Workshop
"Interaction, Disorder, Elasticity"
April 3-7, 2023 at Les Houches (France)

ÉCOLE DE PHYSIQUE DES HOUCHES

Book of abstracts

The workshop is organised in association with the CNRS Groupement de recherche ***Interaction*, *Désordre*, *Elasticité*** (**GDR IDE**), started in 2022. It will cover the four following topics, with long and short talks, as well as a poster session:

- **Interfaces in materials**
- **Structural glasses: from replicæ to mean-field dynamics and beyond**
- **Memory in matter**
- **Friction, fracture and granular materials**

ORGANISATION

Elisabeth Agoritsas - DQMP, University of Geneva (Switzerland)

Vivien Lecomte - LIPhy, CNRS/Université Grenoble-Alpes (France)

Damien Vandembroucq - PMMH, CNRS/ESPCI Paris (France)

cnrs GDR Groupement de recherche iDE Interaction, Désordre, Elasticité

LIPhy Laboratoire interdisciplinaire de Physique

UNIVERSITÉ Grenoble Alpes

Physique et Mécanique des Milieux Hétérogènes UMR 7636

SCHEDULE

	Sunday 02/04	Monday 03/04	Tuesday 04/04	Wednesday 05/04	Thursday 06/04	Friday 07/04
09:00		V. Jeudy	B. Guiselin	M. Mungan	J.-F. Molinari	M. Biroli
09:30						M. G. Izzo
10:00				J. Barés		Coffee break
10:30		Coffee break	Coffee break	Coffee break	Coffee break	D. Kuruncsi-Papp
11:00		P. Paruch	P. Urbani	F. Lechenault	D. Dalmas	Discussion
11:30				Y. Lahini		
12:00		Discussion	Discussion	Discussion	Discussion	
12:30		Lunch break	Lunch break	Lunch break	Lunch break	Lunch/end
13:00						
13:30						
14:00						
14:30		M. Bernard	S. Rossi	Free afternoon for discussions	A. Amon	
15:00	Arrival	U. Dattani	S. Patinet		E. Bayart	
15:30		T. Mäkinen	D. Korchinski		R.García-García	
16:00		Coffee break	Coffee break		Coffee break	
16:30						
17:00		K. Gosh	L. Laurson		T. de Geus	
17:30		Flash talks	Poster session		S. Bonfanti	
18:00					M. Terzi	
18:30						
Evening	Dinner	Dinner	Dinner	Dinner	Conference dinner	

CONFIRMED SPEAKERS

LECTURES

- Benjamin GUISELIN (LP-ENS Lyon — France) — *Demystifying the overlap order parameter in disordered systems*
- Vincent JEUDY (LPS, Université Paris-Saclay — France) — *Disentangling universal and non-universal behaviors of domain walls in thin magnets*
- Jean-François MOLINARI (EPFL, Lausanne — Switzerland) — *Richness and complexity of sliding mechanisms at a frictional interface*

INVITED TALKS

- Ada ALTIERI (MSC, Université Paris Cité — France) — *Methods and properties of disordered systems to capture the complexity of large ecosystems*
- Axelle AMON (Institut de Physique de Rennes — France) — *Emergence and dynamics of a laboratory seismic fault*
- Jonathan BARES (L2C, Université de Montpellier — France) — *Loss of memory of an elastic line on its way to limit cycles*
- Elsa BAYART (LP-ENS Lyon — France) — *How localized disorder affects the onset of frictional sliding*
- Davy DALMAS (EC Lyon — France) — *Real contact area reduction under shear in elastomer/glass contacts : contributing mechanisms for wide range of normal loads*
- Reinaldo GARCÍA-GARCÍA (Universidad de Navarra — Spain) — *Athermal Mean-Field Elastoplastic Models with Yield-Stress Criterion and Stress Difussion: A Tale on the Energy Conservation Principle*
- Frédéric LECHENAULT (LPENS Paris — France) — *Exploring experimental physics with machine learning: assessment of analogue seismicity and memory manipulation*
- Muhittin MUNGAN (Universität zu Köln — Germany) — *Memory formation in driven disordered systems – dead or alive*
- Sylvain PATINET (PMMH, ESPCI, Paris — France) — *Relaxations in supercooled liquids: Connection between thermal excitations and local yield stresses of their inherent states*
- Patrycja PARUCH (DQMP, Genève — Switzerland) — *Avalanche statistics, nonlinear dynamics, and self-affine roughening of ferroelectric domain walls during polarisation switching*
- Saverio ROSSI (LPTMC, Paris — France) — *Role of disorder in the yielding transition: an investigation through elasto-plastic models*
- Pierfrancesco URBANI (IPhT, Paris-Saclay — France) — *Theory of glasses in infinite dimensions*

CONTRIBUTED TALKS

- Massimilen BERNARD (LP-ENS Paris — France) — *Random diffusion model and anomalous roughening*
- Marco BIROLI (LPTMS, Université Paris-Saclay — France) — *Critical number of walkers for a resetting search process*
- Silvia BONFANTI (NOMATEN — Poland) — *Compositional disorder induces quasi-localized modes in high entropy alloy crystals*
- Umang. A DATTANI (The Institute of Mathematical Sciences, Chennai — India) — *Cavitation instabilities in amorphous solids*
- Tom DE GEUS (EPFL, Lausanne — Switzerland) — *Criticality and nucleation of slip at the frictional interface*
- Kanka GHOSH (LSPM, Universite Sorbonne Paris Nord — France) — *Insights of plasticity-driven phase transformation mechanism of 2D solids using Poincaré representation: Bridging atomistic and mesoscopic methods*
- Maria Grazia IZZO (SISSA, Trieste — Italy) — *Acoustic-like excitations in structural glasses by a mean field approach: Rayleigh scattering and disorder-induced mixing of polarizations*

- Daniel KORCHINSKI (University of British Columbia — Canada) — *Temperatures effects and criticality in a mesoscopic model of amorphous yielding*
- David KURUNCZI-PAPP (Tampere University — Finland) — *Dislocation avalanches from strain-controlled loading: A discrete dislocation dynamics study*
- Yoav LAHINI (Tel Aviv University — Israel) — *Memory, adaptation, and aging in crumpled sheets and networks of instabilities*
- Lasse LAURSON (Tampere University — Finland) — *Asymmetric roughness and internal degrees of freedom of driven elastic interfaces in random media*
- Tero MAKINEN (Aalto University— Finland) — *History effects in the creep of a disordered brittle material*
- Mert M. TERZI (PMMH, ESPCI, Paris — France) — *Structure of grain boundaries in Landau-type theory of crystal plasticity*

