Lydia Bieri, University of Michigan.
Title: Structures of Gravitational Waves: A Geometric-Analytic Point of View.
Abstract: The Einstein equations describe the laws of the universe and lie at the core of General Relativity. Their very nature is geometric, they can be written as a system of nonlinear hyperbolic partial differential equations. Mathematical General Relativity investigates these equations with the goal of solving problems from physics. In this talk, I will present geometric-analytic investigations of these equations answering questions about gravitational waves and their memory effect, a permanent change of the spacetime. Typically, they are produced during the mergers of black holes or neutron stars and in core-collapse supernovae. They propagate through the spacetime as variations in curvature. In 2015, gravitational waves were observed for the first time by Advanced LIGO (and several times since then). Interesting structures of spacetimes reflect in gravitational radiation. I will also discuss some new structures and discuss their mathematical as well as physical relevance.

Alberto Bressan, Pennsylvania State University.
Title: Multiple solutions of the 2-dimensional Euler equations.
Abstract: The talk will be concerned with the classical Euler equations describing a 2-dimensional inviscid, incompressible fluid. The goal is to find “simplest possible” examples of initial data admitting multiple solutions. We thus consider initial vorticity concentrated on two wedges, symmetric w.r.t. the origin, with density locally in $L^p$.

Recent numerical simulations by Wen Shen (2017) have shown that, by approximating this same initial data with functions in $L^\infty$ in two different ways, one obtains two distinct limit solutions. One contains a single spiraling vortex, while the other solution contains two vortices.

Toward a rigorous proof of the existence of such solutions, one needs to combine (i) a posteriori error estimates for the numerical computation, valid on a bounded domain where the solution is smooth, with (ii) an analytic construction of the solution in a neighborhood of infinity, and (iii) an analytic construction of the solution in a neighborhood of one or two spirals’ centers where singularities occur.

Luis Caffarelli, University of Texas, Austin.
Title: The interaction between local and non local diffusion.
Abstract: I will present several instances in which quantities that have different type of diffusion, infinitesimal and long range, interact and will concentrate in a couple of particular structures.

Felix Finster, University of Regensburg.
Title: Causal fermion systems from the perspective of calculus of variations and PDEs.
Abstract: The theory of causal fermion systems is an approach to fundamental physics. Giving quantum mechanics, general relativity and quantum field theory as limiting cases, it is a
candidate for a unified physical theory. From the mathematical perspective, causal fermion systems provide a framework for generalized, possibly non-smooth geometries. The dynamics of a causal fermion system is described by a variational principle, the so-called causal action principle.

The aim of the talk is to give a simple introduction from the perspective of calculus of variations and partial differential equations.

Irene M. Gamba, University of Texas, Austin.

Title: The Cauchy problem and BEC stability for the Quantum Boltzmann-Condensation System at very low temperature.

Abstract: We discuss a new model for a coupled quantum Boltzmann-Condensation system that describes the evolution of the interaction between a well formed Bose-Einstein Condensate (BEC) and the quasi-particles cloud interacting with the condensed part. The kinetic dynamics of the quasi-particles, derived as weak turbulence kinetic model from a quantum Hamiltonian, is valid for a dilute regime at which the temperature of a bosonic gas is very low compared to the Bose-Einstein condensation critical temperature. In particular, the system couples the density of the condensate from a Gross-Pitaevskii type equation to the kinetic equation through the dispersion relation in the kinetic model and the corresponding transition probability rate from pre to post collision momentum states.

We show the well-posedness of the Cauchy problem to the system for bounded solutions with a sufficiently large number of statistical moments and prove stability leading to a global in time existence and uniqueness of bounded, finite energy solutions to an initial value problem for the quantum Boltzmann-Condensation system. The proof entices finding qualitative properties of the solution such as instantaneous creation of polynomial and exponential moments ($L^1$-weighted norms), and finding estimates that related to the initial mass and boundness relation between condensed particles and quasi-particles.

This is work in collaboration with Ricardo J. Alonso and Minh Binh Tran.

Zaher Hani, University of Michigan.

Title: On the kinetic description of the long-time behavior of dispersive PDE.

