ReaDiNet 2019: Mathematical analysis for biology and ecology

September 23rd to 25th - Nancy

Room A008 - INRIA Nancy Grand Est

Monday, September 23

Welcome break from 9:30

- **10:00 - 10:10 : Opening by Jean-Stéphane Dhersin**, Scientific Deputy Director at CNRS in charge of International Relations of the INSMI, **and David Dos Santos Ferreira**, head of the PDE group at Institute Elie Cartan of Lorraine.
- **10:10 - 10:50 : Hiroshi Matano**, Meiji University

  Front propagation in an epidemiological model with mutation II

Coffee break

- **11:20 - 12:00 : Delphine Salort**, Sorbonne Université,

  Qualitative properties on a Fokker-Planck equation in neurosciences

- **12:00 - 12:40 : Inkyung Ahn**, Korea University

  Effect of spatial heterogeneity on predator-prey models with prey-taxis

Lunch

- **14:00 - 14:40 : Jae-Kyoung Kim**, KAIST

  Mechanisms for robust oscillation against spatial stochastic intra-inter cellular kinetics

- **14:40 - 15:20 : Bin Xie**, Shinshu University,

  Ergodic property of stochastic Cahn-Hilliard equation with the logarithmic free energy

- **15:20 - 16:00 : Philippe Carmona**, Université de Nantes

  Winter is coming: pathogen emergence in seasonal environments

Coffee break

- **16:30 - 17:10 : Tadahisa Funaki**, Waseda University

  Motion by mean curvature and coupled KPZ from particle systems

- **17:10 - 17:50 : Denis Villemonais**, Université de Lorraine

  Aggregation and relaxation modes for agents with density dependent preference function

Tuesday, September 24

- **9:30 - 10:10 : Quentin Griette**, Université de Bordeaux

  Concentration and singular waves in a nonlocal reaction-diffusion equation

- **10:10 - 10:50 : Joe Yuichiro Wakano**, Meiji University

  On the diffusion limit of a model of cultural evolution

Coffee break

- **11:20 - 12:00 : Chiun-Chuan Chen**, National Taiwan University

  A necessary condition for the existence of non-monotone waves of discrete 3-species competition models

- **12:00 - 12:40 : Chueh-Hsin Chang**, Tunghai University

  Existence and instability of traveling pulses of generalized Keller-Segel equations

Lunch

- **14:00 - 14:40 : Poster session 1** *(see the abstracts for details)*

  Yueyuan Gao, Tohoku Univ., **Louis Garenaux**, Univ. Toulouse Paul Sabatier, **Frederique Noel**, Univ. Nice, **Gwenael Peltier**, Univ. Montpellier, **Lu Xu**, Univ. Paris Dauphine

- **14:40 - 15:20 : Jong-Shenq Guo**, Tamkang University

  Existence of traveling wave solutions to a nonlocal scalar equation with sign-changing kernel

- **15:20 - 16:00 : Philippe Souplet**, Université Paris 13

  Blow-up profiles for the parabolic-elliptic Keller-Segel chemotaxis system in dimensions $n \geq 3$

Coffee break

- **16:30 - 17:10 : Yong-Jung Kim**, KAIST

  Discontinuous reaction and discontinuous diffusion

- **17:10 - 17:50 : Hyowon Seo**, Kyung Hee University

  Mathematical models for the spread of a rumor

Conference dinner

Wednesday, September 25

- **9:30 - 10:10 : Chang-Hong Wu**, National Chiao Tung University

  Global dynamics on one-dimensional excitable media

- **10:10 - 10:50 : Fernando Peruani**, Université de Nice

  Intermittent collective motion and information propagation fronts in biological systems

Coffee break

- **11:20 - 12:00 : Masaharu Nagayama**, Hokkaido University

  Theoretical analysis of a mathematical model for a self-propelled motion

- **12:00 - 12:40 : Natsuhiko Yoshinaga**, Tohoku University

  Cell-sized confinement controls generation and stability of a protein wave for spatiotemporal regulation in cells

Lunch

- **14:00 - 14:40 : Poster session 2** *(see the abstracts for details)*

  Meriem Bouguezzi, Univ. Paris Sud/CEA, **Michael Brunengo**, Univ. Nice, **Wonhyung Choi**, Korea Univ., **Vincent Hass**, Univ. Lorraine/INRIA, **HoYoun Kim**, KAIST, **Mamoru Okamoto**, Hokkaido Univ.

