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Avalanche Dynamics and Precursors of Catastrophic Events

Les Houches, 4-8 February 2019

Book of abstracts

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Avalanche Dynamics and Precursors of Catastrophic Events

	Monday		Tuesday		Wednesday		Thursday		Friday
09:00	Opening								
	Session 1		Session 3		Session 5		Session 7		Session 9
09:10	K Dahmen	09:00	E Vives	09:10	C Maloney	09:00	T Giamarchi	09:10	A Planes
09:40	JL Barrat	09:30	JC Géminard	09:40	E Ferrero	09:30	G Durin	09:40	C Reichardt
10:10	D Houdoux	10:00	P Ispanovity	10:10	T De Geus	10:00	A Saxena	10:10	L Viitanen
10:30	Coffee	10:30	Coffee	10:30	Coffee	10:30	Coffee	10:30	Coffee
11:00	J Baró	11:00	L Ponson	11:00	M Popović	11:00	S Santucci	11:00	A Bérut
11:20	N Oyama	11:20	V Vasisht	11:20	C Liu	11:30	Z Neda	11:20	Discussion and closure
11:40	Flash talks (40min)	11:40	Flash talks (40min)	11:40	Discussion	11:50	Discussion		
12:30	Lunch	12:30	Lunch	12:30	Lunch	12:30	Lunch	12:30	Lunch
	Session 2		Session 4		Session 6		Session 8		
17:00	S Sastry	17:00	E Salje	17:00	S Fielding	17:00	D Marsan		
17:30	S Roy	17:30	L Berthier	17:30	M Alava	17:30	F Renard		
18:00	Discussion	18:00	Discussion	18:00	Poster Session	18:00	Break		
18:30		18:30	Poster Session			18:30	J Failletaz		
19:00	Welcome drink	19:00				19:00	Discussion		
19:30	Dinner	19:30	Dinner	19:30	Dinner	19:30	Dinner Savoyard		

Sessions:

Session 1: Non-universal features in avalanche dynamics

Session 2: Conditions for universality in avalanche dynamics

Session 3: Precursors of catastrophic events

Session 4: Avalanches in transient dynamics

Session 5: Coarse grained models for avalanche dynamics

Session 6: Yielding transition

Session 7: Depinning transition

Session 8: Instability in solid earth systems

Session 9: Other systems exhibiting avalanche dynamics

AIM OF THE WORKSHOP

In nature as well as in many technical applications, one encounters the sometimes problematic phenomenon of intermittent dynamics, e.g. in form of stick-slip motion, associated to strongly correlated dynamics of complex geometrical objects over scales that can span many orders of magnitude. Examples range from the atomic to the tectonic scale, including avalanches in magnetic materials, superconductors, deformation of glasses, cascades of irreversible rearrangements in soft matter systems, critical dynamics of imbibition fronts and crack growth; mechanical response of granular and porous media, wood, and geological flows, such as snow avalanches and earthquakes.

Understanding the complex, nonlinear spatio-temporal response of these systems, and the connections between different scales is crucial for physical predictions, and for the development of reliable models for engineers. Recent theoretical and experimental progress makes this a timely forum for an interdisciplinary effort to advance this important emerging research area.

INVITED SPEAKERS

- Mikko Alava,
- Jean-Louis Barrat
- Ludovic Berthier
- Karin Dahmen
- Gianfranco Durin
- Jérôme Faillettaz
- Ezequiel Ferrero
- Jean-Christophe Géminard
- Thierry Giamarchi
- Péter Ispanovity
- Ferenc Kun
- David Marsan
- Cynthia Reichhardt
- Antoni Planes
- Francois Renard
- Mark Robbins
- Ekhard Salje
- Stéphane Santucci
- Srikanth Sastry
- Avadh Saxena
- Damien Vandembroucq
- Eduard Vives

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Focus of the workshop

1. Non-universal features in avalanche dynamics

This session will focus on introducing the main reasons for non-universal features in avalanche dynamics, such as the presence of inertia, transient phenomena and other non-critical situations where avalanches still play a dominant role for the overall dynamics. This first session also aims at setting the general theme of the conference to set the focus within the different research areas on non-universal features and precursors of catastrophic events in avalanche dynamics.

2. Conditions for universality in avalanche dynamics

Much effort has been invested to classify different systems exhibiting avalanche dynamics into universality classes regarding the underlying nature of disorder and the specifies in the interaction kernel (short or long ranged, strictly positive or with altering signs). This session aims at clarifying the conditions under which one can expect universality and what should be the good classification criteria.

3. Precursors of catastrophic events

One of the most urging questions to solve, also with respect to technical application, such as failure prediction and the forecast of extreme events in natural phenomena, is to find possible definitions of precursors of large events in the time series of avalanches. This third session will be completely dedicated to this topic and introduce this general theme also for the discussions within the follow-up sessions.

4. Avalanches in transient dynamics

Some first works are now concentrating on avalanches in transient dynamics instead of being interested in the stationary state dynamics. In many cases this dynamics appear not to be critical, but they are nevertheless in some situations still governed by avalanche type events. This session will concentrate on the specific role of initial conditions and parameter dependence on the avalanches in the transient dynamical regimes, a topic very important for applications were transient dynamics are ubiquitous.

5. Coarse grained models for avalanche dynamics

The development of mesoscopic models, such as spring block models, mesoscopic elasto-plastic models, birth-death processes and various other coarse grained descriptions can help in understanding better the basic mechanisms for non-universal features in avalanche dynamics. This session will focus on some recent advances in these modeling techniques and its application ranges.

6. Yielding transition

The yielding transition has been quite controversial with respect to its belonging in a specific universality class, especially the belonging to the depinning universality class has been shown to be questionable. Depending on the observables considered and the dynamical regime of interest the reasoning can be very different. This session is suppose to sort out the necessary numerical (and experimental) tests needed to converge the understanding of this strongly debated subject.

7. Instability in solid earth systems

Geophysical systems with avalanche dynamics, such as snow avalanches and earthquakes are related to very similar questions compared to the depinning and the yielding transition and this workshop aims at isolating common questions that can be tackled in a common framework.

8. Depinning transition

The depinning transition is probably the best understood dynamical transitions exhibiting avalanche dynamics. We hope that the knowledge and concept transfer of this research field will promote as well the understanding in other fields. On the other hand the study of transient dynamics and situations with non-universal dynamics have also not been strongly addressed in this context and thus the focus will lie on these new questions in the field of the depinning transition.

9. Other systems exhibiting avalanche dynamics

Beyond the above examples for systems exhibiting avalanche dynamics there is a myriad of systems dealing with strongly correlated intermittent dynamics, as is the case for example in Martensites, in neural network systems, in social sciences, in vulcanic eruptions and solar flare dynamics. Thus we give in this last session the possibility to develop the understanding of avalanches in a very broad framework to promote the knowledge transfer between a vast number of different fields.

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Invited talks and oral contributions

Avalanches in solids: predicting universal and non-universal dynamics

Karin Dahmen*[1]

[1]University of Illinois – United States

Abstract

A simple model for avalanches of slipping weak spots is used to predict avalanche dynamics in a wide range of solid materials and on a wide range of scales. For experiments and applications it is important to know which aspects of the dynamics are universal and which are not. Using tools from statistical physics and the renormalization group, as well as simulations, the model can be used to extract predictions for both. The results explain unusual temporal profiles and interesting time series properties. Connections to systems in biology and astrophysics will also be discussed.

