# Driven Disordered Systems 2014 – Book of abstracts

(http://dds2014.sciencesconf.org)

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GDR PHENIX meeting organized on June 5-6 2014, at the *Laboratoire Interdisciplinaire de Physique* (LIPhy), in the University Joseph-Fourier of Grenoble, by the team *Physique Statistique et Modélisation* (PSM).

*Organizing committee*: Elisabeth Agoritsas, Jean-Louis Barrat, Eric Bertin, Ezequiel Ferrero and Kirsten Martens.

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In a wide range of physical systems, the presence of structural disorder, either quenched or evolving on large time scales, leads to a complex physical behavior when submitted to a driving force. Such systems include elastic lines evolving in a disordered energy landscape, simultaneously pinned by their surrounding disorder and pulled at by an external driving force (for example magnetic domain walls in presence of a magnetic field) and soft materials under an external shear rate (gels, foams, granular materials, ...).

The goal of this reunion is to promote exchanges between the scientists of different communities (depinning, rheology and mechanical response of amorphous systems) and to compare their different approaches. Is there a place for similar concepts in the different types of forced disordered systems? The focus will be on methods stemming from statistical physics (multi-scale methods, bridging of micro-macro descriptions, study of fluctuations. . . ), both from a theoretical and an experimental point of view.

| *Invited speakers* | *Oral contributions* | *Poster contributions* |
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| Ludovic Berthier | Nicolas Brodu | Karol Asencio |
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| Olivier Dauchot | Michael L. Falk | Vincent Démery |
| Marc-Antoine Fardin | Reinaldo García García | Giacomo Gradenigo |
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| Vincent Jeudy | Vivien Lecomte | Takeshi Kawasaki |
| Anaël Lemaître | Robin Masurel | Simon Merminod |
| | Laurent Ponson | Christophe Perge |
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| | Menka Stojanova | Jean-François Trochet |
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Groupe Physique Statistique et Modélisation (PSM): http://www-liphy.ujf-grenoble.fr/-PSM-
GDR PHENIX website: http://www.ens-lyon.fr/PHENIX/

## 1 Invited speakers

### **Ludovic Berthier** (Laboratoire Charles Coulomb, Montpellier)

***Thinning or thickening? Multiple rheological regimes in dense suspensions of soft particles***

The shear rheology of dense colloidal and granular suspensions is strongly nonlinear, as these materials exhibit shear-thinning and shear-thickening, depending on multiple physical parameters. I will present results from computer simulations of the rheological behaviour of a simple model of soft repulsive particles at large densities, showing that nonlinear flow curves reminiscent of experiments on real suspensions are obtained. By using dimensional analysis and basic elements of kinetic theory, we can rationalize these multiple rheological regimes and disentangle the relative impact of thermal fluctuations, glass and jamming transitions, inertia and particle softness on the nonlinear flow curves.

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### **Zoe Budrikis** (SMM Lab, Turin)

***From shear transformations to depinning transitions: lattice models for amorphous plasticity.***

Plastic deformation of amorphous materials on the microscale is subject to fluctuations, characterized by power-law distributed avalanches and localization of deformations. These complex behaviours have received a great deal of attention from both physicists and engineers. From a theoretical point of view, the challenge is to construct a picture which captures all the relevant physics in a unified way. One fruitful approach is a depinning model in which local randomness competes with long-range interactions. Because the interactions are long-range, one would naively think that such a model can be described by mean field theory, but simulations have cast doubt on this [1]. We have simulated significantly larger systems than previously studied [2] and have shown that while mean field theory is correct when external stresses are small, when stresses are larger this picture breaks down, as a result of localization.

[1] M. Talamali et al, "Avalanches, precursors, and finite-size fluctuations in a mesoscopic model of amorphous plasticity", *Phys. Rev. E* **84**, 016115 (2011).
[2] Z. Budrikis & S. Zapperi, "Avalanche localization and crossover scaling in amorphous plasticity", *Phys. Rev. E* **88**, 062403 (2013).

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### **Luca Cipelletti** (Laboratoire Charles Coulomb, Montpellier)

***A microscopic view of the yielding transition in concentrated emulsions***
(L. Cipelletti, E. D. Knowlton and D. J. Pine)

We use a custom shear cell coupled to an optical microscope to investigate at the particle level the yielding transition in concentrated emulsions subjected to an oscillatory shear deformation [1]. By performing experiments lasting thousands of cycles on samples at several volume fractions and for a variety of applied strain amplitudes, we obtain a comprehensive, microscopic picture of the yielding transition. We find that irreversible particle motion sharply increases beyond a volume-fraction dependent critical strain, which is found to be in close agreement with the strain beyond which the stress-strain relation probed in rheology experiments significantly departs from linearity. The shear-induced dynamics are very heterogenous: quiescent particles coexist with two distinct populations of mobile and 'supermobile' particles. Dynamic activity exhibits spatial and temporal correlations, with rearrangements events organized in bursts of motion affecting localized regions of the sample.

[1] E. D. Knowlton, D. J. Pine, & L. Cipelletti, "A microscopic view of the yielding transition in concentrated emulsions", arXiv:1403.4433 [cond-mat.soft].

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**Olivier Dauchot** (ESPCI, Paris)

***Vibrated granular media, an experimental way towards jamming.***

Disordered media such as foams, emulsions, colloidal suspensions, granular media and glasses acquires rigidity when cooled down or compressed.