- **14:40 - 15:20 : Jia-Yuan Dai**, NCTS

  Spiral waves in circular and spherical geometries

- **15:20 - 16:00 : Danielle Hilhorst**, Université Paris Sud

  Mathematical analysis of some PDE systems describing the time evolution of chemotactic E. coli colonies

Coffee break & discussions

ABSTRACTS

Inkyung Ahn

Effect of spatial heterogeneity on predator-prey models with prey-taxis

We consider a diffusive predator-prey system with prey-taxis that has ratio-dependent and Holling-type functional responses in a spatially heterogeneous environment. Prey-taxis implies that a predator exhibits directed movements in the presence of a prey. It is known that there is no effect of prey-taxis on a predators invasion in a spatially homogeneous environment. In this study, we will examine the influence of spatial heterogeneity and prey-taxis on the invasion of a predator for ratio-dependent and Holling type models, respectively. In a spatially heterogeneous environment, both the prey-taxis and diffusion of species play important roles in a predator invasion. However, there are distinct features between these two models without prey-taxis. The diffusion of a predator has no effect on the invasion of the predator in a ratiodependent model, whereas the diffusion of predator affects the invasion of the predator in the model with Holling type functional response model. The results are obtained by investigating the local stability of a semi-trivial solution using an eigenvalue analysis. Furthermore, for the Holliing type functional response model, it is seen, by using the average Lyapunov function, that invasion of a predator implies permanence of ecological systems.

Philippe Carmona

Winter is coming: pathogen emergence in seasonal environments

Seasonality drives fluctuations in the probability of pathogen emergence, with dramatic consequences for public health and agriculture. We show that this probability of pathogen emergence can be vanishingly small before the low transmission season. We derive the conditions for the existence of this winter is coming effect and identify optimal control strategies that minimize the risk of pathogen emergence. We generalize this framework to account for different forms of environmental variations, different modes of control and complex pathogen life cycles. We illustrate how this framework can be used to improve predictions of Zika emergence at different points in space and time.

Chueh-Hsin Chang

Existence and instability of traveling pulses of generalized Keller-Segel equations

Keller-Segel (KS) Equations exhibit the phenomenon of chemotaxis and it is difficult to find the traveling pulse solutions for the minimal model. In this talk, we talk about the existence and instability of traveling pulses of the KS equations with nonlinear chemical gradients and small diffusion by the geometric singular perturbation theory and spectral analysis. We show that there exists some range such that we have the existence of traveling pulses if the traveling speed belongs to this range. We also prove the instability of traveling pulses in some exponentially weighted spaces. This is a joint work with Y. S. Chen, John M. Hong and B. C. Huang.

Chiun-Chuan Chen

A necessary condition for the existence of non-monotone waves of discrete 3-species competition models

For the continuous Lotka-Volterra competition-diffusion system, we have derived some necessary conditions for the existence of non-monotone waves of 3-species via an N-barrier method. Since discrete models are also very important for theoretical ecology, it is an interesting problem whether this method can be generalized to a discretized Lotka-Volterra system. One of the difficulties in the study comes from how to balance the interactions between the discrete differential operator and the continuous differential operator. Through a more delicate construction of the N-barrier, we are able to over the difficulty and obtain a lower bound estimate for the total amount of the species in the 2-species system. We then establish a necessary condition for the existence of non-monotone waves of 3-species by applying the lower bound estimate.

Jia-Yuan Dai

Spiral waves in circular and spherical geometries

Pattern formation of spiral waves on two-dimensional media has been observed in physiological, chemical, biological, and physical models. In this talk I focus on spiral waves governed by the complex Ginzburg-Landau equation in the circular and spherical geometries. The methodology for solving the existence problem is twofold. First, I establish a proper functional approach for local bifurcation analysis. Second, I use the method of shooting curves to extend all bifurcation curves globally. Then I discuss local stability of spiral wave solutions, and how noninvasive spatio-temporal delays may lead to a change of stability.