Keywords: avalanche dynamics, universality, time series properties

*Speaker

Creep dynamics of athermal amorphous materials:

Jean-Louis Barrat*[1]

[1]Laboratoire Interuniversitaire de Physique – Université Grenoble Alpes – France

Abstract

Yield stress fluids display complex dynamics, in particular when driven into the transient regime between the solid and the flowing state. Inspired by creep experiments on dense amorphous materials, we implement mesocale elasto-plastic descriptions to analyze such transient dynamics in athermal systems. Both our mean-field and space-dependent approaches consistently reproduce the typical experimental strain rate responses to different applied steps in stress. Moreover, they allow us to understand basic processes involved in the strain rate slowing down (creep) and the strain rate acceleration (fluidization) phases. The fluidization time increases in a power-law fashion as the applied external stress approaches a static yield stress. This stress value is related to the stress over-shoot in shear start-up experiments, and depends on sample preparation and age.
Refs:

Mean-field scenario for the athermal creep dynamics of yield stress fluids
Chen Liu, Kirsten Martens and Jean-Louis Barrat
Phys. Rev. Lett. 120, 028004 (2018)
arXiv:1705.06912

Creep dynamics of athermal amorphous materials: a mesoscopic approach
Chen Liu, Ezequiel E. Ferrero, Kirsten Martens and Jean-Louis Barrat
Soft Matter (2018)
arXiv:1708.09194

Keywords: creep

*Speaker

Plastic flow and localization in an amorphous material

David Houdoux*[1], Axelle Amon[1], and Jérôme Crassous[2]

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[2]Institut de Physique de Rennes (IPR) – Universite de Rennes 1, CNRS : UMR6251 – France

Abstract

The study of the failure in a granular material is essential for a better understanding of soil behaviors. For this, the failure can be described according a frictional point of view. Here, strain localization appears from the moment when applied stress reaches a threshold given by Mohr-Coulomb criteria. On another side, it is now admitted that in a more general field of amorphous media, strain localization can be interpreted as the accumulation of local rearrangements. Such reorganization is characterized by an anisotropic redistribution of the stress known as "Eshelby" stress. Consequences inside the material are the triggering of new plastic flows and so on. As a result, local plastic events promote avalanching behaviors along oriented microscopic bands which lead to a final shear band.
Here, we present a study of the plastic response of a granular material progressively loaded during a biaxial test compression in plane strain conditions. Using a dynamic light scattering probe (DWS), we study experimentally the evolution of the plastic field and its fluctuations which organize progressively in order to form permanent shear band. We show that the plastic field can be decomposed in two components evolving on two decoupled strain increment scales. A slowly varying and coarse-grained part which concentrates along a macroscopic direction corresponding to the Mohr-Coulomb angle; and a fluctuating part which can be directly linked to an Eshelby-like stress redistribution.
The two fields have independent and coexisting characteristic orientations but the question of independence or correlation between them is still open. Even if the two orientations observed are apparently unrelated it could be possible that the slow field inherits its characteristics from the fluctuations in a non-trivial manner.

Keywords: plastic deformations, granular material, Morh Coulomb, Eshelby tensor, DWS, biaxial test

*Speaker

The path from micromechanical models to a point process description of failure and the prediction of catastrophic events.

Jordi Baró*†[1] and Alvaro Corral[1]

[1]Centre de Recerca Matemàtica – Spain

Abstract

Sudden violent events altering otherwise quiescent systems pose a generalized threat to human societies and infrastructures. The details on the physical processes leading to earthquakes, volcanic eruptions or the collapse of man-made structures have been elusive since the first rational models of Leonardo da Vinci in the fifteenth century. Reductionist models can explain the fundamental laws, but have a limited applicability to the heterogeneous and complex real systems. The urge for practical tools to anticipate catastrophic events incited a parallel development of (i) stochastic point process models for hazard assessment based upon empirical statistical laws and, more recently, (ii) micromechanical models derived from a branch of statistical physics.
Seismology is the most paradigmatic example of this dichotomy [1]. Point process models are currently used for hazard assessment: from simple proportional hazard models to renewal models for characteristic earthquakes or Hawkes processes —more specifically, 'epidemic type aftershock sequences' (ETAS) models— reproducing the production of aftershocks [2]. On the other hand, a wide category of anthropogenic and natural disasters, including seismology, can be modelled within the context of mechanical failure. Empirical statistical laws implemented in point process models such as characteristic recurrent events, scale invariance and activity acceleration can be reproduced and understood in conceptual models of both frictional sliding [3] and brittle fracture [4]. Conversely, the production of aftershocks, or event-event triggering phenomena [2], is a more challenging issue not naturally reproduced in micromechanical models. Recently, theoretical and numerical studies related aftershock production to transient phenomena such as: stress transfer and afterslip due to viscoelasticity; pore-pressure diffusion; heat transfer; features of the coseismic slip governed by rate and state friction; or remote triggering by elastic waves.

We compare the characteristics of the aftershock sequences in experimental and field catalogs with synthetic data sets obtained from micromechanical conceptual models incorporating such transient behavior. Since the actual triggering relationships are known in the conceptual models, the numerical results can be used to validate statistical techniques for spatio-temporal identification of triggering [5]. Finally, the same synthetic catalogs can be described in terms of stochastic point processes. Specifically, the parameters of an appropriate ETAS model fitting the catalog can be linked to the physical variables of the micromechanical model.

*Speaker

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Vere-Jones, D. (2010). *Foundations of statistical seismology.* Pure and applied geophysics, 167(6-7), 645-653.

Ogata, Y. (1999). *Seismicity analysis through point-process modeling: A review.* In Seismicity patterns, their statistical significance and physical meaning (pp. 471-507). Birkhäuser, Basel.

Dahmen, K., Ertaş, D., & Ben-Zion, Y. (1998). *Gutenberg-Richter and characteristic earthquake behavior in simple mean-field models of heterogeneous faults.* Physical Review E, 58(2), 1494.

De Arcangelis, S. Redner, H.J. Herrmann. *A random fuse model for breaking processes.* Journal de Physique Lettres, 1985, 46 (13), pp.585-590.5

Baiesi, M. and Paczuski, M., 2004. *Scale-free networks of earthquakes and aftershocks.* Physical review E, 69(6), p.066106.

Keywords: aftershocks, triggering, point processes, brittle fracture, transient effects

Vortex-Clusters in Three-Dimensional Dense Granular Flow

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[1]MathAM-OIL, National Institute of Advanced Industrial Science and Technology – Japan
[2]Graduate School of Arts and Sciences, The University of Tokyo – Japan
[3]RACMaS, Tohoku University – Japan

Abstract

Molecular dynamics simulations on dense granular packings under a very slow simple shear flow have revealed that the statistical properties of the non-affine velocity field are consistent with those of classical turbulence of viscous fluid. However, such observations have been limited to two-dimensional systems and knowledge about three dimensional systems is still missing[1]. In this work[2], we con- ducted direct numerical simulations on three-dimensional dense granular flow and found that the statis- tical property is not turbulent-like in three dimension.

