderate deviations for additive functionals of stochastic lattice gas models.

题目：Fluctuating-rate model and associated rate formula for phenotype transition in single-cell biology

报告人：葛颢(北京大学)

摘要：Stochastic processes become more and more popular to model the mesoscopic biophysical dynamics, especially in single-cell biology. We proposed a fluctuating-rate model for the stochastic biochemical dynamics in a single cell, which is indeed stochastic coupled Ordinary Differential Equations. We also found that the fluctuating-rate model yields a nonequilibrium landscape function, which, similar to the energy function for equilibrium fluctuation, provides the leading orders of fluctuations around each phenotypic state, as well as the transition rates between the two phenotypic states. The rigorous proof needs to integrate the well-known Donsker-Varadhan theory and Freidlin-Wentzell theory in such an averaging case.

We further apply this model to Lac operon, and show that the stochastic gene-state switching can significantly broaden the environmental parameter ranges for the existence of bistability induced by positive feedback, which can be

beneficial dealing with unpredictable environmental changes. We also demonstrate that the phenotype transition rates can help to distinguish two categories of bistability.

题目：Semi-Markov decision processes with a risk probability criterion

报告人：郭先平(中山大学)

摘要：This paper is the first attempt to investigate the risk probability criterion in semi-Markov decision processes with loss rates. The goal is to find an optimal policy with the minimum risk probability that the total loss incurred during a first passage time to some target set exceeds a loss level. First, we establish the optimality equation via a successive approximation technique, and show that the value function is the unique solution to the optimality equation. Second, we give suitable conditions, under which we prove the existence of optimal policies, and develop an algorithm for approximating an optimal policy. Finally, we apply our main results to a business system.

题目：Stochastic maximum principle for stochastic recursive optimal control problem under volatility ambiguity

报告人：嵇少林(山东大学)

摘要：We study a stochastic recursive optimal control problem in which the cost functional is described by the solution of a backward stochastic differential equation driven by G-Brownian motion. Some of the economic and financial optimization problems with volatility ambiguity can be formulated as such problems. Different from the classical variational approach, we establish the maximum principle by the linearization and weak convergence methods. (This is a joint work with Mingshang Hu).

题目：Cycle renewals and circulation fluctuations of some Markov processes

报告人：蒋达权(北京大学)

摘要：Markov chains are widely used to model various stochastic systems in physics, chemistry, biology, etc. The trajectories of a recurrent Markov chain constantly form various cycles. For a family of cycles passing through the same set of states, we prove that the distributions of the forming times of these cycles, respectively conditioned on that the corresponding cycle is formed earlier than the others, are exactly the same. This cycle symmetry can be regarded as a generalization of the Haldane relation for reversible enzyme kinetics. We then prove that this cycle symmetry leads to the large deviation principle for the sample circulations along these cycles, in which the rate function has a non-obvious symmetry. This symmetry implies the Gallavotti-Cohen type fluctuation theorem for the sample net circulations. We also obtain the transient fluctuation theorem and the integral fluctuation theorem in non-equilibrium statistical physics for sample circulations. Similar results hold for diffusion processes on the circle.

题目：Branching processes, trees and stochastic equations

报告人：李增沪(北京师范大学)

摘要：A continuous-state branching process is the mathematical model for the random evolution of a large population of small individuals. The trajectory of the process was constructed in Dawson and Li (2006, 2012) as the strong solution to a stochastic integral equation driven by Gaussian and Poisson time-space noises. The genealogical structure of population is represented by a continuum random tree, which was uniquely characterized by its height process. The later was constructed by Le Gall and Le Jan (1998) as a functional of a spectrally positive L\'evy process. A different construction of the height process was recently given by Li, Pardoux and Wakolbinger (2015) in terms of a stochastic integral equation driven by Poisson point processes. The advantage of this new construction is it can be generalized easily to the situation of interactive branching. In this talk, we present a number of stochastic integral equations in the theory of continuous-state branching processes and continuum random trees. We also explain how those stochastic equations can be used in the study the structural properties of the models.