Abstract: Wave turbulence theory claims that at very long timescales, and in appropriate limiting regimes, the effective behavior of a nonlinear dispersive PDE on a large domain can be described by a kinetic equation called the “wave kinetic equation”. This is the wave-analog of Boltzmann’s equation for particle collisions. We shall consider the nonlinear Schrödinger equation on a large box with periodic boundary conditions, and explore some of its effective long-time behaviors at time scales that are shorter than the conjectured kinetic time scale, but still long enough to exhibit the onset of the kinetic behavior. (This is joint work with Tristan Buckmaster, Pierre Germain, and Jalal Shatah).

Joachim Krieger, EPFL Lausanne.

Title: Blowup dynamics via energy concentration and their stability properties for nonlinear wave equations.

Abstract: I will discuss recent developments related to a blow up construction which was originally conceived for the critical Wave Maps problem but has since found applications to a wide variety of problems, including Schrödinger type equations as well as very recently quasilinear wave equations. A point of interest are stability properties of these solutions, as well as some conjectures about general classifications.
Tai-Ping Liu, Academia Sinica, Taipei & Stanford University.
Title: On the well-posedness theory for weak solutions.
Abstract: The standard Hadamard well-posed theory often is not verified for weak solutions of evolutionary partial differential equations. Weak solutions are constructed by certain compactness estimates. Such a construction does not offer sufficient structure for the solutions for the verification of the well-posed theory. Well-known examples of weak solutions, for which there is no well-posed theory, include the Leray solutions for incompressible Navier-Stokes equations and DiPrenna-Lions solutions for the Boltzmann equation. For incompressible Euler equations, weak solutions constructed by Scheffer V. using convex integration shows that there is no well-posed theory. De Lellis C, Szkelyhidi L. apply this to compressible Euler equations. There is, however, a well-posed theory for the weak solutions of system of hyperbolic conservation laws. However, this well-posed theory is not in the standard Hadamard sense. After reviewing these, we will explain a recent well-posed theory, done by Shih-Hsien Yu and the author, for the weak solutions of the compressible Navier-Stokes equations.

Jonathan Luk, Stanford University.
Title: High frequency limits and Burnett’s conjecture in general relativity.
Abstract: It is known in the physics literature that “high-frequency weak limits” of solutions to the Einstein vacuum equations are not necessarily vacuum solutions, but may have a non-trivial stress-energy-momentum tensor, which can be viewed physically as “effective matter fields” arising from back-reaction of high frequency gravitational waves. Burnett conjectured nonetheless that any such limit is isometric to a solution to the Einstein-massless Vlasov system. We prove that Burnett’s conjecture is true under a symmetry assumption and a gauge condition. This is a joint work with Cécile Huneau.

Tao Luo, City University of Hong Kong.
Title: Nonlinear Stability of Gaseous Stars.
Abstract: In the Newtonian mechanics frame work, the motion of a gaseous star is modelled by the PDEs of compressible Euler-Poisson or Navier-Stokes-Poisson equations. The nonlinear stability of two equilibrium configurations, rotating and non-rotating star solutions, will be discussed in this talk. The rotating star solutions are those for the Euler-Poisson equations with prescribed total mass and angular momentum (or angular velocity), for which the nonlinear orbital stability will be discussed from the energy-minimizing point of view, by using the approach developed by Arnold for Hamiltonian systems, using the conservative laws of total mass, energy and angular momentum. The key issue here is that the energy functional is not positive definite. This part consists of the nonlinear orbital stability for both the polytropic stars and white dwarfs with the total mass beneath the Chandrasekhar limit, based on the joint work with J. Smoller. The second part of this talk is on the nonlinear asymptotic stability of non-rotating viscous gaseous stars in the framework of the free boundary problem of compressible Navier-Stokes-Poisson equations with physical vacuum singularity, based on the joint work with Zhouping Xin and Huihui Zeng. The key issue here is to deal with the strong degeneracy of the system near vacuum states and identify the suitable higher order nonlinear weighted functionals to establish the higher order regularity uniform both in time and all the way up to the vacuum boundary.
Clément Mouhot, Cambridge University.
Title: Quantitative hypocoercivity for collisional particle systems with confinement.
Abstract: We present recent results obtained with Carrapatoso, Dolbeault, Hérau, Mischler and Schmeiser in which we develop quantitative methods for estimating the spectral gap of hypocoercive kinetic equations that combines the local conservation laws of fluid mechanics and a confining force. This involves commutator estimates with global correctors and new quantitative inequalities of Korn type. Such results are a step towards constructing global solutions near equilibrium to the Boltzmann equation with a confining potential.

