SITE RESEARCH CENTER ON STABILITY, INSTABILITY, AND TURBULENCE

Long Time Behavior and Singularity Formation in PDEs - Part VI Conference, Abu Dhabi, January 8-12, 2024

Venue: New York University Abu Dhabi, Room A3-002 West Administration Building

MONDAY, JANUARY 8	
08:30	*Bus departs hotel for campus*
09:00-09:45	*Coffee break outside the conference room*
09:45-10:00	**Provost Arlie Petters** opening remarks
10:00-11:00	**Monica Musso** will speak on long time behavior for vortex dynamics in the 2 dimensional Euler equations Abstract: The evolution of a two dimensional incompressible ideal fluid with smooth initial vorticity concentrated in small regions is well understood on finite intervals of time: it converges to a super position of Dirac deltas centered at collision-less solutions to the point vortex system, in the limit of vanishing regions. Even though for generic initial conditions the vortex point system has a global smooth solution, much less is known on the long time behavior of the fluid vorticity. We consider the case of two vortex pairs traveling in opposite directions. Using gluing methods we describe the global dynamics of this configuration. This work is in collaboration with J Davila (U. of Bath), M. del Pino (U of Bath) and S. Parmeshwar (Imperial College London).
11:00-12:00	**Taoufik Hmidi** will speak on leapfrogging motion in fluid dynamics Abstract: In this talk I will discuss some aspects on the leapfrogging phenomenon in the vortex dynamics for Euler equations in the plane. We show that under suitable constraints, four concentrated vortex patches leapfrog for any time. When observed from a translating frame of reference, the evolution of these vortex patches can be described as a non-rigid time periodic motion. Our proof hinges upon two key components. First, we desingularize the symmetric four point vortex configuration, which leapfrogs in accordance with Love's result, by concentrated vortex patches. Second, we use some tools from KAM theory to effectively tackle the small divisors problem and deal with the degeneracy in the time direction. This is a joint work with

	Zineb Hassainia and Nader Masmoudi.
12:00-13:30	*Lunch outside the conference room (A3-002 West Administration Building)*
13:30-14:30	**Diego Córdoba** will speak on Blow-up of classical solutions for the incompressible Euler equations Abstract: In this talk we will discuss recent results on the blow-up problem of classical solutions for the incompressible Euler equations with finite energy. We will construct solutions that has instantaneous gap loss of Sobolev regularity in the plane and finite time singularities in the whole space. Joint works with Luis Martinez-Zoroa, Wojciech Ożański and Fan Zheng.
14:30-15:00	*Coffee break outside the conference room*
15:00-16:00	**Azam Gholami** will speak on flower wave patterns in the CHD-BZ reaction in the presence of spatial heterogeneities Abstract: In this work, we investigate the effects of millimeter-sized obstacles on the chemical waves in the CHD-Belosouv-Zabotinsky reaction, in which the classical organic substrate malonic acid is replaced by 1,4- cyclohexanedione (CHD). Our experiments show that an arrangement of cylindrical obstacles can significantly influence the chemical waves in the CHD-BZ reaction. We observed circular waves with a period of about 1 min that started almost synchronously at the pillars and propagated outward. However, after two cycles of outward propagating circular waves, wavefront instability sets in and flower patterns form. Interestingly, the number of petals depends on the pillars diameters and is higher for larger diameters. This instability occurs in an open-lid environment where evaporation plays an important role. In a closed lid environment, the waves remain circular and do not break. These experiments underline the importance of Marangoni flows which are driven by gradients in chemical concentration or temperature at the interface. We are currently performing simulations of the Navier-Stokes equation coupled with a reaction-diffusion system to understand the underlying mechanism of instability. This work is a joint work with Mohamed Ali and Nader Masmoudi.
16:00-17:00	*Discussions and poster session*
17:15	*Bus departs campus for hotel*
19:00	*Dinner at the hotel*
TUESDAY, JANUARY 9	
07:45	*Bus departs hotel for campus*
08.30-09:30	**Massimiliano Berti** will speak on instability of Stokes waves Abstract: In this talk I will discuss some recent results about the stability/instability of pure gravity periodic traveling water waves -- called Stokes waves — subject to long wave

