News from Disordered Elastic Systems

September 6-10, 2021 — Spetses (Greece)

Organisation

Elisabeth Agoritsas – PCSL, EPFL (Switzerland)
Vivien Lecomte – LIPhy, Université Grenoble-Alpes (France)
Damien Vandembroucq – PMMH, ESCPI Paris (France)
Frédérique Auger (Administrative manager) – PMMH, ESCPI Paris (France)

Venue

Anargyrios & Korgialenios School of Spetses (AKSS), Spetses island, Greece

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Description

The theoretical framework of disordered elastic systems has been successfully applied, over the last decades, to a wide range of physical systems with very different microphysics and characteristic scales, ranging for instance from ferromagnetic domain walls, superconductor vortices, biophysics interfaces to fracture cracks and earthquakes. Experimentally, it provides effective descriptions at a mesoscopic scale, theoretically tractable and experimentally testable. From a fundamental point of view, it encompasses prototypical models of classical statistical physics, where the role of disorder can be systematically investigated, while triggering the development of new theoretical tools to tackle out-of-equilibrium issues.

Recent developments have extended the initial scope of this framework, for instance in active materials or in glassy problems. Analogies have also been drawn with non-equilibrium soft matter problems, such as the shearing of amorphous materials, which present a yielding transition similar the depinning transition of driven manifolds in disordered media. Theoretical developments in the physics of glassy phenomena and in algorithmics have also been made.

The goal of this workshop is to welcome newcomers to the field while pushing this framework towards new exciting research directions.

Contents

Contents according to the programme

THURSDAY 09/09:

- Kristina Davitt - Measurements of wetting hysteresis and dynamics with controlled disorder
- Kirsten Martens - Importance of elastic interactions for relaxation processes and residual stresses in soft disordered solids
- Jérôme Weiss - Damage avalanches in quasi-brittle materials
- Jérôme Crassous - Micro-slips in an experimental granular shear band replicate the spatiotemporal characteristics of natural earthquakes
- Julien Tailleur - Pressure in active systems: from the lack of equation of state to hidden conservation laws
- Frédéric van Wijland - Surface tensions in active matter
- Yariv Kafri - The long-ranged influence of disorder on active systems
- Sylvain Patinet - Local shear relaxations in supercooled liquids: when soft zones are fast
- David Richard - Comparison of computational methodologies for predicting plastic activity in amorphous materials

FRIDAY 10/09:

- Gilles Tarjus - Functional Renormalization Group for disordered systems: Contrasting perturbative and nonperturbative approaches
- Kay Wiese - Universal force correlations at depinning, and what they teach us (part I)
- Cathelijne ter Burg - Universal force correlations at depinning, and what they teach us (part II)
- Lev Truskinovsky - Variety of scaling regimes in crystal plasticity

Detailed schedule

	Sunday 5	Monday 6	Tuesday 7	Wednesday 8	Thursday 9	Friday 10
9:00-10:00		Giamarchi	Rosso	Lemaître	Davitt	Tarjus
10:00-10:40		Coffee break	Coffee break	Coffee break	Coffee break	Coffee break
10:40-11:20		Jeudy	Barès	Tanguy	Martens	Wiese
11:20-12:00		Guruciaga	Bonamy	Mungan	Weiss	ter Burg
12:00-12:40		Kolton	de Geus	Ros	Crassous	Truskinovsky
12:40-14:30		Lunch break	Lunch break	Lunch break	Lunch break	Lunch break / Free - Departure from the AKSS venue
14:30-15:10	Arrival at the AKSS venue	Paruch	Maloney	Free - Discussions	Tailleur	Free - Departure from the AKSS venue
15:10-15:50	Arrival at the AKSS venue	Mayya	Le Doussal	Free - Discussions	van Wijland	Free - Departure from the AKSS venue
15:50-16:30	Arrival at the AKSS venue	Atis	García-García	Free - Discussions	Kafri	Free - Departure from the AKSS venue
16:30-18:30	Arrival at the AKSS venue	Coffee break - Discussions	Coffee break - Discussions	Free - Discussions	Coffee break - Discussions	Free - Departure from the AKSS venue
18:30-19:10	Arrival at the AKSS venue	Caballero	Ferrero	Free - Discussions	Patinet	Free - Departure from the AKSS venue
19:10-19:50	Arrival at the AKSS venue	Purrello	GDR	Free - Discussions	Richard	Free - Departure from the AKSS venue
20:30	Dinner at AKSS	Free	Conf dinner	Free	Conf dinner	Free

1 Severine Atis

Chemical avalanches and reaction fronts universal behavior

Resulting from the balance between molecular diffusion and nonlinear chemical kinetics, reaction-diffusion processes can generate Fisher waves: self-sustained fronts that propagate like progressive waves, and present in systems ranging from combustion physics to population dynamics. In this presentation, I will show that when coupled with a disordered flow, the reaction front fluctuations display scaling laws consistent with the universal behavior predicted by the Kardar-Parisi-Zhang stochastic growth model. Depending on the mean flow amplitude, the system encompasses three distinct universality classes associated with different front morphologies and dynamical behaviors. Finally, I will show the existence of two depinning transitions with distinct critical behaviors leading to the formation of chemical wave avalanches of two different types.

- Microbial range expansions on liquid substrates, S. Atis, B. T. Weinstein, A. W. Murray, & D. R. Nelson, *Physical Review X* **9**, 021058 (2019).
- Avalanches dynamics in reaction fronts in disordered flows, T. Chevalier, A. K. Dubey, S. Atis, A. Rosso, D. Salin, & L. Talon, *Physical Review E* **95**, 042210 (2017).
- Experimental evidence for three universality classes for reaction fronts in disordered flows, S. Atis, A. K. Dubey, D. Salin, L. Talon, P. Le Doussal, K. J. Wiese, *Physical Review Letters* **114**, 234502 (2015).
- Avalanche shape and exponents beyond mean-field theory, A. Dobrinevski, P. Le Doussal, & K. J. Wiese, *EPL (Europhysics Letters)* **108**, 66002 (2015).
- Autocatalytic reaction fronts inside a porous medium of glass spheres, S. Atis, S. Saha, H. Auradou, D. Salin, & L. Talon, *Physical Review Letters* **110**, 148301 (2013).
- Phase diagram of sustained wave fronts opposing the flow in disordered porous media, S. Saha, S. Atis, D. Salin, & L. Talon, *EPL (Europhysics Letters)*, **101**, 38003 (2013).
- CHEMO-hydrodynamic coupling between forced advection in porous media and self-sustained chemical waves, S. Atis, S. Saha, H. Auradou, J. Martin, N. Rakotomalala, L. Talon, & D. Salin, *Chaos: An Interdisciplinary Journal of Nonlinear Science* **22**, 037108 (2012).
- Facet formation in the negative quenched Kardar-Parisi-Zhang equation, H. Jeong, B. Kahng, & D. Kim, *Physical Review E* **59**, 1570 (1999).
- Anisotropic surface growth model in disordered media, H. Jeong, B. Kahng, & D. Kim, *Physical Review Letters* **77**, 5094 (1996).
- Strong pinning of propagation fronts in adverse flow, T. Gueudré, A. K. Dubey, L. Talon, & A. Rosso, *Physical Review E*, **89**, 041004 (2014).

2 Jonathan Barés

Triggering low intensity avalanches to control crackling dynamics: global and local approach

When submitted to a slow driving, many physical systems respond with a jerky dynamics also called *crackling*. These systems encompass a large diversity of phenomena going from fracture or damage to imbhibition and even plasticity to mention a few. These crackling dynamics come with rare extreme events that can have devastating effects as for the case of earthquakes or avalanches. Since these large events are, so far, impossible to predict it is paramount to be able to control their occurrence and reduce their intensity.