We propose a new understanding from the perspective of avalanche dynamics. This interpretation can explain the power law behavior of energy spectra both in two and three dimension, although the turbulent- like interpretation is valid only in two dimension. Furthermore, we analyzed the spatial structures of collectively moving particles by looking at the vorticity field. Although the system does not show the turbulent-like behavior in three dimension, the structural analysis based on the vorticity field allows us to extract a diverging length scale which a conventional simple spatial correlation function cannot detect.

References

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N. Oyama, H. Mizuno, and K. Saitoh, arXiv: 1805.05449 (2018).

Keywords: Dense granular flow, Jamming, Vorticity

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Transient and Steady State Avalanches in cyclically sheared glasses

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Abstract

Plastic deformation events in sheared glasses have been investigated widely, focussing on the statistics of the magnitudes of these events, or avalanches, in a variety of ways, in particular upon approaching the yielding transition. The statistics of avalanches approaching yielding show significant differences for uniformly sheared glasses and cyclically deformed glasses. In the latter case, glasses are found to anneal and attain progressively lower energies before reaching steady states. Considering platic events in the steady state, it has been found that avalanches do not exhibit growing sizes as the yielding transition is approached, as observed in some studies of avalanches under uniform deformation. To investigate the nature of the differences, we consider avalanches in the transient regime before a steady state is reached. We also consider different ways in which the magnitude of avalanches may be quantified, and the nature of these events when the shearing is performed at finite rates and temperatures. Results are compared with those for uniform deformation under athermal quastistatic deformation.

Keywords: Avalanches, transient regime

*Speaker

Scaling Theory of Giant Frictional Slips in Decompressed Granular Media

Saikat Roy*[1], George Hentschel[1], and Itamar Procaccia†[1]

[1]Weizmann Institute for Science [Rehovot] – Israel

Abstract

When compressed frictional granular media are decompressed, generically a fragile configuration is created at low pressures. Typically this is accompanied by a giant frictional slippage as the fragile state collapses. We show that this instability is understood in terms of a scaling theory with theoretically computable amplitudes and exponents. The amplitude diverges in the thermodynamic limit hinting to the possibility of huge frictional slip events in decompressed granular media. The physics of this slippage is discussed in terms of the probability distribution functions of the tangential and normal forces on the grains which are highly correlated due to the Coulomb condition.

Keywords: granular matter, avalanches, frictional slips, jamming

*Speaker

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Acoustic Emission Avalanches in Coal and Charcoal under uniaxial compression: influence of microstructure

Eduard Vives*†[1], Yangyang Xu[2], Angeles Borrego[3], Antoni Planes[1], and Xiangdong Ding[2]

[1]Departament de Física de la Matèria Condensada, Universitat de Barcelona – Spain
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Abstract

A systematic study of acoustic emission avalanches in coal and charcoal samples under slow uniaxial compression is presented. The samples exhibit a range of organic composition in terms of chemical elements and very different microstructures due to the variable proportions of organic components and a range of degree of evolution. The experimental analysis focuses on the energiesof the individual acoustic emission events as well as on the time correlations between successive events. The studied samples can be classified into three groups. The more homogeneous samples (group I) with pores in the micro and nano scales, with signatures of hardening effects in the stress-strain curves, exhibit the cleanest critical power-law behaviour for the energy distributions with a critical exponent epsilon=1.4. The more heterogeneous samples,with voids, macropores and granular microstructures (group III), show signatures of weakening effects and a larger effective exponent close to the value epsilon=1.66, but in some cases truncated by exponential damping factors. The rest of the samples (group II) exhibita mixed behaviour still compatible with an effective exponent epsilon=1.4 but clearly truncated by exponential cutoffs. Concerning time correlations, all samples exhibit very similar (universal) waiting time distributions although some differences can be observed for the aftershock Omori distributions.

Keywords: Acoustic Emission Avalanches in Coal and Charcoal uniaxial compression

*Speaker
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Large scale events in response to tiny perturbations : two experimental examples provided by the study of solid friction and of granular avalanches.

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[5]Instituto de Física de São Carlos (IFSC) – Av. Trabalhador são-carlense, 400 - Pq. Arnold Schimidt CEP: 13566-590 - São Carlos - SP - Brasil Telefone: (16) 3373-9758 / (16) 3373-8810, Brazil

[6]Departamento de Fısica, Universidad de Santiago de Chile, – Chile

[7]Universidad de Santiago de Chile (USACH) – Chile

Abstract

We report on two experimental studies aiming at revealing the effect of tiny mechanical vibrations of the stability of loaded mechanical systems.
On the one hand, we consider the classical configuration of a nominally flat and horizontal substrate upon which a solid block is pulled by means of a linear spring. Due to the frictional nature of the interface between the solid and the substrate, the system can exhibit a stick-slip motion, constituted of starts and stops, an oscillatory or a continuous motion depending of the pulling velocity and stiffness of the spring. We will show how this picture is altered when additional mechanical vibrations are imposed to the whole. In addition, we will study the response of the system at rest to a mechanical perturbation.

On the other hand, we consider the classical configuration of a granular material partially filling a rotating drum, i.e. a cylinder with horizontal axis. Due to the peculiar rheology of the granular matter, the system can exhibit, at constant rotation speed of the container, either an intermittent dynamics, constituted of a periodic occurrence of independant avalanches, or a continuous avalanche. Again, we will show how this picture is altered when additional mechanical vibrations are imposed to the whole and, in addition, study the response of the system at rest to a mechanical perturbation.
Both systems have in common that, at rest, energy is loaded in the system, either elastic energy in the spring or potential energy of gravity. They also have in common the non-linearity of their mechanical properties, due to the frictional nature of either the interface between the

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solid and the substrate or the contact between the grains. We shall see that their response to tiny mechanical vibrations exhibits common features, in particular, that the ability of the vibrations to destabilize the systems is mainly characterized by their typical velocity.

Keywords: granular avalanches

Acoustic emission of crystalline micropillars

Péter Ispánovity*[1], Dávid Ugi[1], Gábor Péterffy[1], and István Groma[1]

[1]Eötvös Loránd University – Hungary

Abstract

Plastic deformation of crystalline materials is usually a sequence of local slip events of various magnitude. These events correspond to local collective rearrangements of lattice dislocations. Experimental investigations of these avalanche-like fluctuations were originally performed on bulk specimens using acoustic emission (AE). It was found that both the energy and amplitude of the recorded events are power-law distributed hinting at the critical nature of plastic deformation. This phenomenon was later also demonstrated during the compression of tiny specimens, typically of size in the range of 1 um. During these so-called micropillar experiments the same type of events cause large unpredictable stress-drops and/or strain increments in the recorded stress-strain curves.

In this talk we show results on coupling these two experimental techniques in order to obtain a more detailed picture of the underlying avalanche dynamics. Micropillars are milled from a Zn single crystal and are oriented for easy basal slip. The samples are mounted on an AE sensor and compressed in situ in a scanning electron microscope. We find that the acoustic events measured during compression are in perfect agreement with the stress drops measured by a flat punch nanoindenter. The statistical analysis of the data obtained by the two methods reveal correlations between various parameters and also yield information of the internal dynamics of individual events. These results, confirmed by discrete dislocation dynamics simulations, provide the missing link between the quantities measured by AE and mechanical properties of the individual events.

