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# Abstracts (v. Feb. 4, 2015)

## Speakers

**Paulo Arratia**, University of Pennsylvania
Title: Yielding, Plasticity, and Microstructure in a 2D Jammed Material under Shear Deformation

Abstract: In this talk, I will discuss an experimental investigation on the yielding and plastic deformation of disordered solids. Experiments are performed on colloidal particles that are adsorbed at an oil-water interface and form a dense disordered monolayer. The rheological properties (G', G") of this dense monolayer are obtained in a custom-built interfacial stress rheometer that uses a magnetic needle within the material. This configuration allows for the simultaneous characterization of both microstructure (tracking ~105 particles) and bulk rheology. Results show that for oscillatory shear below a certain strain amplitude, the microstructure becomes reversible after a transient. Above this strain amplitude, the microstructure continues to evolve through many irreversible events. We argue that this boundary between a reversible and irreversible steady state is a yielding transition, and that our experiments measure a meaningful yield stress. Further, we find that reversible plastic deformation is possible. That is, the material can reorganize itself so that the link between plasticity and irreversibility is broken: the material flows slightly, and yet at the end of each deformation cycle, it is exactly unchanged.

**Jorg Baschnagel**, Institut Charles Sadron
Title: Shear modulus of simulated glass-forming systems

Abstract: The static shear modulus G can be thought of as an order parameter distinguishing the liquid (G=0) from the glass (solid, G>0). There has been recent interest in determining the temperature (T) dependence of G when approaching the glass transition temperature ($T_g$) from below. Here we present simulation results for G(T) for binary glass-forming liquids in 2 and 3 dimensions. We compare various approaches, employed in the literature, to calculate G(T), such as the (equilibrium) stress-fluctuation formalism and non-equilibrium methods determining the response of the glass to an externally imposed stress or strain. Our results indicate that G(T) vanishes continuously as Tg is approached from below, and we can understand this behavior from the interplay of affine and nonaffine particle displacements. This is, however, in contrast to other works, suggesting that G jumps discontinuously at $T_g$. In some of these studies, G is identified with the plateau found at intermediate times for the shear-stress autocorrelation function [C(t)] in the canonical ensemble. It could be that this difference is related to the ensemble (constant strain versus constant stress) in which C(t) is determined. Some support for this speculation comes simulations for a network system with permanent crosslinks.

**Robert Behringer**, Duke University
Title: Jamming of frictional grains

Abstract: This talk will focus on the properties of frictional granular materials near jamming. We have shown that frictional systems differ from their frictionless counterparts in that they exhibit jammed, fragile, and unjammed states, all at the same packing friction. We generate the jammed states by applying shear strain to unjammed packings for densities that lie below the lowest packing fraction for which there is an isotropic jammed state. Although we achieve these shear jammed states by applying a particular protocol, consisting of shear strain, the resultant states are well characterized by several system-wide parameters, including pressure, shear stress, non-rattler fraction. This talk will explore the role of friction, the nature of relevant order parameters, properties of the force networks, and the nature of fluctuations.

**Ludovic Berthier**, Université de Montpellier & CNRS
Title: Nonequilibrium phase transitions and glassy dynamics in active and deformable particle systems

Abstract: We discuss how a variety of nonequilibrium driving forces introduced by natural biological activity or by a physical self-propulsion or self-deformation mechanisms generically affect the structure, dynamics and phase behavior of dense particle systems. We use theory and computer simulations to analyse simple models of such active materials, and explore connections with experimental studies of active and driven colloidal systems, biological tissues, or bacterial colonies.

**Jasna Brujic**, New York University
Title: Glassy physics in proteins, lipids and emulsion droplets

Abstract: TBA

**Chiara Cammarota**, Sapienza University of Rome
Title: Relaxation-path selection due to entropy-energy competition in activated glassy dynamics

Abstract: The description of activated relaxation of glassy systems in the multi-dimensional configurational space is a long-standing open problem. I this talk I will report on my recent numerical and analytical studies of the equilibrium and out-of equilibrium dynamics of a number of models with rough potential energy landscapes. These models range from abstract trap models to the Random Energy Model (REM) (a paradigm for glass phenomenology) providing examples of dynamics where typical relaxation channels go over finite potential energy barriers despite the presence of less-energy-demanding escaping paths in configurational space; this phenomenon is naturally expected to be relevant in the thermally activated regime of realistic models of glass-formers. I will show that in the systems we studied typical dynamical paths episodically reach a high fixed threshold energy unexpectedly giving rise to a simple thermally activated aging phenomenology. In order to unveil this peculiar aging behaviour I will introduce a novel description of the dynamics in terms of spontaneously emerging dynamical basins. This result establishes the first quantitative connection between aging in simple and fully solvable thermally-activated systems like trap models and the observed more complex dynamics that could characterise out-of-equilibrium relaxation in realistic glass-like systems.

