SITE Research Center Talk Series November 2021 to August 22

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2021

NOVEMBER 2

Slim Ibrahim

- Title: **Revisit singularity formation for the inviscid primitive equations**
- Abstract: The primitive equation is an important model for large scale fluid model including oceans and atmosphere. While solutions to the viscous model enjoy global regularity, inviscid solutions may develop singularities in finite time. In this talk, Slim will review the methods to show blowup, and share more recent progress on qualitative properties of the singularity formation.

Charles Collot

- Title: **On the derivation of the Kinetic Wave Equation in the inhomogeneous setting**
- Abstract: The kinetic wave equation arises in weak wave turbulence theory. In this talk we are interested in its derivation as an effective equation from dispersive waves with quadratic nonlinearity for the microscopic description of a system. We focus on the space-inhomogeneous case, which had not been treated earlier. More precisely, we will consider such a dispersive equations in a weakly nonlinear regime, and for highly oscillatory random Gaussian fields with localised envelopes as initial data. A conjecture in statistical physics is that there exists a kinetic time scale on which, statistically, the Wigner transform of the solution (a space dependent local Fourier energy spectrum) evolve according to the kinetic wave equation.
  Charles will present a joint work with Ioakeim Ampatzoglou and Pierre Germain in which they approach the problem of the validity of this kinetic wave equation through the convergence and stability of the corresponding Dyson series. They are able to identify certain nonlinearities, dispersion relations, and regimes, and for which the convergence indeed holds almost up to the kinetic time (arbitrarily small polynomial loss).

NOVEMBER 9

Jacek Jendrej

- Title: **Soliton resolution for energy-critical equivariant wave maps**
- Abstract: We consider wave maps R^(1+2) -> S^2, under the assumption of equivariant symmetry. We prove that every solution of finite energy resolves, as time passes, into a superposition of harmonic maps (solitons) and radiation. It was proved in works of Côte, and Jia and Kenig, that such a decomposition holds along a sequence of times. We show that the resolution holds continuously in time via a “no-return lemma” based on the virial identity. The proof combines a modulation analysis of solutions near a multi-soliton configuration with the concentration-compactness method.Joint work with Andrew Lawrie from MIT.

NOVEMBER 16

Alexandru Ionescu

- Title: **On the asymptotic stability of shear flows and vortices**
- Abstract: Alexandru will talk about some recent work on the global linear and nonlinear asymptotic stability of two families of solutions of the 2D Euler equations: shear flows on bounded channels and vortices in the plane. This is joint work with Hao Jia.

NOVEMBER 23

Van Tien Nguyen

- Title: **Singularities in the Keller-Segel system**
- Abstract: The talk will give an update on the study of singularities in the 2D and higher dimensional Keller-Segel system that arises in modeling chemotaxis phenomena in biology or gravitational interaction of a cloud of particles. It's interesting to know that the blowup dynamics are quite different between the 2D case and the higher dimensional case. We will present a constructive method based on spectral analysis and energy-type estimates for the question of the existence of blowup solutions, especially collapsing-ring blowup solutions in the higher dimensional case whose radially symmetric profile is linked to the traveling-wave of Burgers equation. These are joint works with C. Collot (Cergy), T. Ghoul (NYUAD), and N. Masmoudi (NYUAD).

NOVEMBER 23

Francisc Bozgan

- Title: **Local Well-posedness of the Modified KP-I equations**
- Abstract: We present local well-posedness results for the modified third order KP-I equation in the partially periodic setting H^s(RxT) and the periodic setting H^s(TxT). Also, we have a local well-posedness result for the modified fifth order KP-I equation in the partially periodic setting H^s(RxT).

DECEMBER 7

Tristan Leger

- Title: **Internal modes and radiation damping for quadratic Klein-Gordon in 3d**
- Abstract: In this talk recent results on the asymptotic behavior of small solutions to a quadratic Klein-Gordon equation with potential will be presented. This question is paramount to the understanding of asymptotic stability of special solutions (solitons for example). The main novelty isthe presence of an internal mode. In this setting new difficulties arise, chief among which are the anomalously slow L1�decay of the radiation (worse than in the linear case) as well as its poor spatiallocalization. We will start by giving some background on the space-time resonance method, state and explain our main result. Some elements of the proof will also be presented. This is joint work with Fabio Pusateri.