Keywords: crystal plasticity, micropillar, acoustic emission

*Speaker

Precursors to compressive failure in quasi-brittle solids as depinning avalanches: an experimental test of the theory

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[1]Institut Jean Le Rond D'Alembert – Sorbonne Universités, UPMC, CNRS – France
[2]North Carolina State University – United States

Abstract

Quasi-brittle failure results from the evolution of a large number of interacting microcracks spreading through the material microstructural disorder. Despite this complexity, quasi-brittle materials under slowly increasing compressive load exhibit a remarkably robust failure behaviour: during a first stage, damage grows and accumulates through bursts of failure events that are both localized in space and time. This intermittent dynamic is characterized by scale free statistics with exponents that vary weakly with the type of materials and the loading conditions. Ultimately, the damage localizes into a macroscopic band that leads to the catastrophic failure of the specimen.
Recently, it was proposed that localization emerges from the coalescence of damaged clusters that interact through the elastic field [1,2]. It was then proposed that the avalanches preceding localization were reminiscent of the depinning of an effective manifolds the elastivity of which emerges from the elasto-damageable properties of the loaded material [3,4]. In this study, we test this scenario by investigating the precurors to localization during compressive tests of 2D cellular disordered solids. The dimensionnality of the sytem allows to track the local spatial structure of avalanches at the scale of individual cells, while a balance of energy performed at the specimen scale allows to measure their global properties (size, duration...). The combination of this local and global characterization of precursors reveal the complex spatio-temporal structure of damage avalanches allowing for a critical comparison with the prediction of the depinning model.

E. Berthier, V. Démery and L. Ponson, Damage spreading in quasi-brittle heterogeneous materials: I. Localization and failure, J. Mech. Phys. Solids 102, 101-124 (2017).

V. Dansereau, V. Démery, E. Berthier, J. Weiss & L. Ponson, Fault orientation in damage failure under compression, arXiv:1712.08530.

V. Démery, V. Dansereau, E. Berthier, L. Ponson & J. Weiss, Fault orientation in damage failure under compression, arXiv:1712.08537.

E. Berthier et al. Damage spreading in quasi-brittle heterogeneous materials: II. Statistics of precursors to failure (in preparation).

*Speaker

Effect of damping on the Yielding transition in soft disordered solids

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Abstract

Soft disordered solids such as emulsions, foams or colloidal pastes, yield and eventually flow under an imposed shear deformation. These materials often termed as yield stress material are ubiquitous in every day life (eg., food, paint, consumer and pharmaceutical products, wet cement etc.,). Controlling the flow properties of these materials is hard due to significant flow inhomogeneities that develop upon yielding [1]. Understanding the nature of yield transition in these systems hence have acquired an immense interest recently. Description of the yielding transition as non-equilibrium phase transition and predictability of the onset of yielding by studying the statistics of stress avalanches is much debated topic [2-6]. The fundamental understanding of yielding would let one to develop materials with better mechanical properties. A lot of current studies looking in to the microscopic aspects of yielding have focused on systems which are subject to shear deformation in an athermal quasistatic limit (using methods like conjugate gradient minimization). In soft dense disordered systems, the response to external perturbation like shear would have ingredients both from the elastic as well the viscous effects[7-8]. Hence in this work we focus on understanding the yielding transition as well as the formation of shear bands, in a system where the viscous interaction are explicitly managed. In a system made of soft repulsive polydisperse spheres, we perform shear simulations at $T=0$, solving the dissipative paticle dynamics (DPD) equation of motion [9]. By varying the damping coefficient associated with the drag forces, we study the load curves (stress vs. strain), both in quasi-static conditions as well as low shear rate. We find that initial linear response of the sample as well as the stress over-shoot do not show much dependence on the the damping conditions. The decay of stress from the over-shoot towards the steady state clearly depends on the extent of under damping. A sharp jump in stress is observed in the undamped conditions, leading to formation of shear bands. With the increasing damping, the sample smoothly crosses over to the steady state, with lack of shear banding phenomenon. To gain further insights into these observations, we study the local yield stress distribution as well as the avalanche distributions before and after the stress overshoot for different damping coefficient.

Keywords: Yielding transition, soft disordered solids, shear banding, effect of inertia

*Speaker

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Barkhausen noise in complex ferroic materials

Ekhard Salje*[1]

[1]Cambridge University – United Kingdom

Abstract

Ferroelectric field switching in BaTiO3 generates 'Barkhausen noise' when domain walls are displaced. We show by acoustic emission spectroscopy that electric field switching of 90o boundaries generates large strain fields, which emit acoustic phonons during ferroelectric hysteresis measurements. Domain wall interactions and jamming generate the 'crackling noise' that follows scale invariant avalanche dynamics: the avalanche energy and amplitude Probability Distribution Functions, pdf, follow power laws with exponents ϵ =1.65 (energy) and α = 2.25 (amplitudes). Aftershocks are very common and follow Omori law with probability _˜ t-p where t is the time elapsed after the main-shock and p is the Omori exponent p_˜1. Double power law was found for inter-event times with exponents 0.9 and 2.2. Crackling noise in complex materials, such as Mo-alloys under stress, show extensive mixing between different noises from different sources. Typical is noise from collapsing holes, dislocations and moving twin boundaries which all combine to generate the macroscopic noise pattern. In different experiments , sandwiches of materials with different noise characteristics are submitted to the same external field. the noise from each component is known so that the combination can be explored in detail. Previous theoretical results are confirmed and recipes are give how to disentangle such complex noise patterns.
References:

Intermittent flow under constant forcing: Acoustic emission from creep avalanchesSalje, E.K.H.; Liu, Hanlong; Jin, Linsen; et al.
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Keywords: transient systems, domain boundaries, ferric materials

*Speaker

A random critical point separates brittle and ductile yielding transitions in amorphous materials

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Abstract

We combine an analytically solvable mean-field elasto-plastic model with molecular dynamics simulations of a generic glass-former to demonstrate that, depending on their preparation protocol, amorphous materials can yield in two qualitatively distinct ways. We show that well-annealed systems yield in a discontinuous brittle way, as metallic and molecular glasses do. Yielding corresponds in this case to a first-order nonequilibrium phase transition. As the degree of annealing decreases, the first-order character becomes weaker and the transition terminates in a second-order critical point in the universality class of an Ising model in a random field. For even more poorly annealed systems, yielding becomes a smooth crossover, representative of the ductile rheological behavior generically observed in foams, emulsions, and colloidal glasses. Our results show that the variety of yielding behavior found in amorphous materials does not result from the diversity of particle interactions or microscopic dynamics per se, but is instead unified by carefully considering the role of the initial stability of the system.

Keywords: elasto, plastic model

*Speaker

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Mesoscopic models for amorphous plasticity: Is quenched disorder necessary?