Andrea Nahmod, University of Massachusetts, Amherst.
Title: Optimal local well-posedness for the periodic derivative nonlinear Schrödinger equation.
Abstract: In this talk we explain how to close the existing gap in the local well-posedness theory for the periodic derivative nonlinear Schrödinger’s equation, which is $L^2$ critical. We achieve this result by a delicate analysis of the structure of the solution and the construction of an adapted nonlinear submanifold of a suitable function space. This constructive procedure is inspired by the theory of para-controlled distributions developed by Gubinelli-Imkeller-Perkowski and by Cantellier-Chouk in the context of stochastic PDE. Our proof and results however, are purely deterministic. This is joint work with Yu Deng and Haitian Yue.

Jeffery Rauch, University of Michigan.
Title: Boundedness of Flat Jump Discontinuities of Hyperbolic PDE.
Abstract: This talk concerns a battle between dispersion that tends to make solutions spread and get smaller, and transport that governs the propagation without decay of jump discontinuities across characteristic hyperplanes. Except for the jumps, stuff spreads and decays while the jump does not. The $L^2(\mathbb{R}^d)$-norm is conserved. The jump in first derivatives usually grow linearly in time. I will describe with enough precision that these conflicting behaviors are reconciled. For large time the jump is a sort of isolated boundary layer. I have recently proved that the solutions are uniformly bounded in space time. Under suitable hypotheses. I think that Sobolev norms with $\epsilon > 0$ derivatives are not bounded.

Sohrab Shahshahani, University of Massachusetts, Amherst.
Title: Tidal energy in Newtonian two-body motion.
Abstract: In this work, based on essential linear analysis by Christodoulou, we study the tidal energy for the motion of two gravitating incompressible fluid balls with free boundaries, obeying the Euler-Poisson equations. The orbital energy is defined as the mechanical energy of the center of mass of the two bodies. When the fluids are replaced by point masses, according to the classical analysis of Kepler and Newton, the conic curve describing the trajectories of the bodies is a hyperbola when the orbital energy is positive and an ellipse when the orbital energy is negative. If the point masses are initially very far, then the orbital energy, which is conserved in the case of point masses, is positive corresponding to hyperbolic motion. However, in the motion of fluid balls the orbital energy is no longer conserved, as part of the conserved energy is used in deforming the boundaries of the bodies. This energy is called the tidal energy. If the tidal energy becomes larger than the total energy during the evolution, the orbital energy must change its sign, signaling a qualitative change in the orbit of the bodies. We will show that under appropriate conditions on the initial configuration this change of sign occurs. This is joint work with Shuang Miao from Wuhan University.
Roman Shvydkoy, UIC at Chicago.
Title: Hypocoercivity method in alignment models of collective behavior.
Abstract: In this talk we discuss long time behavior of solutions to systems of Cucker-Smale type. Such systems describe collective dynamics of “agents” in a variety of applications. When interactions between agents is long range and space filling, asymptotic behavior is characterized by the phenomena of unconditional alignment and flocking. In degenerate situation, with zones of indifference and spacial lapses in communication, proving such statements stumbles upon lack of coercivity in the classical energy equation, as well as possible lack of connectivity of the flock. In this talk we will present several ways to circumvent this difficulty on the discrete, kinetic and macroscopic levels of description.

Gigliola Staffilani, MIT.
Title: Some results on the almost everywhere convergence of the Schrödinger flow.
Abstract: In this work we are concerned with the question of almost everywhere convergence of the nonlinear Schrödinger flow in both the continuous and the periodic case. We will review the extraordinary progress made in the continuous and linear case and we will illustrate some progress recently made in the nonlinear case using both a deterministic and a probabilistic approach. This is joint work with Erin Compaan and Renato Luca.

