Abstracts of Invited Talks

Ricardo J. Alonso Rice University

"Emergence of exponentially weighted Lp-norms and Sobolev regularity for the Boltzmann equation"

We consider the homogeneous Boltzmann equation for Maxwell and hard potentials without cutoff and study the appearance and propagation of Lp-norms, including polynomial and exponential weights. Propagation of Sobolev regularity with such weights is also considered. Classical and novel ideas are combined to elaborate an elementary argument that proves the result in the full range of integrability $p \in [1, \infty]$ and singularity $s \in (0, 1)$. For the case $p = \infty$, we use an adaptation of the classical level set method by De Giorgi.

Claude Bardos Retired University Denis Diderot

"A baby version of the Landau damping and a road map to the Quasilinear approximation"

The quasi linear approximation is a basic tool in Plasma Physic. People relate it to the Landau Damping with the belief that the material included in Mouhot-Villani may contribute to a better understanding and more complete proofs.
In Mouhot Villani or Cagliotti Maffei one shows, that $F(x, v, t)$ the solution of the Vlasov equation converges weakly for $t \to \infty$ to an x independent function $\overline{F}(v)$ and that the difference

$$F(x - vt, v, t) - \overline{F}(v)$$

converges to 0 in $L^\infty(\mathbf{T} \times \mathbf{R}^\mathbf{d})$. Hence the Electric field goes also goes to 0.
Here instead of letting $t \to 0$ I will consider the problem for a finite time $0 \leq t \leq T < \infty$ and introduce (in agreement with physic) a scaling parameter $\epsilon \to 0$. Besides that one observes that with the presence of "Penrose " unstabilities for linearized problem the situation is really different.
For random electric field one obtains a complete proof while for self consistent potential many things become simpler and in the understanding of the quasilinear approximation striking similarities appears.

Dapeng Bi Northeastern University

"Mechanical Heterogeneity in Tissues Promotes Rigidity and Controls Cellular Invasion"

As early as 400 BCE, the Roman medical encyclopaedist Celsus recognized that tumours are stiffer than surrounding tissue. This is the very reason that doctors tell their patients to feel for lumps during a prostate or breast self-exam. However, recent studies have shown that cancer cells are actually softer than their healthy counterpart. This causes an apparent paradox: how can a tumour made up of softer cancer cells be more stiff than healthy tissue? I will present the latest work by my group which swe offer a possible resolution of this paradox using biophysical theory and modeling. In this work, we taken into account not only the overall softness of cancer cells, but also how much heterogeneity (variation) is found among cancer cells. To our surprise, we found that heterogeneity can strongly influence tumor stiffness, making it possible to have a rigid tumor that contains many soft cells. Furthermore, this rigidity onset is far below the contact percolation threshold of rigid cells. These results give rise to a separation of rigidity and contact percolation processes that leads to distinct types of solid states. We also investigate the influence of heterogeneity on tumor invasion dynamics. There is an overall impedance of invasion as the tissue becomes more rigid. Invasion can also occur in an intermediate heterogeneous solid state that is characterized by significant spatial-temporal intermittency.

Robijn Bruisma UCLA

"Invariant Theory and Orientational Phase Transitions"

The Landau theory of phase transitions has been productively applied to phase transitions that involve rotational symmetry breaking, such as the transition from an isotropic fluid to a nematic liquid crystal. I will discuss fundamental problems that arise when it is applied to rotational symmetry breaking transitions of more complex particle clusters that involve order parameters characterized by larger values of the index L of the dominant spherical harmonic that describes the broken symmetry state and show how the combination of a geometrical method based on the analysis of the space of invariants with modern visualization tools provides a resolution to these problems.