PREVIOUS MEETINGS

This meeting follows up on the line of previous workshops and meetings organised on the subject, in particular:

- Driven Disordered Systems (Grenoble, 2014)
- Dynamical Phase Transitions in Driven Systems (Grenoble 2016)
- Yielding of Amorphous Solids (Paris, 2017)
- Crackling Noise in Materials (Stockholm, 2018)
- Yielding versus depinning in disordered systems (Paris, 2018)
- Avalanche Dynamics and Precursors of Catastrophic Events (Les Houches, 2019)
- Yielding phenomena in disordered systems (Bariloche, 2019)
- News from Disordered Elastic Systems (Spetses, 2021)
- Avalanche 2022 - Avalanche dynamics and precursors of catastrophic events (Hungary, 2022)

The first meeting of the GDR IDE took place in Grenoble in November 2022:

- 1ères Journées du GDR IDE "Interaction Désordre Élasticité" (Grenoble, 2022)

with a non-official 'kick-off' meeting in September 2021:

- News from Disordered Elastic Systems (Spetses, 2021)

The main motivation of the GDR IDE is to enhance the collective dynamics on disordered systems, in the same spirit as the previous GDR "Systèmes élastique désordonnés" (GDR 2284) that was funded from 2001 to 2005 (NB. Much of the talks material is still available on their associated webpages.)

- Première rencontre du GDR 2284: Systèmes élastiques - Du désordre à la plasticité (St-Flour, 2001)
- Deuxième rencontre du GDR 2284: Systèmes élastiques - Du désordre à la plasticité (Carcassonne, 2002)
- Troisième rencontre du GDR 2284: Systèmes élastiques - Du désordre à la plasticité (Asnelles-sur-mer, 2003)
- Ecole thématiques du GDR 2284: Systèmes élastiques - Verres - Plasticité et fracture (Autrans, 2004)
- Quatrième rencontre du GDR 2284: Systèmes élastiques - Du désordre à la plasticité (Vogué, 2005)

ORAL CONTRIBUTIONS (in chronological order)

Monday April 3

Vincent JEUDY (LPS, Université Paris-Saclay — France)

— Disentangling universal and non-universal behaviors of domain walls in thin magnets

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The manipulation of magnetic textures such as domain walls and skyrmions in ultra-thin films and nanowires is important for the development of magnetic memories [1, 2] and raises many issues of fundamental physics. A magnetic domain wall presents a great variety of dynamical regimes, which depends on the strength and on the nature (magnetic field or spin polarized current) of the driving force. For a sufficiently large force, the walls move in flow regimes limited by dissipation and controlled by the dynamics of wall magnetic texture. At sufficiently low drive, the pinning of walls by disorder results in a thermally activated creep motion over effective pinning energy barriers, and in a depinning regime, associated to the collapse of pinning energy barrier.

Since the seminal paper of Lemerle et al. [3], it is well known that domain walls, driven by low magnetic field in ultrathin films, may be described in the general statistical physics framework as elastic objects moving in disordered media. Domain walls present universal behaviors, which are similar to those encountered in various physical systems such as domain motion in ferroelectric materials, motion of vortex glass in superconductors, earthquakes, propagation of crack lines… However, progresses in the understanding of domain wall universal behaviors beyond the zero-drive limit were realized only in the past ten years. The major locks were the difficulty to accurately identify the different dynamical regimes [4], and the entanglement between universal and non-universal behaviors.

For this course, we will discuss the universal behaviors of an elastic line in a random short range pinning disorder, from the analysis of domain wall dynamics illuminated by theoretical predictions, and the revelation of universal scaling functions accounting for both drive and thermal effects on the creep and depinning motion [5-6]. We will also discuss the interplay between universal and non-universal behaviors, from the example edge pinning effects in nanotracks [7]. Finally, we will show how the identification of purely non-universal behaviors allows to compare quantitatively the pinning properties of different magnetic materials [8] and to address the interaction between domain wall and disorder [9].

[1] R. Bläsing *et al.*, *Proceedings of the IEEE*, **108**, 1303, (2020); doi: 10.1109/JPROC.2020.2975719. [2] A. Fert, V. Cros, and J. Sampaio, Nat. Nanotechnol. **8**, 152 (2013). [3] S. Lemerle *et al.*, Phys. Rev. Lett., **80**, 849 (1998). [4] J. Gorchon *et al.*, Phys. Rev. Lett. **113**, 027205 (2014). [5] R. Diaz Pardo et al., Phys. Rev. **B 95**, 184434 (2017). [6] V. Jeudy *et al.*, Phys. Rev. Lett. **117**, 057201 (2016) [7] L. Herrera Diez et al., Phys. Rev. **B 98**, 054417 (2018); S. DuttaGupta *et al.*, Nat. Phys. **12**, 333 (2015); Yamanouchi et al., Science **317**, 1728 (2007) [8] V. Jeudy et al., Phys. Rev. **B 98**, 054406 (2018). [9] P. Géhanne et al., Phys. Rev. Res. **2**, 043134 (2020) ; C. Balan et al. (2023), arXiv:2303.04577

Patrycja PARUCH (DQMP, Genève — Switzerland)

— *Avalanche statistics, nonlinear dynamics, and self-affine roughening of ferroelectric domain walls during polarisation switching*

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 ferroelectric domain walls as a model system in which the disorder landscape, the driving force, temperature quenches and many other parameters can be independently controlled. Here, I will present our scanned probe microscopy studies of roughness, dynamics, and avalanche statistics of ferroelectric domain walls during polarisation switching, including the more complex effects of heterogeneous pinning potentials and out-of-equilibrium behaviour. I will also contrast these observations with 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.

Massimilen BERNARD (LPENS Paris — France)

— *Random diffusion model and anomalous roughening*

We present a growth model with a random diffusion coefficient. It has been previously shown that this interface presents an anomalous scaling, that is there are two roughness exponents, a local and a global one. We will discuss these results, as well as the new results we obtained.