**Bulbul Chakraborty**, Brandeis University
Title: Shear Induced Jamming

Abstract: Solids are distinguished from fluids by their ability to resist shear. In traditional solids, the resistance to shear is associated with the emergence of broken translational symmetry as exhibited by a nonuniform density pattern. In this work, we focus on the emergence of shear rigidity in a class of solids where this

paradigm is challenged. Dry granular materials have no energetically or entropically preferred density modulations. We show that, in contrast to traditional solids, the emergence of shear rigidity in these granular solids is a collective process, which is controlled solely by boundary forces, the constraints of force and torque balance, and the positivity of the contact forces. We develop a theoretical framework based on these constraints, which connects rigidity to broken translational symmetry in the space of forces, not positions of grains. We apply our theory to experimentally generated shear-jammed states and show that these states are indeed characterized by a persistent, non-uniform density modulation in force space, which emerges at the shear-jamming transition.

**Eric Corwin**, University of Oregon
Title: Jamming shapes up: geometry and energy landscape near the jamming transition

Abstract: We examine both the real space and phase space geometry of packings below and above the jamming transition in GPU optimized simulations. Using geometric quantities derived from the Voronoi tessellation we report on a number of new geometric order parameters for jamming as well as the discovery of a new phase transition preceding the mechanical jamming transition. This phase transition corresponds to the appearance of a new kind of symmetry hidden in the shape of the Voronoi cells. We offer several possible routes towards renormalization of this system and discuss whether a field theory could be made to explain the various phases. We further explore the geometry of the very high dimensional phase space associated with a packing and report on direct measurements of the fractal nature of the energy landscape.

**Daniele Coslovich**, Université de Montpellier
Title: Local structure and dynamic heterogeneity: do they correlate?

Abstract: The dynamics of glass-forming liquids is heterogeneous and displays growing spatial correlations upon cooling. Whether such behavior arises from heterogeneities in local structure or more complex forms of amorphous order is a highly debated question. To clarify this issue, we study several model liquids within a coherent simulation framework based on the iso-configurational ensemble. We find that the correlation between the preferred local structure and dynamic heterogeneity is strongly system dependent. The correlation is pronounced in systems that deviate markedly from the mean-field picture of glassy dynamics and weak in models that adhere to it to a good extent. In the model that adheres best to the mean-field paradigm, namely a dense fluid of Gaussian particles, than nature of dynamic heterogeneity differs strikingly from the other liquids: on approaching the mode Coupling critical temperature the fluid develops giant dynamic fluctuations accompanied by nearly Gaussian single-particle dynamics. The observed differences between the models are qualitatively explained in terms of their potential energy landscapes.

**Pablo Damasceno**, University of Michigan
Title: Directional Entropic Forces in Hard Particle Fluids and Crystals

Abstract: One of the simplest classes of glass forming systems is hard particles. Hard particle systems are simple because their behavior is driven by entropy alone. However, the entropy driven behaviors that hard particles manifest may not be simple, and a number of recent investigations have confirmed that hard particles have rich phase behavior. Here, using systems of anisotropic hard shapes, we argue that this phase behavior is driven by directional entropic forces that cause particles to arrange themselves into local dense packing configurations in dense fluids and crystals.

**Karen Daniels**, North Carolina State University
Title: Temperature-like variables in granular materials

Abstract: Statistical mechanics has provided a powerful tool for understanding the thermodynamics of materials. Because granular materials exhibit reproducible statistical distributions which depend in simple ways on macroscopic parameters such as volume and pressure, it is tempting to create a statistical mechanics of athermal materials. I will describe a suite of experiments on two-dimensional granular materials which investigate to what extent these ideas are meaningful. For example, under agitated conditions, we measure both bulk and particle-scale dynamics, and find a number of thermal-like behaviors including diffusive dynamics, a granular Boyle's Law with a van der Waals-like equation of state, and energy equipartition for rotational and translational degrees of freedom. However, the scarcity of free volume within a granular material provides a crucial control on the dynamics, and each of the above thermal-like behaviors is accompanied by interesting caveats. In an apparatus designed to generate a large number of static configurations, we test whether or not various temperature-like variables are able to equilibrate between a subsystem and a bath. We find that while a volume-based temperature known as "compactivity" fails to equilibrate, a stress-based temperature succeeds. This points to the importance of interparticle forces in controlling the mechanics of granular materials.

**Emanuela del Gado**, Georgetown University
Title: Internal stresses, cooperative processes and yielding in poorly connected soft solids

Abstract: Colloidal gel networks are disordered elastic solids that can form even in extremely dilute particle suspensions. With interaction strengths comparable to the thermal energy, their stress-bearing network can locally restructure via breaking and reforming interparticle bonds. This allows for yielding, self-healing, and adaptive mechanics under deformation. Designing such features requires controlling stress transmission through the complex structure of the gel and this is challenging because the link between local restructuring and overall response of the network is still missing. Based on numerical simulations of a minimal model, I will discuss how cooperative dynamics emerge from the mesoscale organization of the gel network and how localisation of stresses and deformations may eventually lead to the material failure.