Tadahisa Funaki

Motion by mean curvature and coupled KPZ from particle systems

Last year in Jeju, we discussed the derivations of motion by mean curvature (MMC) and Stefan problem from microscopic particle systems called Glauber-Kawasaki dynamics and two component Kawasaki dynamics, respectively. The talk is a continuation in a same direction.

To derive MMC, we now start from Glauber-Zero range process, in which an exclusion hard-core rule is replaced by another rule of interaction. We have Allen-Cahn equation with nonlinear Laplacian at an intermediate level. The second topic is the derivation of the coupled KPZ equation, a nonlinear singular (ill-posed) stochastic PDE, from multi-species weakly-asymmetric Zero range process. Boltzmann-Gibbs principle plays a fundamental role for both.

The first part is joint work with D. Hilhorst, S. Sethuraman, P. El Kettani and H. Park, while the second is with C. Bernardin and S. Sethuraman.

Quentin Griette

Concentration and singular waves in a nonlocal reaction-diffusion equation

I consider a reaction-diffusion equation modelling the propagation of a species that possesses a continuum of phenotypic traits. The spatial dynamics of the individuals is modelled by a diffusion process, and the population undergoes a reproduction-mutation-competition dynamics at each spatial point, which is modelled by a nonlocal operator acting on the bounded domain representing the phenotypic space. Under some conditions on the fitness function, the mutation rate and the dimensionality of the domain, a concentration phenomenon is known to happen for the linearized equation, meaning that a singular measure part exists in the principal eigenfunction. I will discuss the validity of this phenomenon for the full (nonlinear) equation, with a particular attention to homogeneous stationary states and traveling waves. In particular, I will talk about the techniques used to construct weak (possibly singular) traveling waves.

Jong-Shenq Guo

Existence of traveling wave solutions to a nonlocal scalar equation with sign-changing kernel

In this talk, we address the existence of traveling wave solutions connecting two constant states to a nonlocal scalar equation with sign-changing kernel. A typical example of such kernel in the neural fields is the Mexican hat type function. We first introduce a new

notion of upper-lower-solution for the equation of wave profile for a given wave speed. Then, with the help of Schauder's fixed point theorem, we construct two different pairs of upper-lower-solutions to obtain traveling waves for a continuum of wave speeds under two different assumptions. Due to the sign-changing nature of the kernel, the wave profiles may take both positive and negative values. Finally, we analyze the limit of the right-hand tail of wave profiles. Under some further condition on the wave speeds, we prove that the right-hand tail limit of the wave profile does exist. In particular, we obtain the existence of nonnegative traveling waves connecting the unstable state 0 and the stable state 1 for wave speeds large enough. This talk is based on a joint work with S.-I. Ei, H. Ishii and C.-C. Wu.

Danielle Hilhorst

Mathematical analysis of some PDE systems describing the time evolution of chemotactic E. coli colonies

We consider an initial-boundary value problem describing the formation of colony patterns of bacteria Escherichia coli. This problem consists of coupled parabolic reaction-diffusion equations including a chemotaxis term in a bounded domain, supplemented with nul-flux boundary conditions and with non-negative initial data. We prove the global in time existence and uniqueness of the solution under some hypotheses on the initial conditions or on the chemoattractant sensitivity function and study its large time behaviour. Moreover, we show that solutions of related problems involving a parabolic-ellliptic-parabolic system and a hyperbolic-elliptic-parabolic system, may blow up in a finite time. This is joint work with Rafal Celinski, Grzegorz Karch, Masayasu Mimura, and Pierre Roux.

Jae-Kyoung Kim

Mechanisms for robust oscillation against spatial stochastic intra-inter cellular kinetics

Circadian clock generates sustained oscillations via transcriptional negative feedback. Although this involves the daily entry of molecules to the nucleus after stochastic diffusion in the cytoplasm, the period is extremely well preserved. In this talk, I will illustrate the mechanism for maintaining robust rhythms against the noise of molecule diffusion, which we identified using the combination of agent based modeling and single cell imaging experiments. Furthermore, the population of individual oscillatory cells can be communicated via intercellular signal to generate synchronous rhythms. Interestingly, even when the signal can reach narrow range of neighboring cells, the system can generate globally synchronous rhythms. I will describe that cells use an intracellular signal amplification to achieve long range temporal synchrony with local signal, which we identified via the combination of delay PDE model and synthetic biology experiments.