In the case of seismicity, it is now well documented that local gentle excitations can induce earthquakes even far away from the excitation point. On another side, to deal with snow hazard in mountains, different devices have been set up which permit to inject locally strong pulses of energy that trigger avalanches. Pushing forward these ideas, is it possible to modify and control the full statistics of a crackling system injecting periodically and locally small amounts of energy at the right place in this system? Is it possible to kill extreme avalanches inducing more smaller avalanches just by sacrificing a small amount of energy?

We present how excitation, more precisely amplitude and frequency can decrease the intensity of extreme events in crackling systems. We use long-range elastic depinning interface as a paradigm to model such a crackling system and add excitations of different natures, intensities and periods. Based on extensive simulations, we unravel that excitation on randomly chosen points along the interface have the same effect as excitation on strongly pinned points. We find that, despite the diversity of control parameters the injected power per unit of front length ($\mathcal{Q}$) is the unique parameter that rule the efficiency of excitation. This efficiency, in terms of extreme event killing, has a maximum for a certain value $\mathcal{Q}_c$ for which the rate of event is maximum. Also, surprisingly, excitations below the Larkin length can even have an effect. This work sheds light on a way to control crackling dynamics appearing in systems as diverse as crack front propagation, moving magnetic walls in amorphous ferromagnets or even neural activity.

- Controlling crackling dynamics by triggering low-intensity avalanches, J. Barés & D. Bonamy, *Physical Review E* **103**, 053001 (2021).
- Crackling versus continuumlike dynamics in brittle failure, J. Barés, L. Barbier, D. Bonamy, *Physical Review Letters* **111**, 054301 (2013).
- Fluctuations of global energy release and crackling in nominally brittle heterogeneous fracture, J. Barés, M.-L. Hattali, D. Dalmas, D. Bonamy, *Physical Review Letters* **113**, 264301 (2014).
- Aftershock sequences and seismic-like organization of acoustic events produced by a single propagating crack, J. Barés, A. Dubois, L. Hattali, D. Dalmas, D. Bonamy, *Nature Communications* **9**, 1253 (2018).
- Seismicity in sheared granular matter, A. A. Zadeh, J. Barés, J. E. S. Socolar, R. P. Behringer, *Physical Review E* **99**, 052902 (2019).
- Crackling to periodic dynamics in granular media, A. A. Zadeh, J. Barés, R. P. Behringer, *Physical Review E* **99**, 040901 (2019).
- Local and global avalanches in a two-dimensional sheared granular medium, J. Barés, D. Wang, D. Wang, T. Bertrand, C. S. O'Hern, & R. B. Behringer, *Physical Review E* **96**, 052902 (2017).

3 Nirvana Belén Caballero

From bulk descriptions to emergent interfaces

Collective structures emerge in all systems of nature. Ferroelectric or ferromagnetic materials, cell membranes, individual cells, or even cell colonies are different at a microscopical level but still share very similar physical properties. In inert systems like ferroelectrics and ferromagnets, the high-speed manipulation of these nanostructures is the prime factor for the development of the next generation of low-power functional devices for computation and communication. In living systems, the emergence of interfaces as a result of collective organization has proven to be crucial for their basic functioning. Tailoring and controlling these emergent structures is thus crucial for the development of technological applications triggering societal progress. Controlling interfaces is difficult since, paradoxically, an inherent feature of collective organization is disorder. In this talk, I will show how rather simple theoretical approaches based on Ginzburg-Landau-type models can be successfully employed to understand diverse disordered systems. In particular, how they turn out to be extremely versatile to probe the effects of different experimental protocols [1,2,3]. I will show how a disordered Ginzburg-Landau model can be reduced to the quenched Edwards-Wilkinson equation [4]. Finally, I will discuss some exciting implications of the Edwards-Wilkinson equation. As, for example, how we can use it to capture the effects of the dominant interactions in biological interfaces [5]. I will use one of our latest results on the quenched Edwards-Wilkinson equation to explain why one can observe roughness exponents which are larger than $\zeta_{KPZ} = 2/3$ [6].

[1] Magnetic domain wall creep and depinning: A scalar field model approach, N. Caballero, E. E. Ferrero, Al B. Kolton, J. Curiale, V. Jeudy, & S. Bustingorry, *Physical Review E* **97**, 062122 (2018).

[2] Degradation of domains with sequential field application, N. Caballero, arXiv:2009.14205 [cond-mat.dis-nn].

[3] Phase separation in membranes due to matter exchange, N. Caballero, K. Kruse, & T. Giamarchi (soon in Arxiv).

[4] From bulk descriptions to emergent interfaces: Connecting the Ginzburg-Landau and elastic-line models, N. Caballero, E. Agoritsas, V. Lecomte, & T. Giamarchi, *Physical Review B* **102**, 104204 (2020).

[5] Roughness and dynamics of proliferating cell fronts as a probe of cell-cell interactions, G. Rapin*, N. Caballero* (*equal contributions), I. Gaponenko, B. Ziegler, A. Rawleigh, E. Moriggi, T. Giamarchi, S. A. Brown, & P. Paruch, *Scientific Reports* **11**, 8869 (2021).

[6] Microscopic interplay of temperature and disorder of a 1D elastic interface, N. Caballero, T. Giamarchi, V. Lecomte, & E. Agoritsas (soon in Arxiv).

[7] [Overviews] Nirvana Caballero, Complex Physics in 2 minutes Science Blog.

4 Daniel Bonamy

Fast cracks in heterogeneous materials: The key role of elastic waves

Predicting when and how brittle solids break is not an easy task: Stress enhancement at defects makes the behavior observed at the macroscopic scale extremely dependent on the presence of material heterogeneities down to very small scales. This translates into large statistical aspects difficult to handle in practice. Engineering sidetracks the difficulty by reducing the problem to the destabilization and subsequent propagation of a pre-existing crack and Linear Elastic Fracture Mechanics (LEFM) relates crack dynamics to few materials constants (elastic modulus, fracture toughness and elastic wave speeds) [1]. The presence of microstructural heterogeneities involves additional complexity. Still, the application of interface growth model and depinning transition to the problem have allowed a global self-consistent approach of crack growth in heterogeneous solids, together with a prediction of induced statistical aspects [2,3]... provided that crack propagation remains slow enough. In this presentation, we will examine the possibility of obtaining, under simplified assumptions, an elastodynamic description of fast crack propagating along an heterogeneous planar interface [4,5,6]. We will see how front waves (FW) form and transport fronts disturbances along the crack edge, without geometric attenuation, at speed depending on overall fracture speed. By examining in details crack interaction with unidimensional strips and radial defects, we will obtain semi-analytic forms of these FW [7]. We will finally discuss how to observe signatures of these FWs in the electrical measurement of high frequency velocity fluctuations measured on dynamic fracture experiments conducted in PMMA

Work done with Alizée Dubois.

[1] *Fracture of Brittle Solids*, B. R. Lawn, Cambridge University Press (1993).

[2] Failure of heterogeneous materials: A dynamic phase transition?, D. Bonamy & E. Bouchaud, *Phys. Rep.* **498**, 1 (2011).

[3] Dynamics of cracks in disordered materials, D. Bonamy, *C.R. Phys.* **18**, 297 (2017).

[4] Dynamic weight functions for a moving crack. I. Mode I loading, J. R. Willis, A. B. Movchan, *J. Mech. Phys. Solids* **43**, 319 (1995).