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Abstract

Mesoscale models of amorphous plasticity are based on the notion of local shear transformations which behave as Eshelby inclusions, undergoing plastic transformations upon reaching a yield condition, and reloading the surrounding material after the transformation. Most variants of this approach employ a disordered landscape where the individual strain-energy functions governing the mechanical behavior of a given local region - the threshold for yielding and the amplitude of post-yield relaxation - are disordered and vary from place to place in the material. In this work, we show that as long as the kernel describing the load redistribution is chosen appropriately, and the system is appropriately initialized, one can use both a single global yield threshold and strain increment and obtain sensible results. Here, we study both steady forward shear and cyclic shear at various amplitude. We note that such a model where the disorder is not strictly quenched and arises only dynamically from the initialization procedure also opens the way to exploring deeper connections with the glass transition itself and to study the effect of quench protocol on the transient behavior of the material – stress overshoot and localization tendency – under both steady and cyclic athermal shear.

Keywords: amorphous, plasticity, yielding, hysteresis, memory, localization, mesoscopic

*Speaker

An overview of universal avalanche statistics at the yielding transition of amorphous solids

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Abstract

In the last years, several groups have described the yielding phenomenon in the deformation of amorphous materials from a statistical physics point of view. To that end, coarse-grained approaches to amorphous solids were introduced, the so-called elasto-plastic models (EPM) [1].
In this talk, I will focus on the statistics of avalanches produced by the characteristic stick-slip behavior close to the yielding transition, enquiring into its properties among different EPM proposals. I will present in particular the less studied case of EPMs with stress-dependent transition rates for local yielding [2], which help us to see how "dynamical" exponents -those related to the driving speed- may depend on the model details while universality stands more strongly for "static" critical exponents.
On the way, the current understanding of yielding from mean-field descriptions and comparison with the depinning transition of an elastic line, will be discussed.
If time permits, I will further comment on the the strain-rate dependence [3] and inertial effects [4] on the statistics of avalanches as we depart, respectively, from the typically addressed quasistatic and overdamped limits.

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Driving Rate Dependence of Avalanche Statistics and Shapes at the Yielding Transition
C. Liu, E.E. Ferrero, F. Puosi, J.-L. Barrat, and K. Martens
Phys. Rev. Lett. 116, 065501 (2016)

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

Keywords: yielding, elastoplastic models, avalanches

*Speaker

Does inertia induce stick-slip in friction?

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Abstract

We study the nucleation of slip between two sliding solids, whereby we focus on a mesoscopic level where the disorder, introduced by the surface roughness, matters. It is at this scale that we can study how different contacts interact through the bulk's elasticity. A result of this interaction is that the detachment of one asperity can trigger that of other contacts in its vicinity. An interesting question is if such collective effects organise into depinning-like avalanches. Vice versa this system allows the clarification of the debated role of inertia on an avalanche-like response [1-3]. We argue that, due to the presence of rare weak sites, the response is smooth in the thermodynamic limit. At the same time we find this mechanism not to be efficient, leading to a stick-slip response in finite systems.

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K. Karimi, E.E. Ferrero, J.-L. Barrat (2017). Inertia and universality of avalanche statistics: The case of slowly deformed amorphous solids. Physical Review E, 95(1), 013003.

Keywords: Friction, Inertia, Hysteresis, Avalanches, Depinning

*Speaker
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Elastoplastic description of sudden failure in athermal amorphous materials during quasistatic loading

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Abstract

The response of amorphous materials to an applied strain can be continuous or instead discontinuous if the initial configuration is very stable. We study theoretically how such a stress drop emerges as the system's initial stability is increased. We show that this emergence is well reproduced by elastoplastic models and is predicted by a mean field approximation, where it corresponds to a continuous transition. In the mean field, failure can be forecasted from the avalanche statistics. We show that this is not the case for very stable materials in finite dimensions due to rare weak regions where a shear band nucleates. To understand the nucleation, we build an analogy with fracture mechanics predicting that the critical nucleation radius of a shear band a_c is proportional to (Sigma - Sigma_b)^(-2), where Sigma is the stress and Sigma_b is the stress that a shear band can carry.

Keywords: yielding, macroscopic failure, shear band nucleation, system preparation

*Speaker

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Yielding and strain localisation in soft materials

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Abstract

This talk will comprise two parts. In the first part, I shall review a body of work concerning criteria for the onset of shear localisation and shear banding in time-dependent flows of complex fluids, in particular in flows that involve yielding: in shear startup, following the imposition of a step stress, and in large amplitude oscillatory shear. These criteria will be exemplified mostly in the context of calculations concerning soft glassy materials, but also with brief summaries of their wider applicability, including in polymeric fluids. The second part of the talk will present some very recent results concerning the dynamics of athermal jammed materials, with a dominant focus on creep and yielding.

Keywords: shear banding, yielding

*Speaker

Avalanches in dislocation plasticity

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Abstract

I review our recent work on the yielding of dislocation systems in 2D and in 3D. This includes both "pure" systems and such where a pinning landscape is introduced by solutes or "impurities". The relation of the results to actual material yielding and to coarse-grained theories is discussed, as well as the analogy to yielding in amorphous materials.

Keywords: dislocation plasticity, yielding

*Speaker

Thermal effects in disordered elastic systems

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Abstract

The combination of disorder and elastic forces produces a cornucopia of interesting effects, that are especially important for the properties of systems as varied as domain walls in ferroic systems, vortices in type II superconductors or skyrmions in magnetic systems.
Although the physics of such competition starts to be understood when temperature can be safely ignored, leading for example to roughness of the elastic objects, much less I known when the temperature plays a crucial role.
I will discuss in this talk some of these effects in particular the one that are connected to the out of equilibrium properties of such structures. I will discuss the results that were obtained by a combination of analytical (Functional Renormalization group technique or variational approaches) and numerical ones.

Keywords: avalanches

*Speaker
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Earthquake-like dynamics of weakly-driven domain walls in ultrathin magnetic film

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Abstract

The vast majority of studies of magnetic domain wall (DW) dynamics in the creep regime has focused on investigating mean properties, most notably the dependence of average DW velocity on applied field [1-4]. Only recently a theoretical work unveiled the existence of spatio-temporal correlations between weakly-driven creep events, in a similar fashion to earthquake dynamics [5].

In this work we demonstrate experimentally these predictions by investigating DW creep dynamics in an ultrathin Ta/CoFeB/MgO film with perpendicular magnetic anisotropy. We use magneto-optical Kerr effect (MOKE) microscopy to detect the expansion of a magnetic bubble under a small perpendicular field H, by acquiring images every 200 ms. Despite the finite temporal resolution, we are able to confirm the aggregation of our DW creep events (portions of bubble growth between two consecutive images) into larger independent clusters. The cluster area distribution exhibits a power law behavior with a depinning exponent *tau*_dep which is consistent with both qEW and qKPZ universality classes. On the other hand, evaluating the structure factor S(q) allows us to unequivocally conclude that DW dynamics in this system belong to the qKPZ class. Indeed, following the procedure in [6], we estimate that the critical lengthscale Lopt separating creep regime at short scales from depinning regime at large scales is comparable to the image pixel size (0.3 μm), resulting in qc _˜ 1/Lopt _˜ 3.3 μm-1. Thus, the equilibrium regime is not accessible through MOKE microscopy in our system and S(q) contains information about depinning only. Best fitting of S(q) provides a depinning roughness exponent ξdep consistent with the qKPZ class (ξdep = 0.63) but not the qEW one (ξdep = 1.25). These unprecedented results shed new light on our understanding of DW dynamics in the ultra-slow creep regime. [1] S. Lemerle et al., Domain Wall Creep in an Ising Ultrathin Magnetic Film, Phys. Rev. Lett. 80, 849 (1998).
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Keywords: magnetic creep, domain wall dynamics, spatio, temporal correlations, universality classes