题目：量子非 Markov 过程

报告人：骆顺龙(中国科学院数学与系统科学研究院，国家数学与交叉科学研究中心)

摘要：在开放系统的研究中如果忽略记忆效应就会得到Markov过程, 从泛函的观点看通常可由算子半群来描述. 但无论是在理论探索还是现实应用中, 正如van Kampen 所言, Non-Markov is the rule, Markov is the exception. 如果存在记忆效应或信息的双向流动, 就会导致非Markov性, 而Markov性通常是作为一种近似或方便的简化. 近年来, 量子信息的快速发展极大地刺激了量子非Markov性的研究. 我们将简述量子非Markov过程的基本概念, 刻画, 应用和若干进展。

题目： Poincare Inequality for Dirichlet Distributions and Infinite-Dimensional Generalizations

报告人：王凤雨(北京师范大学)

摘要： The Dirichlet distribution and its infinite-dimensional generalization arise naturally in Bayesian inference as conjugate priors for categorical distribution and infinite non-parametric discrete distributions respectively. They also arise in population genetics describing the distribution of allelic frequencies. By establishing the sharp Poincare inequality, the exact exponential convergence rate is found for a class of diffusion processes to converge to the Dirichlet distribution. Moreover, the sharp Poincare inequality is extended to the infinite-dimensional setting, and the spectral gap of the corresponding discrete model is derived.

题目：Optimal switching under a regime-switching model with two-time-scale Markov chains

报告人：吴臻(山东大学)

摘要：This talk is concerned with a probabilistic approach to an optimal switching problem. The dynamics of the system consists of a set of diffusions coupled by a finite-state Markov chain. It is shown that the value function and the

optimal strategy can be given in terms of the solution of an obliquely reflected backward stochastic differential equation (BSDE) with Markov chain. The obliquely reflected BSDE also gives a probabilistic interpretation for a system of variational inequalities.

In many physical and biological applications, the underlying Markov chain exhibits two-time-scale structure. In this case, the value function for the original problem is shown to converge to the value function of a limit problem as the fluctuation rate shrinks to zero. The main advantage of this two-time-scale approach is the reduction of dimensionality and computational complexity. The limit problem is much easier to solve and its optimal switching solution leads to approximate solution to the original problem. Finally, a numerical example is provided to demonstrate the convergence result.

题目：Finite Approximation for Unimodular Random Networks

报告人：向开南 （南开大学数学科学学院）

摘要：当 G 是有限图、o 是 G 的均匀随机顶点时，(G,o)是单模随机图。对无穷图 G，无法定义均匀随机顶点。如何定义无穷单模随机图使其包含有限单模随机图序列的所有极限点？此时需用质量运输原理来刻画单模性且产生一个核心问题：任一单模随机图是否是某有限单模随机图序列的极限？更一般地，任一单模随机网络是否是某有限单模随机网络序列的极限？此处网络指顶点与边均带有标记的图。上述看似简单的问题对概率论、群论、图论、遍历论、符号动力系统、算子代数均具有重大的意义；此报告将阐述这点及相关的 Aldous-Lyons 猜想。

题目：Is discrete Liouville quantum gravity metric universal for log-correlated Gaussian fields?

报告人：章复熹 (北京大学)

摘要: Liouville quantum gravity (LQG) is an important model of random surfaces that arises from exponentiating an underlying random media, among which the two-dimensional Gaussian free field (GFF) is arguably the most notable instance. In this paper, we investigate an aspect of universality for the random metric of LQG in the \emph{discrete} level when the underlying random media is in the class of log-correlated Gaussian fields, of which the discrete Gaussian free field is a special case.

We construct a family of log-correlated Gaussian fields, on which we show that the LQG distance between two typically sampled vertices according to the LQG measure is $N^{1+ O(\epsilon)}$, where N is the side length of the box and ϵ can be made arbitrarily small if we tune a certain parameter in our construction. That is, the exponents can be arbitrarily close to 1. Combined with physics prediction that the corresponding exponent is less

than 1 when the underlying field is GFF, our result suggests that such exponent is notuniversal among the family of log-correlated Gaussian fields. (Joint work with Jian Ding)

题目：Limit Theorems for Some Critical Superprocesses

报告人：张蕊(首都师范大学)