Umang. A DATTANI (The Institute of Mathematical Sciences, Chennai — India)

— Cavitation instabilities in amorphous solids

Amorphous solids have diverse applications. But they are also known to fail catastrophically. As evidenced in experiments[1, 2], cavitation instabilities are known to play a role in the fracture of amorphous solids. These instabilities are known to stem from gas+glass coexistence region in the temperature-density phase diagram of these solids[3]. Using numerical simulations, we investigate the occurrence of such instabilities via an athermal quasistatic expansion process, starting from a dense spatially homogeneous amorphous solid [4]. We find many interesting similarities with the well-studied athermal quasistatic shear response of amorphous solids, viz. saddle-node bifurcation, scale-free avalanche size distributions, quadrupolar displacement fields in the homogeneous regime etc. Further, we demonstrate that via a combination of expansion with a secondary deformation, in the form of cyclic shear or local random deformation via activity, it is possible to induce cavitation at higher densities[5].

[1] F. Célarier et al. “Glass Breaks like Metal, but at the Nanometer Scale”. In: Phys. Rev. Lett. 90 (7 Feb. 2003)
[2] Lai-Quan Shen et al. “Observation of cavitation governing fracture in glasses”. In: Science Advances 7.14 (2021)
[3] Srikanth Sastry. “Liquid Limits: Glass Transition and Liquid-Gas Spinodal Boundaries of Metastable Liquids”. In: Phys. Rev. Lett. 85 (3 July 2000)
[4] Umang A. Dattani, Smarajit Karmakar, and Pinaki Chaudhuri. “Universal me- chanical instabilities in the energy landscape of amorphous solids: Evidence from athermal quasistatic expansion”.In: Phys. Rev. E 106 (5 Nov. 2022)
[5] Umang A. Dattani, Rishabh Sharma, Smarajit Karmakar and Pinaki Chaudhuri, 2023 (manuscript under preparation).

Tero MÄKINEN (Aalto University— Finland)

— History effects in the creep of a disordered brittle material

In experimental studies of structural materials the history effects in the material response can have important consequences for the experimental design and the interpretation of the results. We present an experimental study of the history effects in the creep behavior of a disordered brittle material (concrete) under successive loading steps. In addition to the measurement of the mechanical response, the internal damage in the sample is tracked using acoustic emission and ultrasonic tomography. The primary creep rate is observed to follow a (Omori-type) power-law decay with time, but if a load history has previously been imposed on the sample, the observed history effect slows down the creep rate. This effectively makes the material seem more creep resistant than it actually is. Additionally, the energy distribution of the acoustic emission events is observed to follow a power-law distribution without a discernible cutoff. This differs from previous results of the monotonic loading of the same material, suggesting that the damage mechanism for creep differs from the one for monotonic loading. We have modelled the history effect using a progressive damage model where thermal activation has been implemented using a Kinetic Monte Carlo algorithm. Using simulations performed with this model we show that the effect arises from the exhaustion of easy-to-damage volume elements in the sample, depleting the excitation spectra at low stress gap values. We call this mechanism aging-under-stress as it is reminiscent of aging of glasses.

Kanka GHOSH (LSPM, Universite Sorbonne Paris Nord — France)

— *Insights of plasticity-driven phase transformation mechanism of 2D solids using Poincaré representation: Bridging atomistic and mesoscopic methods*

The square-to-triangular (S-T) transition is a well-known example of lattice phase transformation in a two-dimensional solid. This transformation involves a change in the crystal structure from square to triangular lattices which are both high symmetry phases. Differing from conventional reversible weak phase transformations where the phase transformation occurs from a high-symmetry to a low symmetry, lattice, (S-T) transition generates dislocations leading to irreversibility. In this work, we study the inner working mechanism of (S-T) transition that results in plasticity. The athermal molecular statics method is employed to investigate a 2D crystal of square symmetry with its atoms interacting via Lennard-Jones potential. Under a small perturbation, the energy minimization drives the atoms of the system to rearrange themselves into a triangular symmetry with naturally forming grains. Atomic scale deformation gradient and related Cauchy-Green strain tensors have been evaluated to envisage the evolution of the deformation paths assisted by dislocation creation and nucleation within the system. The coarse-grained mesoscopic tensorial model (MTM) is implemented to further realize the phase transformation in the realm of continuum mechanics. MTM exploits the crystal plasticity phenomena considering a Landau-like theory of infinite wells in strain configurational space controlled by the symmetry group GL(2,Z). These GL(2,Z) periodicity domains in the space of metric strain tensors (C) form a hyperbolic surface which can be mapped into a Poincaré disc representation to visualize energy minima and symmetry-related subdomains. This representation reveals that the phase transformation from square to triangular crystal is driven by plastic events which can be captured by the jump of the C metric tensors in the Poincaré disc towards the relevant symmetry zones. Furthermore, a plastically deformed triangular crystal is found to be a mixture of equivalent phases corresponding to the different energy minima (different Landau wells) at its final state. This reconstructive phase transformation incites a non-intuitive transformation where grains are formed and twinning regimes are observed while the system elevates towards a higher symmetry phase. Therefore, these numerical experiments can help unveil the underlying mechanisms for a 2D prototype for martensite-austenite-like phase transformations.

References: 1. Bhattacharya, K., Conti, S., Zanzotto, G. et al. ‘Crystal symmetry and the reversibility of martensitic transformations', Nature 428, 55–59 (2004) 2. R. Baggio, E. Arbib, P. Biscari, S. Conti, L. Truskinovsky, G. Zanzotto, and O. U. Salman, ‘Landau-Type Theory of Planar Crystal Plasticity', Phys. Rev. Lett 123, 205501 (2019) 3. O. U. Salman et al.,‘Discontinuous

yielding of pristine micro-crystals', Comptes Rendus Physique 22, 201(2021)

Tuesday April 4

Benjamin GUISELIN (LP-ENS Lyon — France)

— *Demystifying the overlap order parameter in disordered systems*

The overlap between liquid configurations is at the core of the mean-field description of the glass transition, corresponding to the order parameter for the thermodynamic liquid-to-glass phase transition. More generally, the overlap (or similarity) between the microscopic degrees of freedom of two copies (or replicas) of a system represents an insightful concept when studying disordered systems evolving in rugged free-energy landscapes. In this talk, I will introduce the notion of overlap and emphasize the connection between its probability distribution and the structure of the underlying rough landscape. I will then review methods to measure the overlap probability distribution in computer simulations of realistic systems via biased sampling techniques, with most examples taken from glass transition studies. Experimental determinations of the overlap are notoriously more challenging because microscopic degrees of freedom are not usually accessible and will be mentioned in the concluding part of the talk.