	perturbations (in different depths). The techniques are based on a symplectic version of Kato similarity transformations to study the splitting of colliding eigenvalues.
09:30-10:00	*Coffee break outside the conference room*
10:00-11:00	**Edriss Titi** will speak on Mathematical Analysis of Atmospheric and Oceanic Dynamics Models: Cloud Formation and Sea-ice Models Abstract: In this talk we will present rigorous analytical results concerning global regularity, in the viscous case, and nite-time singularity, in the inviscid case, for oceanic and atmospheric dynamics models. Moreover, we will also provide a rigorous justification of the derivation of the Primitive Equations of planetary scale oceanic dynamics from the three-dimensional Navier-Stokes equations as the vanishing limit of the small aspect ratio of the depth to horizontal width. In addition, we will also show the global well-posedness of the coupled three-dimensional viscous Primitive Equations with a micro-physics phase change moisture model for cloud formation. Eventually, we will also present short-time well-posedness of solutions to the Hibler's sea-ice model.
11:00-12:00	**Francisco Torres de Lizaur** will speak on non mixing of the 3D Euler equations Abstract: In this talk we consider the following non-mixing problem for the 3D Euler equations of ideal hydrodynamics: show that there are pairs of smooth velocity fields, with the same energy and helicity, such that no field close to one can ever evolve into a field close to the other. Here velocity fields are close if their pointwise values, and that of their derivatives up to order k, are similar enough. Khesin, Kuksin and Peralta-Salas proved this in 2014 for k>=4, KAM theorem being behind the regularity threshold. Proving the same result for k smaller remained an open problem. I will present joint work with Robert Cardona where we prove this for all k>=1, by introducing a new framework that assigns contact geometry invariants to large sets of time-dependent solutions on any 3-manifold with any fixed metric.
12:00-14:00	*Lunch will be served outside the conference room*
14:00-15:00	**Claudia Garcia** will speak on Periodic solutions around localized radial profiles for the 2D Euler equations Abstract: In this talk, we address for the 2D Euler equations the existence of rigid time periodic solutions close to stationary radial vortices of type $f_0(\|x\|)$ supported on the unit disk, with f_0 being a strictly monotonic profile with constant sign. We distinguish two scenarios according to the sign of the profile: defocusing and focusing. In the first regime, we have scarcity of the bifurcating curves associated with lower symmetry. However, in the focusing case we get a countable family of bifurcating solutions associated with large symmetry. The approach developed in this work is new and flexible, and the explicit expression of the radial profile f_0 is no longer required as in previous works. The alternative for that is a refined study of the associated spectral problem based on Sturm-Liouville differential equation with a variable potential that changes the sign depending on the shape of the profile and the location of the time period. This is a joint work with Taoufik Hmidi and Joan Mateu.