**Vladimir Dobrosavljevic**, Florida State University
Title: Self-generated stripe glass in frustrated Mott organics

Abstract: Glassy behavior in electronic systems is typically associated with disorder effects, but very recent experiments in quarter-filled Mott organic systems demonstrated self-generated glassy freezing of electrons in absence of disorder. Here we show that interplay of geometric frustration (triangular lattices) and the effects of long-range Coulomb interactions contributes to the emergence of many metastable electron configuration, leading to the formation of a self-generated stripe glass. Results were obtained both using large scale Monte-Carlo simulations and analytical methods based on generalized Parisi-Simpolinsky approaches to glassiness.

**Douglas Durian**, University of Pennsylvania
Title: The granular clogging transition

Abstract: The flow of grains from a hopper can be suddenly arrested by formation of a stable arch or dome over the outlet, which is trouble for applications. This problem is related to jamming, but is distinct due to presence of boundaries and gradients. We argue how the fraction F of clogged configurations may be deduced from the average mass discharged between clogs. And we construct a simple model to account for the observation that F decays exponentially in hole width to the power of dimensionality. Contrary to much

recent work, we thus conclude that the clogging transition is not sharp but rather is defined by observation limits similar to the glass transition.

**Jeppe Dyre**, Roskilde University
Title: Why simple liquids are quasi-universal

Abstract: It has been known for a long time that many simple liquids have surprisingly similar structure as quantified, e.g., by the radial distribution function. A much more recent realization is that the dynamics are also very similar for a number of systems with quite different pair potentials. Systems with such non-trivial similarities are generally referred to as “quasi-universal". From the fact that the exponentially repulsive pair potential has strong virial potential-energy correlations in the low-temperature part of its thermodynamic phase diagram, we here show that a liquid is quasi-universal if its pair potential can be written approximately as a sum of exponential terms with large prefactors. Based on evidence from the literature we moreover conjecture the converse, i.e., that quasi-universality only applies for systems with this property.

**Michael Falk**, Johns Hopkins University
Title: Combined Atomistic/Continuum Modeling of Strain Localization in Metallic Glass

Abstract: The modeling of metallic glass mechanical response, including the prediction of failure, requires the establishment of numerically tractable continuum descriptions of viscoplasticity that incorporate relevant atomistic mechanisms and can be parameterized to metallic glass microstructure. Here we deploy the shear transformation zone (STZ) theory to make quantitative predictions of deformation and failure processes in amorphous solids. This is done in the context of a thermodynamic theory wherein the local disorder is quantified in terms of an effective temperature. Molecular dynamics (MD) simulation is used to parameterize the model. A highly optimized fully Eulerian implementation of the STZ theory is implemented to investigate monolithic metallic glasses and metallic glass crystal composite materials subjected to very large strains, such as those that arise in failure processes such as strain localization. We then perform cross-comparisons between continuum theory and MD predictions using structural parameters that can be independently measured in MD. The onset of failure depends sensitively on the coarse-grained stochastic field that represents the structural inhomogeneity, the details of which determine the mechanical response as well as the onset of instabilities. The properties of this stochastic field are further studied to provide insights into the structure of amorphous solids.

**Silvio Franz**, Université Paris-Sud
Title: The simplest model of jamming

Abstract: I will present a well known machine learning model -the perceptron- as a simple solvable model of jamming of hard objects. There are two regimes: i) a convex optimisation regime where jamming is hypostatic and non-critical; ii) a non convex optimisation regime where jamming is isostatic and critical. The critical jamming phase can be characterized through exponents describing the distributions law of forces and gaps. Surprisingly these exponents coincide with the corresponding ones recently computed in high-dimensional hard spheres. In addition, modifying the perceptron to a random linear programming problem, I will show that isostaticity is not a sufficient condition for singular force and gap distributions. For that, fragmentation of the space of solutions (replica symmetry breaking) appears to be a crucial ingredient. One can hypothesise universality for a large class of non-convex constrained satisfaction problems with continuous variables.

**Frances Hellman**, University of California, Berkeley
Title: Ideality and tunneling level systems in covalently bonded thin film glasses

Abstract: Heat capacity, sound velocity, and internal friction of covalently bonded amorphous Si (a-Si) films with and without hydrogen show that low energy excitations commonly called tunneling or two level systems (TLS) can be tuned over 3 decades, from below detectable limits to the range commonly seen in glassy systems. This tuning is accomplished by growth temperature, thickness, light soaking or annealing, but is remarkably independent of hydrogen content. The lowest TLS films are grown at temperatures near 0.8 of the theoretical Tg, reminiscent of recent work on polymer films and suggestive that vapor deposition produces materials close to an ideal glass. A strong correlation with atomic density in a-Si and in analysis of other glasses in the literature suggests that TLS arise from low density regions. The TLS measured by heat capacity and internal friction are strongly correlated for pure a-Si, but not for hydrogenated a-Si, suggesting that the standard TLS model works for a-Si, but that a-Si:H possess TLS that are decoupled from the acoustic waves measured by internal friction. Additionally, a strong correlation is found between an excess T3 term (well above Debye contribution) and the linear term in heat capacity, suggesting a common origin not previously discussed.

