Banff International Research Station

for Mathematical Innovation and Discovery

Partial differential equations in the social and life science: emergent challenges in modeling, analysis, and computations (13w5106)

Arriving Sunday, March 31 and departing Friday April 5, 2013

MEALS

*Breakfast (Buffet): 7:00 – 9:30 am, Sally Borden Building, Monday – Friday
*Lunch (Buffet): 11:30 am – 1:30 pm, Sally Borden Building, Monday – Friday
*Dinner (Buffet): 5:30 – 7:30 pm, Sally Borden Building, Sunday – Thursday
Coffee Breaks: As per daily schedule, in the foyer of the TransCanada Pipeline Pavilion (TCPL)
***Please remember to scan your meal card at the host/hostess station in the dining room for each meal.**

MEETING ROOMS

All lectures will be held in the lecture theater in the TransCanada Pipelines Pavilion (TCPL). An LCD projector, a laptop, a document camera, and blackboards are available for presentations.

SCHEDULE

Sunday

16:00 Check-in begins (Front Desk – Professional Development Centre - open 24 hours)
17:30-19:30 Buffet Dinner
20:00 Informal gathering in 2nd floor lounge, Corbett Hall (if desired)
Beverages and small assortment of snacks are available on a cash honor system.

Monday

7:00-8:45 Breakfast
8:45-9:00 Introduction and Welcome by BIRS Station Manager, TCPL
9:00-10:00 Pierre-Emmanuel Jabin (University of Maryland)
10:00-10:30 Coffee Break, TCPL
10:30-11:20 Diogo Gomes (Instituto Superior Tecnico, Lisbon)
11:30-12:00 Jan Haskovec (King Abdullah University of Science and Technology)
12:00-13:00 Lunch
13:00-14:00 Guided Tour of The Banff Centre; meet in the 2nd floor lounge, Corbett Hall
14:00-14:50 Jeff Calder (University of Michigan)
15:00-15:30 Coffee Break, TCPL
15:30-16:20 Joan Solà-Morales (Universitat Politècnica de Catalunya)
16:30-17:20 José Antonio Carrillo (Imperial College)
17:30-19:30 Dinner

Tuesday

7:00-9:00 Breakfast
9:00-10:00 Andrea Bertozzi (UCLA)
10:00-10:30 Coffee Break, TCPL
10:30-11:20 Reinhard Illner (University of Victoria)
11:30-12:20 Nancy Rodriguez (Stanford University)
12:30-13:30 Lunch
Free afternoon

Wednesday

7:00-9:00 Breakfast
9:00-10:00 Qiang Du (Pennsylvania State University)
10:00-10:30 Coffee Break, TCPL
10:30-11:20 Richard Tsai (The University of Texas Austin)
11:30-12:20 Lisa Powers (McGill University)
12:30-13:30 Lunch
14:00-14:10 Group Photo; meet in foyer of TCPL (photograph will be taken outdoors so a jacket might be required).
14:10-15:00 Jean-Christophe Nave (McGill University)
15:00- 15:30 Coffee Break, TCPL
15:30-16:20 Yves van Gennip (University of California Los Angeles)
16:30-17:20 Yao Yao (University of Wisconsin Madison)
17:30-19:30 Dinner

Thursday

7:00-9:00 Breakfast
9:00-10:00 Eitan Tadmor (University of Maryland)
10:00-10:30 Coffee Break, TCPL
10:30-11:20 Alexander Lorz (Universite Pierre et Marie Curie)
11:30-12:20 María José Cáceres (Universidad de Granada)
12:30-13:30 Lunch
14:00-14:50 Lorenzo Pareschi (Universita di Ferrara)
15:00-15:30 Coffee Break, TCPL
15:30-16:20 Bertram Düring (University of Sussex)
16:30-17:20 Stephan Martin (Imperial College London)
17:30-18:00 Daniel Matthes (TU Munich)
18:10-19:30 Dinner

Friday

7:00-9:00 Breakfast
9:00-10:00 Alexis Vasseur (Texas, Austin)
10:00-10:30 Coffee Break, TCPL
10:30-11:20 Marco Di Francesco (University of Bath)
11:30-12:20 Yanghong Huang (Imperial College London)
12:30-13:30 Lunch

Checkout by 12 noon.