Pierfrancesco URBANI (IPhT, Paris-Saclay — France)

— *Theory of glasses in infinite dimensions*

I will review the theory of glasses in infinite dimensions. I will discuss the results on the critical exponents of jamming critical systems as well as the theory of elasticity and the yielding transition. Some results on critical relaxation dynamics will be also reviewed.

Ada ALTIERI (MSC, Université Paris Cité — France)

— *Methods and properties of disordered systems to capture the complexity of large ecosystems*

Cases in which the number of interacting components is very large are becoming of general interest in disparate fields, such as in ecology and biology, e.g. for bacteria communities, as well as in complex financial markets where many agents trade and interact simultaneously. Many of these systems appear often to be poised at the edge of stability, hence displaying enormous responses to external perturbations. This feature, also known in physics as "marginal stability", is usually related to the complex underlying network of interactions, which might induce critical behavior.

In this talk, I will present the problem of ecological complexity by focusing on a benchmark in theoretical ecology, the Generalized Lotka-Volterra model with random interactions (in the logistic growth case and more complex settings). Employing techniques rooted in spin-glass theory, I will unveil a complex and rich structure for the organization of the equilibria and relate critical properties to the appearance of glassy-like phases and aging dynamics.

Saverio ROSSI (LPTMC, Paris — France)

— *Role of disorder in the yielding transition: an investigation through elasto-plastic models*

When subjected to an external force, amorphous solids first respond in an essentially elastic manner but after some degree of deformation they yield and may subsequently flow plastically. The yielding transition between these two regimes has received a lot of attention over the last few years. Depending on its preparation, an amorphous solid can break with little or no plastic deformation, as observed in silicate glasses, or it can reach a stationary flowing state, as in foams. It has been recently suggested that a critical point separates these two types of behavior.

In this talk I will discuss how this nonequilibrium transition can be captured via computer simulations of Elasto-Plastic models, in which the effect of the preparation protocol is encoded in the stress distribution at the beginning of the deformation process. The advantage of this approach is the possibility of reaching large system sizes that are inaccessible to present-day atomistic Molecular Dynamics simulations. Scaling behavior and universality of the yielding transition scenario and of the associated critical point can then be studied through finite-size analyses, and the nature and the role of disorder at the transition can be assessed.

Sylvain PATINET (PMMH, ESPCI, Paris — France)

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

M. Lerbinger1, A. Barbot1, D. Vandembroucq1, S. Patinet1 1PMMH, CNRS, ESPCI Paris, Université PSL, Sorbonne Université, Université de Paris, 75005 Paris, France; tel. +33 140795826, e-mail: sylvain.patinet@espci.fr 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 and to study the scaling between the activation energy barriers and the residual plastic strengths. It further provides a way to study the back and forth, reversible 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].

[1] A. Barbot, M. Lerbinger, A. Hernandez-Garcia, R. García-García, M. L. Falk, D. Vandembroucq and S. Patinet, Local yield stress statistics in model amorphous solids, Phys. Rev. E 97, 033001 (2018).
[2] A. Barbot, M. Lerbinger, A. Lemaître, D. Vandembroucq, S. Patinet, Rejuvenation and Shear-Banding in model amorphous solids, Phys. Rev. E 101, 033001 (2020)
[3] S. Patinet, A. Barbot, M. Lerbinger, D. Vandembroucq, A. Lemaître, On the Origin of the Bauschinger Effect in Amorphous Solids, Accepted in Phys. Rev. Lett. 124, 205503 (2020)
[4] D. Richard, M. Ozawa, S. Patinet, E. Stanifer, B. Shang, S. A. Ridout, B. Xu, G. Zhang, P. K. Morse, J.-L. Barrat, L. Berthier, M. L. Falk, P. Guan, A. J. Liu, K. Martens, S. Sastry, D. Vandembroucq, E. Lerner, M. L. Manning, Predicting plasticity in disordered solids from structural indicators, Physical Review Materials 4, 113609 (2020)
[5] D. Fernández Castellanos, S. Roux, S. Patinet, Insights from the quantitative calibration of an elasto-plastic model from a Lennard-Jones atomic glass, Comptes Rendus Physique, Académie des sciences (2021).

Daniel KORCHINSKI (University of British Columbia — Canada)

— *Temperatures effects and criticality in a mesoscopic model of amorphous yielding*

Amorphous solids are a disparate class of materials, including glasses, foams, emulsions, and granular packings. Surprisingly, they exhibit some shared universal behaviour in their mechanical response to load, with an initially elastic regime giving way to a jerkily flowing state characterized by intermittent bursts of activity dubbed ``avalanches''. This driven state is a dynamical phase transition, exhibiting avalanches and rheological behaviour characterized by nontrivial critical exponents. This yielding transition has been extensively studied in the zero-temperature limit, where the presence of long-range elasticity and an anisotropic stress propagator leads to a

intriguing universality class distinct from many other examples of self-organized criticality. Comparatively little work studies the effects of temperature on the self-organized criticality of this system. In this talk, I will discuss how temperature, driving rate, and finite-size effects compete to truncate avalanches and tune the system away from criticality. Using a mesoscale model of amorphous plasticity equipped with a temperature dependent activation of weak-sites, we derive a phase-diagram for the critical behaviour and various scaling results in temperature and finite-size truncated phases [1]. In the continuously flowing state, when avalanches overlap, we also find a change in the flow exponents at high temperature, which we will compare to data obtained at other scales.
[1] D. Korchinski and J. Rottler, Dynamic Phase Diagram of Plastically Deformed Amorphous Solids at Finite Temperature, Phys. Rev. E 106, 034103 (2022).

Lasse LAURSON (Tampere University — Finland)

— *Asymmetric roughness and internal degrees of freedom of driven elastic interfaces in random media*

I will briefly discuss two key properties of driven elastic interfaces in quenched random media. First, considering the rough morphology of a broad class of driven elastic interfaces at the depinning threshold, we show that due to a symmetry breaking caused by the direction of the external driving force, elastic interfaces with local, long-range, and mean-field elasticity exhibit asymmetric roughness. It is manifested as a skewed distribution of the local interface heights, and can be quantified by using detrended fluctuation analysis to compute a spectrum of local, segment-level scaling exponents which depend on the difference of the segment height from the mean interface height [1]. Second, for line-like domain walls in disordered ferromagnetic thin films, the field-driven dynamics is complicated by internal degrees of freedom of the domain walls. We develop a model of domain walls in disordered thin films with perpendicular magnetic anisotropy capturing such features, and use it to study the depinning transition. For weak disorder, excitations of the internal magnetization of the domain wall are rare, and the depinning transition takes on exponent values of the quenched Edwards-Wilkinson equation. Stronger disorder results in disorder-dependent exponents concurrently with nucleation of an increasing density of Bloch lines within the domain wall [2].
[1] E. Toivonen, M. Molkkari, E. Räsänen, and L. Laurson, Phys. Rev. Lett. 129, 175701 (2022).
[2] A. Skaugen and L. Laurson, Phys. Rev. Lett. 128, 097202 (2022).