Yong-Jung Kim

Discontinuous reaction and discontinuous diffusion

In this talk we consider the solution of a reaction-diffusion equation when the diffusion operator and nonlinear reaction term are discontinuous. We will consider a contact driven tumor growth as an example of a discontinuous reaction and discontinuous diffusion equation.

Hiroshi Matano

Front propagation in an epidemiological model with mutation II

This is a continuation of my talk given at the GDRI confenrence in Jeju in the fall of 2018. We consider an epidemiological model involving mutations in pathogen, with spatially periodic coefficients. This is a spatially heterogeneous extension of the model proposed by Griette and Raoul in 2016. For simplicity, we consider two types of pathogens, wild and mutant, and assume that mutation occurs reciprocally between the two types at a certain rate.

More specifically, the model is given in the form of a two-species reaction diffusion system that is of the cooperative nature for small density of infected population and of the competitive nature for large density. I first summarize the results I presented last year on the existence of traveling waves and on the spreading speed of propagating fronts starting from compactly supported initial data. I will then present some results we have obtained more recently, on the stability and asymptotic profile of the propagating fronts and also discuss some questions related to homogenization. This is joint work with Quentin Griette of Bordeaux.

Masaharu Nagayama

Theoretical analysis of a mathematical model for a self-propelled motion

Mathematical modelling can not only be used to clarify the mechanism of characteristic features of self-propelled motion, but also to design an original self-propelled system. In this talk, we explain how spatio-temporal features of self-propelled motion can be reproduced by a mathematical model. The model is composed of a reaction-diffusion equation for camphor molecule layer on water surface, and an equation of motion for a self-propelled object. We next treat the existence and stability of a constant velocity solution of the mathematical model, and finally report the motion of multiple self-propelled objects using a numerical simulation and a mathematical analysis.

Fernando Peruani

Intermittent collective motion and information propagation fronts in biological systems

Intermittent motion is observed in biological systems at all scales, from bacterial systems to sheep herds. First, I will discuss how Escherichia coli and Merino sheep explores surfaces by alternating stop and moving phases. Specifically, I will show that the mathematical description of the observed intermittent motion requires the use of three behavioral states in both biological systems. Then I will focus on large groups of individuals (e.g. sheep) to show that the emergence of intermittent collective motion involves an activation wave that spreads over a collection of initially static agents. We will see that the velocity of active agents, where both, the magnitude and direction of the agents velocity play a crucial role. Furthermore, we will learn that when the individual that initiates the collective motion phase is located at the group boundary and moves away from the group, the information front speed is lower than when the agents move towards the center of the group. Finally, we will see that as agents moving speed is increased above a threshold the physics of the problem changes, and a shock wave emerges.

Delphine Salort

Qualitative properties on a Fokker-Planck equation in neurosciences

We are going to present a PDE model that describe the evolution of a network of neurons that interact via their common statistical distribution. We will focus above all on qualitative and asymptotic properties of solutions describing convergence to a stationary state, blow up or synchronization phenomena. We will discuss the assumptions that are needed, on the coupling between the neurons and the intrinsic dynamic of neurons, to obtain complex patterns. This talk is based on collaborations with M. Caceres, J. A. Carrillo, K. Ikeda, B. Perthame, P. Roux, R. Schneider, D. Smets.

Hyowon Seo

Mathematical models for the spread of a rumor

The spread of rumor can be described by SIR type equations or physiologically structured models. These rumor spreading models are a sort of the transmission dynamics of infectious diseases in a population. In this talk, I will introduce two different types of rumor spreading models: (i) SIR type ordinary differential equations, and (ii) age-structured partial differential equations. By obtaining the basic reproduction number, we can expect the global behavior of rumor (or rumor outbreaks) in the SIR type model. Also, we consider the thermodynamic limit problem to check phase transitions.