[5] Dynamics and instabilities of planar tensile cracks in heterogeneous media, S. Ramanathan, D. S. Fisher, *Phys. Rev. Lett.* **79**, 877 (1997).

[6] Perturbative simulations of crack front waves, J. Morrissey & J. R. Rice, *Journal of the Mechanics and Physics of Solids* **48**, 1229 (2000).

[7] Dynamic crack growth along heterogeneous planar interfaces: Interaction with unidimensional strip, A. Dubois & D. Bonamy, *Phys. Rev. E* **103**, 013004 (2021).

5 Jérôme Crassous

Micro-slips in an experimental granular shear band replicate the spatiotemporal characteristics of natural earthquakes

We study experimentally the fluctuations of deformation naturally emerging along a shear fault within compressed frictional granular medium. Using laser interferometry, we show that the deformation inside this granular gouge occurs as a succession of localized micro-slips distributed along the fault. We show that the associated distributions of released seismic moments, the memory effects in strain fluctuations, as well as the time correlations between successive events, follow the empirical laws of natural earthquakes.

PLASTICITY AND SHEAR EVENTS IN GRANULAR MATERIALS

- Micro-slips in an experimental granular shear band replicate the spatiotemporal characteristics of natural earthquakes, D. Houdoux, A. Amon, D. Marsan, J. Weiss, J. Crassous, *Communications Earth & Environment* **2**, 1 (2021).
- Plastic flow and localization in an amorphous material: experimental interpretation of the fluidity, D. Houdoux, T. B. Nguyen, A. Amon, J. Crassous, *Physical Review E* **98**, 022905 (2018).
- Eshelby inclusions in granular matter: Theory and simulations, S. McNamara, J. Crassous, and A. Amon, *Phys. Rev. E* **94**, 022907 (2016).
- Spatial repartition of local plastic processes in different creep regimes in a granular material, A. Pons, T. Darnige, J. Crassous, E. Clement, A. Amon, *EPL* **28001**, 113 (2016).
- Mechanical fluctuations suppress the threshold of soft-glassy solids: The secular drift scenario, A. Pons, A. Amon, T. Darnige, J. Crassous, and E. Clément, *Phys. Rev. E* **92**, 020201(R)(2015).
- Emergence of cooperativity in plasticity of soft glassy materials, A. Le Bouil, A. Amon, S. McNamara & J. Crassous, *Phys. Rev. Lett.* **112**, 246001 (2014).
- A biaxial apparatus for the study of heterogeneous and intermittent strains in granular materials, A. Le Bouil, A. Amon, J. C. Sangleboeuf, H. Orain, P. Bésuelle, G. Viggiani, P. Chasle & J. Crassous, *Granular Matter* **16**, 1 (2014).
- Experimental investigation of plastic deformations before granular avalanche, A. Amon, R. Bertoni & J. Crassous, *Phys. Rev. E* **87**, 012204 (2013).
- Hot spots in an athermal system, A. Amon, V. Bau Nguyen, A. Bruand, J. Crassous, & E. Clément, *Phys. Rev. Lett.* **108**, 135502 (2012).
- Experimental study of a creeping granular flow at very low velocity, J. Crassous, J.-F. Métayer, P. Richard, & C. Laroche, *J. Stat. Mech.* **2008**, P03009 (2008).

NON-AFFINITY

- Probing non-affine expansion with light scattering, A. Mikhailovskaya, J. Fade, J. Crassous, arXiv:2101.01642 [cond-mat.soft].

LIGHT SCATTERING IN GRANULAR MATERIAL

- Speckle decorrelation with wavelength shift as a simple way to image transport mean free path, A. Mikhailovskaya, J. Fade, J. Crassous, *The European Physical Journal Applied Physics* **85**, 30701 (2019).
- Spatially resolved measurements of micro-deformations in granular materials using diffusing wave spectroscopy, A. Amon, A. Mikhailovskaya, J. Crassous, *Review of Scientific Instruments* **051804**, 88 (2017).

- Diffusing-wave spectroscopy contribution to strain analysis, M. Erpelding, B. Dollet, A. Faisant, J. Crassous, & A. Amon, *Strain* **49**, 167 (2013).
- Diffusive waves in a dilating scattering medium, J. Crassous, M. Erpelding, & A. Amon, *Phys. Rev. Lett.* **103**, 013903 (2009).
- Diffusive Wave Spectroscopy applied to the spatially resolved deformation of solid, M. Erpelding, A. Amon, & J. Crassous, *Phys. Rev. E* **78**, 046104 (2008).
- Diffusive wave spectroscopy of a random close packing of spheres, J.Crassous, *Eur. Phys. J. E* **23**, 145 (2007).
- Probing creep motion into granular materials with light scattering, L. Djaoiu & J. Crassous, *Granular Matter* **7**, 185 (2005).

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6 Kristina Davitt

Measurements of wetting hysteresis and dynamics with controlled disorder

In this talk, my goal is to describe the types of experiments that we perform and our current interpretations in the hopes of beginning a discussion of how either current data could be looked at in the theoretical framework of disordered systems, or how our experimental capabilities could be employed to access relevant parameters of the problem.

The general goal of our work is to understand wetting on real surfaces. By real, I imply that they exhibit disorder on small scales, either in roughness or chemical heterogeneity. Our idea is that wetting dynamics is an old problem, and that one of the big, remaining questions is the role of thermally-activated motion of the contact line on this inevitable disorder and how it couples to the more well-known hydrodynamics of the problem.

Therefore, our experiments are designed to measure the dynamics over all accessible velocities and to do so on surfaces where we have fine control of what is on the surface. I will describe two systems that we have worked with: smooth, nano-scale topographical bumps and polymer pseudo-brushes of different chain lengths. Some practical conclusions we have drawn from these experiments include that the depinning transition may be inaccessible, the hysteresis and dynamics may be controlled by different scales of defects, and there may be other sources of dissipation to contend with.

- Controlled defects to link wetting properties to surface heterogeneity, R. Lhermerout & K. Davitt, *Soft Matter* **14**, 8643 (2018).
- Thermally activated motion of a contact line over defects, H. Perrin, R. Lhermerout, K. Davitt, E. Rolley, & B. Andreotti, *Soft Matter* **14**, 1581 (2018).
- A moving contact line as a rheometer for nanometric interfacial layers, R. Lhermerout, H. Perrin, E. Rolley, B. Andreotti, & K. Davitt, *Nature Communications* **7**, 12545 (2016).
- Defects at the nanoscale impact contact line motion at all scales, H. Perrin, R. Lhermerout, K. Davitt, E. Rolley, & B. Andreotti, *Physical Review Letters* **116**, 184502 (2016).

7 Ezequiel Ferrero

The yielding of amorphous solids at finite temperatures [arXiv:2107.06365]

We analyze the effect of temperature on the yielding transition of amorphous solids using different coarse-grained model approaches. On one hand we use an elasto-plastic model, with temperature introduced in the form of an Arrhenius activation law over energy barriers. On the other hand, we implement a Hamiltonian model with a relaxational dynamics, where temperature is introduced in the form of a Langevin stochastic force. In both cases, temperature transforms the sharp transition of the athermal case in a smooth crossover. We show that this thermally smoothed transition follows a simple scaling form that can be fully explained using a one-particle system driven in a potential under the combined action of a mechanical and a thermal noise, the stochastically-driven Prandtl-Tomlinson model. Our work harmonizes the results of simple models for amorphous solids with the phenomenological $\sim T^{2/3}$ law proposed by Johnson and Samwer [*Phys. Rev. Lett.* **95**, 195501 (2005)] in the framework of experimental metallic glasses yield observations, and extend it to a generic case. Finally, our results strengthen the interpretation of the yielding transition as an effective mean-field phenomenon.