Wednesday April 5

Muhittin MUNGAN (Universität zu Köln — Germany)

— Memory formation in driven disordered systems – dead or alive

Memory formation and ageing are abundant in many soft matter systems. The disorder underlying these systems gives rise to a rich energy landscape, consisting of a large number of metastable states. These landscapes are accompanied by a plethora of pathways, along which such systems can evolve when exposed to a varying temperature or mechanical load. The resulting dynamics can be rather complex, giving rise to dynamically critical phenomena such as irreversibility and yielding. At the same time, such system exhibit parallels with the adaptive evolution of biological populations in time-varying environments. In this talk I will present a general framework to analyze the dynamics and memory formation of driven disordered systems. I will then show how this framework can be applied to understand both the response of a cyclically sheared amorphous solid, as well as the antibiotic resistance evolution of a microbial population subject to time-varying drug concentrations.

Jonathan BARES (L2C, Université de Montpellier — France)

— Loss of memory of an elastic line on its way to limit cycles

Under an oscillating mechanical drive, an amorphous material progressively forgets its initial configuration and might eventually converge to a limit cycle. Beyond quasistatic drivings, how and why structurally disordered systems loose or record such memory remains theoretically challenging. Here we investigate these issues in a minimal model system –with quenched disorder and memory encoded in a spatial pattern– where the oscillating protocol can formally be replaced by a constant-velocity driving. We consider an elastic line driven at zero temperature in a fixed disordered landscape, with periodic boundary conditions and a tunable system size. This setting allows us to control the area swept by the line at each cycle in a given disorder realisation, as would the amplitude of an oscillating drive. We find that the line converges to disorder-dependent limit cycles, jointly for its geometrical and velocity profiles. Moreover, the way it forgets its initial condition strongly depends on the intermittent versus crackling dynamics it displays depending on the system size. After rationalising these results, we discuss their implications for the response of amorphous materials under oscillating protocols.

Frédéric LECHENAULT (LPENS Paris — France)

— *Exploring experimental physics with machine learning: assessment of analogue seismicity and memory manipulation*

I will present two recent examples of machine learning invocations in experimental physics.

The first situation is that of a seismic analogue, namely crackling noise in the response of knitted fabric. Large amounts of experimental data allow us to train neural networks to predict future events. However, the meaning and usefulness of such predictions being rather unclear, we develop a framework based on game theory and reinforcement learning to assess the quality of the predictions, resulting in a clear evaluation of the predictions, and operational risk management policies.

The second situation consists in writing memory in a multi-stable system – bistable spring in series - using reinforcement learning. The feat here is that the controller produces control solutions that are optimal in the sense that they verify a scaling relation that can be physically motivated a posteriori, thus exhibiting some form of “understanding”’ of the underlying physics.

Yoav LAHINI (Tel Aviv University — Israel)

— *Memory, adaptation, and aging in crumpled sheets and networks of instabilities*

A thin sheet that has been crumpled many times exhibits many of the complex behaviors akin to nonequilibrium disordered systems: intermittent response, crackling and avalanche dynamics, hysteresis, adaptation, and memory formation in response to cyclic drive, and slow relaxations and aging under constant load. We show that all these behaviors emerge from a single structural property - the collective dynamics of many localized bistable elements within the sheet, each acting as a hysteretic, two-state degree of freedom. Indeed, a numerical model of a disordered network of bistable elastic elements reproduces all the behaviors mentioned above while highlighting the role of interactions and frustration in driving these behaviors. The emerging picture is of a disordered system with a complex energy landscape, reminiscent of a mechanical spin-glass, that self-organizes to a state which lies on the verge of instability.

Thursday April 6

Jean-François MOLINARI (EPFL, Lausanne — Switzerland)

— *Richness and complexity of sliding mechanisms at a frictional interface*

Thibault Roch[1], Efim Brener[3,4], Eran Bouchbinder[2], and Jean-Francois Molinari[*1]

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Summary We provide a comprehensive theoretical and numerical framework to understand why, how, and to what extent frictional rupture can be viewed as an ordinary fracture process for sliding interfaces with generic rate and state friction laws. We also describe the emergence of steady self-healing slip pulses under velocity-driven conditions. Finally, we show that complexity can emerge in seemingly simple systems that feature no material disorder and bulk nonlinearity.

Frictional rupture is common in the technological and natural world, from squeaking brake pads to earthquakes along geological faults. A general framework for understanding and interpreting frictional rupture commonly involves an analogy to ordinary crack propagation. An important feature of the analogy to cracks is the existence of a reduction in the stress-bearing capacity of the ruptured interface, which means a drop from the applied stress realized far ahead of a propagating rupture to the residual stress left behind it. However, this analogy is far from obvious since the residual stress does not drop to zero for frictional ruptures. Additionally, frictional systems can host slip pulses, which are a rupture mode that is fundamentally different from the classical representation of a crack. It is not yet clear how and under what conditions the very same frictional system can feature both crack-like rupture and slip pulses.

In the first part of this talk, we show that stress drops in frictional rupture are related not only to the physics of the contact interface but also to wave radiation and long-range bulk elastodynamics [1]. The emergence of a stress drop is a transient effect affected by the wave travel time. Once the necessary conditions for an effective crack-like behavior are met, frictional rupture dynamics can be described by a crack-like fracture mechanics energy balance equation [2].

In the second part of this talk, we show that homogeneous rate-and-state dependent frictional systems, driven at a prescribed boundary velocity (as opposed to a prescribed stress) in a range where the frictional interface is rate-weakening, generically host self-healing slip pulses [3]. Such velocity-driven frictional systems are then shown to exhibit coarsening dynamics saturated at the system length in the sliding direction, independently of the system's height, leading to steadily propagating pulses. The latter may be viewed as a propagating phase-separated state, where slip and stick characterize the two phases. The single pulse properties are comprehensively understood using a crack-like fracture mechanics energy balance equation.