Blake Temple, University of California, Davis.
Title: The Regularity Transformation Equations: How to smooth a crinkled map of spacetime.
Abstract: We have now discovered, in a framework much more general than GR shock waves, that the regularization of non-optimal connections is determined by a system of nonlinear elliptic equations with matrix valued differential forms as unknowns, the Regularity Transformation equations, or RT-equations. The mathematical problem is whether the condition that Riem(Γ) have the same regularity as its connection Γ, (or equivalently dΓ the same regularity as Γ), is sufficient to allow for the existence of a coordinate transformation which perfectly cancels out the jumps in the leading order derivatives of δΓ, thereby raising the regularity of the connection and the metric by one order – a delicate problem. The initial value problem in GR is incomplete in each Sobolev space without resolving the problem of non-optimal solutions. In this talk we introduce the RT-equations, discuss their derivation from

the so called Riemann-flat condition, and describe our first existence theorem for the RT-equations in the general case when Γ, Riem(Γ) ∈ W^{m,p}, m?1, p > n. The result is the following theorem: Given any connection satisfying Γ(x), Riem(Γ(x)) ∈ W^{m,p} in x-coordinates, m ≥ 1, p > n, there always exists a coordinate transformation x → y such that Γ(y) ∈ W^{m+1,p}, Riem(Γ(y)) ∈ W^{m,p}. This implies all discontinuities in m-th derivatives of δΓ cancel out, the transformation x → y raises the connection regularity by one order, and Γ exhibits optimal regularity, (Γ one order more regular than Riem(Γ)), in y-coordinates. The problem of optimal regularity for the hyperbolic Einstein equations is thus resolved by elliptic regularity theory in L^p-spaces applied to the RT-equations.

Michael Weinstein, Columbia University.
Title: Dynamics of waves in systems with spectral band-degeneracies.
Abstract: Spectral band degeneracies in periodic media are a source of novel phenomena with implications for the physical properties novel materials, e.g. topological insulators, metamaterials. We shall review recent work on a) the propagation of semi-classical wavepackets through spectral band degeneracies (w/ A.B. Watson and J. Lu), and b) the dynamics of waves, which
are spectrally localized near Dirac points, in honeycomb media and their deformations (w/ A. Drouot, C. L. Fefferman, J.P. Lee-Thorp, and Y. Zhu).

**Zhouping Xin, Chinese University.**

**Title:** Transonic Shocks in Curved Nozzles.

**Abstract:** In this talk, I will discuss some results on transonic shock problems for the steady compressible flows in nozzles with variable cross sections. We will focus on flows with shocks with physical boundary conditions, such as the given receiver pressure at the exit as proposed by Courant-Friedrich’s. This will be a nonlinear free boundary value problem with nonlinear boundary conditions for mixed typed equations. First, I will present some results on the structural stability of Courant-Friedrich’s transonic shock solutions for a general classes of general 2-dimensional Nozzles which are generic small perturbation of straight expanding nozzles. However, the focus will be on transonic shock problems for nozzles which are generic small perturbations of a 2-dimensional flat nozzle so that the position of the normal shock is arbitrary. Existence of single or multiple transonic shocks will be discussed in terms of the geometry of the nozzle and the given exit pressure. Based on an elaborately designed linear free boundary value problem. Some ideas of analysis will be presented.

**Huihui Zen, Tsinghua University.**

**Title:** On The Life-Span of Smooth Solutions to the 3-D Vacuum Free Boundary Problem for Compressible Euler Equations with Frictional Damping and Physical Singularity.

**Abstract:** The compressible Euler equations with frictional damping is closely related to the porous media equation, for which the basic understanding of the finite mass is provided by the Barenblatt self-similar solution. Due to the slow (sublinear) growth rate of the gas-vacuum interface for the Barenblatt solution, it has been a challenging problem to establish the long time dynamics of vacuum boundary in 3D perturbations for compressible Euler equations with frictional damping and physical singularity. In this talk, these issues will be addressed and the estimates on the life-span of smooth solutions will be discussed.