PREPRINTS ON YIELDING AND DEPINNING

- The yielding of amorphous solids at finite temperatures, E. E. Ferrero, A. B. Kolton, E. A. Jagla, arXiv:2107.06365 [cond-mat.dis-nn] (2021).
- The fate of shear-oscillated amorphous solids, C. Liu, E. E. Ferrero, E. A. Jagla, K. Martens, A. Rosso, L. Talon, arXiv:2012.15310 [cond-mat.soft] (2021).

PUBLISHED ARTICLES ON YIELDING AND DEPINNING

- Universal critical exponents of the magnetic domain wall depinning transition, L. J. Albornoz, E. E. Ferrero, A. B. Kolton, V. Jeudy, S. Bustingorry, J. Curiale, *Phys. Rev. B* **104**, L060404 (2021).
- Creep motion of elastic interfaces driven in a disordered landscape, E. E. Ferrero, L. Foini, T. Giamarchi, A. B. Kolton, A. Rosso, *Annual Review of Condensed Matter Physics* **12**, 111 (2021).
- Properties of the density of shear transformations in driven amorphous solids, E. E. Ferrero, E. A. Jagla, *J. Phys.: Condens. Matter* **33**, 124001 (2021).
- Elastic interfaces on disordered substrates: From mean-field depinning to yielding, E. E. Ferrero, E. A. Jagla, *Phys. Rev. Lett.* **123**, 218002 (2019).
- Criticality in elastoplastic models of amorphous solids with stress-dependent yielding rates, E. E. Ferrero, E. A. Jagla, *Soft Matter* **15**, 9041 (2019).
- Deformation and flow of amorphous solids: Insights from elastoplastic models, A. Nicolas, E. E. Ferrero, K. Martens, J. L. Barrat, *Rev. Mod. Phys.* **90**, 045006 (2018).
- Creep dynamics of athermal amorphous materials: a mesoscopic approach, C. Liu, E. E. Ferrero, K. Martens, J.-L. Barrat, *Soft Matter* **14**, 8306 (2018).
- Damage accumulation in silica glass nanofibers, S. Bonfanti, E. E. Ferrero, A. L. Sellerio, R. Guerra, S. Zapperi, *Nano Letters* **18**, 7, 4100 (2018).
- Magnetic domain wall creep and depinning: a scalar field model approach, N. B. Caballero, E. E. Ferrero, A. B. Kolton, J. Curiale, V. Jeudy, S. Bustingorry, *Physical Review E* **97**, 062122 (2018).
- Spatiotemporal patterns in ultraslow domain wall creep dynamics, E. E. Ferrero, L. Foini, T. Giamarchi, A. B. Kolton, A. Rosso, *Physical Review Letters* **118**, 147208 (2017).

- Inertia and universality of avalanche statistics: The case of slowly deformed amorphous solids, K. Karimi, E. E. Ferrero, J.-L. Barrat, *Physical Review E* **95**, 013003 (2017).

- Driving rate dependence of avalanche statistics and shapes at the yielding transition, C. Liu, E. E. Ferrero, F. Puosi, J.-L. Barrat, K. Martens, *Physical Review Letters* **116**, 065501 (2016).

- Relaxation in yield stress systems through elastically interacting activated events, E. E. Ferrero, K. Martens, J.-L. Barrat, *Physical Review Letters* **113**, 248301 (2014).

- Uniqueness of the thermodynamic limit for driven disordered elastic interfaces, A. B. Kolton, S. Bustingorry, E. E. Ferrero, A. Rosso, *Journal of Statistical Mechanics: Theory and Experiment* **2013**, P12004 (2013).

- Numerical approaches on driven elastic interfaces in random media, E. E. Ferrero, S. Bustingorry, A. B. Kolton, A. Rosso *Comptes Rendus Physique* **14**, 641 (2013).

- Non-steady relaxation and critical exponents at the depinning transition, E. E. Ferrero, S. Bustingorry, A. B. Kolton, *Physical Review E* **87**, 032122 (2013).

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8 Reinaldo García-García

Connections between the Yang-Lee edge singularity problem and the statistics of avalanche energies at the depinning transition

Avalanches are ubiquitous in driven disordered systems in general and in depinning systems in particular. In spite of the important role played by dissipation mechanisms in that context, the statistics of dissipated energies at the depinning transition have not been explored in full depth. We present here a preliminary study of the energy released in mean-field avalanches at the depinning transition. We find an exact mapping linking the moment generating function of avalanche energies with the generating functions corresponding to two related non-hermitian quantum field theories (QFT)s: the Yang-Lee model for the edge singularity problem and the Euclidean MPT-symmetric $ig\phi^3$ QFT. The implied connection to the minimal model of the edge singularity suggests the possibility of studying dissipation at depinning using simple equilibrium spin models.

9 Tom de Geus

Critical flow properties of a frictional interface

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Quasi-statically sliding a solid block over a nominally flat surface proceeds by stick slip: macroscopic slip events are punctuated by periods of loading. We identify how macroscopic slip is nucleated by collective asperity detachments. This insight allows us to make a prediction for the stress at which macroscopic slip is nucleated (1). Quasi-static sliding in the thermodynamic limit proceeds at a stress σ_c whereas in a finite system, events are rare, causing stress to build-up at a stress $\sigma_n > \sigma_c$. In this talk, we push on to identify σ_c as the minimum of the interface's effective flow curve. The corresponding finite slip rate is rationalised by a newly identified scaling relation, as follows. We propose a model that includes asperity-level disorder, elastic interaction between local slip events, and inertia. Thereto we model the frictional interface as a continuum in which the asperity contacts are modelled using 'blocks' that represent one or several asperity contacts. Each block thereby responds elastically up to a yield stress, upon which it releases part of its built-up elastic energy. As the blocks model a sequence of asperity contacts, each time with a different strength, the yield stresses a drawn randomly from some distribution. We identify a non-monotonic effective flow curve that is decomposed as follows. The interface itself is unstable: blocks are effectively weaker in the presence of mechanical noise (that acts as a sort of temperature), while the amount of noise increases with the rate of activity. This flow curve is well-fitted using a commonly used phenomenological macroscopic friction law $\sigma \sim \log v$ (without such behaviour being assumed microscopically), where σ is the stress and v is the slip rate. The interface is stabilised by dissipation, leading to an effective flow curve (2). During steady-state flow, the dissipation comes fully from friction. During the nucleation of flow, however, the interface experiences effective dissipation through the energy spent on the acceleration of the bulk material around the propagating 'fracture' (2, 3), leading to an effective flow curve $\sigma \sim v - \log v$, that has a minimum that we denote σ_c (with a corresponding finite slip rate v_c). We find that σ_c is a critical point for the dynamics of the frictional interface. When the system is loaded quasi-statistically at σ_c, the system displays avalanches of 'asperity detachments' whose size, radius, and duration are power law distributed. This fact allows us to identify a new scaling relation for friction that confirms that the slip rate, $v_c \equiv v(\sigma_c)$, is finite and independent of the avalanche radius Avalanches of 'asperity' detachements a not very frequent in a finite system, allowing the system to build up stress beyond σ_c: a finite system displays stick slip, whereby σ_c is the average stress after slip events. Nucleation of these slips is governed by a fracture-like instability as follows. Inside an avalanche the stress dynamically drops to σ_c, the avalanche therefore acts as a scar in the material. Following Griffith's stability criterion for fracture, the scar is unstable if its radius is bigger than $A_c \sim (\sigma - \sigma_c)^{-2}$. When this happens, is finally governed by the rate of avalanches, which is determined by the distribution of barriers after a slip event, whose distribution is empirically found to display a so-called pseudo-gap (the distribution follows a power law $P(x_\sigma) \sim x_\sigma^\theta$ at small argument, with x_σ that is needed to yield a block locally). This characteristic (1) leads us to conclude that stick slip is finite size effect, and allows us to predict the stick-slip amplitude as a function of the system size. Finally, when the system is driven at a stress $\sigma < \sigma_c$, which can occur for example when the system is thermally relaxed after a slip event, the avalanches are cut off by the disorder, and therefore nucleation of slip cannot occur in this case.