In 1998 Liu and Nagel presented a (Temperature-Stress- Density) phase diagram, the so-called "Jamming diagram", the purpose of which was to encompass in a unique framework the glass transition and the emergence of yield stress, two challenging issues in modern condensed matter physics. Since then, the jamming of soft spheres at zero temperature has been extensively studied both numerically and theoretically. The observation of remarkable scaling properties on the approach to 'point J' led to the conjecture that the properties of this 'critical point' could determine the properties of dense particle systems throughout the whole jamming diagram. However it has been shown that even model experiments on colloids are rather far away from the scaling regime. Is it that the J-point has little to say about real system?

We investigate the statics and the dynamics of the contact network of an horizontally shaken bidisperse packing of photoelastic discs, close to jamming, we observe a remarkable dynamics of the contact network. It exhibits strong dynamical heterogeneities, which are maximum at a packing fraction $\varphi^*$, distinct and smaller than the packing fraction $\varphi^\dagger$, where the average number of contact per particle starts to increase. We demonstrate that the two cross-overs, one for the maximum dynamical heterogeneity, and the other for structural jamming, converge at point J in the zero mechanical excitation limit. Our grains are frictional and are far from thermal equilibrium. However we succeed in mapping these behaviors onto those observed for thermal soft spheres and demonstrate that essential features of the J-point indeed describe our vibrated granular system.

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**Marc-Antoine Fardin** (ENS, Lyon)

***Shear-banding in complex fluids***

By "shear-banding", scientists can mean several things. For some non-Hookean solid materials, "shear-banding" refers to the notion of strain localization. Similarly, for some non-Newtonian fluids "shear-banding" refers to the notion of strain rate localization. In both cases, for solids or for fluids, shear-banding is linked to a sharp inhomogeneity in the deformation or deformation rate field. Clear domains of different strains or strain rates are identifiable. I will discuss recent studies on the characteristics and possible origins of shear-banding in yield stress fluids and viscoelastic solutions. In particular, I will mention differences between steady and transient shear-banding, and between purely mechanical and concentration-coupled shear-banding.

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**Jacques Ferré** (LPS, Orsay)

***2D melting and fluctuations at the spin reorientation transition in a Pt/Co(0.5nm)/Pt film***
(J. Ferré, N. Bergeard, J.P. Jamet and A. Mougin at the LPS, Université Paris-Sud, Orsay)
(E. Bourhis and J. Gierak at the Laboratoire de Physique et Nanostructures, Marcoussis)

Since a long time, phase transitions in two dimentional systems have interested much the scientific community. These are even more exciting for systems exhibiting competing interactions and/or frustration that may induced instabilities and slow dynamics. Since the seventies, Berizinskii-Kosterlitz-Thouless-Nelson-Halperin-Young (KTNHY) have pointed out that the transiton between smectic and nematic phases in liquid crystals could be a good example, but only few dynamic investigations were performed so far in this system.

In this talk, a study of instabilities and the apparition of strong spatio-temporal fluctuations is proposed in out-of-plane demagnetized stripe domain patterns of a Pt/Co(0.5 nm)/Pt utrathin film. The domain structure was visualized by polar magneto-optical Kerr effect microscopy and its evolution studied in the spin reorientation transition temperature region associated with competitive dipolar and anisotropy energies. A two-dimensional-stripe melting transition was evidenced when increasing the temperature before reaching an in-plane spin state. The slow dynamics were driven by short-range instabilities on magnetic defects which trigger long-range transverse wall fluctuations. The spatial and temporal behavior of stripe-like "floating" patches was evidenced and studied. Movies will help to analyze slow dynamics in this novel archetypal system. Dynamics cannot be simply interpreted here by the KTNHY model previously proposed for liquid crystals.

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**Vincent Jeudy** (LPS, Orsay)

***Field-driven domain wall motion in ferromagnetic films with weak disorder***
(V. Jeudy, J. Ferré, J. Gorchon, A. Mougin and J.-P. Jamet at the LPS, Université Paris-Sud, Orsay)
(S. Bustingorry and A. Kolton at the Centro Atomico Bariloche, CNEA, Bariloche, Argentina)
(T. Giamarchi, DPMC, University of Geneva, Switzerland)

Magnetic domain wall motion presents a great variety of dynamical regimes. For a sufficiently large driving force, the motion is limited by dissipation and the domain wall can move in different flow regimes. For a low driving force, the presence of disorder leads to pinning which dramatically modifies the response to the force. The different encountered dynamical regimes as the creep and the depinning regimes can be compared to predictions of theories developed to describe elastic interface dynamics in the presence of weak disorder. In this talk, a brief overview of experimental results on magnetic field driven domain wall dynamics is proposed. We discuss in particular the pinning dependent regimes in ultrathin ferromagnetic Pt/Co/Pt films. New experimental results on the temperature dependence of domain wall motion are presented together with a fully consistent theoretical analysis. This allows the evidence of distinct creep, TAFF (thermally activated flux flow), depinning and flow regimes and to directly extract important parameters such as the thermal rounding exponent and the thermal crossover exponents of the Larkin length. The microscopic characteristic of pinning is also deduced from the macroscopic domain wall motion. Finally, some recent developments and perspectives on domain wall motion driven by an electric current are presented.

**Anaël Lemaître** (Laboratoire Navier, Marne la Vallée)

***Signature of flow and relaxation events in amorphous glasses and supercooled liquids under shear***

Using numerical simulation of a 2D Lennard-Jones system, we study the crossover from shear thinning to Newtonian flow. We find that the short-time elastic response of our system essentially does not change through this crossover, and show that, in the Newtonian regime, thermal activation triggers shear transformations, i.e., local irreversible shear events that produce Eshelby (long-ranged, anisotropic) deformation fields as previously seen in low-T glasses. Quite surprisingly, these Eshelby fields are found to persist much beyond the relaxation time, and shear thinning to coincide with the emergence of correlations between shear relaxation centers.