Philippe Souplet

Blow-up profiles for the parabolic-elliptic Keller-Segel chemotaxis system in dimensions $n \geq 3$

We study the blow-up asymptotics of radially decreasing solutions of the parabolic-elliptic Keller-Segel system in space dimensions $n \geq 3$, in a ball or in the whole space. In view of the biological background of this system [5] and of its mass conservation property, blowup is usually interpreted as a phenomenon of concentration or aggregation of the bacterial population. Understanding the asymptotic behavior of solutions at the blowup time is thus meaningful for the interpretation of the model.

Under mild assumptions on the initial data, for $n \geq 3$, we show [7] that the final profile satisfies

$$C_1|x|^{-2} \leq u(x,T) \leq C_2|x|^{-2},$$

with convergence in $L^1(B_R)$. This is in sharp contrast with the two-dimensional case, where solutions are known to concentrate to a Dirac mass at the origin (plus an integrable part) – cf. [4, 6, 8]. For any radial decreasing blowup solution, we also obtain the refined space-time estimate

$$u(x,t) \leq \Big(\frac{1}{u(0,t)} + C|x|^2\Big)^{-1},$$

hence

$$u(x,t) \leq C(T-t+|x|^2)^{-1}$$

for type I blowup solutions. Previous work [3, 2, 1] had shown that radially decreasing self-similar blowup solutions (which satisfy the above estimates) exist in dimensions $n \geq 3$ and do not exist in dimension 2. Our results thus show that the profiles displayed by these special solutions actually correspond to a much more general phenomenon.

This is a joint work with Michael Winkler, Institut für Mathematik, Universität Paderborn.

References:

[1.] Giga, Y., Mizoguchi, N., Senba, T.: Asymptotic behavior of type I blowup solutions to a parabolic-elliptic system of drift-diffusion type. *Arch. Ration. Mech. Anal.* 201 (2011), 549-573.

[2.] Guerra, I.A.; Peletier, M.A.: Self-similar blow-up for a diffusion-attraction problem. *Nonlinearity* 17 (2004), 2137-2162.

[3.] Herrero, M.A., Medina, M., Velázquez, J.J.L.: Self-similar blowup for a reaction-diffusion system. *Journal of Computational and Applied Mathematics* 97 (1998), 99-119.

[4.] Herrero, M.A., Velázquez, J.J.L.: Singularity patterns in a chemotaxis model. *Math. Ann.* 306 (1996), 583-623.

[5.] Keller, E.F., Segel, L.A.: Initiation of slime mold aggregation viewed as an instability. *J. Theoret. Biol.* 26 (1970), 399-415.

[6.] Senba, T., Suzuki, T.: Chemotactic collapse in a parabolic-elliptic system of mathematical biology. *Adv. Differential Equations* 6 (2001), 21-50.

[7.] Souplet Ph., Winkler M.: Blow-up profiles for the parabolic-elliptic Keller-Segel system in dimensions $n \geq 3$. *Comm. Math. Phys.* 367 (2019), 665-681.

[8.] Suzuki, T.: Free energy and self-interacting particles. Progr. Nonlinear Differential Equations Appl. 62, Birkhäuser Boston Inc., Boston, MA, 2005.

Denis Villemonais

Aggregation and relaxation modes for agents with density dependent preference function

We study a model of interacting agents evolving in a finite complete graph with transition rates depending on the temperature of the system and of the number of agents in each state through a preference function. We show that, depending on the temperature and of the shape of the preference function, the system can exhibit aggregation of the agents on a single site or quick relaxation to the uniform distribution over all sites.