Finally, we study slip complexity in finite-size frictional systems and show that it emerges in the presence of elasto-frictional instabilities and wave reflections from finite boundaries, even without material disorder [4]. The slip events have broad statistical distributions and can be classified into two types, with small non-propagating events following a power-law distribution, and large propagating events following a log-normal distribution. The complexity arises from self-generated stress and interfacial heterogeneity, leading to spatiotemporal complexity and intricate interactions between slip events, the interface state and its history, and triggering/arrest effects mediated by wave reflections from finite boundaries.

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Axelle AMON (Institut de Physique de Rennes — France)

— *Emergence and dynamics of a laboratory seismic fault*

Granular materials are amorphous and athermal materials whose mechanical properties are still poorly understood and for which friction and disorder play a fundamental role in the mechanical response. When brought to failure, they share with many other amorphous soft materials the characteristic of exhibiting localization of deformation : all the deformation is concentrated in shear bands forming slip planes within the material. During my talk I will show how a shear band in a granular medium is a model for a physicist both to understand the plasticity of amorphous materials and to study earthquakes dynamics. In particular, I will present recent results obtained in our group giving new insights on the origin of aftershocks in earthquakes sequences.

Elsa BAYART (LP-ENS Lyon — France)

— *How localized disorder affects the onset of frictional sliding*

The most basic model of a seismic fault is an interface formed by two solid bodies in contact. The onset of sliding of the blocks in contact is preceded by the propagation of a detachment front, weakening the microasperities that resist to shear. This front has been shown to be a true shear crack, nucleation and propagation phases being well described by fracture mechanics. In this study, we consider how local disorder affects the onset of sliding of a frictional system. Through laboratory experiments, we consider the dynamics of a mixed-constituted interface consisting of solid-solid sections and a section along which a granular material is introduced. We show that this disordered patch drastically influences the macroscopic dynamics of the interface through a modification of the fracture nucleation process. Our results shed light on the importance of the local properties of a frictional interface when considering its global dynamics.

Davy DALMAS (EC Lyon — France)

— *Real contact area reduction under shear in elastomer/glass contacts : contributing mechanisms for wide range of normal loads*

We revisit experimentally the sliding behavior of a single smooth elastomeric sphere (PDMS) in contact with a smooth glass plate by looking into details at the local behavior at the interface. By tracking the positon of small particles inserted in the elastomer close to the interface, we show the existence of two main local mechanisms responsible for the evolution of the real contact area: peeling/laying at the rear/front of the contact and in-plane deformation. Then, we investigate experimentally the dynamics of elastomer/glass contacts near the friction transition under increasing shear for the widest loading range in the literature and show the effects of a on the mechanisms responsible for the area reduction.

Tom DE GEUS (EPFL, Lausanne — Switzerland)

— Criticality and nucleation of slip at the frictional interface

Slip at a frictional interface occurs via intermittent events. Understanding how these events are nucleated, can propagate, or stop spontaneously remains a challenge, central to earthquake science and tribology. In the absence of disorder, rate-and-state approaches predict a diverging nucleation length at some stress σ^*, beyond which cracks can propagate. We argue for a flat interface that disorder is a relevant perturbation to this description [1]. We justify why the distribution of slip contains two parts: a powerlaw corresponding to 'avalanches', and a 'narrow' distribution of system-spanning 'fracture' events. We derive novel scaling relations for avalanches, including a relation between the stress drop and the spatial extension of a slip event. We compute the cut-off length beyond which avalanches cannot be stopped by disorder, leading to a system-spanning fracture. The scaling of this emerging length-scale bears some resemblance with a Griffith-criterion. However, we stress that its origin in completely different, and that the similarity is an unfortunate coincidence. We successfully test these predictions in a minimal model of frictional interfaces. Furthermore, we propose how the stress drop decreases with the system size, and how that depends on the surface properties [2].

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Silvia BONFANTI (NOMATEN — Poland)

— Compositional disorder induces quasi-localized modes in high entropy alloy crystals

We investigate the low-frequency vibrational properties of High Entropy Alloys (HEAs), an emergent class of materials with exceptional mechanical performance. HEAs are designed by mixing several metallic species in nearly the same amount. They can exist in either a glassy state, characterized by positional disorder, or a crystal state, which displays distinctive compositional disorder. Compositional disorder in HEA-crystals arises due to the random distribution of atomic species on the lattice sites. Previous studies have shown that the low frequency density of states in glassy systems exceeds Debye's contribution typical of crystalline counterparts and is proportional to the fourth power of the frequency due to positional disorder. However, not much is is known about the density of states of HEAs and its relationship with the compositional disorder that distinguishes HEA crystals from conventional crystals. To address this topic, here we analyze a realistic model of HEA in amorphous, intermediate, and crystal states. We show that the quartic laws hold across all levels of positional disorder and remarkably in HEA-crystals. The associated quasi-localized vibrations, however are highly suppressed compared to the glassy counterpart. Our work offers a unified perspective on the vibrational properties of high entropy alloys, offering insight into the behavior of these promising materials.

Mert M. TERZI (PMMH, ESPCI, Paris — France)

— *Structure of grain boundaries in Landau-type theory of crystal plasticity*

The structure and properties of grain boundaries are key to understand behavior and properties of polycrystalline materials. A conventional way of representing grain boundaries in materials science is the 'structural unit' theory. To show that such units represent locally optimized atomic arrangements we use a novel mesoscopic tensorial model of crystal plasticity which is essentially an elasticity theory with globally periodic energy landscape. The individual energy wells in such a Landau-type theory represent equivalent configurations of a crystal lattice which are distinguished by lattice invariant shears. The theory introduces a mesoscopic cutoff distance which defines a length scale below which the deformation can be considered as homogeneous. In this presentation we show the results of the application of this approach to the study of the fine structure of grain boundaries separating patches of the lattice with different orientations which constitute characteristic random textures. We show that the minimization of elastic energy in this framework leads naturally to the segmentation of the grain boundary into highly ordered blocks of strongly interacting (self-locked) dislocations. We show that the mesoscopic tensorial theory allows one to study the fine structure of such 'structural units' and identify their sub-structural blocks which would not be appparent in the conventional approach.