** 5-day workshop participants are welcome to use BIRS facilities (BIRS Coffee Lounge, TCPL and Reading Room) until 3 pm on Friday, although participants are still required to checkout of the guest rooms by 12 noon. **

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ABSTRACTS

Andrea Bertozzi (UCLA)
Title: Mathematics of Crime.
Abstract: There is an extensive applied mathematics literature developed for problems in the biological and physical sciences. Our understanding of social science problems from a mathematical standpoint is less developed, but also presents some very interesting problems, especially for young researchers. This lecture uses crime as a case study for using applied mathematical techniques in a social science application and covers a variety of mathematical methods that are applicable to such problems. We will review recent work on agent based models, methods in linear and nonlinear partial differential equations, variational methods for inverse problems and statistical point process models. From an application standpoint we will look at problems in residential burglaries and gang crimes. Examples will consider both "bottom up'' and "top down'' approaches to understanding the mathematics of crime, and how the two approaches could converge to a unifying theory.

María José Cáceres (Universidad de Granada)
Title: Fokker-Planck equations in Neuroscience.
Abstract: In this talk we present Fokker-Planck models, which describe the behavior of neuronal networks. Specifically, we analyse the Nonlinear Noisy Leaky Integrate and Fire (NNLIF) model for neurons networks, where the main parameters in the model are the connectivity of the network and the noise. NNLIF describes the neuronal membrane potential considering as variable only the voltage, we will also discuss some extensions to models with conductance variables. (This talk is based on works in collaboration with J. A. Carrillo, B. Perthame and L. Tao).

Jeff Calder (University of Michigan)
Title: A Hamilton-Jacobi equation for the continuum limit of non-dominated sorting.
Abstract: Non-dominated sorting is a fundamental problem in multi-objective optimization, and is equivalent to several important combinatorial problems. It can be used to, for instance, combine results from multiple search engines, or retrieve images from a database that are similar to multiple queries. In a recent work, we proved that non-dominated sorting of random points in Euclidean space has a continuum limit that corresponds to solving a Hamilton-Jacobi partial differential equation. In this talk, I will describe this result, sketch the proof, and give some theoretical and practical applications.

José Antonio Carrillo (Imperial College)
Title: Stable stationary states for repulsive-attractive potentials.
Abstract: In this talk we consider local minimizers (in the topology of transport distances) of the interaction energy associated to a repulsive-attractive potential. We show how the dimensionality of the support of local minimizers is related to the repulsive strength of the potential at the origin. This is related to pattern formation in some simple models of collective behavior.

Marco Di Francesco (University of Bath)
Title: Nonlocal transport vs nonlinear diffusion: from particle description to large time asymptotics.
Abstract: Aggregation phenomena in microbiology and animal biology can be often described by PDEs of "transport" type, with a "nonlocal" velocity field. I shall quickly provide a formal derivation of those PDEs from particle-based ODEs. I shall then highlight their variational structure, which often leads to well-posedness in a probability-measure sense. A major issue is providing a mathematical description of the emergence (or not) of collective behaviour, or "multiple" behaviour in the large-time asymptotics, depending on the choice of the initial conditions or other parameters. This issue has been partly investigated in the recent literature (cf. chemotaxis with two species). I will briefly describe recent results on the existence and uniqueness of non trivial steady states for a model with quadratic diffusion (in collaboration with M. Burger), and a recent work in preparation on the finite time blow up and "multiple collapse" for a "purely nonlocal" model with two species of agents (with S. Fagioli, PhD student from L'Aquila).

Qiang Du (Pennsylvania State University)
Title: Volume-constrained nonlocal diffusion problems and their numerical approximations.
Abstract: We exploit the use of a recently developed nonlocal vector calculus to study a class of volume-constrained nonlocal diffusion problems on bounded domains. The nonlocal vector calculus provides striking analogies between the nonlocal model and classical models for diffusion as well as the notion of local and nonlocal fluxes. The analytical framework also allows us to consider finite-dimensional approximations using both discontinuous or continuous Galerkin methods. Results on convergence, error analysis and condition number estimates are presented in both nonlocal setting and in local limit.