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10 Thierry Giamarchi

Disordered Elastic Media

Disordered Elastic Systems (DES) are ubiquitous in nature with microscopic realizations ranging from domain walls in ferroic materials, contact line in wetting, periodic systems such as pinned vortex lattices in type II superconductors or charge density waves in metals, or even more quantum systems such as Wigner crystals in heterostructures or more recently in TMD materials. In all these systems an elastic structure is in competition with the intrinsic disorder existing in the material. This competition leads to a particularly rich physics akin to the one of glasses. Last but not least, these systems can easily be put our of equilibrium by application of an external force. I will review in this talk the basic concepts that underpin the physics of DES both on the static and dynamic side and will discuss how we can make progress on this very difficult class of problems by exploiting the rich diversity of microscopic realization. If time permits I will also address the outstanding open questions both in- and out- of equilibrium, as well as the potential connections with other classes of disordered systems.

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11 Pamela Guruciaga

Domain-wall roughness in magnetic thin films: crossover length scales and roughness exponents

Domain-wall dynamics and roughness are closely related to each other and to universal features of disordered systems. Although there are different ways to quantify the fluctuations of the position of an interface, they all present self affinity as a result of scale invariance. In other words, the roughness evolves with a characteristic length scale L as $L^{2\zeta}$, with ζ the roughness exponent. In the case of magnetic domain walls, this exponent can be associated with different static and dynamic regimes [1], hence the importance of measuring it. Indeed, there exist many reports of experimentally determined roughness exponents in magnetic thin films, but their values generally differ from those predicted theoretically by the equilibrium, depinning and thermal reference states. In this work, we study the roughness of domain walls in GdFeCo [2] and Pt/Co/Pt [3] thin films over a large range of magnetic field and temperature. We show that our results, as well as those previously reported in the literature, can be rationalised in a new framework that considers crossover lengths between scales characterised by some of the different expected roughness exponents. We also show that the typical crossover lengths in these materials are on the micrometer scale, and therefore within the range of observation of the domain walls.

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12 Vincent Jeudy

Universal and material dependent dynamic behaviors of domain walls in thin magnetic films

The controlled displacement of spin texture as magnetic domain walls (DWs) is at the basis of potential applications to magnetic memory storage and neuromorphic computation. However, DWs are very sensitive to weak pinning defects, which strongly reduce their mobility and produce roughening and stochastic avalanche-like motion. The interplay between weak pinning disorder, DW elasticity, thermal fluctuations and an external drive leads to different dynamical regimes also encountered for interfaces in ferroelectrics, contact lines in wetting, bacterial colonies, failure propagation... In this variety of physical systems, the interfaces are expected to present both universal [1-3] and non-universal (material and temperature) dependent behaviors.

Disentangling universal from material dependent behaviors is particularly important for understanding the pinning dependent dynamics, i.e., the so-called thermally activated creep and depinning regimes. In this talk, I will discuss a set of recent studies on the dynamics and roughness of DWs driven by magnetic field [4-5] and spin-transfer effects (spin polarized current) [6], in thin ferromagnetic films with perpendicular anisotropy. The comparison of experimental results obtained for different magnetic materials and a wide range of temperature reveals universal scaling functions accounting for both drive and thermal effects on the creep [4] and depinning [5] regimes, including critical exponents. Similar universal behaviors are encountered for DWs driven by spin-transfer torques, despite directional properties of interaction between current and DWs [6] and in contrast to some previous interpretations reported in the literature [7].

Interestingly a self-consistent phenomenological model describing both the creep and depinning dynamics allows to extract material and temperature depend parameters [8] and to address the strength and length scale of the interaction between DWs and pinning disorder [9]. These findings could be also relevant for a wide variety of elastic interfaces moving in weak pinning disordered media.

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13 Yariv Kafri

The long-ranged influence of disorder on active systems

The talk will describe the impact of quenched random potentials on active matter. By developing a methodology for studying these systems both bulk and boundary disorder will be considered. For dilute systems it will be shown that bulk disorder leads to generic long-range correlations, decaying as a power-law, and steady-state currents. Disorder localized along a wall confining the system leads to long-range density modulations and eddies whose amplitude decays as a power law with the distance from the wall, but whose extent grows with it. Following this, the talk will consider scalar active system whose sole hydrodynamic mode is the density. These are known to exhibit a motility induced phase separation in dimensions $d \leq 2$. It will be shown that bulk potential disorder destroys the transition in dimensions d<4, while boundary disorder destroys it in dimensions $d < 3$.

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14 Alejandro Kolton

Curvature-driven AC-assisted creep dynamics of magnetic domain walls

The dynamics of micrometer-sized magnetic domains in ultra-thin ferromagnetic films is so dramatically slowed down by quenched disorder that the spontaneous elastic tension collapse becomes unobservable at ambient temperature. By magneto-optical imaging we show that a weak zero-bias AC magnetic field can assist such curvature-driven collapse, making the area of a bubble to reduce at a measurable rate, in spite of the negligible effect that the same curvature has on the average creep motion driven by a comparable DC field. An analytical model explains this phenomenon quantitatively.

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- Pedagogical Games:
  Would you like to play with Phi4 Domain Walls?
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- Reviews:
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15 Pierre Le Doussal

Avalanches in long-range depinning

Disordered elastic interfaces display avalanche dynamics near the depinning transition. For short-range interactions, avalanches correspond to compact reorganizations of the interface. These are well described by the present scaling theory, the functional RG field theory and are well characterized numerically. For long-range elasticity, an avalanche is a collection of spatially disconnected clusters, a key probe of avalanche dynamics for the experiments, but which are not yet well understood. I will describe a recent work [1] where we identify and determine numerically the main observables. From there we determine the scaling properties of the clusters and relate them to the roughness exponent of the interface and the range of the interaction.

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16 Anaël Lemaître

Elasto-plastic events in glasses and liquids

TBA

17 Craig Maloney

Revisiting the yielding transition… again and again and again.

We present results on the yielding transition as probed by cyclic shear in an elastoplastic model for amorphous matter driven at the athermal, quasi static (AQS) limit. After a transient, the steady state falls into one of three cases in order of increasing strain amplitude: *(i)* pure elastic behavior with no plastic activity, *(ii)* limit cycles where the state recurs after an integer period of strain cycles, and *(iii)* irreversible plasticity with longtime diffusion. The number of cycles N required for the system to reach a periodic orbit diverges as the amplitude approaches the yielding transition between regimes (ii) and (iii) from below, while the effective diffusivity D of the plastic strain field vanishes on approach from above. Both of these divergences can be described by a power law. We further show that the average period T of the limit cycles increases on approach to yielding. We also discuss the nature of the various limit cycles in the reversible plastic regime, focusing on local motifs which can have periods which are divisors of the global period.