## 2 Oral contributions

**Nicolas Brodu** (INRIA Bordeaux – Geostat)

***Measuring 3D forces at each contact within a stressed granular medium with refraction index matching tomography.***

We experimentally probe a granular system at the microscale to obtain particle positions, inter-particle contacts and the associated forces. These data are obtained by using a laser sheet scanning technique, followed by dedicated reconstruction algorithms. We then apply multiple cycles of uniaxial compression and decompression to a collection of hydrogel particles. Although the particles interact via a purely repulsive Hertzian force law, $f \sim x^{3/2}$, when the particles are pushed together by a distance, $x$, the global force response, F, to global compression by $X$ grows much faster than $X^{3/2}$. We show that this response is due to changes in the microstructure. We find that changes in F in response to a macroscale stresss/strain are related to changes in system-wide measures of the microstructure and the inter-grain force, in addition to the increases of the forces at contacts. These data are consistent with a scaling relation that connects the observed microscopic response of the particles to the independently measured macroscopic pressure inside the packing.

**Jérôme Crassous** (Université Rennes 1)

***Microstructure of a plastic flow before failure***
(Antoine Le Bouil, Axelle Amon, Sean McNamara and Jérôme Crassous)

We investigate experimentally the plastic flow of a model athermal and amorphous material before failure. We considered the flow of a disordered granular material made of glass spheres. The applied stress field is controlled and homogeneous in two directions [1]. This creates an elongational granular flow followed by a failure of the material. The stress-strain loading curve shows plastic deformations followed by a stress plateau associated to the failure of the material. We visualize the granular flow using a dynamic light scattering setup. The scattered light is recorded with a camera, and correlation functions of the scattered intensities are calculated. We then obtain map of "activity" on a surface of the material. This method is very sensitive, the measured local strains being in the range 10-4-10-5 [1,2].

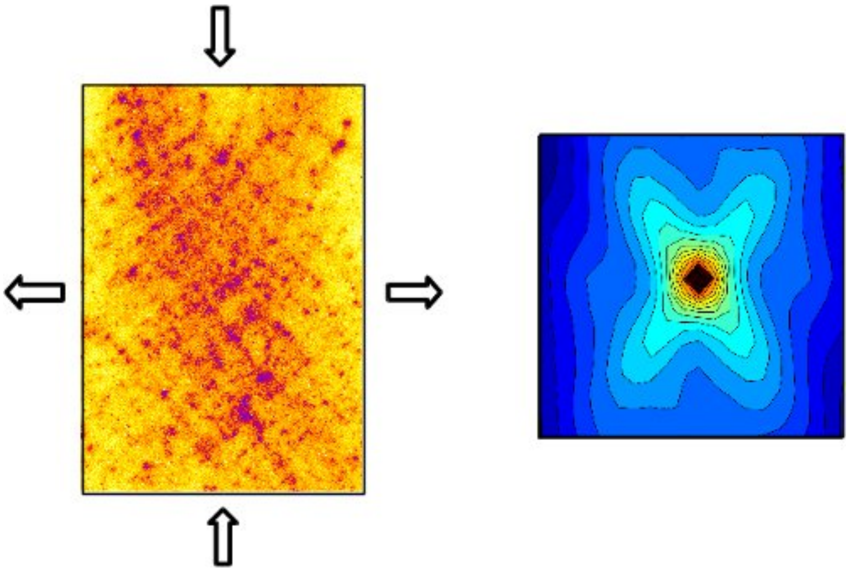

Figure 1: *Left:* Snapshot of the micro-structure of the plastic flow of a granular material. Red color corresponds to important activity. Arrows are the flow directions. *Right:* Correlation function of the deformation showing the correlation of deformations in two axes.

The fluctuating part of the plastic flow shows strong fluctuations around their mean values (see Fig. 1 *left*). Those fluctuations are correlated on distance of typically 50 bead diameter in two directions symmetric to the directions of loading (see Fig. 1 *right*). Those directions are nearly constant during the loading. The mean plastic flow organize slowly during the loading to form shears bands in the sample. The orientations of the final shear bands are given by a Mohr-Coulomb analysis, and are different of the directions where fluctuation are correlated.

The structure of the fluctuations of the plastic flow may be understood with a micro-mechanical approach. We consider for this the effect of localized plastic deformations. The modifications of the internal stress fields to such reorganizations are calculated using the solution of the Eshelby inclusion problem. The preferential directions of fluctuations may then be interpreted as the directions of maximal internal stress redistribution into the sample [3].

[1] A. Le Bouil, A. Amon, S. McNamara & J. Crassous, “Emergence of cooperativity in plasticity of soft glassy materials”, arXiv:1402.7304 [cond-mat.soft].
[2] M. Erpelding, A. Amon, & J. Crassous, “Diffusive Wave Spectroscopy applied to the spatially resolved deformation of solid”, *Phys. Rev. E.* **78**, 046104 (2008).
[3] A. Le Bouil, A. Amon, J.-C. Sangleboeuf, H. Orain, P. Bésuelle, G. Viggiani, P. Chasle, & J. Crassous, “A biaxial apparatus for the study of heterogeneous and intermittent strains in granular materials”, *Granular Matter* **16**, 1 (2014).

