RESPONSE THEORY AND ITS APPLICATIONS IN GEOPHYSICAL FLUID DYNAMICS
OCTOBER 14-16, 2019 INSTITUT HENRI POINCARÉ

Monday 14 (Amphi Hermite, ground floor IHP)
Session 1 (Chair: Galatolo)
9:30-10:30 Mathieu
10:30-11:00 coffee
11:00-12:00 Froyland
Session 2 (Chair: Coudene)
14:00-15:00 Dijkstra
15:00-15:30 coffee
15:30-16:30 Korepanov
16:45-17:30 (and beyond) panel discussion
Ghil (lead), Ashwin, Lucarini

Tuesday 15 (Amphi Hermite, ground floor IHP)
Session 1 (Chair: Wouters)
9:30-10:30 Smania
10:30-11:00 coffee
11:00-12:00 Wormell
Session 2 (Chair: Vytnova)
14:00-15:00 Faggionato
15:00-15:30 coffee
15:30-16:30 Pollicott
16:45-17:30 (and beyond) panel discussion
Liverani (lead), Baladi, Pollicott, Ruelle

Wednesday 16 (Amphi Darboux, ground floor of IHP)
Session 1 (Chair: Sedro)
9:30-10:30 Padberg-Gehle
10:30-11:00 coffee
11:00-12:00 Saussol
(Amphi Hermite, ground floor IHP)
Session 2 (Chair: Bahsoun)
13:30-14:30 Todd
14:30-15:00 coffee

Titles and Abstracts

Henk A. Dijkstra, Utrecht
Title: Applications of response theory in climate change research
Abstract: Response theory has proven to be a highly useful tool in climate change research. To illustrate this, I will focus on two relevant problems in this presentation. The first is the problem of the Point of no Return in climate change, i.e. determining when it is too late to avoid dangerous climate change. The second problem is on the identification of so-called emergent constraints. These are empirical relationships that appear in ensembles of climate models between one characteristic of the current climate and another one under projections of future climate change.

Alessandra Faggionato, Rome La Sapienza
Title: Low temperature scaling of linear response coefficients in strongly disordered systems
Abstract: We consider a random walk on a discrete torus with disorder and introduce the conductivity matrix by linear response to a weak external field. As a byproduct of homogenisation and percolation theory we show that the infinite volume limit of the conductivity matrix is proportional the so called effective diffusion matrix D and we derive the low temperature Arrhenius scaling of D, when the disorder of the medium is due to energetic barriers. We then analyze similar issues for Mott variable range hopping, which is the basic mechanism of electron conduction in strongly disordered amorphous media as doped semiconductors. In this case, the low temperature scaling corresponds to Motts law. Time permitting we will present further results on the mobility matrix associated to an oscillating external field.

Gary Froyland, UNSW
Title: Optimal linear response and response of slow mixing structures in geophysical fluids.
Abstract: I will consider the question of optimal linear response in a variety of dynamical settings, and will describe applications to maximising observations and enhancing mixing rates. Linear response for coherent sets in geophysical flows will also be discussed.

Alexey Korepanov, Exeter
Title: Deterministic fast-slow systems driven by superdiffusive noise
Abstract: I plan to talk about fast-slow systems of a skew product type, where the fast process (noise) is generated by a slowly mixing dynamical system, such as Pomeau-Manneville maps, in the regime when Birkhoff sums converge to a Lvy process. I will describe limiting slow processes under natural conditions. This is a joint work with Ilya Chevyrev, Peter Friz and Ian Melbourne.

Pierre Mathieu, Université d'Aix-Marseille
Title: Some aspects of response theory for stochastic dynamics
Abstract: We study linear response theory for reversible Markov processes. In the first part of the talk, Ill quickly review some results (and questions) for diffusions in a random environment and in particular the linear response formula for the effective speed. (This is the so-called Einstein relation.) The second part of the talk will be about possibly degenerate diffusions on a torus with possibly time-dependent coefficients and how far we are from a good understanding of linear response in such a situation. In both cases, well insist on the role of an appropriate choice of the observables.