**Rob Hoy**, University of South Florida
Title: Effect of chain stiffness on the competition between crystallization and glass-formation in model polymers

Abstract: TBA

**Yoav Kallus**, Santa Fe Institute
Title: Random packing lattices

Abstract: Bravais lattices provide a uniquely accessible entrée into high-dimensional sphere packing. For centuries mathematicians have used them to obtain results about optimal packing in high dimensions. Now that high dimensions have become relevant in glass physics, we use lattice ensembles to obtain surprising results in dimensions significantly above those accessible with amorphous fluids.

**John Kieffer**, University of Michigan
Title: Network structural evolution and glass formation

Abstract: We employ a combined computational and experimental approach, including reactive MD simulations and concurrent Brillouin and Raman light scattering, to elucidate the structure and properties of glass-forming systems. In particular, Brillouin scattering allows us to measure the complex mechanical modulus of materials in situ during glass formation at GHz frequencies, either as a result of cooling systems from the liquid state or due continued cross-linking reactions in thermoset polymer materials. Raman scattering serves to monitor chemical changes, and using MD simulations we generate structural models we explore to interpret the experimental observations. All three techniques of investigation allow us to probe processes within overlapping frequency ranges. Indeed, high frequencies provide unique insights into the dynamic response of network structures, such as the ability to measure the adiabatic moduli and the fact that when probed at high frequencies the loss peaks associated with individual relaxation mechanisms are more widely dispersed on the temperature scale, and thus more easily identifiable. Here we contrast the behavior of inorganic and organic network forming systems, and discuss evidence for transitions between distinct amorphous states in oxides as well as a peculiar type of post cure relaxation in epoxy resulting in the enhancement of non-bonding interactions.

**Daphne Klotsa**, University of Cambridge
Title: Packing polyhedra: from ancient math to advanced materials

Abstract: Nanoparticles and colloids of various polyhedral shapes are synthesized and used as building blocks for self-assembly. It has been shown in simulations that a plethora of complex crystals and quasicrystals can form entropically solely due to the anisotropic shape of the particles. At the limit of maximum density, the densest packings, as have been studied in math for centuries, becomes the relevant quantity. However, a general understanding of how changes in shape affect packings and assemblies remains largely unexplored. Here, we study continuous families of polyhedra to demonstrate richness and complexity in behavior as a function of shape. We investigate connections between assemblies and densest packings, discuss the possibility of predicting one from the other and outline general guidelines for experiments.

**Seung-Hun Lee**, University of Virginia
Title: Spin jam in a frustrated magnet

Abstract: Can a glassy state exist in the absence of defects? This long-standing problem in condensed matter physics will be addressed in this talk by discussing glassy states found in frustrated magnets. Of particular interest is a quasi-two-dimensional triangular lattice of bi-pyramids. Recently, we found that although classically the ground state of the system is a spin liquid, quantum corrections break the classical degeneracy into a set of aperiodic spin configurations forming local minima in a rugged energy landscape. A consequence of the complex energy landscape is, upon cooling, the system gets trapped in one of the local minima, leading to a glassy state that we call a spin jam. More recently, we have performed systematic neutron scattering experiments on $SrCr_{9p}Ga_{12-9p}O_{19}$ (SCGO(p)) with various values of the magnetic concentration, p, covering almost the entire region of p. Our results clearly revealed existence of a unique spin jam state in the vicinity of the clean limit p=1.

**Ludwik Leibler**, ESPCI
Title: TBA

Abstract: TBA

**Vassiliy Lubchenko**, University of Houston
Title: Quantitative Theory of the Structural Glass Transition

Abstract: Recent results on quantitative, first-principles estimates of alpha-relaxation barriers, glass transition temperatures, and cooperativity lengths in actual substances will be reported. We establish an intrinsic relation between the magnitude of free energy fluctuations in glassy liquids and the activated barrier for alpha-relaxation. A simple, universal expression for the barrier emerges in which the molecular detail enters through the bulk modulus and the configurational entropy. A simple view of a glassy liquid as a locally metastable, degenerate pattern of frozen-in stress emerges in the present description.

**Hernan Makse**, City College of New York
Title: Unifying statistical mechanics framework for packings: from spherical to non-spherical particles with adhesion, friction and for any dimension

Abstract: Random packings of objects of a particular shape are ubiquitous in science and engineering. However, such jammed matter states have eluded systematic theoretical treatments due to the strong positional and orientational correlations involved. In recent years progress on a fundamental description of

jammed matter could be made by starting from a constant volume ensemble in the spirit of conventional statistical mechanics. Recent work has shown that this approach, first introduced by S. F. Edwards more than two decades ago, can be cast into a predictive framework to calculate the packing fractions of both spherical and nonspherical hard particles, with or without adhesion and friction, and for any dimension. Furthermore, cavity methods from spin glass theory can now be adapted to the calculation of important jammed variables such as force distributions, coordination numbers, yield stresses and vibrational density of states for all the above mentioned systems, providing unifications between glasses and jammed matter.