DECEMBER 14

[Raphaël Côte]

- Title: **Solitons interaction for the damped non linear Klein-Gordon equation**
- Abstract: The damped Klein-Gordon equation is a model for dispersive and dissipative equations: it still admits stationnary solutions, which are nonetheless unstable (and which we call soliton). We will present some recent works with Yvan Martel, Xu Yuan and Lifeng Zhao on the description of 2-solitons, and in one space dimension, on the resolution in solitons.

2022

JANUARY 25

[Didier Clamond]

- Title: **Water wave determination from seabed measurements**
- Abstract: Surface waves determination from pressure measurements at the seabed leads to an ill-posed inversion problem. For two-dimensional steady waves in irrotational motion, using elementary complex analysis, the problem can be solved exactly in an analytic implicit form. For practical purposes, the implicit relations must be solved iteratively. We show that simple fixed-point iterations converge, even for extreme waves with angular crests.

FEBRUARY 1

[Sylvain Lamprier]

- Title: **Spatio-temporal and Video Prediction with State-based Neural Models**
- Abstract: An increasing number of works combining neural networks and differential equations for spatio-temporal forecasting have been proposed for the last few years. Some of them show substantial improvements for the prediction of dynamical systems or videos compared to standard RNNs by defining the dynamics using learned ODEs. In this talk, we first present our recent approach for adapting such works for stochastic data. We introduce a novel dynamic model for stochastic video prediction which, unlike prior image-autoregressive models, decouples frame synthesis and dynamics. The dynamics of the model are governed in a latent space by a residual update rule, which is motivated by discretization schemes of differential equations. This endows our method with several desirable properties, such as temporal efficiency and latent space interpretability. Then, we will present a second method, more specifically focused on learning disentangled spatial and temporal representations of spatio-temporal phenomena, with the aim of more accurately predicting future tendencies from initial observations. We propose to model the evolution of partially observed spatiotemporal phenomena with unknown dynamics by taking inspiration from a formal method for the analytical resolution of PDEs: the functional separation of variables. We experimentally demonstrate the performance and broad applicability of our method against prior state-of-the-art models on physical and synthetic video datasets.

FEBRUARY 28

Yves Le jan

- Title: **Brownian flows**
- Abstract: Yves will present a survey on flows defined by stochastic differential equations, and other methods.

MARCH 1

Manuel Del Pino

- Title: **Dynamics of concentrated vorticities in 2d and 3dEuler flows**
- Abstract: A classical problem that traces back to Helmholtz and Kirchhoff is the understanding of the dynamics of solutions to the Euler equations of an inviscid incompressible fluid when the vorticity of the solution is initially concentrated near isolated points in 2d or vortex lines in 3d. We discuss some recent results on the existence and asymptotic behavior of these solutions. We describe, with precise asymptotics, interacting vortices, and traveling helices. We rigorously establish the law of motion of ”leapfrogging vortex rings”, originally conjectured by Helmholtz in 1858.

MARCH 17

Qiang Xu

- Title: **Homogenization error of unsteady flow ruled by Darcy's law**
- Abstract: This talk is devoted to studying homogenization error for non-stationary Stokes equations on perforated domains, which originally developed by J.-L. Lions. We now present a sharp error estimate in the sense of energy norms, where the main challenge is to control the boundary layers caused by the incompressibility condition. We start from a brief introduction to homogenization theory, and then move to the ideas of non-standard two-scale expansions. To obtain the optimal error, we introduce some refined regularity estimates for corrector without compatibility conditions between initial and boundary data, as well as, the well posedness of the effective equations in Bochner space. As a result, we further explain how we handle the boundary-layer correctors associated with Bogovskii's operator. This work is cooperated with Dr. Li Wang and Prof. Zhifei Zhang in Peking University.