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18 Kirsten Martens

Importance of elastic interactions for relaxation processes and residual stresses in soft disordered solids

In this talk I shall discuss the effect of elasticity on relaxation dynamics in soft disordered solids within two examples: in systems where the relaxation process is thermally activated and in systems that relax after a prior deformation. In both cases the long range elastic interactions lead to interesting physical phenomena. In the case of thermally assisted relaxation we calculate the mean-square displacement within a two-dimensinal mesoscopic model, and we determine the dynamical structure factor for tracer particle trajectories. The ballistic regime at short time scales is associated with a compressed exponential decay in the dynamical structure factor, followed by a subdiffusive crossover prior to the onset of diffusion. We relate this crossover to spatiotemporal correlations. In the case of shear cessation in athermal systems we find that an increase in shear rate prior to the shear cessation leads to lower residual stress states. We rationalise our findings using a mesoscopic elasto-plastic description that explicitly includes a long range elastic response to local shear transformations. We find that after flow cessation the initial stress relaxation indeed depends on the pre-sheared stress state, but the final residual stress is majorly determined by newly activated plastic events occurring during the relaxation process. Our simplified coarse grained description not only allows to capture the phenomenology of residual stress states but also to rationalise the altered material properties that are probed using small and large deformation protocols applied to the relaxed material.

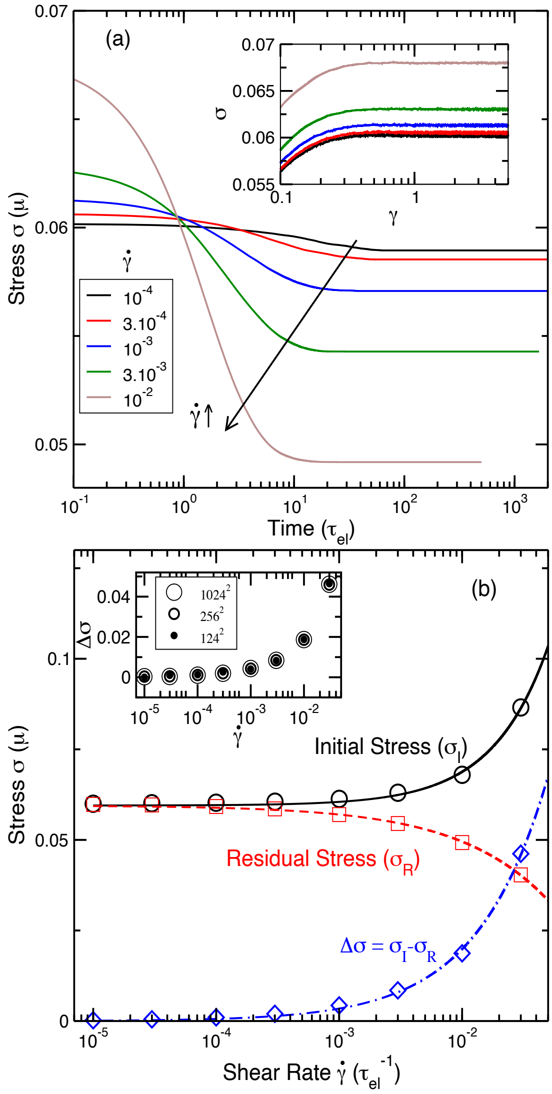

Figure 1: (Top) Relaxation of shear stress (σ) when the external drive (imposed shear-rate) is switched off, while in steady state flow. The arrow shows the direction of increasing shear-rate ($\dot{\gamma}$). The inset shows the load curve (σ vs. strain γ) showing the start-up flow for different shear rates, prior to switch-off. (Bottom) The stress σ_I at the shear switch-off (red square), the residual stress σ_R reached at the end of stress relaxation (black circle) and $\Delta\sigma = \sigma_I - \sigma_R$ (blue diamond), shown for $N = 1024^2$ as a function of the imposed shear rate (system size dependence is shown in the inset).

19 Ashwij Mayya

Precursors to compressive failure as depinning avalanches: Application to structural health monitoring

Compressive failure in structural materials such as mortar, rock and ceramics results from the localization of damage in a plane. It is preceded by bursts of damage activities revealed by power-law distributed acoustic emissions following remarkably robust statistics. Whether these precursors are the cause or the consequence of localization is still an open question. In this study, we explore experimentally the intermittent dynamics of damage growth and its relationship with localization using full-field measurements in bi-dimensional cellular materials under slowly increasing load. Our multi-scale investigation provides a comprehensive statistical description of the failure precursors, revealing their spatial and temporal organization through the succession of highly correlated damage clusters. This complex dynamics can be described by simple scaling laws, displaying a divergence of the size and the duration of these clusters at the approach of the localization threshold. These features are captured by a continuum mechanics model of damage growth in disordered elasto-damageable solids that accounts for the long-range interactions between the constitutive elements of the specimen. Despite striking similarities with critical phenomena, our model shows that the process of damage localization is not a second-order phase transition. Instead, damaging materials stay at some finite distance from criticality, the increase of the size and the duration of precursors close to failure being reminiscent of a standard bifurcation in presence of disorder. Our findings support the description of compressive failure as an instability in which the growing fluctuations preceding it play a marginal role, except providing warning signals. By disentangling the relationship between the collective growth of damage and compressive failure, our study paves the way for the development of predictive tools of structural health monitoring inferring the residual lifetime of materials from the statistical analysis of failure precursors and advanced modeling tools for the design of safer structures.

- Damage spreading in quasi-brittle disordered solids: II. What the statistics of precursors teach us about compressive failure, E. Berthier, A. Mayya, & L. Ponson, (2021), arXiv:2107.14763 [cond-mat.stat-mech].

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20 Muhittin Mungan

Topology of the energy landscape of sheared amorphous solids and the irreversibility transition

Muhittin Mungan (U. Bonn), joint work with Ido Attia, Karin Dahmen, Ido Regev, and Srikanth Sastry

BACKGROUND:

Understanding the response of a disordered configuration of particles to an externally imposed forcing, such as stress or strain, is important in order to characterize the transitions between rigid and flowing states in a wide variety of soft matter systems. Examples include the jamming transition in granular materials [1] and the yielding transition in amorphous solids [2]. The interplay between the deformation energy cost and gain, as the configuration adapts to the imposed forcing, gives rise to a rich dynamics on a complex energy landscape. One example of such dynamics is the response of a disordered system to an oscillatory driving. For small driving amplitudes, this can lead to cyclic response: a repeated sequence of microscopic configurations whose period is commensurate with that of the driving. The cyclic response encodes information and possesses "memory" about the forcing that caused it. Memory effects of this kind have been observed experimentally as well as numerically in a variety of cyclically driven systems, including colloidal suspensions and amorphous solids under oscillatory shear [3–6]. For a recent comprehensive review of memory phenomena see [7].

An important feature of the cyclic response in amorphous solids is that for small shear amplitudes, the steady state cyclic response is typically achieved after a short transient, generally a few driving cycles. As the amplitude of shear is increased, transients become increasingly longer and eventually, at a critical shearing amplitude, the dynamics becomes completely irreversible. The critical shear strain at which this occurs marks the onset of what has been called the irreversibility transition. It is believed that this is also the point at which yielding occurs [8–10].