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**Marc Durand** (MSC, Université Paris Diderot)

***Statistical mechanics of two-dimensional shuffled foams: prediction of the correlation between geometry and topology***

Two-dimensional foams are characterized by their area distribution $p(A)$ and number-of-sides distribution $p(n)$. When the liquid fraction is very low (“dry” foams), their bubbles are polygonal, with shapes that are locally governed by the laws of Laplace and Plateau. Bubble size distribution and packing (or "topology") are crucial in determining e.g. rheological properties or coarsening rate. When a foam is shuffled (either mechanically or thermally), $p(A)$ remains fixed, but bubbles undergo "T1" neighbour changes, which induce a random exploration of the foam configurations. We explore the relation between the distributions of bubble areas (geometry) and number-of-sides (topology). We develop a statistical model which takes into account physical ingredients and space-filling constraints. The model predicts that the mean number of sides of a bubble grows linearly with its radius, and also relates the topological and geometrical disorders in a shuffled foam. At low size dispersity, we identify and quantitatively discuss a crystallization mechanism whereby topological disorder vanishes.

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**Michael L. Falk** (Johns Hopkins University)

***Competition Between Cavitation and Flow in Amorphous Solids***

Fracture in metallic glasses is characterized by interesting residual surface morphologies that, depending on the sample, suggest either cavitation or extensive viscous flow. Here we undertake molecular dynamics simulations of cavitation in a $Zr_{50}Cu_{50}$ metallic glass and show that these exhibit a waiting time dependent cavitation rate. On short time scales nucleation rates and critical cavity sizes are commensurate with a classical theory of nucleation that accounts for both the plastic dissipation during cavitation and the cavity size dependence of the surface energy. All but one parameter, the Tolman length, can be extracted directly from independent calculations or estimated from physical principles. The distribution of these inherent heterogenous nucleation sites are investigated showing a range of both local surface energies and plastic susceptibilities. On longer time scales shear relaxations result in a systematic decrease of cavitation rate. This cross-over in cavitation rate can be used to quantify the activation barrier of the competing process, shear transformation zone (STZ) activity. It is evident that the differing history and stress dependence of the activation barriers for STZ activity and cavitation may account for the range of behavior from brittle to ductile behavior in this class of materials.

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**Reinaldo García García** (PMMH, CNRS/ESPCI, Paris)

***Eddy currents and Barkhausen noise: Possible breakdown of Middleton theorem.***
(R. García-García and E. Jagla)

It has been argued by means of numerical simulations [1], and recently proved formally [2], that while eddy currents account for the leftward asymmetry of Barkhausen noise pulses and give rise to aftershocks in the dynamics of magnetic avalanches, the statistics of these avalanches remains unchanged, and the validity of the Middleton theorem, unaltered. These statements are based on the study of a modification of the ABBM model which includes retardation effects due to the relaxation of eddy currents. We show that this model, however, misses some important features of the domain wall motion because in its derivation, the Faraday law has been oversimplified. When the Faraday law is properly considered, the resultant equation of motion for the domain wall is highly nonlinear and non-trivial effects, as the breakdown of the Middleton theorem, may arise.

[1] S. Zapperi, C. Castellano, F. Colaiori, & G. Durin, "Signature of effective mass in crackling-noise asymmetry", *Nature Physics* **1**, 46 (2005).
[2] A. Dobrinevski, P. Le Doussal, & K. J. Wiese, "Statistics of avalanches with relaxation and Barkhausen noise: A solvable model", *Phys. Rev. E* **88**, 032106 (2013).

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**François Landes** (LPTMS, Université Paris Sud, Orsay)

***Avalanche statistics in disordered visco-elastic interfaces***

Recently, it has been pointed out that several basic features of avalanche dynamics are induced at the microscopic level by relaxation processes, usually neglected by conventional models. I will present a minimal model with relaxation and its mean field treatment, and give an outline of the finite dimensional results. In mean-field, our model yields a periodic behavior (with a new, emerging time scale), with events that span the whole system. In finite dimension (2D), the mean-field system-sized events become local, and numerical simulations give qualitative and quantitative results similar to the earthquakes observed in reality. This is linked to our recent article:
E. A. Jagla, François P. Landes, & A. Rosso, "Viscoelastic Effects in Avalanche Dynamics: A Key to Earthquake Statistics", *Phys. Rev. Lett.* **112**, 174301 (2014).

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**Vivien Lecomte** (LPMA, Université Paris 6 & 7)

***Interfaces in random media with short-range correlated disorder.***

One-dimensional boundary interfaces between different phases are described at macroscopic scales by a rough fluctuating line, whose geometrical properties are dictated by the disorder in the underlying medium, by the temperature of the environment, and by the elastic properties of the line. A widely used and successful model is the directed polymer in a random medium, pertaining to the Kardar-Parisi-Zhang (KPZ) universality class. Much is known for this continuous model when the disorder is uncorrelated, and it has allowed to understand the static and dynamical features of experimental systems ranging from magnetic interfaces to liquid crystals. We show that short-range correlations in the disorder at a scale $\xi > 0$ modify the uncorrelated (i.e. zero $\xi$) picture in a non-obvious way. If the geometrical fluctuations are still described by the celebrated 2/3 KPZ exponent, characteristic amplitudes are however modified even at scales much larger than $\xi$, in a well-controlled and rather universal manner. Our results are also relevant to describe the slow (so called 'creep') motion of interfaces in random media, and more formally (trough replicæ) one-dimensional gases of bosons interacting with softened delta potential. We also discuss results obtained in the same spirit for the depinning force of interfaces with long-range elasticity.