Luis Caffarelli University of Texas

"Interactions among different diffusivity"

On this lecture I will consider various examples of interaction of different orders: surfaces with volumes, different orders of diffusivity, free boundary and transmission conditions, and the associated existence and regularity properties

Maria Carvalho Rutgers University and University of Lisbon

"Spectral Gaps and Entropy Production for Kinetic Master Equations with Degenerate Jump Rates"

The original Kac model concerned Maxwellian molecules, for which the collision rate does not depend on the magnitude of the relative velocity of the colliding particles this model is now well-understood at both the level of spectral gaps and entropy production. More physically realistic models, especially for hard sphere collisions, still pose significant challenges. In recent work with Carlen and Loss, the Kac conjecture for the spectral gap was proved for hard sphere collisions and in fact for the full range of collision models all the way from Maxwellian to Super-Hard Spheres. The investigation of Super-Hard Sphere collisions was initiated by Villani, who showed that "speeding up" the rate of high energy collisions led to the strong entropy production inequalities that Cercignani had conjectured. However, his result depends on suppressing the degeneracy at low energies. It is natural to conjecture, that as with the spectral gap, entropy production bounds of Cercignani type hold for super hard sphere collisions without suppressing the low energy degeneracy.

Thomas Chen University of Texas

"Boltzmann equations via Wigner transform and dispersive methods"

In this talk, we present some of our recent work on the analysis of Boltzmann equations with tools of nonlinear dispersive PDEs. The starting point of our approach is to map the Boltzmann equation, by use of the Wigner transform, to an equation similar to a Schrodinger equation in density matrix formulation with a nonlinear self-interaction. We prove local well-posedness, propagation of moments, and small data global well-posedness in spaces defined by weighted space-time norms of Sobolev type. This is joint work with Ryan Denlinger and Natasa Pavlovic.

Emanuela Del Gado Georgetown

"Topology, softness and rigidity in gel networks"

Soft matter (colloids, polymers, proteins…) often self-assembles into gels where rigidity emerges in diverse structures with a variety of mechanical features. Through the interplay between their microstructure with an imposed deformation, gels can be stretched, squeezed, fractured or flow, but controlling and being able to design such processes (think for example of soft inks for 3D printing technologies) requires a fundamental understanding that is still lacking. Interesting new insight into the emergence of rigidity and the role of the network topology can be gained through theoretical/computational approaches. I will give an overview of the novel insight gained into the aging, the uniquely wide-ranged viscoelastic spectra and the presence of a topologically controlled softness in gel networks. Such findings can help understand the nontrivial mechanical response of soft gels in different contexts, develop constitutive models and theories further, and design smart materials.

Doug Durian University of Pennsylvania

"The Statistical Mechanics of Granular Clogging"

The gravity-driven flow of grains from a hole in a hopper is an iconic granular phenomenon. It's different from a fluid in that the rate is constant also in that it can suddenly and unexpectedly clog. How does the susceptibility to clogging decrease with increasing hole size, and is there a well-defined clogging transition above which the system never clogs? This problem is distinct from jamming due to the presence of boundaries and gradients. We show how the fraction F of flow configurations that cause a clog may be deduced from the average mass discharged between clogs. We construct a simple model to account for the observation that F decays exponentially in hole width to the power of dimensionality. Thus the clogging transition is not sharp but rather is defined by observation limits, similar to the glass transition. When the system is immersed in water, F barely changes. Therefore, grain momenta play only a secondary role in destabilizing weak incipient arches and the crucial microscopic variables are likely the grain positions. Work is now in progress to distinguish free-flowing versus clog-causing position microstates using machine learning.

Jeremy England MIT and GlaxoSmithKline AI/ML

"Adaptation by Least-rattling in Driven Multi-particle Assemblies"

In general, the steady-state behavior of a nonequilibrium system can be a function of all kinetic factors governing transitions between pairs of microstates. Therefore, in contrast with thermal equilibrium, it cannot generally be assumed that the probabilities of microstates may be computed from their local properties, because the overall connectivity of states can be decisive in shaping the whole distribution. For a broad class of "messy," many-body dynamical systems, however, it is possible to argue for a simplification that allows one to link steady-state probability to a local measure of dynamical fluctuation called "rattling." Accordingly, we show in a diverse sampling of examples from experiment and simulation – a robot swarm, an oscillating mechanical network, and a random spin glass in a time-varying field – that rattling serves as a powerful predictive principle for explaining emergent adaptive organization in materials and active matter collectives driven far from equilibrium.