摘要: Let $X=\{X_t, t\ge 0; \P_\mu\}$ be a critical superprocess starting from a finite measure μ.Under some conditions, we first prove that $\lim_{t\to\infty}t{\P}_{\mu}\left(\|X_t\|\ne 0 \right)=\nu^{-1}\langle \phi_0,\mu\rangle$, where ϕ_0 is the eigenfunction corresponding to the first eigenvalue of the infinitesimal generator L of the mean semigroup of X, and ν is a positive constant.Then we show that, for a large class of functions f, conditioning on $\|X_t\|\ne 0$, $t^{-1}\langle f, X_t\rangle$ converges in distribution to $\langle f,\psi_0\rangle_m W$, where W is an exponential random variable, and ψ_0 is the eigenfunction corresponding to the first eigenvalue of the dual of L. Finally, if $\langle f,\psi_0\rangle_m=0$,we prove that, conditioning on $\|X_t\|\ne 0$, $\left(t^{-1}\langle \phi_0, X_t\rangle,t^{-1/2}\langle f, X_t\rangle\right)$ converges in distribution to $\left(W,G(f)\sqrt{W}\right)$, where $G(f)\sim\mathcal{N}(0,\sigma_f^2)$ is a normal random variable, and W and $G(f)$ are independent.

题目: L^p-maximal hypoelliptic regularity of nonlocal kinetic Fokker-Planck operators

报告人：张希承(武汉大学)

摘要： Let $u(t,x,v)$ and $f(t,x,v)$ satisfy the following nonlocal kinetic Fokker-Plank equation in R^{1+2d} in the weak sense: $$\partial_t u=\Delta^{\frac{\alpha}{2}}_v u+v\cdot\nabla_x u+f,$$
where $\alpha\in(0,2]$ and $\Delta^{\frac{\alpha}{2}}_v$ is the usual fractional Laplacian.
We show that for any $p\in(1,\infty)$, there is a constant $C=C(p,\alpha,d)>0$ such that for any $f\in L^p(R^{1+2d})$,
$$\|\Delta_x^{\frac{\alpha}{2(1+\alpha)}}u\|_p+\|\Delta_v^{\frac{\alpha}{2}}u\|_p\leq C\|f\|_p,$$
where $\|\cdot\|_p$ is the usual L^p-norm in R^{1+2d}. Potential applications to linearized Boltzmann equation are also introduced. (This is a joint work with Zhen-Qing Chen).

题目：Mathematical modeling the pathway of human breast cancer

报告人：张兴安 (华中师范大学)

摘要：In order to understand the mechanism of human breast cancer we use the growth rates of clonal expansion of intermediate cells and mutation rates as parameters and build two-six stage models to fit the agespecific incidence of breast cancers in the surveillance, epidemiology, and end results (SEER) registry. We propose four types of different mechanisms for the human breast cancer and test those mechanisms by Chi-square test. Our results suggest that loss of functions of instability genes is an early event in the tumorigenesis, which is useful for early diagnosis of breast cancer.

The clonal expansion of intermediate cells must depend on the hormone expression level of females, which implies that it may be effective for females to receive hormone blocking therapy for breast cancer before their menopause.

题目：Some quantitative methods for characterizing reversible cell lineage

报告人：周达(厦门大学)

摘要：The paradigm of cell plasticity suggests reversible relations of different cellular phenotypes, which extends the conventional theory of cell hierarchiy. This talk will present some quantitative characteristics of reversible cell lineage in comparison to hierarchical cell lineage. Two types of stochastic models will be discussed: forward-time branching process and backward-time coalescent process. For the former, we will show the advantage of the reversible model in capturing both the steady-state and transient dynamics. For the latter, we will present a coalescent-based statistical method for inferring the de-differentiation rate from differentiated cell to stem cell.

题目：A maximum likelihood implementation of an isolation-with-migration model for three species
报告人：朱天琪 (中科院)

摘要：The isolation-with-migration models account for the phylogenetic structure of the populations while accommodating gene flow among them. We extend our previous maximum likelihood implementation of the symmetrical isolation-with-migration model for three species to accommodate arbitrary loci with two or three sequences per locus. The method is useful for analyzing genome-scale sequence data. We conduct a simulation study to examine the statistical properties of the likelihood ratio test for gene flow and analyzed a Drosophila dataset.