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**Robin Masurel** (SIMM ESPCI, Paris)

***Stress relaxation of highly disordered viscoelastic materials.***

Amorphous polymers present relaxation times which are distributed over 4 to 8 decades. These dynamical heterogeneities control their macroscopic mechanical properties. In the glass transition zone, mesoscopic domains present a high contrast of modulus with their neighbors leading to a complex macroscopic mechanical response. We propose to model polymer glasses in their glass transition domains using finite element methods. We thus distribute statistically relaxation times over domains – remaining in the linear domain. This approach gives us an image of the local stress repartition composed by high stress stripes which form a percolating network around the glass transition. We compare these results with a mean field approach and discuss physically the stress relaxation in these highly disordered systems.

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**Laurent Ponson** (Institut Jean le Rond d'Alembert, Paris)

***On the relevance of depinning concepts to describe damage spreading and localization in disordered materials***

In this talk, I will discuss the transition to failure in quasi-brittle materials that break through the spreading and the localization of a large number of micro-cracks. We develop a mesoscale model based on thermodynamic principles that describes the dissipation of elastic energy stored in a material submitted to some external mechanical loading into damage. A key feature of our approach is that localized energetically favorable microcracking events lead to some peculiar stress redistribution that controls the spreading of microcracks and ultimately the catastrophic failure of the sample through damage localization. We show that the evolution of the microcracking process can be predicted from the knowledge of a redistribution kernel that is calculated and used to predict catastrophic failure under different loading conditions. The connection of our approach with depinning like models will be finally discussed.

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**Francesco Puosi** (LIPhy, Grenoble)

***Time dependent elastic response to a local shear transformation in amorphous solids***
(F. Puosi, J. Rottler and J.-L. Barrat)

The elastic response of a two-dimensional amorphous solid to induced local shear transformations, which mimic the elementary plastic events occurring in deformed glasses, is investigated via Molecular Dynamics simulations. If we average over disorder, i.e., considering different spatial realizations of the transformation, the long time equilibrium response matches the prediction of the Eshelby inclusion problem for a continuum elastic medium. We characterize the effects of inertia on the propagation of the elastic signal. A crossover from a propagative transmission in the case of underdamped dynamics to a diffusive one for overdamping is evidenced. In the latter case, the full time dependent elastic response is in surprising agreement with the theoretical prediction, obtained solving the diffusion equation for the displacement field in an elastic medium.

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**Menka Stojanova** (Institut Lumière Matière, Lyon)

***Energy's probability distribution in scale invariant processes: the effect of time correlations***

We analyzed the subcritical propagation of a crack in a sheet of paper by combining high frequency acoustic emission measurements and low frequency direct imaging. Paper being an inhomogeneous, disordered material, fracture proceeds through a succession of discrete events. Both methods show that the energy of these events is power-law distributed. However, the exponent determined with image acquisition is lower than the one found by analysis of the acoustic emission. This difference is a consequence of the existence of time correlations (aftershocks) between the events. Since aftershocks can't be resolved by the low frequency image acquisition, image analysis results in a lower, misleading value of the energy exponent [1]. Indeed, when lowering the frequency of analysis of the acoustic signal the estimated exponent decreases until reaching the value estimated by image analysis for a frequency equal to the image's frame rate. This result emphasizes the importance of having a high enough temporal resolution for data acquisition when observing a system that presents time correlations.

[1] M.Stojanova, S. Santucci, L. Vanel, & O. Ramos, "High Frequency Monitoring Reveals Aftershocks in Subcritical Crack Growth", *Phys. Rev. Lett.* **112**, 115502 (2014).

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**Damien Vandembroucq** (PMMH, CNRS/ESPCI, Paris)

***Finite statistical size effects in compressive strength***

(J. Weiss, L. Girard, L. Gimbert, D. Amitrano, and D. Vandembroucq)

The larger structures are, the lower their mechanical strength. Already discussed by Leonardo da Vinci and Edmé Mariotte several centuries ago, size effects on strength remain of crucial importance in modern engineering for the elaboration of safety regulations in structural design or the extrapolation of laboratory results to geophysical field scales. Under tensile loading, statistical size effects are traditionally modeled with a weakest-link approach. One of its prominent results is a prediction of vanishing strength at large scales that can be quantified in the framework of extreme value statistics. Despite a frequent use outside its range of validity, this approach remains the dominant tool in the field of statistical size effects. Here we focus on compressive failure, which concerns a wide range of geophysical and geotechnical situations. We show on historical and recent experimental data that weakest-link predictions are not obeyed. In particular, the mechanical strength saturates at a nonzero value toward large scales. Accounting explicitly for the elastic interactions between defects during the damage process, we build a formal analogy of compressive failure with the depinning transition of an elastic manifold. This critical transition interpretation naturally entails finite-size scaling laws for the mean strength and its associated variability. Theoretical predictions are in remarkable agreement with measurements reported for various materials such as rocks, ice, coal, or concrete. This formalism, which can also be extended to the flowing instability of granular media under multiaxial compression, has important practical consequences for future design rules.

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**Kay Wiese** (LPTENS, Paris)

***Avalanches***

Magnetic domain walls, charge density waves, contact lines, and cracks are all elastic systems, pinned by disorder. Changing an external parameter, they remain stuck before advancing in sudden rapid motion, termed avalanche. After an introduction into the phenomenology, I present work based on the functional renormalization group, which allows to go beyond the usual toy-model or mean-field description, and to obtain the avalanche-size distributions in any dimension, the distribution of velocities in an avalanche, as well as the shape of an avalanche, both at fixed size and fixed duration.