**M. Lisa Manning**, Syracuse University
Title: Using random matrices to define the boson peak in disordered solids

Abstract: A wide range of disordered solids, including glasses, polymers, and granular solids exhibit a so-called “boson peak” in their vibrational spectra. The origin of the boson peak is still debated, and even its definition - an excess of modes above the Debye prediction - is a bit fuzzy. Recent work to characterize the vibrational eigenvectors of disordered solids revealed that that eigenvector statistics of modes in the boson peak are nearly identical, and numerical results demonstrate that this universal distribution is common to a large class of dense random matrices. This indicates that any random matrix that satisfies a minimal set of requirements possesses a boson peak, and suggests that random matrix eigenvector statistics provide a more robust and illuminating definition of the boson peak. Additionally, sparse random matrices diverge from the universal distribution as the coordination number approaches a dimension-dependent critical value; these matrices precisely capture the scaling of the boson peak frequency as a material approaches a rigidity transition.

**Xiaoming Mao**, University of Michigan
Title: Mechanical instabilities at finite temperature

Abstract: Mechanical instability is an important concept in the study of glass transitions because it describes the point where the solid state loses its stability. The isostatic point, where the number of degrees of freedom and the number of constraints become equal, has been shown to be crucial in understanding many aspects of mechanical instability. In this talk I will discuss how fluctuations change what we know about the isostatic point. I will present our recent theoretical developments on fluctuation effects near isostaticity in a simple square lattice model, which exhibits a continuous transition at T=0 from one ground state to exponentially many ground states. We show that interestingly, at finite temperature, because of the sub-extensive number of floppy modes at the isostatic point, this transition is driven to be a first-order transition, sharing intriguing similarities with Brazovskii’s theory on finite wavelength instability which has been applied to understand pattern formation problems.

**John Mauro**, Corning, Inc.
Title: Statistical Modeling of Glass in Industry

Abstract: In this presentation, I review several practical uses of statistical mechanical modeling of glass in industrial research. Topics will include energy landscape theory, topological constraint theory, and relaxation behavior. Use of statistical modeling now enables the design of new glass compositions starting from fundamental physical considerations.

**Scott Milner**, Pennsylvania State University
Title: T1 Process and Dynamics in Glass-Forming Hard-sphere Liquids

Abstract: To study the relationship between dynamics and structure in a glass-forming liquid, we introduce a purely geometric criterion for locally mobile particles in a dense hard-sphere fluid: namely, “T1-active” particles, which can gain or lose at least one Voronoi neighbor by moving within their free volume with other particles fixed. We obtain geometrical and dynamical properties for monodisperse hard-sphere fluids using a new “crystal-avoiding” MD simulation that effectively suppresses crystallization without altering the dynamics. We find that the fraction of T1-active particles vanishes at random close packing, while the percolation threshold of T1-inactive particles is essentially identical to the commonly identified hard-sphere glass transition

**Kunimasa Miyazaki**, Nagoya University
Title: Thermodynamic glass transition of randomly pinned systems

Abstract: TBA

**Michael Moore**, University of Manchester
Title: Learning about glasses from studies of disks in a narrow channel

Abstract: Disks in narrow channels have many features in their static and dynamical properties which mimic those of three dimensional glasses. However, their equilibrium properties can be determined exactly from transfer matrix calculations. We have studied their dynamical properties via event driven molecular dynamics simulations. Their glassy behavior can be related to structural ordering in this system.

**Arvind Murugan**, Harvard University
Title: Associative Memory in Materials

Abstract: Associative memory in neural networks have been studied for over 30 years as a way to program a frustrated spin network with multiple stable states. Such stable states are interpreted as “memories” which can be robustly retrieved without interference from other stored memories. We show that a diverse range of synthesis methods in materials science can be modified to produce materials with associative memory; such materials can be programmed to have multiple stable behaviors, each of which can be specifically elicited by external signals. For example, we show that a set of particles can be induced to self-assemble into one of many different structures by using different seeds. We show analogous multistable behavior in polymer folding and in the folding of membranes (origami). We argue that these are just the first of many responsive multipotent materials that can be designed using mathematical analogies with frustrated spin networks.

**Corey O’Hern**, Yale University
Title: Using Hard-sphere Models to Design Bulk Metallic Glasses

Abstract: We perform molecular dynamics simulations to compress binary hard spheres into jammed packings as a function of the compression rate, size ratio, and number fraction of small particles to determine the connection between the glass-forming ability (GFA) and packing efficiency in bulk metallic glasses (BMGs). We define the GFA by measuring the critical compression rate Rc, below which jammed hard-sphere packings begin to form “random crystal” structures with defects. We find that for systems with size ratios greater than 0.8 that do not de-mix, Rc decreases strongly with $\Delta\phi_J$, where $\Delta\phi_J$ is the difference between the average packing fraction of the amorphous packings and random crystal structures at Rc. Systems with size ratios less than 0.8 partially de-mix, which promotes crystallization, but we still find a strong correlation between Rc and $\Delta\phi_J$. We show that known metal-metal BMGs occur in the regions of parameter space with the lowest values of Rc for binary hard spheres. Our results emphasize that maximizing GFA in binary systems involves two competing effects: minimizing the size ratio to increase packing efficiency, while maximizing the size ratio to prevent demixing.