Bertram Düring (University of Sussex)
Title: Kinetic Models for Opinion Formation.
Abstract: We discuss some kinetic models for opinion formation. The time evolution of the opinion distribution is described by (systems of) Boltzmann-like equations. We show that at suitably large times, in presence of a large number of interactions in each of which individuals change their opinions/positions only little, the Boltzmann-type equations are well-approximated by Fokker-Planck type equations, which admit different, non-trivial steady states.

Diogo Gomes (Instituto Superior Tecnico, Lisbon)
Title: Time dependent mean-field games.
Abstract: In this talk we discuss various techniques to establish existence of regular solutions to mean-field games with local dependence on the measures. Our methods are based upon various a-priori estimates coupled with continuation methods.

Jan Haskovec (King Abdullah University of Science and Technology)
Title: Flocking dynamics and mean-field limit in the Cucker-Smale-type model with topological interactions.
Abstract: We consider a Cucker-Smale-type model for flocking, where the strength of interaction between agents depends on their topological distance, measured in units of agents' separation (number of intermediate individuals separating the agents), which makes the model scale-free. This is motivated by recent extensive observations of starling flocks, which suggested that interaction ruling animal collective behavior depends on topological rather than metric distance, as was the case in the classical Cucker-Smale and the vast majority of other flocking models. We study the conditions leading to asymptotic flocking in the topological model, defined as the convergence of the agents' velocities to a common vector. The shift from metric to topological interactions requires

development of new analytical methods, taking into account the graph-topological nature of the problem. Moreover, we show how to pass to the mean-field limit as the number of individuals tends to infinity, recovering kinetic and hydrodynamic descriptions. In particular, we introduce the novel concept of topological distance in continuum descriptions, which is applicable to a broad variety of models of collective behavior.

Yanghong Huang (Imperial College London)
Title: Dynamics and steady states of nonlinear diffusion equations with long-range attractions.
We study the dynamics and steady states of a nonlocal aggregation equation with nonlinear diffusion arising in many contexts of biology and population dynamics. The nonlinear diffusion is power law type (like the porous medium equation) and the aggregation kernel is radial, attractive and integrable, with smoothness. The critical power for the nonlinear diffusion is shown to be quadratic. The steady states and their bifurcation diagrams are qualitatively different when the exponent of the nonlinear diffusion is larger or smaller than two. The dynamics of general random non-negative initial data also exhibits some coarse-graining behaviour.

Reinhard Illner (University of Victoria)
Title: Epidemiology on random graphs.
Abstract: Classical epidemiology models assume that the population is well mixed, clearly a simplistic and unrealistic assumption. More recently, population structures have been modelled as random graphs. I will discuss how the propagation of a disease occurs on such a structure and what the basic reproduction number looks like. An ODE model first suggested by Miller and Volz will be presented and generalized to heterogeneous populations, where the graph structure reflects different groups. The behaviour of the basic reproduction number in such contexts will be discussed (it always decreases if connections are severed, but there are subtleties).

Pierre-Emmanuel Jabin (University of Maryland)
Title: New regularity estimates for compressible transport phenomena.
Abstract: I will present new, critical regularity estimates for the advection of particles or biological organisms. Those are transported by a rough velocity field with unbounded divergence. This creates two major challenges in order to control the oscillations of the density: The lack of smoothness of the velocity and possible compressions or dilatations.

Alexander Lorz (Universite Pierre et Marie Curie)
Title: A population model with small density cut-off
Abstract: The question of 'cutting the tail' of the solution of an elliptic equation arises naturally in several contexts and leads to a singular perturbation problem with a strong cut-off. We consider both the PDE with a drift and the symmetric case where a variational problem can be stated.
It is known that, in both cases, the same critical scale arises for the size of the singular perturbation. More interesting is that in both cases another critical parameter (of order one) arises that decides when the limiting behaviour is non-degenerate. We study both theoretically and numerically the values of this critical parameter and, in the symmetric case, ask if the variational solution leads to the same value as for the maximal solution of the PDE. Finally we propose a weak formulation of the limiting Bernoulli problem which incorporates both Dirichlet and Neumann boundary condition.
This work is in collaboration with Benoit Perthame, UPMC Univ Paris 06, CNRS UMR 7598, Laboratoire Jacques-Louis Lions, 4, pl. Jussieu F75252 Paris cedex 05.
INRIA-Rocquencourt, EPI BANG. Institut Universitaire de France and Peter Markowich, King Abdullah University of Science and Technology (KAUST), CSMSE Division, Thuwal 23955-6900. Saudi Arabia.