## 3 Poster contributions

**Karol Asencio** (Universidad de Navarra, Pamplona, Spain)

***Compaction of faceted particles***

We have been working with cubic particles in a cylinder applying alternating rotations, and we have found similar behavior to reported for granular particles when they are subjected to taps. During the process of compaction may be formed microstructures causing jumps or steps in the evolution of packing fraction. Finally we will point out some issues about the study on the evolution of particles orientations.

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**Catherine Barentin** (Institut Lumière Matière, Lyon)

***Capillary rise of yield stress fluid***

We study experimentally the capillary rise of a yield stress fluid and propose an extension of the Jurin's law to such complex systems which is validated. Using the Taylor geometry, we show that measuring the final imbibition height allows for the determination of both the surface tension and of the yield stress. Moreover these measurements are sensitive to the flow boundary conditions. The capillary rise of the yield stress fluid is indeed strongly affected by the existence (or not) of slippage, which is directly linked to the roughness of the capillary walls. In summary contrary to the case of simple fluids the capillary rise of yield stress fluids corresponds to a dynamical arrest, depends strongly on the wall roughness and does not depend on the capillary gap for high values of the yield stress.

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**Nicolas Brodu** (INRIA Bordeaux – Geostat)

***Inferring statistically singular points to highlight the structure of large environmental data sets***

With the advent of sensors of ever increasing resolution in the spatial, temporal and spectral domains, massive data sets pile up in databases without being exploited. The automatic inference of the most interesting features in the data in a statistical sense, the most singular points, would help dig through these data sets. Indeed, the interesting dynamics is often concentrated in only a small portion of the data and at relevant scales, which are not necessarily that of the acquisition. We work both on the methodological aspects for analyzing the data and the computational aspects necessary to produce practical algorithms. In order to extract the singular points, a first approach is to rely on micro- canonical analysis. A second is to adopt a predictive stance and postulate that relevant information is concentrated in regions that are least predictable. Both perspectives will be discussed in this presentation, as well as the notion of optimal wavelets.

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**Vincent Démery** (University of Massachusetts, Amherst, USA)

***From microstructural features to effective toughness in disordered brittle solids***
(Vincent Démery with Laurent Ponson, Alberto Rosso and Vivien Lecomte)

The failure of brittle solids occurs through the propagation of a crack and can be modeled by the motion of an elastic line in a disordered landscape. The effective toughness of the material is the critical load at which this line unpins from the heterogeneities and acquires a non zero average velocity: it is a crucial quantity for applications, that we want to deduce from the microstructural features of the material. First, a numerical study allows to identify two pinning regimes: strong disorder leads to individual pinning, where the effective toughness is set by the toughest defects, and weak disorder leads to collective pinning, where the effective toughness is set by the variance of the toughness distribution. In the collective pinning regime, the effective toughness is computed perturbatively, giving insight into the role of disorder geometry.

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**Giacomo Gradenigo** (LPTMS - IPhT/CEA)

***Fluctuating hydrodynamic theories for a driven granular fluid: study of out-of-equilibrium correlations***

In a driven granular fluid energy is continuously gained from a thermal bath and lost through inelastic collisions. The irreversible nature of this dynamics produces some correlations between the hydrodynamics fields, that are absent at equilibrium. In this talk we summarize some results on the spectrum of velocity structure factors in a driven granular fluid. This spectrum can be calculated analytically from a standard fluctuating hydrodynamic theory and theoretical predictions are found in good agreement with the results of both event-driven molecular dynamic simulation and real experiments, realized with a monolayer of inelastic beads fluidized with a vertical shaking.

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**Sara Jabbari-Farouji** (LIPhy, Grenoble)

***Mechanisms of plastic deformation in glassy and semi-crystalline polymers***

Upon slow enough cooling, crystallisable polymers form partially crystalline structures that consist of stacking chain folded lamella and amorphous regions. Semi-crystalline polymers have a larger stiffness and toughness compared to their amorphous counterparts. Although there is a wide agreement on their structure [1] mechanisms of deformation, particularly in the non-linear regime of response, are poorly understood. In order to gain an insight into the mechanical response of semi-crystalline and glassy polymers, we perform molecular dynamics simulations. We employ a coarse-grained model for semiflexible polymers (CG-PVA) [2] which displays both crystallization and glassy behavior via changing the cooling rate. We investigate the mecha nical response of polymers by means of uniaxial tensile tests [3]. We address two key issues: *i)* How do ordered and amorphous regions transform under uniaxial tension? *ii)* How do mechanical properties of semicrystalline polymers differ from glassy ones?

We obtain the stress-strain curves for both glassy and semicrystalline samples at various temperatures. In a good agreement with experimental results, we find that semicrystalline samples are stiffer in the linear and strain-softening regime. However, in the limit of large deformations, i.e. in the strain-hardening regime, glassy samples exhibit a stronger response than the semicrystalline ones. We analyze the configurations of samples along the flow curve by characterizing their structure factor, mean-squared internal distance and size distribution of crystalline domains. For semi-crystalline samples, in the elastic (linear) regime, deformation leads to a slight stretching of all the chains. Upon further increase of strain and yielding of samples, we observe a partial loss of crystallinity accompanied by partial alignment of crystallites with the tensile direct ion. Very large deformations cause unfolding of lamella and further stretching and alignment of chains along the tensile direction. In glassy samples, small deformations leads to stretching of chains and further increase of tension leads to a greater extent stretching and alignment of chains with tensile direction.