Friday April 7

Reinaldo GARCÍA-GARCÍA (Universidad de Navarra — Spain)

— *Athermal Mean-Field Elastoplastic Models with Yield-Stress Criterion and Stress Diffusion: A Tale on the Energy Conservation Principle*

The linear relation between stress diffusion and plastic activity proposed to close the equations describing mean-field models of amorphous materials based on athermal local yield-stress and diffusive stress redistribution, $D = \alpha\Gamma$, is in some situations in conflict with the principle of conservation of energy, a cornerstone of physics. We pay attention to this inconsistency and discuss how one could modify such models (including the linear closure) so that the energy conservation principle is recovered. We then revisit the rheological properties predicted by the model under this perspective.

Marco BIROLI (LPTMS,Université Paris-Saclay — France)

— Critical number of walkers for a resetting search process

We study a one-dimensional gas of \$N\$ Brownian particles that diffuse independently, but are either {\it simultaneously} or {\it independently} reset to the origin at a constant rate \$r\$. We compute the mean first passage time to a target and study it's dependence on the number of particles \$N\$. We observe that there exists a second-order phase transition below which resetting is an optimal strategy and above which resetting serves no purpose. Our analytical results are confirmed by numerical simulations.

Maria Grazia IZZO (SISSA, Trieste — Italy)

— *Acoustic-like excitations in structural glasses by a mean field approach: Rayleigh scattering and disorder-induced mixing of polarizations*

The topological disorder in structural glasses on meso/nanoscopic scale generates an inhomogeneous spatial distribution of the elastic moduli. The glass can thus be modeled as a random medium with spatial fluctuating elastic moduli to which it is associated a stochastic Helmholtz equation and the related Dyson equation. The solution of the Dyson equation is the ensemble averaged elastodynamic response of the system to an impulsive force. It thus in principle provides a fully characterization of the dynamics of the model system, though on the state of the art it cannot be exactly solved. We mathematically provide an approximate solution of the Dyson equation, so-called Generalized Born Approximation (GBA), by including second-order terms of the perturbative Neuman-Liouville series expansion of the self-energy, where truncating the expansion to first-order terms leads to the Born approximation. As unprecedented results for mean field Random Media Theories the GBA allows i) a realistic estimation of the strength of the attenuation related to Rayleigh scattering, beyond reproducing the typical forth-power wavevector dependence; ii) to describe, together with amplitude and phase velocity, the polarization properties of acoustic-like excitations in structural glasses. In particular, this analytical approach permits to identify distinct features so far observed in the dynamic structure factor of several structural glasses and unambiguously attribute them to the so-called mixing of polarizations. Contrast with experimental measures reveals an excellent agreement. This work aims to show that a quantitative and unified, including amplitude, phase velocity and polarization, description of acoustic dynamics in structural glasses by a mean field approach is possible.

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David KURUNCZI-PAPP (Tampere University — Finland)

— *Dislocation avalanches from strain-controlled loading: A discrete dislocation dynamics study*

We study strain-controlled plastic deformation of crystalline solids via simple 2D as well as more realistic 3D discrete dislocation dynamics simulations. To this end, we characterize the average stress-strain curves as well as the statistical properties of strain bursts and the related stress drops as a function of the imposed strain rate. The dislocation systems exhibits strain-rate sensitivity such that a larger imposed strain rate results in a higher average stress at a given strain. The sizes and durations of the dislocation avalanches are power law distributed up to a cutoff scale, and exhibit temporally asymmetric average shapes. We discuss the dependence of the results on the driving parameters and compare our results to those from previous simulations where quasistatic stress-controlled loading was used.

POSTER CONTRIBUTIONS (in alphabetical order)

Mikko Alava (Aalto University, Aalto — Finland)

— *Avalanches in plasticity: shear bands in the PLC phenomenon*

Localized shear bands are the key feature of the Portevin–LeChatelier effect in metal alloys. The microscopic dynamics of solute atoms and dislocations combines to produce macroscopic effects: serrations in stress-strain curves and shear bands that are visible to the eye. I discuss observations of such avalanching behavior and its interpretation by memory and aging effects [1] and as architypical manifestations of driven particles in disordered landscapes [2].

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Ralph Bulanadi (DQMP, Genève — Switzerland)

— *Induced and Innate Defects in Ferroelectrics and their Effects on Switching Dynamics*

Ferroelectric materials, such as lead titanate, spontaneously retain electrical dipoles, allowing the coexistence of macroscopic polarisation domains with different orientations. The walls between such domains have been modelled as a disordered elastic system, both static and during motion, and their dynamics have been observed to follow avalanche statistics. The universality of these classifications allows for modelling of domain walls at larger scales than typically possible via ab initio methods. While recent studies have focused on the importance of strongly varying disorder landscapes in the films [1], little is known about the role of strong vs. collective pinning.

Here we report scanning probe microscopy studies into the switching dynamics of lead titanate thin films with varied and controlled defect disorder, in order to enhance our understanding of ferroelectric domain walls as a disordered elastic system. The films, grown on strontium titanate substrates, present strain-relieving a-domains that extend through the film along the in-plane crystallographic axes. Varying point defect densities have also been introduced via bombardment with He2+ ions. The jerky motion of 180° domain walls in these films under sequential bias scans were imaged using piezoresponse force microscopy and analysed using in-house developed computation tools [2,3].

We observe that increased point defect bombardment is associated with a loss in crystallinity observable via x-ray diffraction measurements. Under increasing voltage bias, all samples follow avalanche statistics with similar critical exponents, regardless of bombardment defect density. a-domains appear to act as extended strong pinning sites, imposing directional constraints on the domain wall motion along the film crystallographic axes. This effect is dominant in the non-bombarded sample, leading to large scale domain wall jumps between configurations determined by the a-domain position. In the irradiated samples, similar jumps are observed in the absence of a-domains that are nonetheless oriented in the direction of the crystallographic axes.

In this complex disorder landscape, our observations suggest that point defects migrate to, or form in, directions oriented with crystallographic axes, yielding domain wall pinning behaviour that remains statistically similar across films with varying ion bombardment.