Stephan Martin (Imperial College London)
Title: Explicit derivation and stability of coherent patterns of motion in kinetic swarming models.
Abstract: In my talk I will first review some modeling concepts describing the behavior of individuals in an animal swarm of e.g. fish or birds, and focus on a model of self-propelled interacting particles. It is a well-known fact that even minimalistic interactions rules allow for the emergence of coherent macroscopic patterns observed in nature, when applied to all members of a swarm. In the mean-field limit approach, a kinetic PDE is used to model the evolution of a particle density rather than tracing individuals separately. Its macroscopic closure allows for a compact description of some coherent patterns, such as flocks or mills. I will then discuss the possibility to explicitly compute the stationary density profile of such states using a particular type of interaction potential called Quasi-Morse. Flock and mill profiles can be predicted with a cheap numerical procedure that does not necessitate particle simulations. Finally, I will present a result on the stability of flock solutions, where we are able to show that under mild assumptions the stability of the interaction potential (in a first-order aggregation model) inherits to the family of flock solutions in our second-order model.

Daniel Matthes (TU Munich)
Title: A coupled system of gradient flows for chemotaxis.
Abstract: We consider a system of two coupled non-linear drift-diffusion equations modeling the behavior of bacteria: one equation governs the production and degradation of a chemical signal substance, the other describes the according movement of the bacteria. Unlike in the parabolic-parabolic Keller-Segel model, the chemical substance has a fixed saturation level. The equation system can be cast in the form of a gradient flow with respect to a joint Wasserstein-L2-metric. The potential, however, is not geodesically lambda-convex because of the coupling between the components. Still, we are able to prove existence and exponential equilibration using variational methods. This is joint work with Jonathan Zinsl (TU Munich).

Jean-Christophe Nave (McGill University)
Title: Evolution of Sets and Solving PDEs with Discontinuous Solutions.
Abstract: In this talk I will present a method to evolve arbitrary surfaces and curves. I will also present a new method to solve problems with jumps on co-dim 1 interfaces.

Lorenzo Pareschi (Universita di Ferrara)
Title: Kinetic modeling and simulation algorithms of self-organized systems interacting with a few individuals.
Abstract: In nature, self-organized systems such as flocks of birds, schools of fish and herds of sheep have to deal with the presence of external agents such as predators or leaders that modify their internal dynamics. Such situations involve a large number of individuals with their own social behavior interacting with a small number of other individuals acting as external point-source forces. Starting from a microscopic description, we derive different kinetic models and introduce a macroscopic model via a suitable hydrodynamic approximation. The efficient numerical solution of such systems is also discussed and several numerical results presented.

Lisa Powers (McGill University)
Title: Centroidal Voronoi Tessellations of Rigid Bodies
Abstract: The Centroidal Voronoi Tessellation (CVT) is an optimal configuration of points in convex domains. These tessellations are used in many areas from facility location problems to mesh generation. In this talk, we extend the notion of a CVT from points to rigid bodies in two and three dimensions. Given a finite set of shapes, we optimize their location via translation and rotation by minimizing a suitable cost function. The CVT optimization problem for points is typically tackled

using quasi-Newton methods and an iterative algorithm called Lloyd's method--we will discuss extensions of both to the rigid body case. The optimization problem for rigid bodies is challenging in part because integrals over generalized Voronoi regions must be calculated. The novelty of our algorithm is that the generalized Voronoi diagram is never explicitly calculated. We will discuss the optimization problem and the integration algorithm in depth, and present numerical results.

Nancy Rodriguez (Stanford University)
Title: Non-local effects in Social Phenomenon.
Abstract: In a world that connected more and more everyday it is has become essential to include non-local effect when modeling any type of social phenomenon. In this talk I will first introduce some evidence of the need to include non-local effects in modeling. Second, I will discuss some progress made on the idea of "blocking" wave propagation for a non-local equation, which is motivated by an application to criminal activity. This has consequences in other areas like ecology, pest control, and nerve-pulse propagation.