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[2] H. Meyer & F. Muller-Plathe, *J. Chem. Phys.* **115**, 7807 (2001).
[3] S. Jabbari-Farouji, A. Makke, J. Rottler, M. Perez, O. Lame & J.-L. Barrat, (in manuscript).

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**Takeshi Kawasaki** (Laboratoire Charles Coulomb, Montpellier)

***Power law divergence of the viscosity in dense athermal suspensions by large scale computer simulations***

We perform large scale computer simulations and finite size scaling analysis to establish the functional form of the divergence of the Newtonian viscosity in dense suspensions of frictionless athermal particles approaching the jamming transition. We use finite pressure simulations of soft repulsive particles with homogeneous shear flow whose shear rate is $\dot{\gamma}$. We obtain the limit of Newtonian viscosity as $N \to \infty$, $P \to 0$, and $\dot{\gamma} \to 0$ where $N$ is the particle number and $P$ is the value of pressure. We extend previous analysis by about 2 orders of magnitude and find that $\eta = \eta_\infty(\phi_J - \phi)^{-\alpha}$ is obeyed over more than 4 orders of magnitude.

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**Simon Merminod** (MSC, Université Paris Diderot)

***Order and disorder in a driven magnetic granular monolayer***

Basic constituents of matter experience continuous competition between thermal agitation and interactions, leading to global structuring. We present here a macroscopic example of such a structuring using a two-dimensional system of particles mechanically agitated and interacting via tunable magnetic interactions.

Soft-ferromagnetic particles are placed on a vibrating rough plate and vertically confined, so that they perform a horizontal Brownian motion in a cell. When immersed in an external vertical magnetic field, the particles become magnetized and thus interact according to a $1/r^3$ dipolar potential. Therefore, such a granular medium displays properties that depend not only on its density, but also on the tunable particle interactions intensity [1].

At high magnetic field and low particle area fraction, a hexagonal crystal-like structure sets up due to high magnetic repulsion between particles [2]. In contrast, when increasing the particle area fraction while keeping the magnetic field at high value, we observe that the particles self-organize into a labyrinthine, amorphous-like structure which is mostly constituted by small chains of particles. Analogous labyrinthine structures arising from the competition between agitation and non-contact interactions have been obtained using for instance ferrofluids [3] and colloidal particles [4]. However, assemblies of macroscopic particles had so far never been reported to display such striking structuring properties.

We characterize these different phases using relevant statistical tools. Our aim is to provide a better understanding of the order-disorder phase transitions induced by the competition between agitation and non-contact interactions in many-particle systems. This model system should be useful as a new approach in the study of the 2D solidification dynamics as well as of the 2D amorphous systems.

[1] S. Merminod, M. Berhanu, & E. Falcon, "Transition from a dissipative to a quasi-elastic system of particles with tunable repulsive interactions", accepted in *Europhys. Lett.* (2014), arXiv:1404.3943 [cond-mat.soft].
[2] J. Schockmel, E. Mersch, N. Vandewalle, & G. Lumay, "Melting of a confined monolayer of magnetized beads", *Phys. Rev. E* **87**, 062201 (2013).
[3] F. Elias, C. Flament, J.-C. Bacri, & S. Neveu, "Macro-organized patterns in ferrofluid layer: experimental studies", *J. Phys. I France* **7**, 711 (1997).
[4] Y. Han, Y. Shokef, A. M. Alsayed, P. Yunker, T. C. Lubensky, & A. G. Yodh, "Geometric frustration in buckled colloidal monolayers", *Nature* **456**, 898 (2008).

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**Christophe Perge** (ENS, Lyon)

### ***Creep and brittle failure of a protein gel under stress***

Biomaterials such as protein or polysaccharide gels are known to behave qualitatively as soft solids and to rupture under an external load. Combining optical and ultrasonic imaging to shear rheology we show that the failure scenario of a protein gel is typical of brittle solids: after a power-law creep regime fully accounted for by linear viscoelasticity and homogeneous deformation, fractures nucleate and grow logarithmically perpendicularly to shear up to sudden rupture. A single equation accounting for those two successive processes nicely captures the full rheological response. The failure time follows a decreasing power-law with the applied shear stress strongly reminiscent of the Basquin law of fatigue for solids. These results are in excellent agreement with recent fiber-bundle models that include damage accumulation on elastic fibers and exemplify protein gels as model brittle soft solids.

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**Elsen Tjhung** (Laboratoire Charles Coulomb, Montpellier)

### ***Dynamic criticality in periodically driven colloidal suspensions***

Non-equilibrium phase transitions have been studied intensively in recent years. For instance Pine et al. [1, 2] studied a colloidal system driven out of equilibrium by periodic shearing. They have found that below certain critical point (which depends on the density and shearing amplitude), the system evolves into an absorbing state in which all the particles move reversibly in response to the external periodic shearing. In this work, we consider an even simpler model which can be thought as the isotropic case of [2] but still possessing a similar absorbing phase transition. This model is motivated by experimental studies of soft colloidal suspension driven out of equilibrium via periodic heating and cooling. As a result, the size of the colloids can expand and contract periodically. Contrary to [2], we find that the critical behaviour in our model is independent of the activity parameter (i.e. driving amplitude). In addition, both our model and [2] also exhibit a very heterogeneous dynamics to which comparison to glassy systems [3] can be made, and we suggest a number of simple experimental measurements to reveal this dynamic criticality.