Raffaele Esposito University of L'Aquila

"Hydrodynamic Limit of a Kinetic Gas Flow Past an Obstacle"

Given a fixed obstacle and a non-zero small velocity at the infinity, we consider the classical fluid dynamic problem of the flow with zero velocity on the obstacle and non zero velocity at infinity. The fluid on the kinetic scale is described by the Boltzmann equation and the kinetic boundary conditions are given by the diffuse reflection with fixed wall temperature and zero mean velocity. For small Knudsen numbers we construct the unique steady Boltzmann solution flowing around such an obstacle with the prescribed velocity for large x. It approaches the corresponding incompressible Navier-Stokes steady flow, as the Knudsen number goes to zero and establish the error estimate between the Boltzmann solution and its Navier-Stokes approximation. Our method consists of new L^6 and L^3 estimates in the unbounded exterior domain to be associate with an L^2-L^\infty strategy, as well as an iterative scheme preserving the positivity of the distribution function.

Bill Gelbart UCLA

"Continuing the search for the hydrogen atom of viruses"

What is the simplest virus? What do we mean by "simple" and what do we mean by "virus"? I discuss these questions in the context of several "simplest-virus" candidates, arguing that they are most naturally ones whose genomes are single-stranded (ss) RNA molecules (as opposed to the usual double-stranded [ds] DNA). Three particular examples are considered: an insect virus and a plant virus that have as few as two to four genes distributed on two to three molecules, and a mammalian virus with a total of ten genes on a single molecule. The common -- and simplifying -- ingredient in all cases is an enzyme, RNA replicase, introduced to life by viruses, which turns a single RNA molecule into millions within a few hours. I discuss how these viral genomes manage to be strongly replicated and how their "self"-

amplification can be harnessed to make useful gene delivery systems, especially when they are spontaneously packaged by protein into virus-like particles with high symmetry and stability.

Ajay Gopinathan University of California, Merced

"Frustration-induced phases in collectively moving cell clusters"

Flocks of birds and schools of fish are delightful and awe-inspiring examples of collective motion that we see in nature, where groups of individuals, each possessing only limited, local information, nevertheless come together and display coordinated motion. This phenomenon also extends to much smaller scales, as in migrating clusters of cells that mediate physiological processes such as embryonic development, wound healing and cancer metastasis. In this talk, I shall describe our work on modeling such clusters, highlighting how frustration can arise at the group level because of heterogeneity in behavior among members of the cluster. I shall show how this frustration can be resolved leading to new collective phases of motion that are experimentally observed in malignant lymphocyte clusters and can be functionally important – enabling robust chemotaxis and "load sharing" among cells.

Randy Kamien University of Pennsylvania

"A new classification of topological defects"

Nearly 50 years ago, homotopy theory was employed to unify our understanding of topological defects in superfluids, superconductors, crystals, and liquid crystals. It was understood, however, that when there is broken translation invariance (as in crystals and some liquid crystals) that this approach required additional constraints. I will demonstrate the problem, propose a solution which allows us to characterise the topological defects in these systems, and demonstrate a new classification in the case of smectic liquid crystals, the simplest of these broken-translational-symmetry states.

Eleni Katifori University of Pennsylvania

"Fluidic metamaterials"

Michael Kiessling Rutgers University

"Microscopic foundations of relativistic kinetic plasma theory"

A recent well-posedness result for a Lorentz-covariant system of N classical point charges and their electromagnetic fields in a Bopp-Land'e-Thomas-Podolsky (BLTP) vacuum, by Kiessling and Tahvildar-Zadeh, paves the ground for the microscopic foundations of relativistic kinetic plasma theory. We propose a pertinent system of kinetic equations which includes radiation-reaction effects on the particle densities. Formally the radiation-reaction vanishes in a mathematical scaling limit which yields a Vlasov-Maxwell-BLTPsystem. In a subsequent limit where the Bopp parameter is send to infinity one obtains the familiar relativistic Vlasov-Maxwell system. Joint work with Yves Elskens.