THIS TALK:

The key insight underlying the research to be presented in this talk is the observation that the complex dynamical features such as the irreversibility transition and yielding are already present in a regime where thermal effects are negligible and the system's response to the forcing is largely rate-independent: the athermal and quasi-static (AQS) regime [11]. As we showed in [I-III], the AQS conditions permit a rigorous description of the dynamics of such systems in terms of a directed state-transition graph, the AQS transition graph. Here the vertices of the AQS transition graph correspond to collections of microscopical partical configurations, the mesostates, that transform purely elastically into each other under the applied shear strain. The transitions between two such mesostates therefore describe purely plastic events. Thus the AQS transition graph captures the plastic events which are at the heart of mechanical irreversibility under applied shear strain. Since the AQS transition graph represents the response of the system to any possible deformation protocol, it provides a birds-eye view of all the possible dynamics. This dynamics is encoded in the topology of the AQS transition graph. Moreover, as we demonstrated in [III], such AQS transition graphs can be directly extracted from atomistic simulations of sheared amorphous solids, such as those in refs. [4, 6].

Building on these ideas we will show how one can extract dynamical features of the irreversibility transition and yielding from the topological properties of AQS transition graphs obtained from simulations of sheared amorphous solids. In this context a useful observable of the transition graph are its strongly connected components (SCCs). SCCs are collection of mesostates that are mutually connected by a sequence of plastic events: there is a sequence of plastic deformations leading from one mesostate A to another mesostate B, and one from B to A. Thus the plastic transitions associated with any periodic response to cyclic shear must be confined to a single SCC. In this sense plastic events conecting mesostates within the same SCCs are reversible, while those corresponding to transitions between different SCCs are irreversible.

An analysis of the SCC cluster sizes extracted from atomistic simulations of a sheared amorphous solid reveals that for small to moderate forcing amplitudes, plastic events are predominantly reversible, and that the irreversibility transition in amorphous solids under oscillatory shear results from a proliferation of irreversible events at larger amplitudes. These results allow us to understand important features of the energy landscape of an amorphous solid.

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21 Patrycja Paruch

From avalanche statistics in ferroelectric domain wall dynamics to inhibitor effects on wound healing

The physics of elastic interfaces in disordered media provides a powerful general framework in which the static and dynamic behaviour of systems as diverse as eroding coastlines, domain walls in ferroic materials, and growing cell colonies can be understood and modelled. In such systems, competition between the flattening effects of elasticity and the fluctuations of the disorder landscape leads to interfacial roughening, critical depinning, and highly non-linear sub-critical dynamics with a power-law distribution of the size of discrete, jerky events (crackling), all characterised by universal scaling exponents whose specific values are related to the dimensionality of the system and its elastic and disorder interactions.

Analytical and numerical models within this framework have focused primarily on uniform interfaces with short-range elasticity and tractable disorder, giving single-valued roughness. In contrast, many physical and biological interfaces present elaborate internal order, significantly higher roughening, and a wider range of dynamics including island nucleation before a propagating front, giving tantalising hints of far greater richness in the effective elastic interactions, the interface structure, and the disorder potential landscape.

Our group addresses these questions experimentally, looking at both physical and biological systems. Here, I will present and compare our scanned probe microscopy studies of roughness and dynamics in ferroelectric domain walls [1], including the more complex effects of heterogeneous pinning potentials [1] and emergent domain wall structure [2], and fluorescence microscopy measurements of proliferating rat epithelial cells [3], contrasting the roughness and dynamics of cell fronts under control conditions with the behaviour when the same cells are confronted with inhibitors targeting a range of different interactions.

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22 Sylvain Patinet

Relaxations in supercooled liquids: Connection between thermal excitations and local yield stresses of their inherent states

M. Lerbinger[1], A. Barbot[1], D. Vandembroucq[1], S. Patinet[1]
[1] PMMH, CNRS, ESPCI Paris, Université PSL, Sorbonne Université, Université de Paris, 75005 Paris, France

While deeply supercooled liquids exhibit divergent viscosity and increasingly heterogeneous dynamics as the temperature drops, their structure shows only seemingly marginal changes. Understanding the relaxation processes involved in this dramatic slowdown is a key question for understanding the glass transition. Here, we study a binary Lennard-Jones mixture in the supercooled regime using molecular dynamic simulations. At low temperatures, thermal relaxation proceeds in a series of activated jumps between inherent structures, i.e. local minima of the potential energy landscape. From these inherent dynamics, we recover information about the location and kinetics of thermally activated rearrangements. By employing a local shear test method that gives access to the shear stress thresholds, we observe a strong connection between the local rate of thermal relaxations and their residual plastic strengths. The correlation is dominated by the softest shear orientations and increases with decreasing temperature, the underlying potential energy landscape playing an increasing role in the dynamics. For the lowest temperature investigated, the maximum correlation is comparable with the best values of literature dealing with the structure-property mapping, but here providing a real-space picture of relaxation processes. Our detection method of thermal rearrangements allows us to investigate the first passage time statistics. The variation of the local activation energy barriers with the stress distance to thresholds is shown to be compatible with the catastrophe theory scaling. It further provides a way to study the back and forth thermal rearrangements whose relative rates increase as the temperature is lowered. By emphasizing the analogy in real space between thermal relaxations in supercooled liquids and plastic shear transformation of amorphous solids, these results shed new light on the nature of relaxations of glassy systems.

LIST OF KEY REFERENCES

In relation to our previous works, the local yield stress method employed here has been shown to be highly helpful to capture the barrier dependencies to glass preparation [1], shear banding [2], plastically induced anisotropy [3] and has been found to be one of the best structural indicators to predict plastic activity in athermal amorphous solids [4]. It is, therefore, an ideal tool for documenting, in a very rich way, what happens "inside" an amorphous solid and better characterizing the relationship between structure and plasticity. From a practical point of view, it makes it possible to envision a more quantitative multi-scale modeling strategy as demonstrated in [5].

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23 Víctor Hugo Purrello

The role of inertia in the depinning transition: from a single particle to elastic interfaces

The study of elastic interfaces in random media is relevant for understanding generic properties displayed by a variety of experimental systems, such as domain walls in ferromagnetic materials or wetting fronts on a rough substrate, and to successfully classify them into universality classes. In this presentation we consider a system composed of massive particles, adding thus inertia to some of the most used models for interfaces. First, we consider a single particle, driven with a constant force in a periodic potential and subjected to a dissipative friction. As a function of the drive and mass –or drive and damping– the phase diagram of this paradigmatic model is well known to present a pinned, a sliding, and a bistable regime. The latter is a unique feature introduced by the inertia, and it is also present for systems of higher dimension d. We introduce several models for $d = 1$ with an inertial term, characterizing the depinning transitions and finding changes in the universality class. Finally, we introduce a quenched-Edwards-Wilkinson model, adding mass to each element of the interface. We analyse its bistable regime and we estimate its critical mass numerically. Our method could be used as a framework to study massive interfaces over periodic or disordered potentials.

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24 David Richard

Comparison of computational methodologies for predicting plastic activity in amorphous materials

Imposing an external driving, amorphous solids can flow via a succession of plastic rearrangement of localized particles. Numerous numerical and experimental studies have shown that loci of plastic instability in glasses are triggered by spatially localized soft spots in direct analogy with dislocations present in crystalline solids, although the population and microscopic structure of the former being significantly different from the latter. The detection and nature of such "amorphous defects" have received a lot of attention, one of the goals being to predict from the microscopic structure itself which regions are likely to undergo a rearrangement upon deformation. In this context, I will present various structural indicators ranging from purely structural to highly non-linear methods that require the knowledge of the interactions between constituents. I will then discuss in detail indicators that are constructed from an analysis of the potential energy landscape and present novel anisotropic descriptors that consider the tensorial nature of the coupling of a single soft spot with the loading geometry.