**Carlos Ortiz,** University of Pennsylvania
Title: Creep and Dynamical Heterogeneities of Fluid-Driven Granular Flows

Abstract: TBA

**Massimo Pica Ciamarra**, Nanyang Technological University
Title: Cage-jump motion and macroscopic dynamics in glass formers

Abstract: Glass formers have a sluggish and heterogeneous dynamics characterized by a single particle intermittent motion, as particles rarely succeed jumping out of the cages formed by their neighbours. Here I describe how the single particle intermittent motion is related to the macroscopic dynamics. First I present numerical results on different glass forming systems, and experimental results on hard-spheres, showing that jumps are irreversible events. This allows to predict the long time diffusion constant from properties of the cage-jump motion evaluated on a time of the order of the ballistic one, and thus to relate the short and the long time dynamics. Then I rationalize the relaxation process and the emergence of spatio-temporal correlations in terms of the cage-jump dynamics. In particular, I show that in the moderately supercooled regime the distribution of the number of jumps per particle develops a transient heterogeneous shape, while in the deeply supercooled regime it acquires a transient bimodal shape. This bimodal shape allows to unambiguously identify two temporarily coexisting immobile and mobile phases. Experiments of hard sphere like colloids, firstly we show that the properties of the cage-jump motion allows a short time prediction of the diffusion constant. Secondly, we rationalize the relaxation process and the emergence of spatio-temporal correlations in terms of the cage-jump dynamics. The scenario of two coexisting immobile and mobile phases is supported by the presence of structural heterogeneities and by the transient bimodal distribution of the number of jumps per particle, with the number of jumps acting as a critical order parameter for the transition of dynamical arrest.

**Dragana Popovic**, Florida State University
Title: Glassy charge dynamics in strongly correlated systems with disorder

Abstract: There is increasing evidence that glassy or far-from-equilibrium behavior may underlie many phenomena exhibited by strongly correlated electronic materials with disorder. Their complex behavior is believed to reflect the presence of many competing degrees of freedom and associated competing ground states. Therefore, a central issue in the physics of such systems is understanding the nature of the ground states, the quantum phase transitions between them, and the associated dynamics. This talk will describe experimental work designed to address the problem of complexity in two model systems: two-dimensional (2D) electron system in Si near a metal-insulator transition and a quasi-2D $La_{2-x}Sr_xCuO_4$ (LSCO), a prototypical copper oxide, near a doping-driven superconductor-insulator transition. The 2D electron system in Si exhibits all the well-known manifestations of glassiness, such as slowing down of the dynamics and onset of correlated statistics, non-exponential relaxations, diverging equilibration times, aging and memory, making it an excellent model system for studying the nearly universal glassy behavior exhibited by a large class of both 3D and 2D nonequilibrium systems. In LSCO, the high-$T_c$ superconductivity emerges with doping from a dynamically heterogeneous, charge glass state characteristic of the insulating phase. The similarities and differences between the two systems will be discussed.

**David Reichman**, Columbia University
Title: Many-Body Localization: A Quantum Glass Transition

Abstract: The necessary requirements for an isolated classical system with generic non-equilibrium initial conditions to reach equilibrium are well understood. The same cannot be said for quantum mechanical systems. In recent years increasing attention has been paid to the problem of disordered electrons with short-

ranged interactions, namely the interacting variant of Anderson's classic problem of quantum diffusion on a disordered lattice. At present, compelling evidence exists that such an interacting system can undergo a type of quantum glass transition which has been named the "many-body localization" transition. I will review the evidence in favor of this transition. I will then focus on the dynamics in the ergodic phase which are surprisingly rich. The experimental and theoretical implications for the dynamical behavior described will be discussed.

**C. Patrick Royall**, University of Bristol
Title: A structural mechanism for the glass transition : beyond the length scale conundrum

Abstract: Among the key challenges to our understanding the glass transition is that it is accompanied by little apparent change in structure. Recently geometric motifs representing locally favoured structures (LFS) have been identified in supercooled liquids. However a causal link between LFS and vitrification, such as identical scaling of dynamic and structural length scales, remains elusive.

**Michael Schmiedeberg**, Heinrich-Heine-Universität Düsseldorf
Title:The glass transition as a mixture of random organization and jamming

Abstract: By choosing appropriate protocols, both the random organization and the athermal jamming transition can be studied within a unifying model system. We explore the model system for a mixture of the protocols and compare our results to the behavior of soft spheres at small but non-zero temperatures.