MARCH 31

Maurizio Grasselli

- Title: **Allen-Cahn-Navier-Stokes systems for incompressible binary fluids**
- Abstract: Phase separation in a binary liquid (e.g. oil and vinegar) is a phenomenon which can be described as a competition between a entropy mixing effects and demixing effects due to the internal energy (i.e. the attraction of molecules of the same liquid), provided that, for instance, the temperature is low enough. Liquid-liquid phase separation has recently become a sort of new paradigm in Cell Biology. Quoting from E. Dolgin [Nat. 555, 300-302 (2018)]: "Not only is phase separation intuitive, but it seems to be everywhere. Droplets of proteins and RNAs are turning up in bacteria, fungi, plants and animals. Phase separation at the wrong place or time could create clogs or aggregate of molecules linked to neuro degenerative diseases, and poorly formed droplets could contribute to cancers and

might help explain the ageing process." Well-known mathematical models for phase separation (e.g. in binary alloys) are given by the so-called Cahn-Hilliard equation or by the (conserved) Allen-Cahn equation. In the case of liquids, such equations must be suitably coupled with the Navier-Stokes equations for the averaged velocity of the binary mixture. This talk will be focused on Allen-Cahn-Navier-Stokes systems with some remarks on inviscid and pure transport cases.

APRIL 7

Philippe Souplet

- Title: **A Liouville-type theorem in a half-space and its applications to the gradient blow-up behavior for superquadratic diffusive Hamilton-Jacobi equations**
- Abstract: We consider the superquadratic diffusive Hamilton-Jacobi equation $u_t-\Delta u=|Du|^p$ with $p>2$, in a smooth bounded domains of R^n ($n\ge 2$) under homogeneous Dirichlet conditions, which is known to undergo boundary gradient blow-up (BGBU) phenomena. First, for the elliptic problem in a half-space, we prove a Liouville-type classification, or symmetry result, which asserts that any solution has to be one-dimensional. This turns out to be an efficient tool to study the BGBU behavior for the parabolic problem. Namely, we show that in a neighborhood of the boundary, at leading order, solutions display a global ODE type behavior of the form $u_{\nu\nu}\sim -|u_\nu|^p$, with domination of the normal derivatives upon the tangential derivatives. This leads to the existence of a universal, sharp blow-up profile in the normal direction at any BGBU point, and moreover implies that the behavior in the tangential direction is more singular. In single-point BGBU cases, the tangential profile can be precisely determined under additional assumptions. Related results on the time rates will be also presented. The ODE type behavior and its connection with the Liouville-type theorem can be considered as an analogue of the well-known results of Merle and Zaag (1998) for the subcritical semilinear heat equation, with the significant difference that for the latter, u itself blows up and the ODE behavior is in the time direction (instead of the normal spatial direction). This is based on a series of joint works with R. Filippucci, P. Pucci, A. Porretta, A. Attouchi.

JUNE 13

Dongfen Bian

- Title: **Onset of nonliear instabilities in monotonic viscous boundary layers**
- Abstract: In this talk we will introduce the recent results about the nonlinear stability of a shear layer profile for Navier Stokes equations near a boundary. This question plays a major role in the study of the inviscid limit of Navier Stokes equations in a bounded domain as the viscosity goes to 0. We mainly study the effect of cubic interactions on the growth of the linear instability here. In the case of the exponential profile and Blasius profile we obtain that the nonlinearity tames the linear instability. We thus conjecture that small perturbations grow until they reach a magnitude $O(\nu^{1/4})$ only, forming small rolls in the critical layer near the boundary. This is based on joint works with Emmanuel Grenier from Ecole Normale Superieure de Lyon, France.

JUNE 13

Eliot Pacherie

- Title: **Asymptotic stability in a traffic flow model**
- Abstract: We consider the ARZ traffic flow model, and two particular solutions of it : a constant flow of cars, or a congestion modelled by a travelling wave. In both cases, we give a criteria to show the stability of these flows, both at the linear and nonlinear level. This is a joint work with Tej-Eddine Ghoul and Nader Masmoudi.