Joe Yuichiro Wakano

On the diffusion limit of a model of cultural evolution

We investigate a new approach for identifying the contribution of horizontal transmission between groups to cross-cultural similarity. This method can be applied to datasets that record the presence or absence of artefacts, or attributes thereof, in archaeological and ethnographic assemblages, from which popularity spectra can be constructed. Based on a Moran-type continuous-time process, the previous study has derived the exact formula of the popularity spectrum. This formula has a complicated form and here we aim to derive the approximate formula by using Kimuras diffusion method. Under a certain scaling limit, we heuristically construct a corresponding diffusion process. Applying Kimuras site-frequency spectrum formula for infinite-site models, we obtain a simple approximate formula of the popularity spectrum. Numerical check shows that the approximate formula is in somewhat good agreement with the exact formula. Several properties such as reachability to 100%, the effect of the number of groups on the number of distinct traits, and phase transition at very high fidelity of vertical transmission can be analyzed by using the diffusion approximation. This is a joint work with Yutaka Kobayashi (Kochi University of Technology).

Chang-Hong Wu

Global dynamics on one-dimensional excitable media

The FitzHugh–Nagumo system has been studied extensively for several decades. It has been shown numerically that pulses are generated to propagate and then some of them are annihilated after collision. In this talk, we shall consider a one-dimensional free boundary

problem in the singular limit of a FitzHugh–Nagumo type reaction-diffusion system to get better understanding on these complicated dynamics. First, we introduce the weak solutions to study the continuation of the classical solutions beyond the annihilation time. Applying the notion of symbolic dynamics, we can classify the type of propagation of interfaces and then the global dynamics can be obtained. This is a joint work with Yan-Yu Chen and Hirokazu Ninomiya.

Bin Xie

Ergodic property of stochastic Cahn-Hilliard equation with the logarithmic free energy

We consider the ergodic properties of the stochastic Cahn-Hilliard equation with singular nonlinearity by the approach of establishing dimension-free Harnack inequalities. We mainly consider the stochastic Cahn-Hilliard equation with the singularities of the logarithmic free energy at one and minus one, and the conservation of the solution in its spatial variable. We consider both the degenerate colored noise and non-degenerate white noise. For the highly degenerate space-time colored noise, the asymptotic log-Harnack inequality is established under the so-called essentially elliptic conditions, which implies the asymptotic strong Feller property. For non-degenerate space-time white noise, the Harnack inequality with power is established. Based on the joint work with L. Goudenège.

Natsuhiko Yoshinaga

Cell-sized confinement controls generation and stability of a protein wave for spatiotemporal regulation in cells

The Min system, a system that determines the bacterial cell division plane, uses changes in the localization of proteins (a Min wave) that emerges by reaction-diffusion coupling. Although previous studies have shown that space sizes and boundaries modulate the shape and speed of Min waves, their effects on wave emergence were still elusive. Here, by using a microsized fully confined space to mimic live cells, we revealed that confinement changes the conditions for the emergence of Min waves. In the microsized space, an increased surfacetovolume ratio changed the localization efficiency of proteins on membranes, and therefore, suppression of the localization change was necessary for the stable generation of Min waves. Furthermore, we showed that the cell-sized space strictly limits parameters for wave emergence because confinement inhibits both the instability and excitability of the system. These results show that confinement of reaction-diffusion systems has the potential to control spatiotemporal patterns in live cells.

POSTER PRESENTATIONS

Meriem Bouguezzi: *Modeling of pit propagation and stabilization of a solution to a self-similar profile in a very simplified context*

The prediction of long-term corrosion behavior of repository waste canister is needed to ensure that its physical integrity will not be affected during its expected life time. One particular corrosion phenomena that could affect the canister made in austenitic stainless steel is pitting corrosion. It is a localized corrosion form by which cavities or holes are produced in the material. By understanding these processes, it will be possible to better fight the degradation of the materials and to select the most suitable protection method. One of the approaches used to determine the long-term behavior of metal structures is based on the development of models using a deterministic approach that presupposes a description of the metal-environment systems by a complex system of physico-chemical equations.

The aim of this work is to model and simulate the pit propagation in a stainless steel taking into account the complexity of its development (anodic dissolution, diffusion, migration and reaction). From a mathematical point of view, this problem can be identified as a Stefan problem involving a convection-reaction-diffusion system. Due to the complexity of the problem, we chose to start in one-space dimension to create a pertinent and efficient numerical scheme which will allow us to simulate the time evolution of the pit propagation. The model will be developed step by step to gradually integrate the complexity of the chemical system, first by taking the diffusion into account and then including the migration related to the potential difference in the partial differential equation system.