Chuck Knobler UCLA

"The Role of RNA in Controlling the *in vitro* Co-Self-Assembly of Viruses"

The simplest of viruses consist of a container, the capsid, made up of many copies of a single protein that surrounds a single-stranded (ss) RNA genome. Some of these viruses are able to self-assemble in vitro when the pure capsid protein (CP) is mixed with pure RNA in a buffer under appropriate conditions of pH and ionic strength. In the case of the plant viruses CCMV (cowpea chlorotic mottle virus) and BMV (brome mosaic virus) the 28-nm diameter capsid is icosahedral, consisting of 180 CP, and the enclosed RNA is 3000 nt in length. But the in vitro assembly can be carried out around RNAs other than the wild-type that differ in sequence and length leading to virus-like particles (VLPs) that may have different diameters, appear as multiplets in which a single RNA is shared between two or more capsids or lack icosahedral symmetry. We have examined how the properties of the RNA control assembly by carrying out: a) Assemblies with RNAs that differ in length – ranging from 140 to 12,000 nucleotides – and primary structure, including homonuclear molecules such as polyU and polyA; b) Competition experiments in which two different RNAs compete for a limited amount of CP.

Jorge Kurchan Superieure

"Multithermalization"

When a system is coupled to baths with different temperatures and widely separated characteristic timescales, it `multithermalizes': a generalization of the Gibbs-Boltzmann distribution. The construction gives a physical view of replicas, without involving analytical continuations.

Qin Li University of Wisconsin, Madison

"Boundary Layers in kinteic-fluid coupling"

Many kinetic equations have the corresponding fluid limit. In the zero limit of the Knudsen number, one derives the Euler equation out of the Boltzmann equation and the heat equation out of the radiative transfer equation. While there are good numerical solvers for both kinetic and fluid equations, it is not quite well-understood when the two regimes co-exist. In this talk, we model the layer between the fluid and the kinetic using a half-space equation, study the well-posedness, design a numerical solver, and utilize it to couple the two sets of equations that govern separate domains.

Tom Lubensky University of Pennsylvania

"Effective Medium Theory for Rigidity Percolation and Jamming Transitions"

Effective Medium theory (EMT) has proven to be a powerful tool for the study of properties of random electronic and elastic media. Though it does not provide (except in some cases) accurate predictions of critical exponents, it does provide detailed and often sophisticated predictions of qualitative behavior, including crossover functions near mechanical critical points. This talk will review some recent results for rigidity percolation transitions principally in filamentous networks stabilized by bending forces. An often noted weakness of EMT treatment is that it generally predicts rigidity transitions in which the bulk and shear moduli grow continuously from zero above the transition rather than jamming-like transitions in which the bulk modulus jumps discontinuously while the shear modulus grows continuously from zero at the transition. The EMT and numerical simulations of a model system consisting of a honeycomb lattice decorated with next-nearest neighbor bonds yields a Jamming-like critical point terminating a line of rigidity percolation transitions.

Xiaoming Mao University of Michigan

"How does rigidity emerge and disappear in low density soft matter?"

Rigidity is a central theme in soft matter as it controls how materials deform and flow under stress. Due to their complicated, disordered structures, characterizing rigidity of soft materials poses a grand challenge for theory. Classical theories of rigidity percolation and jamming are wonderful examples of understanding rigidity in disordered soft matter. However, new questions arise when we examine rigidity in more varieties of soft matter: Why colloidal gels have rigidity at volume fractions far below classical thresholds for rigidity? When low density soft materials fail under stress do they behave differently from crystals? We will discuss these questions in this talk, introduce mathematical frameworks for understanding rigidity, and explore scenarios where we can we use what we learn to control how soft matter solidify and flow.

Rossana Marra University of Rome "Tor Vergata"

"Stationary solutions to the Boltzmann equation in the hydrodynamic limit"

The stationary solutions to the Bolzmann equation, despite their relevance in applications, are much less studied than the initial value problem and no general existence theory is yet available.