Avalanches in Magnetic Materials with Topological Defects: Skyrmions, Merons and Vortices

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Abstract

Using particle based models [1] and numerical simulations we demonstrate that slowly driven Skyrmions [2] interacting with random pinning centers move via correlated jumps or avalanches in chiral magnets. The avalanches exhibit power-law distributions in terms of their duration and size. The average avalanche shape for different avalanche duration is found to be scalable to a universal function. This is in agreement with theoretical predictions for systems in a non-equilibrium critical state. In contrast to vortices, a distinguishing feature of Skymions is the influence of the non-dissipative Magnus force. As the ratio of the Magnus force to damping is increased, the universality class of the behavior changes and the average avalanche shape becomes increasingly asymmetric. In addition, individual avalanches exhibit motion in the direction perpendicular to the density gradient. We contrast these results with that of Skyrmions with half the topological charge called Merons. The latter have been predicted and recently observed in experiments on thin films of chiral magnets. A comparative study of avalanches in Skyrmions, Merons and vortices provides important insights into the interplay between nonequilibrium physics and topology of materials. (This work was done in collaboration with Sebastian A. Diaz, Univ. Basel; Daniel P. Arovas, Univ. California at San Diego; Charles Reichhardt, Cynthia J. O. Reichhardt and Shizeng Lin, Los Alamos National Lab.)

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Keywords: Magnus force, universal function, nonequilibrium critical state, chiral magnets

*Speaker

New insights on the unstable peeling dynamics of adhesive tape: Transfer of bending to kinetic energy controls peel front micro-instability

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Abstract

During the peeling of an adhesive tape, the stick-slip dynamics of the detachment front is probably the most common example of a dynamical instability in rupture: everyone has experienced this screechy sound when peeling-off packing tape, due to the periodic velocity oscillations of the peel front. However, despite a large number of studies, such mechanical instability remains nowadays a puzzling challenge, and still causes industrial problems. Recent studies have demonstrated that the unstable front dynamics is even a more complex process, involving a secondary instability at much smaller spatio-temporal scales than the macroscopic stick-slip.

Thanks to an extensive experimental study in addition to a careful preparation of adhesive-substrate joints, we have been able to unveil the precise characteristics of this peel front micro-instability. In particular, the amplitude of this instability scales with its period as Tˆ1/3, with a pre-factor evolving slightly with the peel angle, and increasing systematically with the bending modulus of the tape backing. A local energy balance of the detachment process shows that the elastic bending energy stored in the tape region that will detach during the micro-slip is converted into a kinetic energy increase of the peeled tape during a micro-stick-slip cycle. Our model allows a quantitative description of the observed scaling-law linking amplitudes and periods of the micro-instability, and in particular its dependency with the peeling angle, as well as with the bending modulus and lineic mass of the ribbon.

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Keywords: peeling dynamics of adhesive tape

*Speaker

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Depinning transition of a soft dewetting line

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[5]Babeș-Bolyai University, Cluj-Napoca – Romania

Abstract

Kinetic roughening of a dewetting liquid layer is studied experimentally and theoretically on surfaces with controlled pinning centers following the setup proposed by de Genens [1,2] (see Figure 1). Both as a function of the density of the pinning center and the liquid layer thickness we observe critical roughening and consequently depinning transitions [3.4]. An elegant simulation method, suitable for investigating the dewetting dynamics of thin and viscous liquid layers is used to understand the experimental results [5]. The computational model allows for the tearing of the layer, which leads to a new propagation regime resulting in non- trivial collective behavior. The large deformations observed for the interface is a result of the interplay between the substrate inhomogeneities and the capillary forces. Experimental and computer simulation results are in good qualitative agreement.
The research was supported by the UEFISCDI research grant: PN-III-P4-PCE-2016-0363.

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Keywords: depinning transition, dewetting, scaling at criticality

*Speaker

Earthquakes as a result of nucleating slip, or as the termination of a cascade of smaller ruptures?

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Abstract

Two approaches are typically followed when attempting to model the route leading to earthquake occurrence: (1) the fault is seen as a frictional interface, and models can be proposed to account for the weakening of the fault as it slowly starts to slip, leading to the existence of a nucleation, self-accelerating phase; (2) earthquakes can trigger one another (eg aftershocks), and the stochastic process of earthquakes generating new earthquakes that generate new ones and so on allows to model how many ruptures are organized in space and time; in this framework, small earthquakes can trigger a large rupture, the pre-seismic phase of this large rupture being then seen not as a nucleating slip-accelerating phase, but as an accelerating cascade of small earthquakes. These two approaches are notably different in their premises, and contradict one another. However, it can be shown that the 2nd is simply a linear approximation of the 1st, that naturally allows to account for a large number of contributing earthquakes to the overall fault system deformation.

Keywords: earthquakes

*Speaker
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Evolution of precursors when approaching failure in rocks

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Abstract

The road to failure in rocks is important to unravel the existence and dynamics of precursors of catastrophic events such as earthquakes and landslides. We have developped a new experimental technique where X-ray dynamic microtomography is coupled to rock deformation to image in-situ the formation of microcractures in rock samples when loaded up to failure. Several kinds of rocks representative of the Earth's crust were loaded under conditions of pressure of several kilometers depths and imaged at micrometer scale resolution using synchrotron tomography. Microfractures, precursors to system-size failure could be detected and their evolution was followed with time. Results allow testing theoretical models of failure in heterogeneous materials that have predicted the existence of power-laws and considered failure as a critical phenomenom. Our experimental results show the existence of several power law evolutions toward failure and demonstrate that precursors to macroscopic failure exist and follow predicttible trends.