This is a project with Danielle Hilhorst, Florence Lequien, Hiroshi Matano, Fabien Rouillard and Jean-François Scheid. In this poster we present the mathematical modeling of pit propagation in space dimension one and we also prove the stabilization of the solution to a self-similar profile in a very simplified context in a joint study with Y. Miyamoto.

Michael Brunengo: *Deformation of an elastic material paired with a tree structure*

In order to model effects of automated treatment of respiratory physiotherapy with focused pulses, we study deformation of an elastic material under oscillating constraints on its boundaries linked to a symmetrical and dichotomous tree built as series of cylinders, idealizing bronchial tree. To do so, under infinitesimal strain theory, we constraint airflow created by material volume change to flow in the considered tree and to go through hydrodynamic resistance. This coupling adds friction to material deformation and acts retroactively on it by flow network of the tree. Moreover, the dimensionless system of equations gives a better understanding on the influence of model parameters and could suggest physiological information on airflow inside an idealized bronchial tree and its eigen pulsations.

Wonhyung Choi: *A free boundary problem for a SIS reaction-diffusion model with risk-induced dispersal*

In this poster, we consider a free boundary problem for a spatial SIS (susceptible-infected-susceptible) reaction-diffusion model, where the dispersal of the infected individuals is non-uniform. This non-uniform dispersal, called a risk-induced dispersal (RID), is a strategy for eradicating an infectious disease that is dependent on the condition at the infected individuals location. For a spatial heterogeneous environment, we define a regional-basic reproduction number $\mathcal{R}_0^x := \beta(x)/r(x)$, where $\beta(x)$ and $r(x)$ are the infection and recovery rate at a location x, respectively. RID describes that the infected individuals escape from the region at a high dispersal rate when $\mathcal{R}_0^x > 1$, whereas, they move at a low dispersal rate when $\mathcal{R}_0^x < 1$. In this study, we examine the free boundary problem for a SIS reaction-diffusion model using the RID strategy. First, we investigate the spreading-vanishing dichotomy of infectious diseases when the infected individuals disperse based on the RID strategy. By defining a total basic reproduction number $\mathcal{R}_0$, we also show that RID of infected individuals is a better strategy compared to uniform-dispersal for the disease to vanish. Finally, we obtain the spreading speed of an infection when the infectious disease spreads.

Yueyuan Gao: *Numerical simulation of density driven flow coupled to heat transport in porous media*

In this poster presentation, we consider a model problem proposed in the computer program SEAWAT documentation, which is a simplified representation of what may occur in a coastal carbonate platform. It consists in a two-dimensional cross section of a confined coastal aquifer initially saturated with relatively cold seawater with a temperature of $5°C$. Warmer fresh water with a temperature of $25°C$ is injected into the coastal aquifer along the left boundary to represent the flow from inland areas. The warmer fresh water flows to the right, where it discharges into a vertical ocean boundary. The ocean boundary is represented with hydrostatic conditions based on the fluid density calculated from seawater salinity at $5°C$. No flow conditions are assigned to the top and bottom boundaries. Mathematically, we solve a system of three nonlinear parabolic equations for the salt concentration C, the temperature Θ and the hydraulic head h together with the Darcys law by a generalized finite volume method. It is joint work with Danielle Hilhorst and Huy Cuong Vu Do.

Louis Garenaux: *Asymptotic stability for the extended FKPP equation*

The extended FKPP equation is a perturbed version of the Fisher-KPP reaction-diffusion PDE. It admits travelling wave solutions that where shown [Rottschafr-Wayne] to be asymptoticaly stable in a wheighted Sobolev space. In the well known FKPP case, [Faye-Holzer]

showed that this decay occurs at speed $t^{-3/2}$. Using the same method of proof (spectral analysis of the linear operator, pointwise bounds on the Green kernel), I work on showing a similar result: in the extended case, a class of perturbation decays at algebraic speed.