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25 Valentina Ros

Activated dynamics in glassy random landscapes: towards high-dimensional instantons

High-dimensional random functionals emerge ubiquitously when modelling the energy landscapes of complex systems, and are typically glassy: exploring them with stochastic dynamics is non-trivial due to the abundance of metastable minima that trap the system for very large times. The resulting slow dynamics is dominated by activated processes, which correspond to instantons of an associated dynamical theory. While we know how to compute instantons in low-dimension, in high-dimension the proliferation of metastable and transition states renders the problem more complicated. In the talk I will focus on a simple class of random energy functionals in high-d and discuss (i) how to use tools of random matrix theory to gain information on the distribution and reciprocal arrangement of the local minima and transition states in configuration space, and (ii) how to exploit this information to build simple dynamical instantons describing activated jumps between nearby minima. I will conclude by commenting on the generalisation of these results to the more complicated setting of the elastic manifolds in random media.

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26 Alberto Rosso

The mechanical response of amorphous materials: Uniform vs Oscillatory shear

Describing the response to an external mechanical loading is a central task in studying amorphous materials. Upon uniform loading, some of them are ductile, melting progressively, while others are brittle, breaking along thin stripes called shear bands. The transition among these two regimes is still controversial. Oscillatory deformation of these systems has recently drawn great attention. Compared to the uniform case, under oscillatory shear, the material reaches a well defined stationary state for each deformation amplitude. I will discuss the two protocols and highlight the relations between the emerging stationary "phases" under oscillatory deformation and the observations for uniform shear.

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27 Julien Tailleur

Pressure in active systems: from the lack of equation of state to hidden conservation laws

Active particles dissipate energy to exert self-propelling forces on their environment. This microscopic drive out of equilibrium leads to rich behaviors, from the flocking of birds to the motility-induced phase separation of self-propelled colloids or bacteria, that have attracted a lot of attention in the past. This exchange of momentum with the environment also impacts their collective mechanical properties, a topic which has been much less studied. In this talk, I will review recent developments concerning the mechanical pressure of active systems. I will show how the pressure exerted by an active fluid on its container generically depends on the nature of the latter. In exceptional cases, a hidden conservation law restores the existence of an equation of state. The pressure then becomes a state variable and controls, for instance, the coexistence density in phase-separated systems.

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28 Anne Tanguy

Extremal models and continuous mesoscopic modeling of wetting (1D) and plasticity (3D) problems

After having discussed mechanical instabilities in the context of wetting, crack propagation and plastic deformation of solid materials, we will focus on the description of wetting front propagation on heterogeneous surfaces, and shear banding in glasses. The case of a contact problem in glasses we will discussed in details as a paradigm example of the role of a proper description of disorder on the thermo-mechanical proposerties of amorphous materials.

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29 Gilles Tarjus

Functional Renormalization Group for disordered systems: Contrasting perturbative and nonperturbative approaches

I will discuss, hopefully in a pedagogical way, the functional renormalization group (FRG) method and two implementations (which I will refer to as "perturbative" and "nonperturbative") that have been used for describing the physics at large scale of disordered systems. I will explain why the RG must be functional for the systems under study and try to clarify the domains of application and the benefits of the "perturbative" and "nonperturbative" approaches.

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30 Cathelijne ter Burg

Universal force correlations at depinning, and what they teach us (part II)

[See also Kay Wiese for part I]

In this talk I will discuss the paper : Force-Force correlations in disorder magnets. We will study the force-force correlation in Barkhausen experiments. Depending on the range of spin interactions we find two universality classes. For short-ranged elasticity, we find the universal correlator predicted by the functional renormalization group in $d = 2$. For long-ranged elasticity we observe its 1-loop solution. In all cases force-force correlations grow linearly at small distances, as is assumed in the ABBM model, but in contrast to the latter are bounded at large distances. As a consequence avalanches are anti-correlated. This also leads us to a novel insight that can be used to attest for the quality of samples. I will end this talk by presenting results on the finite temperature effects on the force-force correlator.

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31 Lev Truskinovsky

Variety of scaling behaviors in nanocrystalline plasticity

We use a minimal integer-valued automaton model of crystal plasticity to show that with growing disorder crystals undergo a crossover from spin-glass marginality to criticality characterizing the second order brittle-to-ductile transition. We argue that this crossover is behind the nonuniversality of scaling exponents observed in physical and numerical experiments. The nonuniversality emerges only if the quenched disorder is elastically incompatible, and it disappears if the disorder is compatible.

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32 Frédéric van Wijland

Surface tensions in active matter

We analyze the surface tension exerted at the interface between an active fluid and a solid boundary in terms of tangential forces. Focusing on active systems known to possess an equation of state for the pressure, we show that interfacial forces are of a more complex nature. Using a number of macroscopic setups, we show that the surface tension is a combination of an equation-of-state abiding part and of setup- dependent contributions. The latter arise from generic setup-dependent steady currents which "dress" the measurement of the "bare" surface tension. The former shares interesting properties with its equilibrium counterpart, and can be used to generalize the Young-Laplace law to active systems. Finally, we show how a suitably designed probe can directly access this bare surface tension, which can also be computed using a generalized virial formula.

33 Jérôme Weiss

Damage avalanches in quasi-brittle materials

Disordered quasi-brittle materials, such as rocks, concrete, coal,.., fail from the progressive development of internal damage, defined as local softening resulting from microcracking. This progressive damage process is of tremendous importance in civil engineering (concrete) or geophysics (rocks). Both classical (Griffith) and statistical (Weibull) fracture mechanics fail to understand this type of rupture: classical fracture mechanics resumes disorder to a single pre-existing crack within an otherwise homogeneous medium, while Weibull's approach is purely statistical, ignoring interactions between damage events. Failure through progressive damage involves disorder (e.g. pores and aggregates in concrete), a local threshold mechanics (to nucleate microcracks), and long-ranged elastic interactions between damage events, leading to an intermittent dissipation of elastic energy through damage avalanches. Consequently, we proposed, from theoretical considerations and an extensive experimental dataset on concrete, an analogy between this problem and elastic depinning, the three-dimensional damage field representing the elastic manifold. This leads to several predictions in terms of damage evolution towards final failure (the critical point), size effects on strength, or the internal dynamics of damage avalanches (the avalanche shape). We found many of these predictions to fit remarkably well experimental data, with critical exponents agreeing with mean-field depinning. This allowed us to revisit some basic concepts of mechanical and civil engineering, such as the "characteristic strength". On the other hand, we also raise some key differences between our problem and classical depinning. The first one is the non-convex nature of the interaction kernel in our case, leading to a progressive localization of damage avalanches towards failure. In addition, damage avalanche shapes are strongly asymmetric, unlike classical depinning predictions, meaning that they decelerate much slower than they accelerate. We ascribe this to the contribution of viscoelasticity at the local scale in these quasi-brittle materials, leading to memory effects.

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34 Kay Wiese

Universal force correlations at depinning, and what they teach us (part I)

[See also Cathelijne ter Burg for part II]

We study the force-force correlator for disordered elastic systems. We show that each of the relevant universality classes, namely equilibrium, and depinning, the latter possibly with long-range correlations or additional KPZ terms, has its own universal function. The nicest example are Barkhausen experiments, where we observe two distinct universality classes, depending on the range of spin interactions. For short-ranged elasticity, we find the universal correlator predicted by the functional renormalization group in $d = 2$. For long-ranged elasticity we observe its 1-loop solution. In all cases force-force correlations grow linearly at small distances, as is assumed in the ABBM model, but in contrast to the latter are bounded at large distances. As a consequence, avalanches are anti-correlated, i.e. reduced in size, at short distances. Finally, for peeling and unzipping of a DNA double strand, we observe both the equilibrium fixed point with its characteristic 4/3 roughness exponent, as the distinct depinning fixed point.

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