Keywords: fracture, earthquake, X, ray tomography, critical phenomenon

*Speaker

Precursors and time forecast of avalanching glacier instabilities

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Abstract

Avalanching glacier instabilities are gravity-driven failure phenomena occurring in natural heterogeneous media. Such events have a potential to cause major disasters, especially when they are at the origin of a chain of processes involving other materials such as snow (snow avalanche), water (flood) and/or debris (mudflow). The reliable forecasting of such catastrophic phenomena combined with a timely evacuation of the endangered areas is often the most effective way to cope with such natural hazards. Unfortunately, accurate time prediction of such events remains a somewhat daunting task as (i) natural materials are heterogeneous, (ii) the heterogeneity is difficult to quantify and measure, and (iii) the rupture is a non-linear process involving such heterogeneities. Although often located in a remote high-mountain environment, avalanching glacier instabilities offer an interesting starting point for investigating early-warning perspectives of break-off events, as a glacier consists of a unique material (ice) lying on well-defined bedrock. This relative simplicity of the system allows the focus to be placed on the rupture processes leading to the initiation of the instability. In general, it is possible to distinguish three types of avalanching glacier instabilities according to the thermal properties of their ice/bedrock interface. If temperate or polythermal, the presence of liquid water in the glacier plays a key role in the initiation and the development of the instability as its presence influences the basal properties of the ice/bedrock interface (diminution of friction, lubrication or loss of support). In such cases, several preliminary conditions to be fulfilled can be identified, but an accurate time forecast of an impending break-off event is still far from being possible. If the ice/bed interface is partly temperate, the presence of melt water may reduce the basal resistance, which promotes the instability. No clear and easily detectable precursory signs are known in this case, and the only way to infer any potential instability is to monitor the temporal evolution of the thermal regime. If the ice/bedrock is cold, glaciers are entirely frozen to their bedrock. This situation appears in the case of high altitude hanging glaciers located entirely in accumulation zone. The snow accumulation is mostly compensated by periodic break-off of ice chunks, occurring once a critical point in glacier geometry is reached. The instability results from the progressive accumulation of internal damage due to an increasing stress regime caused by glacier thickening. The maturation of the rupture was shown to be associated with a typical time evolution of both surface velocities and passive seismic activity. A prediction of the final break-off is then possible using these precursory signs.

Keywords: avalanches, precursors, glaciers

*Speaker

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Avalanche dynamics in ferroelastics and strain glasses

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Abstract

Ferroelastic/martensitic transitions are often preceded by nanoscale, modulated textures associated with local symmetry breaking effects. Disorder and long-range anisotropic interactions are acknowledged to be the essential ingredients for these precursors to occur. In some circumstances due to the screening of long-range correlations, the ferroelastic transition is kinetically arrested and the system becomes frozen into a strain glass phase. We will discuss a phase-field model that reproduces the behaviour of such systems. We will show that the strain glass phase occurs for small elastic anisotropy and/or large disorder, while a ferroelastic twinned phase occurs at large anisotropy and/or low disorder. The model predicts that these systems respond to an applied stress through avalanches, which show supercritical behaviour in the former case, whereas in the latter case the distribution of avalanches becomes subcritical. Criticality is found close to a critical value of the anisotropy, which depends on the amount of disorder, at which the ferroelastic transition is suppressed. We will illustrate these results with experimental data for martensitic transitions and show that the model predictions are in good agreement with experiments. Present results suggest that the study of avalanche behaviour is a suitable, alternative method to characterize strain glasses.

Keywords: ferroelastics, strain glass, avalanches

*Speaker

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Avalanche Dynamics for Active Matter in Heterogeneous Media

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Abstract

Using numerical simulations, we examine the dynamics of run-and-tumble disks moving in a disordered array of fixed obstacles. As a function of increasing active disk density and activity, we find a transition from a completely clogged state to a continuous flowing phase, and in the large activity limit, we observe an intermittent state where the motion occurs in avalanches that are power law distributed in size with an exponent of $\beta = 1.46$. In contrast, in the thermal or low activity limit we find bursts of motion that are not broadly distributed in size. We argue that in the highly active regime, the system reaches a self-jamming state due to the activity-induced self-clustering, and that the intermittent dynamics is similar to that found in the yielding of amorphous solids. Our results show that activity is another route by which particulate systems can be tuned to a nonequilibrium critical state.

Keywords: active matter, jamming, self, clustering

*Speaker

Statistics of T1 rearrangement events in two-dimensional foam

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Abstract

In the rheological view point, foams are a classic example of viscoelastic yield stress fluids. That is, depending on the imposed stress they show the characteristics of both solids and liquids.
At imposed stresses below a critical value the bubble configuration remains (roughly) static, while
the bubble shapes deform storing energy.
At imposed stresses above the critical value the bubbles move past one another
resulting in irreversible deformation where the energy is dissipated by the drag due to bubble motion.
Flowing two-dimensional foams deform plastically in sequences of neighbor rearrangements of
bubbles, known as T1 events.
There, elastic energy stored in the bubble deformations is released by avalanches of these events.
The number of T1 in a single avalanche and the energy associated to it need not necessarily be proportional [1].

While in a perfect idealized periodic monodisperse bubble assembly the T1 events have constant
waiting time and event magnitudes [2] explicitly determined by the global strain,
in a disordered system this is not the case.
Disorder in a foam can appear due to bubble size distribution or imposed geometric restrictions.
We designed and realized a disk shaped Hele-Shaw geometry, where the foam inlet is located at
its center generating a radial flow of disordered monodisperse foam towards the disk edges.
Using the geometry, we study the statistics of T1. Here we observe a power law like waiting time distribution with an exponent of 1.6. We rationalize this clustering of T1 events
according to the observation that a T1 modifies the shape of even its next nearest neighbors [3],
thus, enabling the possibility that the initial T1 triggers the following ones.
In the future, we plan to change the properties of carrier liquid by adding particles.
This should have similar effect as changing the structural disorder shown here.

*Speaker

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Keywords: Foam, T1 event, rheology

Creeping Avalanches of Brownian Granular Suspensions

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Abstract

We study the flowing dynamics of "Brownian granular suspensions" made of grains that are dense enough to settle down and form a well defined pile, but small enough to be sensitive to thermal fluctuations. Namely, we study the avalanche dynamics of a pile of micron-sized silica grains (1.5 to 4.4 microns) in miniaturized rotating drums (100 microns in diameter, 50 microns in depth) filled with water. Contrary to what is expected for classical granular materials, the avalanches do not stop at a finite angle of repose. Independently of the initial inclination angle, below an angle of ˜10○ we observe a creep regime where the piles slowly flow until they become completely flat. In this regime, the relaxation is logarithmic in time and widely varies with the particle size. The creep is slower when the Péclet number (the ratio between the weight of the grains and the thermal agitation) is increased: the smaller grains (1.5 microns) flow in a few minutes whereas the bigger grains (4.4 microns) flow in months. We propose a simple 1D model based on Kramer's escape rate to describe this creep flow that is not observed in athermal granular materials.

Keywords: colloids, avalanche dynamics, thermal agitation, Brownian granular materials, creep regime