JUNE 13

Julian Barreiro-Gomez

- Title: **The role of stochastic differential games of mean-field type in smart cities applications**
- Abstract: This brief talk aims to show how the stochastic differential games contribute to the optimal solution of large-scale engineering problems emerging in smart cities where several dynamical interactions occur, e.g., the water distribution system, the crowd management, the traffic flow, power systems, among many others. We show that the general simplest problem statement leads to a complex PIDE system involving a backward Hamilton-Jacobi-Bellman equation coupled with a forward Fokker-Plank-Kolmogorov equation. Then, we discuss how this complexity can be handled for specific cases pursuing to develop real implementation. As an example, we focus on the crowd evacuation problem. Finally, future directions we are currently working on involving machine learning and stability are presented.

JUNE 13

Wenqing Li

- Title: **Backdoor attack detection in deep neural networks: a coherence optimization based method**
- Abstract: Backdoor attacks impose a new threat in Deep Neural Networks (DNNs), where a backdoor is inserted into the neural network by poisoning the training dataset, misclassifying inputs that contain the adversary trigger. The major challenge for defending against these attacks is that only the attacker knows the secret trigger and the target class. The problem is further exacerbated by the recent introduction of ``Hidden Triggers,'' where the triggers are carefully fused into the input, bypassing detection by human inspection and causing backdoor identification through anomaly detection to fail. To defend against such attacks, in this work we systematically analyze how representations, i.e., the set of neuron activations for a given DNN when using the training data as inputs, are affected by backdoor attacks. We propose PiDAn}, an algorithm based on coherence optimization purifying the poisoned data. Our analysis shows that representations of poisoned data and authentic data in the target class are still embedded in different linear subspaces, which implies that they show different coherence with some latent spaces. Based on this observation, the proposed PiDAn algorithm learns a sample-wise weight vector to maximize the projected coherence of weighted samples, where we demonstrate that the learned weight vector has a natural ``grouping effect'' and is distinguishable between authentic data and poisoned data. This enables the systematic detection and mitigation of backdoor attacks. Based on our theoretical analysis and experimental results, we demonstrate the effectiveness of PiDAn in defending against backdoor attacks that use different settings of poisoned samples on GTSRB and ILSVRC2012 datasets in comparison with the state-of-the-art methods. Our PiDAn algorithm can detect more than 90\% infected classes and identify 95% poisoned samples.

JUNE 13

Sai Venkata Ramana Ambadipudi

- Title: **collective phenomena in heterogeneous traffic: power-laws and phase transitions**

JUNE 14

Hatem Hajri

- Title: **Stability of neural network classifiers**
- Abstract: Stability of neural network classifiers is a key issue in several domains such as defense and security. Indeed neural network classifiers are known to be vulnerable to malicious adversarial perturbations of inputs named adversarial attacks. In this talk we start by reviewing standard methods to fool neural network classifiers. In a second part of the talk, we focus on stabilising neural networks behaviour and discuss some methods for this goal. Then, we introduce a new technique based on randomised smoothing and the geometry of covariance matrices to reach state-of-the-art certification performance in small domains. Illustrations of this method on classical machine learning datasets will be provided.

JUNE 21

Mohamed Ali

- Title: **Self-similarity and stability analysis of flow: a numerical approach**
- Abstract: Mohamed will discuss the motivation of using Computational Fluid Dynamics to conduct a stability analysis of flow. Linear, non-linear and optimum optimization problems related to stability analysis will be discussed with some applications. Special attention will be given to the stability analysis of (i) the Batchelor vortex (swirling jet type) used to model the trailing vortex of aircraft and (ii) the helical vortex generated at the tip of a rotating blade. The self-similarity of the 3D helical vortex will be investigated. Then, the results of the stability analysis of the perturbed helical vortex with selected frequencies will be presented.

JUNE 24

Philip Isett

- Title: **Local Dissipation of Energy for Continuous Incompressible Euler Flows**
- Abstract: Philip will discuss the construction of continuous solutions to the incompressible Euler equations that exhibit local dissipation of energy and the surrounding motivations. A significant open question, which represents a strong form of the Onsager conjecture, is whether such solutions exist that locally dissipate energy while having the maximal possible regularity of being 1/3-Hölder continuous.