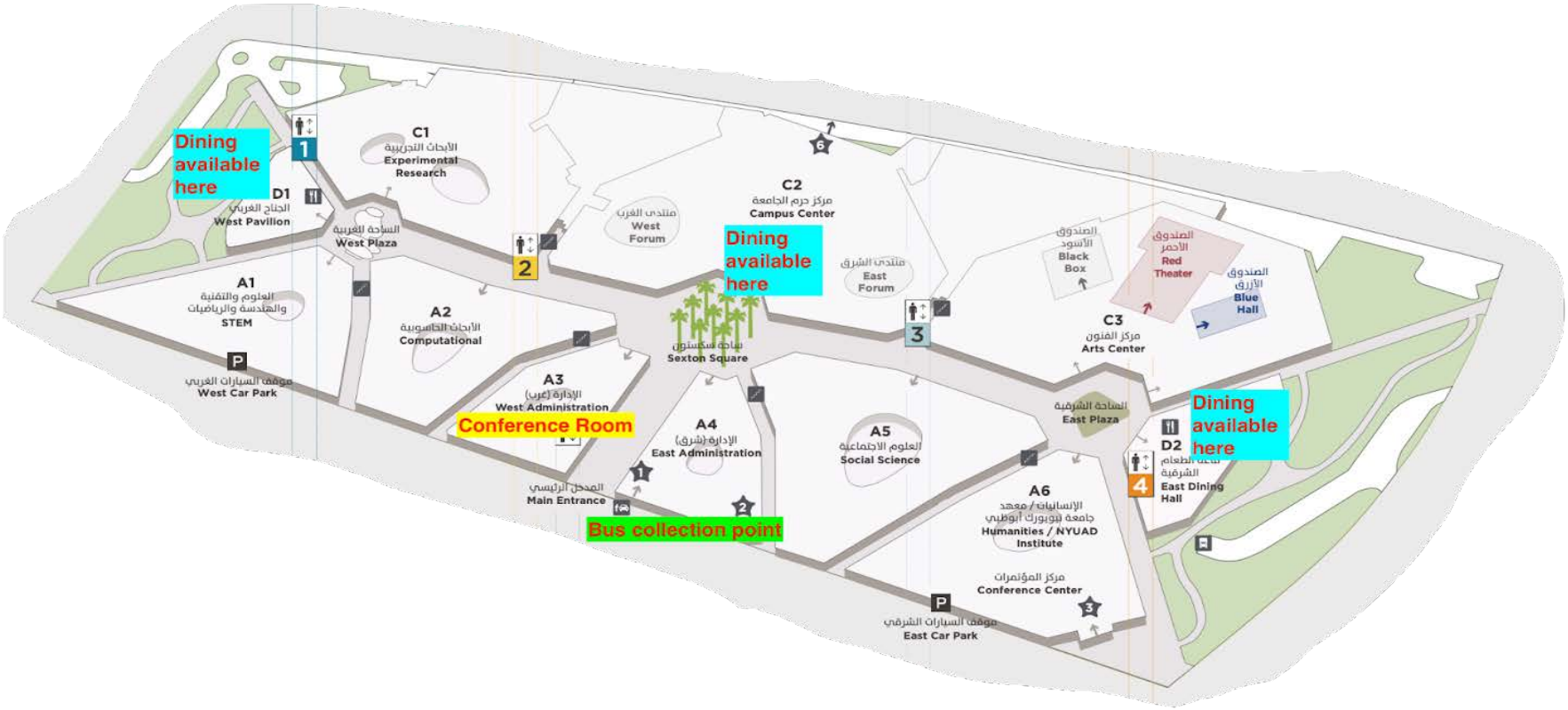
15:00-15:30	*Coffee break outside the conference room*
15:30-17:00	*Discussions and poster session*
17:15	*Bus departs campus for the hotel (please refer to the map of campus at the end of this document for location)*
19:30	*Bus collects everyone from the hotel to go to dinner at Al Dhafra Restaurant on a boat*
20:00	*We board the boat at Al Marina (near Marina Mall)*
22:00	*Boat returns to the marina*
22:30	*Bus takes everyone back to the hotel*
WEDNESDAY, JANUARY 10	
07:45	*Bus departs hotel for campus*
08.30-09:30	**Hajer Bahouri** will speak on on the global well-posedness problem for the derivative nonlinear Schrödinger equation on the Torus Abstract: The aim of this talk is to present a new joint result with Galina Perelman about the global well-posedness problem for the derivative nonlinear Schrödinger equation (DNLS) with periodic boundary conditions. Contrary to the more classical integrable systems such as KdV and 1D-cubic NLS, DNLS is non coercive as it can be witnessed by the concrete example of algebraic solitons whose mass is 4π. Just recently, this issue has been solved on the real line. However, the corresponding results on the Torus known up-to-date concern data with mass less than~4π. In this work we breach the barrier of~4π thanks to a combination of PDE arguments and a refined analysis of the spectral system associated with DNLS in the periodic setting.
09:30-10:00	*Coffee break outside the conference room*
10:00-11:00	**Raphaël Danchin** will speak on the two-dimensional incompressible inhomogeneous Navier-Stokes equations with rough density via dynamic interpolation Abstract: The incompressible inhomogeneous Navier-Stokes system (INS) governs the evolution of fluids which, although incompressible, have non constant density. This is a coupling between a transport equation for the density, and an evolution equation similar to the "classical" Navier-Stokes equation for the velocity. It is known since Kazhikhov's seminal paper in 1974 that any initial data with finite energy velocity and strictly positive bounded density generates a global weak solution of finite energy for (INS). But, except in the constant density case and in dimension two, it is not known whether these solutions are unique. In this talk, I will give a sufficient condition on the initial velocity, slightly stronger than the finite energy condition but still at the critical level of regularity, ensuring the