Joan Solà-Morales (Universitat Politècnica de Catalunya)
Title: Instability and bifurcation in a trend depending price formation model.
Abstract: A well-known model due to J.-M. Lasry and P.L. Lions that presents the evolution of prices in a market as the evolution of a free boundary in a diffusion equation is suggested to be modified in order to show instabilities for some values of the parameters. This loss of stability is associated to the appearance of new types of solutions, namely time-periodic solutions, due to a Hopf bifurcation and representing price oscillations, and traveling waves, that represent either inflationary or deflationary behavior. (Joint work with M.P. Gualdani and M.d.M. González).

Ravi Srinivasan (The University of Texas Austin)
Title: Information aggregation and mean-field games.
Abstract: Information flows in large populations have been studied in a variety of contexts. We will discuss some 'Boltzmann-like' models of information aggregation and corresponding mean-field games, in which agents adopt strategies to optimize their individual welfare. Time permitting, we will also touch upon some related work by economists on the role of innovation in economic growth.

Eitan Tadmor (University of Maryland)
Title: Clustering, consensus and critical thresholds in self-organized dynamics.
Abstract: Self-organized dynamics is driven by the interaction of agents with their neighbors. Examples range from consensus of voters and traffic flows to the formation of flocks of birds and tumor growth. When the interaction consists of global self-alignment, the large time behavior leads into consensus or flocking. When the self-alignment is purely local, the dynamics evolves into one or more clusters and the open questions regarding the emergence of consensus are related to the connectivity of the underlying graph.
At the hydrodynamic level, the large time behavior is dictated by the balance between nonlinear convection and convolution-based interaction based on non-local means. Finite time breakdown depends on whether the initial configuration crosses intrinsic, O(1) critical thresholds (CT). We demonstrate this CT phenomena with several n-dimensional prototype models.
These include prolonged life-span of sub-critical 2D shallow-water solutions, 3D restricted Euler and Euler-Poisson equations, and the hydrodynamic descriptions of self-organized dynamics.

Richard Tsai (The University of Texas Austin)
Title: Inverse point source identification problems and applications
Abstract: We present algorithms for the problem of identification or discovery of point sources in a complicated domain.
With robotic applications in mind, in which robots can be sent into the complicated domain to gather data, we develop algorithms that determine in a sequential manner, where in the domain should additional data collected in order to improve the estimate of the source locations.
The governing PDEs under consideration model respectively wave and diffusion phenomena as well as nonlinear reaction-diffusion equations.

Yves van Gennip (University of California Los Angeles)
Title: Partial differential equations on networks.
Abstract: Social networks can be described by graphs very naturally, which allows for both mathematical models describing the networks and mathematical methods to analyze the networks. One example of the latter, is spectral clustering for community detection in a network of social actors. Such methods can often be improved upon by incorporating ideas from partial differential equations, into the discrete graph based methods. In this talk we will focus on graph based analogues of the Ginzburg-Landau functional, Allen-Cahn equation, MBO (Merriman-Bence-Osher) scheme, and mean curvature flow. We will discuss ongoing research into their connections to each other and to the problem of clustering and community detection on graphs.

Alexis Vasseur (Texas, Austin)
Title: Relative entropy applied to stability of shocks in fluid mechanics, and asymptotic limits

Yao Yao (University of Wisconsin Madison)
Title: Quasi-static evolution and congested crowd motion.
Abstract: In this talk we investigate a transport equation with a drift potential, where a constraint on the L^\infty norm is imposed on the density. This model, in a simplified setting, describes the congested crowd motion with a density constraint. When the drift potential is convex, the crowd density is likely to aggregate, and thus if the initial density starts as a patch (i.e. if it is a characteristic function of some set), then the density evolves like a patch. We show that patch evolves according to a quasi-static evolution equation, which is a free boundary problem and has some connection with the Hele-Shaw equation. To show this result we make use of both viscosity solutions theory as well as the gradient flow structure of the problem. This is a joint work with Damon Alexander and Inwon Kim.