When suitable external forces or boundary conditions are included, interesting non equilibrium solutions arise. The main subject of the talk is the study of stationary solutions of the Boltzmann equations, for small Knudsen number, in a general domain in contact with a non-homogeneous thermal reservoir. We are able to answer to the longstanding open problem of the rigorous derivation of the steady incompressible Navier-Stokes-Fourier system from the Boltzmann theory, in the presence of a small external field and a small boundary temperature variation for the diffuse boundary condition. Indeed, by using a new L^2-L^∞ approach and new regularity-gain procedure (a new L^6 estimate), we prove that, near the global equilibrium, there is a unique positive solution to the stationary Boltzmann equation converging to the stationary solution to the incompressible Navier-Stokes-Fourier system. Moreover the solution is exponentially stable for small initial perturbations.

Jeff Morris CUNY City College of New York

"Force Network Analysis in Shear-thickening Suspensions"

Computation simulations inclusive of lubrication hydrodynamics, repulsive forces and contact with friction have been shown to reproduce the primary features found in experimental studies of abrupt shear thickening of dense suspensions. Here, we consider the force network development in this phenomenon, focusing on the behavior of systems at the boundary between continuous (CST) and discontinuous shear thickening (DST). The suspension rheology displays behavior analogous to phase transition, with the control variables being the volume fraction and shear rate. For solid fraction below the critical value (~ 0.55), the suspension exhibits CST, with a finite rate of viscosity increase as shear rate increases. At the critical volume fraction, as the shear rate is increased, the system reaches a critical point at which the viscosity (or stress) has infinite slope, but remains continuous (as would the density at a gas-liquid critical point) and at which the stress fluctuations simultaneously grow. The underlying basis for this behavior in terms of the force network is analyzed by various measures: contact number, percolation, and k-core analyses will be related to the stress response of the material.

Sidney Nagel University of Chicago

"Memory, directed aging and Nature's greed"

In a crystal with only one atom per unit cell, all atoms play the same role in producing the solid's global response to external perturbations. Disordered materials are not similarly constrained and a new principle emerges: independence of bond-level response. This allows one to drive the system to different regimes of behavior by successively removing individual bonds. We can thus exploit disorder to achieve unique, varied, textured and tunable global response or long-range interactions inspired by allosteric behavior in proteins. While this approach is successful for systems with only a few degrees of freedom, it is difficult to scale up the number of elements to be controlled or scale down the size of the individual components. However, because a material has a memory of under what conditions it has been aged, we can direct the aging using Nature's greedy algorithms to achieve a variety of mechanical functionalities.

Corey O'Hern Yale University

"Origin of the Jamming Scaling Exponents"

The mechanical response of packings of purely repulsive, spherical particles to athermal, quasistatic simple shear near jamming onset is highly nonlinear. Previous studies have shown that, at small pressure p, the ensemble-averaged static shear modulus $\langle G-G_0 \rangle$ scales with p^α, where $\alpha \approx 1$, but above a characteristic pressure p^{**}, $\langle G-G_0 \rangle \sim p^\beta$, where $\beta \approx 0.5$. However, we find that the shear modulus G^i for an individual packing typically decreases linearly with p along a geometrical family where the contact network does not change. We resolve this discrepancy by showing that, while the shear modulus decreases linearly within geometrical families, $\langle G \rangle$ also depends on a contribution from discontinuous changes that occur at transitions between geometrical families. For $p > p^{**}$, geometrical-family and rearrangement contributions to
$\langle G \rangle$ have opposite signs and remain comparable for all system sizes. $\langle G \rangle$ can be described by a scaling function that smoothly transitions between the two power-law exponents α and β. We also demonstrate the phenomenon of compression unjamming, where a jammed packing can unjam via isotropic compression.

Charles Radin University of Texas

"Compacting sand by cyclic shear"

If bulk sand is gently sheared cyclically over many cycles the grains eventually rearrange into a dense bulk crystal (mixed fcc/hcp), independent of effects of the container boundary. We found this in the lab last year (Rietz, Radin, Swinney, Schroeter: PRL 2018) and the current work explores this in simulation (Jin, O'Hern, Radin, Shattuck, Swinney).

Kui Ren Columbia University

"Unique determination of coefficients in a semilinear transport equation"

We study an inverse problem in quantitative photoacoustics where we intend to reconstruct the absorption coefficients in a semilinear radiative transport equation. We show that with a finite number of data sets, uniqueness and stability of the inversion can be established in the absence of scattering and in the presence of known isotropic scattering. With data encoded in the full albedo operator, uniqueness and stability can be derived in the case of anisotropic scattering. This is a joint work with Yimin Zhong (UC Irvine).