	existence and uniqueness of a solution in dimension two. We do not impose any smallness condition on the initial data, and no regularity on the density. The constructed solution admits a continuously differentiable flow, which ensures the persistence of the discontinuity interfaces for the density, for example. The proof relies on elementary time weighted energy estimates, and a dynamic interpolation argument that has been used before by T. Hmidi and S. Keraani in a different context. The result is valid in rather general two-dimensional domains.
11:00-12:00	**David Poyato** will speak on mean-field limit for non-exchangeable multi-agent systems Abstract: In this talk I will discuss a recent derivation of the mean-field limit for multi-agent systems on a large class of sparse graphs. More specifically, the case of non-exchangeable multi-agent systems consisting of non-identical agents is addressed, where the heterogeneous distribution of connectivities in the network is known to have critical effects on the collective dynamics. As a result, we obtain a Vlasov equation for the continuum of agents, which still captures the heterogeneous distribution of weights at the macroscopic scale in terms of the so-called extended graphons. Our method of proof does not only involve PDEs and stochastic analysis, but also graph theory through a novel concept of limits of sparse graphs (extended graphons) for the structure of the network, which can be regarded as a new non-trivial extension of the seminal works by L. Lovasz and B. Szegedy for dense graph limits. Our proof allows removing some of the main restrictive hypotheses in the previous literature on the connectivities between agents (dense graphs) and the cooperation between them (symmetric interactions). This is based on a joint work with P.-E. Jabin (Penn State University) and J. Soler (University of Granada).
12:00-14:00	*Lunch will be served in the atrium of the A6 Humanities building with the Quantum Information Theory and Free Probability*
14:30-15:00	*Bus departs campus from the usual collection point in the front of campus to go on the Desert Safari*
20:00-21:00	*Bus departs the Desert Safari location to take everyone back to the hotel*
THURSDAY, JANUARY 11	
07:45	*Bus departs hotel for campus*
08.30-09:30	**Alexander Kiselev** will speak on suppression of chemotactic blow up by active scalar Abstract: Chemotactic blow up in the context of the Patlak-Keller-Segel equation is an extensively studied phenomenon. In recent years, it has been shown that the presence of fluid advection can arrest singularity formation given that the fluid flow possesses mixing or diffusion enhancing properties and its amplitude is sufficiently strong - an effect that is conjectured to hold for more general classes of nonlinear PDE. In this talk, I will discuss the Patlak-Keller-Segel equation coupled with a fluid flow that obeys Darcy's law for incompressible porous media via buoyancy force. It turns out that in contrast with passive advection, this active fluid coupling is capable of suppressing singularity formation at arbitrary small coupling strength: namely, the system always has globally regular solutions.