Kathrin Padberg-Gehle, Lüneberg
Title: Everything flows – identification and characterization of coherent patterns
Abstract: The motion of tracers in fluids flows is crucially influenced by coherent structures. Due to their strong impact on global transport and mixing processes the characterization of these Lagrangian objects is a topic of intense current research. From a probabilistic point of view, coherent sets are regular regions in the physical domain of the flow that move about with minimal dispersion. Coherent sets can be efficiently identified via leading eigenvectors of transfer operators or by using trajectory-based spectral clustering methods. We will review these approaches and apply them to a number of example systems including geophysical flows. We will also report on recent results towards the characterization of sudden changes in coherent patterns.

Mark Pollicott, Warwick
Title: Determining dynamical values via determinants
Abstract: Dynamical determinants carry information about properties of hyperbolic dynamical systems (including linear response) via their periodic orbits.

In this talk we will discuss how to extract this information, with fairly explicit bounds in the case of real analytic systems

Daniel Smania, ICMC-USP-Brazil
Title: When linear response fails
Abstract: Linear response had a quite successful ride in the setting of structurally stable dynamical systems (Ruelle results for Anosov maps, expanding maps of the circle). But even for piecewise expanding maps in the interval the SBR measure is not differentiable with respect to the parameter in a typical smooth family of such systems (Baladi, Baladi & S.). However linear response does hold for smooth families with no bifurcations (Baladi & S.) and there is a universal statistical behaviour for the average of the observable along typical families (de Lima & S.). The situation for maps with critical points is somehow even more challenging. The nice behaviour in families without bifurcations remains (Baladi & S.), but for typical families the regularity of the average of observables with respect to the parameter is even worse (Baladi, Benedicks & Schnellmann). However we (Baladi& S.) believe that fractional derivatives are the appropriated tool to give a more precise description of such irregularities. We will review the previous results and also describe the present developments in a joint work with Viviane Baladi.

Benoît Saussol, Brest
Title: Linear response for some deterministic and random dynamical systems
Abstract: [Joint work with Wael Bahsoun and Marks Ruziboev] We study linear response for deterministic and random compositions of maps. In the deterministic situation a parametrized family of maps T_a is given and we show the differentiability with respect to the parameter a of the absolutely continuous invariant measure. In the random situation the parameter a of the map is chosen at random according to a parametrized family of probability distribution P_b at each iteration, and we study the differentiability of the stationary measure with respect to the distribution b. We especially focus on dynamical systems with some intermittent behaviour, for which there is no spectral gap for the transfer operator such as Pomeau-Manneville maps.

Mike Todd, St Andrews
Title: Hitting, escaping and mixing
Abstract: Escape of mass through small holes in a system; recurrence statistics to asymptotically small neighbourhoods of a point/set; a simple form of extreme event. These are three different ways of looking at close approaches to a part of a dynamical system, and non-trivial limits can be characterised as metastability there. The latter two ways can be easily linked. Here I'll explain work with Bruin and Demers which investigates the circumstances under which the first two can be connected, and new generalised limits formed. This can be seen either through well-behaved transfer operators or through some 'good' large deviations - in 'bad cases the connection fails. The models here are basic interval maps, but we expect the phenomena to be very general.

Caroline Wormell, Sydney
Title: Linear response for macroscopic observables in high-dimensional systems
Abstract: The long-term average response of observables of chaotic systems to dynamical perturbations can often be predicted using linear response theory (LRT), but not all chaotic systems possess a linear response. Macroscopic observables of complex dissipative chaotic systems, however, are widely assumed to have a linear response even if the microscopic variables do not, but the mechanism for this is not well-understood.

We present a comprehensive picture for the linear response of macroscopic observables in high-dimensional weakly coupled deterministic dynamical systems, where the weak coupling is via a mean field and the microscopic subsystems may or may not obey LRT. We derive a stochastic reduction of the dynamics of these observables from statistics of the microscopic system, and then provide conditions for linear response theory to hold in finite-dimensional systems and in the thermodynamic limit. In particular, we demonstrate that in large systems of finite size, linear response is induced by self-generated noise.

In the thermodynamic limit, we will present examples where the macroscopic observable satisfies LRT, although the microscopic subsystems individually violate LRT, as well a converse example where the macroscopic observable does not satisfy LRT despite all microscopic subsystems satisfying LRT when uncoupled. This latter, maybe surprising, example is associated with emergent non-trivial dynamics of the macroscopic observable.
This is joint work with Georg Gottwald.