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Alfredo Fiorentino (Scuola Internazionale Superiore di Studi Avanzati, Trieste — Italia)

— *Hydrodynamic finite-size scaling of the thermal conductivity in glasses*

In the past few years, the theory of thermal transport in amorphous solids has been substantially extended beyond the Allen-Feldman model. The resulting formulation, based on the Green-Kubo linear response or the Wigner-transport equation, bridges this model for glasses with the traditional Boltzmann kinetic approach for crystals. The computational effort required by these methods usually scales as the cube of the number of atoms, thus severely limiting the size range of computationally affordable glass models. Leveraging hydrodynamic arguments, we show how this issue can be overcome through a simple formula to extrapolate a reliable estimate of the bulk thermal conductivity of glasses from finite models of moderate size.

Tristan Jocteur (LIPhy, Université Grenoble Alpes, Grenoble — France)

— *Critical properties of the yielding transition in amorphous materials*

Amorphous materials such as foams, clay, and sand heaps are known as yield-stress materials, which means that they do not flow if the imposed stress is below a certain threshold value. This study investigates the yielding of such materials under a constant stress as an absorbing phase transition, where the global stress acts as the control parameter and the shear rate acts as the order parameter. To this end, we use numerical simulations of an elastoplastic model, along with an external activation field, to perform a finite-size scaling analysis near the critical point. Our analysis enables us to determine the critical exponents β, $\gamma^\prime$, and $\nu_\perp$, which respectively characterize the behavior of the order parameter, its fluctuations, and the correlation length near the critical point. We find that the critical exponent $\gamma^\prime$ is unconventional, with $\gamma^\prime<0$, leading to vanishing fluctuations of the order parameter near the transition. Furthermore, we investigate the large plastic events occurring at the critical point with first results suggesting a power-law distribution in both size and duration.

Dheeraj Kumar (PMMH, CNRS / ESPCI Paris — France)

— Memory effects in a mesoscopic elastoplastic model for glasses under oscillatory deformation

Amorphous solids under oscillatory shear, at small to moderate driving amplitudes, evolve into steady states in which they visit the same sequence of states in the configuration space during each subsequent cycle[1]. Beyond a critical amplitude of driving such periodic responses, also known as limit cycles, disappear and the system attains a steady state exhibiting diffusive motion. This transition presents typical features of a critical transition and has served as a probe to understand yielding in cyclically sheared amorphous solids. Remarkably, the steady states obtained below the critical driving amplitude hold memory encoding features of forcing, such as the driving amplitude[1]. In fact, it has been shown through atomic scale simulations[2-4] and experiments[5] that the memory of driving amplitude can be recovered from these steady states through suitable read-out protocols. We use a novel mesoscopic elastoplastic model[6] for amorphous plasticity to capture such memory effects. In particular, we study the effects of driving amplitude on the extent of memory in the steady states spanning three different regimes, namely: perfectly elastic regime at lowest driving amplitude, reversible plastic regime at moderate driving amplitude, and the diffusive regime at large driving amplitudes where limit cycles are absent. We also study the effect of system size and sample preparation on such memory effects.

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Laura Michel (LPENS, École Normale Supérieure, Paris — France)

— When the dynamical writing of coupled memories with reinforcement learning meets physical bounds

Traditionally, memory writing operations proceed one bit at a time, limiting the storage capacity of materials. A way to overcome this limitation would be to write several bits at once. Although quasi-static operations are typically used for bits manipulation, they are known to reduce the memory capacity of a system. To address this issue, we introduce a model framework for dynamical memory manipulation based on a multi-stable chain of coupled bi-stable spring-mass systems. We show that, using a Reinforcement Learning agent, we can control this highly nonlinear system in force, driving it from any stable or random configuration to any other. Notably, by taking advantage of the underlying physics, the agent shares insightful knowledge by pointing to an optimal system design.

Alessandro Pacco (LPTMS, Université Paris-Saclay, Saclay — France)

— *Paths in spin glass energy landscapes and overlaps between Hessian eigenvectors*

We study statistical properties of high dimensional random energetic landscapes, in particular of the spherical p-spin model. We consider paths interpolating between two minima and inspect the average value of the energy profile along these paths. For geodesic paths (in configuration space) we find that for most initial/final energies the energy encountered along the path reaches a maximum, that gives an upper bound of the typical energy barrier connecting the two minima. The maximum increases while diminishing the correlation between the minima in configuration space, and it is in most of the cases well above the threshold energy that separates the zone where minima proliferate (below) to where saddles proliferate (above). We improve this by considering deviations to these geodesic paths, constructed by imposing a starting direction given by the shallower direction of the Hessian at the initial point. We find that computing the energy profile requires to tackle a random matrix problem where we need to study the correlations between the eigenvectors of the Hessian matrices at the initial and final configurations. Our results indicate that from the softest mode of the Hessian at the first minimum the system “sees” a much easier landscape, full of paths that pass through points below the threshold energy.

Aurélien Rigotti (ISTerre, Université Grenoble Alpes, Grenoble — France)

— *Investigating the rheology of the Marginal Ice Zone through DEM simulations of a frictional 2D granular material*

This study aims at improving the current mesoscale mechanical parametrizations of the MIZ in continuum sea ice models by formulating a coupling between the mesoscale ice strength parameters (apparent viscosity η and elastic modulii K and G) and the state (ice concentration or packing fraction φ, level of damage d, coordination number z, confining pressure P) of the sea ice cover when in a granular regime and in particular in the closely-packed limit. To do so, discrete models are used to emulate the MIZ and estimate d, η, K and G at the scale of an idealized, frictional granular assembly of ice floes and to establish its dependance on the applied shear rate over a wide range of inertial numbers (10 -6 < I < 10 -1) and eventually, its dependance on the floe size distribution and floe shape.

Juan Carlos Verano Espitia (Université Grenoble Alpes, Grenoble — France)

— *The effect of quenched disorder on creep lifetimes of brittle materials*

Using a progressive damage model for which thermally activated damage is taken into account through a kinetic Monte Carlo algorithm [1,2], we studied the effect of quenched disorder on creep lifetimes of brittle materials. We show that the disorder amplifies the thermodynamic temperature, an effect that can be interpreted in an Arrhenius formalism as a pseudo-temperature T_{eff}. This is consistent with Ciliberto et al. [3] from a democratic fiber bundle model with thermally activated fracture. Therefore, quenched disorder also amplifies the thermodynamic temperature in non-mean field models of fracture characterized by a non-convex elastic redistribution kernel. Finally, we studied the implications of this effective temperature effect in the interpretation of macroscopic creep tests in terms of activation volume at the microscale.

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Joint work with: Juan Carlos Verano, Jérôme Weiss, David Amitrano