Jonathan Ben-Artzi (Ben-ArtziJ@cardiff.ac.uk)

Brief CV

2016-	Cardiff University	Senior Lecturer (Associate Professor)
2016-2021	Engineering and Physical Sciences Research Council (EPSRC)	Early Career Fellow
2014-2016	Imperial College London	Junior Research Fellow
2011-2014	Cambridge University	Research Associate
2011	Brown University	PhD under Prof. Walter Strauss

Research interests

I am interested in nonlinear first-order nonlinear PDEs and their phase-space dynamics. In *kinetic theory* we describe gases, fluids and plasmas statistically, via a function f(t,x,v) that measures the density of particles that at the time t are located at the point x and have velocity v. The precise physical model then governs the evolution of f in phase-space via the so-called *Vlasov equation*. The long-term dynamics are extremely difficult to analyze, and lead to abstract problems in dynamical systems and ergodic theory (such as convergence rates in the ergodic theorem).

PhD projects

1) Long-time dynamics in kinetic theory

The long-time behavior of the Vlasov-Poisson and Vlasov-Maxwell systems is an important problem in physics and engineering, and has therefore attracted significant interest in the mathematics community (pure, applied and numerical). In this project you will first familiarize yourself with the state-of-the-art in the field and then explore the following questions:

- A gas of electrons disperses due to the repulsive nature of the electromagnetic force. Can we obtain an optimal rate for this dispersion?
- Existence and uniqueness of solutions is known for plasmas where the magnetic force is neglected (the Vlasov-Poisson system) but when the full set of Maxwell's equations is introduced this is still an open problem. Can we push the limits of what's known and achieve a better understanding of the effect of the magnetic field?
- There are some explicit steady-state solutions of these systems. However, are these solutions stable, or would a slight fluctuation result in a totally different solution? This is an extremely important question for engineers who are attempting to build fusion reactors.

2) The geometry of vector fields and their induced flows

First order differential operators, and the vector fields they generate, are the most basic objects one can imagine in the analysis of PDEs. However, even though solutions are completely deterministic, they exhibit an extremely rich array of possible dynamics. In this project you will explore the relationship between the geometry of the flow, spectral properties of the differential operator generating it and the associated ergodic theorem. The questions you will address are:

- Classify vector fields in canonical terms, i.e. vector fields that are rectifiable, vector fields that are homeomorphic to a periodic flow, etc.
- Study how the geometry of the flow is related to the spectrum of the operator. If there are unbounded trajectories, those should generate spectrum along the entire real line, while periodic trajectories generate a point spectrum.
- Relate the structure of the spectrum to the dynamics, and in particular convergence rates for averages along the flow. In other words, when does the associated ergodic theorem have a rate of convergence? Can we identify optimal functional subspaces on which a rate exists?

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