Sumantra Sarkar Los Alamos

"Multiscale simulation of protein-protein interaction"

Cells use a limited number of mutually interacting protein-protein interaction networks, called cell-signalling network to communicate with each other. The protein components of these signalling networks have been identified and their individual functions understood. However, how they interact with each other to produce a functional cell-signalling network is relatively poorly understood. An important cell signalling network involved in the growth and proliferation of cells is the MAPK pathway, which is activated through the formation of phosphorylated Ras-Raf protein complex. The formation of this complex at biologically relevant concentrations span multiple timescales, rendering traditional theoretical and experimental tools inadequate to study this problem in its entirety. Using recently developed accelerated simulation techniques, we have been able to overcome this barrier and have studied Ras-Raf interaction in biologically relevant concentrations and timescales. In this talk, I shall present new aspects of Ras-Raf kinetics revealed through these simulations and discuss their potential biological implications.

Jen Schwarz Syracuse University

"Biology across scales: From cerebellar shape to the correlated motion of chromatin"

As quantification of the spatial and dynamical structure of living systems continues at a rapid pace, models can be more readily interrogated to the point of needing minor, or even major, revision in order to account for the incoming data. Two examples of revised modeling at different biological scales are presented here, the first being the onset of shape change in the developing cerebellum, the second being the correlated motion of chromatin in a cell's nucleus. In the first example, the recent quantification of the thickness variations in the cerebellar cortex as the cerebellum develops demonstrates that the conventional elastic bilayer wrinkling model is not sufficient to characterize the shape change and so a new "buckling without bending" model with both elastic and fluid-like components is presented. In the second example, a number of large chromatin domains are found to be in close contact with nuclear lamina and so the effect of such lamin-associated domains on the correlated motion of chromatin is presented.

Robert Strain University of Pennsylvania

"Global mild solutions of the Landau and non-cutoff Boltzmann equation"

This paper proves the existence of small-amplitude global-in-time unique mild solutions to both the Landau equation including the Coulomb potential and the Boltzmann equation without angular cutoff. Since the well-known works (Guo, 2002) and (Gressman-Strain-2011, AMUXY-2012) on the construction of classical solutions in smooth Sobolev spaces which in particular are regular in the spatial

variables, has still remained an open problem to obtain global solutions in an $L^{\infty}_{x,v}$ framework, similar to that in (Guo-2010), for the Boltzmann equation with cutoff
in general bounded domains. One main difficulty arises from the interaction between the transport operator and the velocity- diffusion-type collision operator in the non-cutoff Boltzmann and Landau equations; another major difficulty is the potential formation of singularities for solutions to the boundary value problem. In this work we introduce a new function space with low regularity in the spatial variable to treat the problem in cases when the spatial domain is either a torus, or a finite channel with boundary. For the latter case, either the inflow boundary condition or the specular reflection boundary condition is considered. An important property of the function space is that the $L^{\infty}_{T}L^{2}_{v}$ norm, in velocity and time, of the distribution function is in the Wiener algebra $A(\Omega)$ in the spatial variables. Besides the construction of global solutions in these function spaces, we additionally study the large-time behavior of solutions for both hard and soft potentials, and we further justify the property of propagation of regularity of solutions in the spatial variables. To the best of our knowledge these results may be the first ones to provide an elementary understanding of the existence theories for the Landau or non-cuto
Boltzmann equations in the situation where the spatial domain has a physical boundary.
This is a joint work with Renjun Duan (The Chinese University of Hong Kong), Shuangqian Liu (Jinan University) and Shota Sakamoto (Tohoku University).
2010 Mathematics Subject Classifcation. Primary: 82D10, 35Q70, 35Q75, 35B45, 35A02, 35Q70, 35A02.
Key words and phrases. Kinetic Theory, Mild regularity, Landau equation, Boltzmann equation, Non-Cut-Off, Uniqueness, Global solutions.