[1] D. J. Pine, J. P. Gollub, J. F. Brady, & A. M. Leshansky, "Chaos and irreversibility in sheared suspensions", *Nature* **438**, 997 (2005).
[2] L. Corte, P. M. Chaikin, J. P. Gollub, & D. J. Pine, "Random organization in periodically driven systems", *Nature Physics* **4**, 420 (2008).
[3] *Dynamical heterogeneities in glasses, colloids and granular materials*, Eds. L. Berthier, G. Biroli, J.-P. Bouchaud, L. Cipelletti, & W. van Saarloos, Oxford University Press (2011).

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**Jean-François Trochet** (Institut Néel, Grenoble)

***Granular Monolayer subjected to a gradient of vibration***

As function of frequency and mean acceleration into monolayer presents different equilibrium states, ordered pattern, partially ordered or disordered, dynamical or static, probably governed by a competition between energy injection via the vibration gradient and local dissipation.

GDR meeting "Driven Disordered Systems 2014"

***Program of Thursday, June 5***

| | | | |
|---|---|---|---|
| | 10h30-11h15 | Registration | (Refreshments and installation of the posters.) |
| | 11h15 | Jean-Louis Barrat | *Introduction* |
| *Depinning & Yielding* | 11h25 | Zoe Budrikis | *From shear transformations to depinning transitions: lattice models for amorphous plasticity* |
| | 12h10 | Damien Vandembroucq | *Finite statistical size effects in compressive strength* |
| | 12h35 | Vivien Lecomte | *Interfaces in random media with short-range correlated disorder* |
| | 13h-14h | Lunch break | (Poster session) |
| *Jammed systems* | 14h | Ludovic Berthier | *Thinning or thickening? Multiple rheological regimes in dense suspensions of soft particles* |
| | 14h45 | Nicolas Brodu | *Measuring 3D forces at each contact within a stressed granular medium with refraction index matching tomography.* |
| | 15h10 | Olivier Dauchot | *Vibrated granular media, an experimental way towards jamming.* |
| | 15h55-16h30 | Coffee break | (Poster session) |
| *Yielding in Soft Matter* | 16h30 | Luca Cipelletti | *A microscopic view of the yielding transition in concentrated emulsions* |
| | 17h15 | Robin Masurel | *Stress relaxation of highly disordered viscoelastic materials* |
| | 17h40 | Jérôme Crassous | *Microstructure of a plastic flow before failure* |
| | 18h05 | Francesco Puosi | *Time dependent elastic response to a local shear transformation in amorphous solids* |
| | 18h30-19h30 | Refreshments | (Poster session) |
| | 20h | Conference dinner | At the restaurant "Le Téléférique" on the Bastille. |

GDR meeting "Driven Disordered Systems 2014"

***Program of Friday, June 6***

| | | | |
|---|---|---|---|
| *Magnetic interfaces* | 9h | Vincent Jeudy | *Field-driven domain wall motion in ferromagnetic films with weak disorder* |
| | 9h45 | Reinaldo Garcia Garcia | *Eddy currents and Barkhausen noise: Possible breakdown of Middleton theorem* |
| | 10h10 | Jacques Ferré | *2D melting and fluctuations at the spin reorientation transition in a Pt/Co/Pt film* |
| | 10h45-11h20 | Coffee break | (Poster session) |
| *Flow & plasticity dynamics* | 11h20 | Marc-Antoine Fardin | *Shear-banding in complex fluids* |
| | 12h05 | Marc Durand | *Statistical mechanics of two-dimensional shuffled foams: prediction of the correlation between geometry and topology* |
| | 12h30 | Laurent Ponson | *On the relevance of depinning concepts to describe damage spreading and localization in disordered materials* |
| | 12h55 | Michael Falk | *Competition between cavitation and flow in amorphous solids* |
| | 13h20-14h30 | Lunch break | (Poster session) |
| *Avalanches* | 14h30 | Anaël Lemaître | *Signature of flow and relaxation events in amorphous glasses and supercooled liquids under shear* |
| | 15h15 | Kay Wiese | *Avalanches* |
| | 15h40 | François Landes | *Avalanche statistics in disordered visco-elastic interfaces* |
| | 16h05 | Stojanova Menka | *Energy's probability distribution in scale invariant processes: the effect of time correlations* |
| | 16h30 | Happy Hour | (Discussions) |

GDR meeting "Driven Disordered Systems 2014"

***Poster list***

| | |
|---|---|
| Karol Asencio | *Compaction of faceted particles* |
| Catherine Barentin | *Capillary rise of yield stress fluid* |
| Nicolas Brodu | *Inferring statistically singular points to highlight the structure of large environmental data sets* |
| Vincent Démery | *From microstructural features to effective toughness in disordered brittle solids* |
| Giacomo Gradenigo | *Fluctuating hydrodynamic theory for a driven granular fluid: study of out-of-equilibrium correlations* |
| Sara Jabbari-Farouji | *Mechanisms of plastic deformation in glassy and semi-crystalline polymers* |
| Takeshi Kawasaki | *Power law divergence of the viscosity in dense athermal suspensions by large scale computer simulations* |
| Simon Merminod | *Order and disorder in a driven magnetic granular monolayer* |
| Christophe Perge | *Creep and brittle failure of a protein gel under stress* |
| Elsen Tjhung | *Dynamic criticality in periodically driven colloidal suspensions* |
| Jean-François Trochet | *Granular monolayer subjected to a gradient of vibration* |