	The talk is based on joint work with Zhongtian Hu and Yao Yao.
09:30-10:00	*Coffee break outside the conference room*
10:00-11:00	**Yao Yao** will speak on small scale formations in fluid equations with gravity Abstract: In this talk, we discuss some PDEs that describe fluid motion under the influence of gravity, including the incompressible porous media equation and incompressible Boussinesq equation in two dimensions. Using an interplay between various monotone and conserved quantities, we construct rigorous examples of small scale formations as time goes to infinity. These growth results work for a broad class of initial data, where we only require certain symmetry and sign conditions. As an application, we also construct solutions to the 3D axisymmetric Euler equation whose velocity has infinite-in-time growth. (Based on joint works with Alexander Kiselev and Jaemin Park).
11:00-12:00	**Zhifei Zhang** will speak on Nonlinear stability of the 3-D plane Poiseuille flow Abstract: The hydrodynamics stability has been a main theme in fluid mechanics since Reynolds's famous experiment in 1883. This field is mainly concerned with the transition of fluid motion from laminar to turbulent flow. Despite the efforts of many great scientists, the hydrodynamic stability theory was incompletely understood. In order to understand the transition mechanism of laminar flow, Trefethen et al proposed the transition threshold problem “how much disturbance will lead to the instability of the flow and the dependence of disturbance on the Reynolds number”. In this talk, I will introduce recent progress on the stability threshold of the plane Poiseuille flow for the 3-D Navier-Stokes equations in a finite channel with non-slip boundary condition.
12:00-14:00	*Lunch on campus (please refer to the map at the end of this document for available locations). We will provide you with vouchers for you to pay for Lunch*
14:0-15:00	**Salim Messaoudi** will speak on On a truncated thermoelastic Timoshenko system: Existence and stability Abstract: In this work we study the well-posedness and the asymptotic stability of a linear one-dimensional truncated thermoelastic Timoshenko system, where the heat conduction is given by Cattaneo's law. In order to establish the well-posedness, we first solve an auxiliary problem using the semigroup theory and some nontraditional operators. Then, we use this result to solve our main problem. After that, we prove that the presence of the thermal effect in one equation only is strong enough to drive the system exponentially to rest, irrespective to any relation between the coefficients. By the end of the work, we present some numerical tests to illustrate our theoretical findings.
15:00-15:30	*Coffee break outside conference room*
15:30-17:00	*Discussions and poster session*
17:15	*Bus departs campus for the hotel (please refer to map at the end of this document for location)*
19:30	*Eleven minute walk to the Meknes Moroccan Restaurant (refer to map at the end of this*

	document for directions)
FRIDAY, JANUARY 12	
07:45	*Bus departs hotel for campus*
08.30-09:30	**Manuel del Pino** will speak on Overhanging solitary waves in the Water Wave Problem Abstract: In the classical Water Wave Problem, we construct new overhanging solitary waves by a procedure resembling desingularization of the gluing of constant mean curvature surfaces by tiny catenoidal necks. The solutions here predicted have long been numerically detected. This is joint work with Juan Davila, Monica Musso, and Miles Wheeler.
09:30-10:00	*Coffee break outside the conference room*
10:00-11:00	**Mohamed Ali** will speak on Exploring Fluid Dynamics: A Comprehensive Catalog of Research Insights from SITE Research Center Abstract: In this talk, I will discuss various aspects of fluid dynamics studies conducted within the SITE Research Center. This "catalog" serves as a showcase and highlights the dynamics of some flow configurations we are investigating. The presented cases encompass a wide spectrum of fluid dynamics addressing phenomena such as vortex dynamics, heat transfer coupling, flows around bodies, and challenges posed by free boundary problems. Furthermore, the hydrodynamic stability analysis of some flows will be discussed. Our exploration of each case involves a thorough examination, encompassing analytical (theoretical) analysis, any available experimental work, and, notably, a focus on extensive numerical simulations.
11:00-12:00	**Slim Ibrahim** will speak on Phase Transition threshold and stability of magnetic skyrmions Abstract: After a very brief intro to chiral magnets, I will examine the stability of vortex-like configurations known as magnetic skyrmions. These correspond to critical points of the Landau-Lifshitz energy with the Dzyaloshinskii-Moriya (DM) interactions. From an earlier work of Doring and Melcher, it is known that the skyrmion is a ground state when the coefficient of the DM term is small. In my talk, I will quantify an explicit critical threshold of that coefficient above which the skyrmion becomes unstable, while stable below it. In addition, in the unstable regime, I will show how the infimum of energy is not bounded from below, by giving an explicit counterexample with a sort of helical-shape configuration. This mathematically explains the occurrence of phase transition observed in some experiments. This is a joint work with I. Shimizu (Osaka, U.)
12:00-14:00	*Lunch will be served outside the conference room*
14:30	*Bus departs campus for the hotel (please refer to map at the end of this document for location)*

Map of campus



Meknes Moroccan Restaurant