Alison Sweeney University of Pennsylvania

“The Evolution of Equilibrium: thermodynamic pattern formation outside of living cells”

Implicitly, the project of biomaterials and biomimetics considers structures in the topologically extracellular space of organisms: beetle carapace, feathers, butterfly wings, and wood are all extracellular materials. Our work seeks to make this implicit assumption explicit, and understand the material pattern formation that imbues function in these materials via equilibrium thermodynamic theories. This talk will look at two pattern-forming biomaterial systems, plant pollen and squid lenses, in which the relevant pattern and function emerges from equilibration of biological components in the extracellular space. Squid lenses have evolved to explore the patchy particle phase diagram, while pollen patterns form from a phase transition modulated by membrane elasticity. Quantifying the evolution of these systems can provide further insight into molecular function, which can in turn inform efforts to realize these principles in engineered systems.

Maja Taskovic University of Pennsylvania

“On the relativistic Landau equation”

In kinetic theory, a large system of particles is described by the particle density function. The Landau equation, derived by Landau in 1936, is one such example. It models a dilute hot plasma with fast moving particles that interact via Coulomb interactions. This model does not include the effects of Einstein’s theory of special relativity. However, when particle velocities are close to the speed of light, which happens frequently in a hot plasma, then relativistic effects become important. These effects are captured by the relativistic Landau equation, which was derived by Budker and Beliaev in 1956.
We study the Cauchy problem for the spatially homogeneous relativistic Landau equation with Coulomb interactions. The difficulty of the problem lies in the extreme complexity of the kernel in the relativistic collision operator. We present a new decomposition of such kernel. This is then used to prove the global Entropy dissipation estimate, the propagation of any polynomial moment for a weak solution, and the existence of a true weak solution for a large class of initial data. This is joint work with Robert M. Strain.

Vincenzo Vitelli University of Chicago

“Dualities and Non-Abelian Mechanics”

Dualities are mathematical mappings that reveal links between apparently unrelated systems in virtually every branch of physics. Systems mapped onto themselves by a duality transformation are called self-dual and exhibit remarkable properties, as exemplified by the scale invariance of an Ising magnet at the critical point. In this talk, we show how dualities can enhance the symmetries of a dynamical matrix (or Hamiltonian), enabling the design of metamaterials with emergent properties that escape a standard group theory analysis. As an illustration, we consider twisted Kagome lattices, reconfigurable mechanical structures that change shape via a collapse mechanism. Pairs of distinct configurations along the mechanism exhibit the same vibrational spectrum and related elastic moduli. We show that these puzzling properties arise from a duality between pairs of configurations on either side of a mechanical critical point. The normal modes of the self-dual system exhibit non-Abelian geometric phases that affect the semi-classical propagation of wave packets, leading to non-commuting mechanical responses. Our results hold promise for holonomic computation and mechanical spintronics by allowing on-the-fly manipulation of synthetic spins carried by phonons.

David Weitz Harvard University

“Watching and listening to fracture”

This talk will report very high-speed imaging of fracture induced by fluid, combined with acoustic measurements to probe the nature of the fracture. The velocity of the fracture initially moves near the speed of sound, much faster than the fluid. Later the fracture advances more slowly, but typically leads the fluid. Complimentary measurements of the strain in the solid are performed with a new optical measurement technique, Dynamic Speckle Holography, which will also be described.

Lai-Sang Young New York University

“Dynamical systems, statistical mechanics and a model of the brain”

The cerebral cortex is a thin layer of neural tissue in the mammalian brain. It plays key roles in sensory processing, thought, memory, and other conscious behaviors. In this talk, I would like to propose a mathematical idealization of a part of the cerebral cortex, depicting it as a structured network of interacting neurons. It is an attempt to conceptualize cortical dynamics, and to do so in a way that is consistent with neuroanatomy and physiology. Local circuits will be studied as dynamical systems, while individual layers of different cortical areas will be treated borrowing ideas from nonequilibrium statistical mechanics. A biologically-constrained, computational model of the monkey visual cortex will be used to illustrate activity across the cortical surface as cortex responds in real time to certain visual stimuli.