**Jennifer Schwartz**, Syracuse University
Title: Jamming graphs: A local approach of global mechanical rigidity

Abstract: We revisit the concept of minimal rigidity as applied to frictionless, repulsive soft sphere packings in two dimensions with the introduction of the jamming graph. Minimal rigidity is a purely combinatorial property encoded via Laman’s theorem in two dimensions. It constrains the global, average coordination number of the graph, for example. However, minimal rigidity does not address the geometry of local mechanical stability. The jamming graph contains both properties of global mechanical stability at the onset of jamming and local mechanical stability. We demonstrate how jamming graphs can be constructed using local rules via the Henneberg construction such that these graphs are of the constraint percolation type. We then probe how jamming graphs destabilize, or become unjammed, by deleting a bond and computing the resulting rigid cluster distribution. We also study how the system restabilizes with the addition of new contacts and how a jamming graph with extra/redundant contacts destabilizes. The latter endeavor allows us to probe a disc packing in the rigid phase and uncover a potentially new diverging length scale associated with the random deletion of contacts as compared to the study of cut-out (or frozen in) subsystems.

**Kenneth Schweizer**, University of Illinois at Urbana-Champaign
Title: Elasticity-Mediated Activated Relaxation in Colloidal Suspensions, Supercooled Liquids and Thin Films

Abstract: We formulate and apply a predictive, quantitative, force-level theory of activated relaxation in real space that covers in a unified manner the apparent Arrhenius, dynamic crossover and deeply supercooled regimes. The irreversible rearrangement event involves coupled cage-scale hopping and a longer range collective elastic distortion of the surrounding liquid. This results in two interrelated, but physically distinct, contributions to the total barrier. The more strongly temperature and density dependent collective barrier is associated with a growing length scale, the transient localization length, and density fluctuation amplitude. Agreement with experiments and simulations for hard sphere fluids is good. A quasi-universal theory for thermal liquids is constructed via an a priori mapping to an effective hard sphere fluid based on matching the material and thermodynamic state dependent amplitude of long wavelength dimensionless density fluctuations.

The theory is devoid of fit parameters, has no divergences at finite temperature or below jamming, and accurately captures the key features of the alpha relaxation time in molecular liquids over 14 decades in time. Thin films are described by accounting for the modification of near surface caging constraints and confinement-induced reduction of collective elastic effects. Spatial gradients of mobility and vitrification temperatures are predicted as a function of film thickness and temperature, and their consequences compared with dynamic and pseudo-thermodynamic measurements of accelerated relaxation in free-standing films.

**Michael Solomon**, University of Michigan
Title: Role of isostaticity in the slow dynamics of attractive colloids

Abstract: Colloids interacting through short-range attractions exhibit a dynamical transition called gelation. Colloidal gelation results in solid-like mechanical properties because of the effect of short-range attractive interactions on the collective dynamics and microstructure. Here we use experiments to probe the response of attractive colloidal systems to an applied flow. The model system is sterically stabilized poly(methyl methacrylate) spheres (diameter ~ 1 micron) with short-range attractions induced by addition of a non-adsorbing polymer. 3D direct visualization by confocal microscopy is used to characterize the microstructure of the gels. We impose step strain flows of varying magnitude on the attractive colloids and observe the 3D structural change after deformation. We characterize the transition from a dense network to free clusters of particles as a function of the applied strain, and we quantify this local and global structural change by identifying isostatic structures. The connection between these isostatic structures and flow-induced dynamical heterogeneity of the attractive colloids is probed and connected with the nonlinear elasticity of the colloidal gels.

**Grzegorz Szamel,** Colorado State University
Title: Glassy dynamics of athermal self-propelled particles

Abstract: We combine computer simulations and analytical theory to investigate the glassy dynamics in dense systems of athermal particles evolving under the sole influence of self-propulsion. The simulations reveal that when the persistence time of the self-propelled motion is increased, the local structure becomes more pronounced whereas the long-time dynamics first accelerates and then slows down. To explain these seemingly contradictory trends we construct a nonequilibrium mode-coupling-like theory for interacting self-propelled particles. To predict the collective dynamics the theory needs the steady state structure factor and the steady state correlations of the local velocities. It yields nontrivial predictions for the glassy dynamics of self-propelled particles in qualitative agreement with the simulations.

**Hajime Tanaka**, Institute of Industrial Science, University of Tokyo
Title: Roles of growing static structural order in slow glassy dynamics and crystal nucleation

Abstract: The origin of dynamical slowing down towards glass transition is one of the most fundamental unsolved problems in condensed matter physics. Recently roles of growing static order in dynamical slowing down have attracted considerable attention. The random-first-order-transition (RFOT) scenario predicts that the dynamic length grows much faster than the static length. Contrary to this scenario, we find a close link between dynamical and static length for some systems such as polydisperse particle systems and spin liquids. Here we study the nature of the point-to-set (PTS) length, using a polydisperse hard disk system, which is a model that exhibits a growing hexatic order upon densification. The results show that the PTS correlation length closely mirrors the decay length of two-body density correlation, while being decoupled from the steeper increase of the correlation length of hexatic order. This casts a serious doubt on the order agnostic nature of the PTS length and its relevance to slow dynamics at least for our system. Our study shows that in the polydisperse systems, slow dynamics is linked to the growth of bond orientational order rather than that of the

PTS length. We also find that this growth of static structural order also acts as precursors for crystal nucleation. These findings suggests that we need to consider structural ordering (or many-body correlations) such as bond orientational ordering in addition to translational ordering for describing a high-density liquid state.