Vincent Hass: *Individual-based models of adaptive dynamics and long term evolution : the case of small and frequent mutations*

We start with a presentation of the recent biological theory of adaptative dynamics and of the corresponding mathematical results. We will try, in this biological presentation, to be as rigorous as possible, and to discuss the limits of the biological ideas and methods. In particular, we will precisely state the biological hypotheses underlying this theory, that are rarely explicitely described in the literature ([Metz, Geritz et al - 1996] - [Dieckmann and Law - 1996]). We get interested in the main consequences of the biological assumptions of rare mutations and large population, in particular concerning the invasion of a population by a mutant. to obtain an Ordinary Differential Equation (ODE) approaching the evolutionary dynamics of the population : the Canonical Equation of Adaptive Dynamics (CEAD).

Mathematical models of adaptive dynamics, based on measure-valued Markov processes, describe the population at the level of individuals where individuals are characterized by their phenotypes. The mathematical analysis of models of adaptive dynamics aims at understanding the canonical equation. Two main approaches have been developed so far ([Dieckmann, Jabin et al - 2005] - [Champagnat - 2006]) and are based on different time-scales that are related to three main biological assumptions mentioned above. Although successful, both approaches are criticized by biologists in [Waxman and Gavrilets - 2005], since it relies on an unrealistic assumption of rare mutations. The goal of my PhD thesis is to correct this biological controversy by proposing more realistic model and mathematical approaches. In particular, it will be a matter of studying mathematically the consequences of these new biological assumptions on the canonical equation and getting a new time-scales separation.

This project is in progress and the intuitions to be followed to achieve it will be given. It is a joint work with Nicolas Champagnat.

HoYoun Kim: *Disease free equilibrium of two patch SIS epidemic model with starvation driven dispersal*

When an epidemic breaks out, we usually want to know how to be safe from the epidemic. In epidemic models, starvation driven dispersal can act like a survival strategy. Applying starvation driven dispersal to two patch SIS epidemic model can improve the stability of disease free equilibrium.

Frederique Noel: *Model of gas transport in the human lung : existence and uniqueness*

The human lung can be represented by a symmetric tree with 22 dichotomic bifurcations (23 generations). This tree can be separated in two parts : the bronchial tree (17 first generations) and the acinus (6 last generations) where the exchange of gases with blood is made. We developed a one dimension space model to show the gases transport in the lung during a respiration cycle. We proved that this model has a unique solution. We also used this model to compute the optimal ventilation during different exercises. The results are very close to physiological data.

Mamoru Okamoto: *Existence and non-existence of the asymmetrical rotating solution of the reaction-diffusion particle model*

Many researchers have studied the self-motion of camphor and it is now said that the motion of camphor (atop water) is caused by differences in surface tension. Its gradient is induced by a camphor layer development atop the surface. Mathematical models for the camphor motion have been constructed used the above mechanisms and the models reproduce the motion of camphor disks. The mathematical model is investigated numerically, then some types of solutions associated with a collective motion observed in experiments is calculated. It is important result for study of camphor disk's self-propulsion. Nevertheless there are only some proofs of existence for solutions associated with a camphor disk in infinite region, not two camphor disks on bounded periodic region. We saw that non-existence and existence for solutions associated with two camphor disks rotating solution bounded periodic region is related to convexity of a function which expresses between surface tension in air-water interface and concentration of camphor molecular atop water.

Gwenael Peltier: *Accelerating invasions along an environmental gradient*

We consider a population structured by a space variable and a phenotypical trait, submitted to dispersion, mutations, growth and nonlocal competition. This population is facing an environmental gradient: the optimal trait for survival depends linearly on the spatial variable. The survival or extinction depends on the sign of an underlying principal eigenvalue. In the survival case, when the initial data satisfies a so-called "heavy tail" condition, we show that the solution propagates in the favorable direction of survival by accelerating. Our analysis also reveals that the orientation of the initial heavy tail is of crucial importance.

Lu Xu: *Fluctuations in the Euler scaling for a chain of oscillators conserving momentum*

We study the macroscopic fluctuation for a chain of anharmonic oscillators with multiple conservation laws. For equilibrium dynamics, linear Euler system is obtained as the hyperbolic scaling limit of the fluctuation of conserved quantities. For dynamics out of equilibrium, similar result is proved under additional assumption made on weak anharmonicity and strong noises.