**Gilles Tarjus**, Université Pierre-et-Marie-Curie & CNRS
Title: Effective theory of the glass transition

Abstract: TBA

**Katharina Vollmayr-Lee**, Bucknell University
Title: Universal Aging Dynamics in $SiO_2$

Abstract: Using MD simulations, we study the aging dynamics of amorphous $SiO_2$. The system is quenched from a high temperature to below $T_c$. We analyze both single particle jumps, as well as the dynamic susceptibility and the local incoherent intermediate scattering function. Our results for the strong glass former $SiO_2$ for the jump dynamics as well as for the investigated scaling are surprisingly similar to previous results for fragile glass formers.

**Vincenzo Vitelli**, Leiden University
Title: Tunable failure in amorphous solids: fracture and geometry

Abstract: Disordered elastic networks undergo a rigid to floppy transition, as the mean coordination number approaches a critical threshold. Here we show that the mechanism of failure of such networks, in response to quasi-static stretching or compression, consists of meandering cracks whose width diverges at the transition. Thus, upon approaching the critical point, we can effectively zoom inside the fracture process zone, where the response is dominated by non-affine and non-linear deformations. Since applied tensions or compressions can be accommodated by zero-energy bond rotations rather than costly bond stretching, ordinary cracks cannot form and propagate in critical networks. Instead, below a critical length scale that diverges at the transition, the process zone spans the entire system size and the damage pattern consists of a set of uniformly distributed isolated broken bonds. Our findings demonstrate that the divergent size of the failure process zone is a probe of the divergent length scale that accompanies the rigidity and unjamming transition. In addition, they point out a simple route to engineer materials with tunable failure properties.

**Eric Weeks**, Emory University
Title: Flow of amorphous solids modeled with emulsion droplets

Abstract: We use quasi-two-dimensional emulsions as experimental models to study the flow of jammed materials (amorphous solids). Our emulsions are oil droplets in water and are compressed between two parallel glass plates so that the droplets are deformed into pancake-like disks. We use microscopy to observe these droplets as they flow. From the deformed outlines of the droplets, we can measure all of the inter-droplet forces to within 10%. In this way, we study the relationship between the local stresses in the system and the rearrangements as the sample is sheared. In particular, we find that at very slow flow rates (quasi-static flow), we see large avalanches of rearrangements, whereas at higher flow rates rearrangement events occur more frequently but involve fewer droplets. The simplest rearrangement involves four droplets (a “T1 event”) and we confirm theoretical predictions for the quadrupolar spatial pattern of the stress redistribution around the T1 events.

**Matthieu Wyart**, New York University
Title: Low-energy excitations in glasses

Abstract: Rheological properties of dense flows of hard particles are singular as one approaches the jamming threshold where flow ceases, both for aerial granular flows dominated by inertia, and for over- damped suspensions. Concomitantly, the length characterizing velocity correlations appears to diverge at jamming. Here we introduce a theoretical framework that proposes a tentative, but potentially complete description of stationary flows. Our analysis, which focuses on frictionless particles, applies both to suspensions and inertial flows of hard particles. It also predicts the shear- thinning exponent that describes soft particles under certain driving conditions.

**Hajime Yoshino**, Osaka University
Title: Hierarchy of rigidities of hard-sphere glasses

Abstract: Putting shear to glasses is a basic strategy to study the nature of glasses. Recently we analyzed the effect of quasi-static shear on hard-sphere glasses in large-dimensional limit by extending exact results without shear. We obtained exact free-energy functional of the system in terms of the glass order parameter function and the shear-strain, which allows one to compute the shear-modulus and yield stress exactly. We predict that continuous replica-symmetry breaking implies a hierarchy of rigidities which may be accessible experimentally especially around the jamming point. We also discuss results of MD simulations on the stress relaxation and compare with the theoretical prediction.

**Francesco Zamponi**, École Normale Supérieure, Paris
Title: Exact computation of the critical exponents of the jamming transition

Abstract: The jamming transition marks the emergence of rigidity in a system of amorphous and athermal grains. It is characterized by a divergent correlation length of the force-force correlation and non-trivial critical exponents that are independent of spatial dimension, suggesting that a mean field theory can correctly predict their values. I will discuss a mean field approach to the problem based on the exact solution of the hard sphere model in infinite dimension. An unexpected analogy with the Sherrington-Kirkpatrick spin glass model emerges in the solution: as in the SK model, the glassy states turn out to be marginally stable, and are described by a Parisi equation. Marginal stability has a deep impact on the critical properties of the jamming transition and allows one to obtain analytic predictions for the critical exponents. The predictions are consistent with a recently developed scaling theory of the jamming transition, and with numerical simulations. Finally, I will briefly discuss some possible extensions of this approach to other open issues in the theory of glasses.