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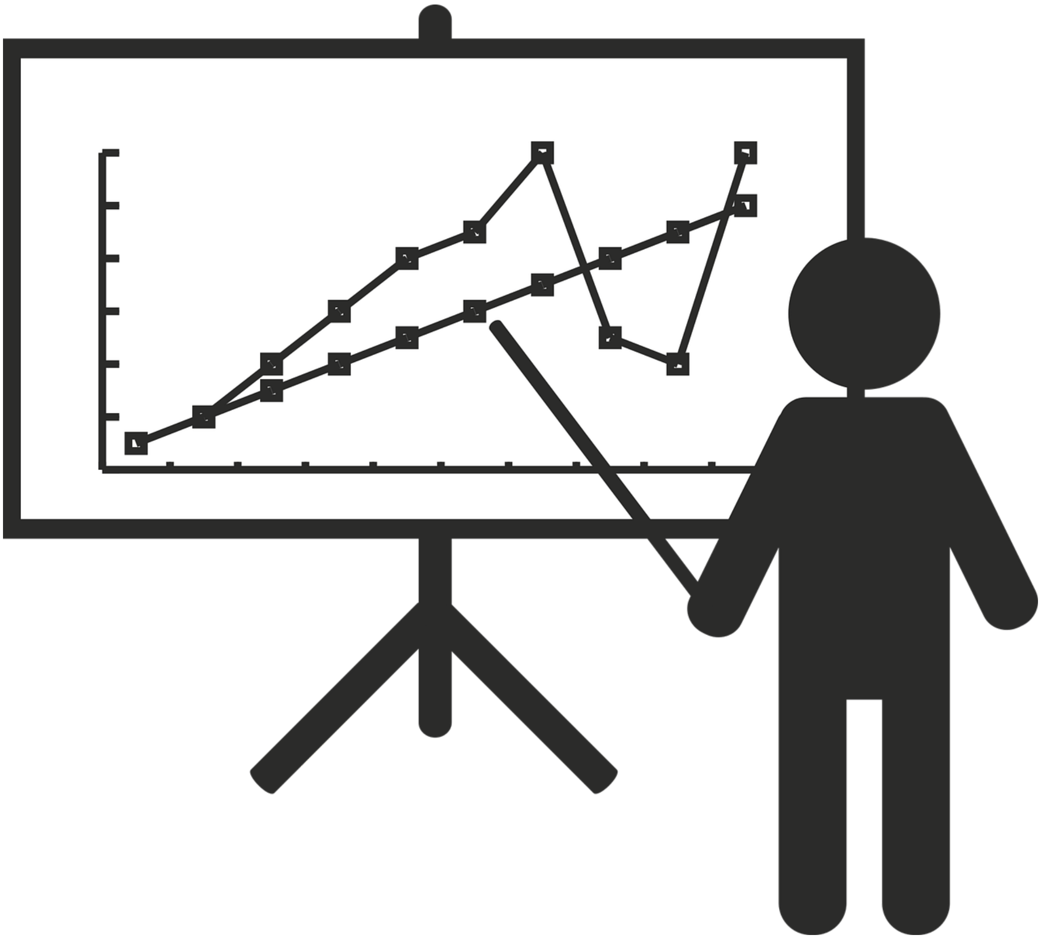
Poster contributions



Out-of-equilibrium dynamics of particle systems in infinite dimension

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Abstract

Dense assemblies of particles are prototypes of structurally disordered systems, such as amorphous solids or yield stress fluids. In infinite dimension their mean-field description becomes exact, and solving their equilibrium dynamics in this limit has been remarkably fruitful in capturing static properties of finite-dimensional systems as well. Here we address their out-of-equilibrium dynamics, paving the way to obtaining a similar infinite-dimensional benchmark for the mechanical or rheological properties of structurally disordered systems.
More specifically, we derive the mean-field dynamical equations that describe a system of pairwise interacting particles, in infinite dimension and in the thermodynamic limit, in a generic setting with arbitrary noise and friction kernels, and possibly under a global shear. We show that the complex many-body dynamics can then be exactly reduced to a single one-dimensional stochastic process, with three effective kernels that have to be determined self-consistently.
In this talk, I will sketch the derivation of this effective dynamics, highlighting in particular the few key ingredients of the high-dimensional physics and their possible relevance for finite-dimensional systems. Since we consider a very general setting, we can model a broad range of situations - equilibrium, quasi-statics, transients or steady-states - such as liquid and glass rheology or active self-propelled particles. I will discuss in particular the comparison between a global shear and local random forces driving of inactive particles.

Keywords: Infinite, dimensional mean, field, out, of, equilibrium, rheology

*Speaker

Avalanche precursors in a frictional model

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Abstract

An experimental approach to study precursors to avalanches is to progressively tilt a box filled with sand and to monitor the events that take place below the avalanche angle. Such experiments have shown the existence of two types of events: localized rearrangements implying only a few grains and large coherent events implying an increasing part of the sample. Those micro-ruptures occur with an angular periodicity, starting from about half of the avalanche angle until the avalanche takes place.

We will present a numerical and theoretical study of a simple one-dimensional model which captures all those experimental features. The model consists in elastically coupled sliders on a frictional incline of variable tilt. This simplified model allows a statistical approach leading to master equations describing the state of the system as a function of the angle of inclination. Our central results are the possibility of incomplete stick-slip events under the threshold and the existence of an internal threshold for the outbreak of rearrangements well below the avalanche.

Keywords: avalanche, stick, slip, precursors

*Speaker

Global and local avalanches in sheared granular Matter

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Abstract

We report on experiments investigating the dynamics of a granular material consisting of a vertical layer of photo-elastic disks sheared by a slider that is pulled by a spring. The motion of the slider proceeds through a sequence of discrete events in which elastic energy stored in the system is rapidly released. We study the PDF of the energy released during these events, as well as their shape, and other seismicity laws. We analyze their variation when the loading speed or the system stiffness is varied to understand their effect on the statistical behavior of the slider. From a more local point of view, by using a fast camera (_˜100Hz) and the photoelastic properties of our particles, we characterize the rapid local stress changes during avalanches. By image processing we detect the local avalanches, as connected components in space and time where the stress rapidly drop. The statistics of these avalanches and their variations with the loading speed are studied as well. The PDFs of avalanches obey power laws both at global and local scales, but with different exponents. We try to understand the distribution and correlation of local avalanches in space and the way they coarse grain to the global avalanches.

Keywords: granular matter, experiment, local avalanche

[*]Speaker

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Magnetic domain wall creep and depinning: A scalar field model approach

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Abstract

Magnetic domain wall motion is at the heart of new magnetoelectronic technologies and hence the need for a deeper understanding of domain wall dynamics in magnetic systems. In this context, numerical simulations using simple models can capture the main ingredients responsible for the complex observed domain wall behavior. We present a scalar field model for the magnetization dynamics of quasi-two-dimensional systems with a perpendicular easy axis of magnetization which allows a direct comparison with typical experimental protocols, used in polar magneto-optical Kerr effect microscopy experiments. We show that the thermally activated creep and depinning regimes of domain wall motion can be reached and the effect of different quenched disorder implementations can be assessed with the model. In particular, we show that the depinning field increases with the mean grain size of a Voronoi tessellation model for the disorder.

Keywords: phi4, Ginzburg, Landau, disorder, domain walls

*Speaker

Development of a large fluctuation in a statistical system

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Abstract

We study the evolution leading to a large fluctuation in a Statistical Mechanical system. We introduce and study analytically a simple model of many identically and independently distributed microscopic variables evolving by means of a master equation. We show that the process producing a non-typical fluctuation is algebraically slow and resembles the kinetics of systems brought across a first order phase transition.

Keywords: Fluctuations, Precursor, Kinetics

*Speaker

Sliding precursors in model patterned interfaces

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Abstract

Over the last years the study of friction has provided a relatively satisfactory image of the static loading of a shear contact and the sliding regime established when two solids are in motion. However, the transition from static friction to kinetic friction is still poorly understood, even less when disorders are introduced at the interface (roughness, interface chemistry, etc.). A better understanding of the transition between these two friction regimes is crucial in various areas ranging from robotics devices (wear at nano scale, haptic devices, ...) to earthquakes or more conventional contact problems (e.g. road/tire or piston /syringe). [4]
In this context, we studied the dynamics of frictional interfaces at the onset of kinetic friction by in-situ observation and evaluation of the real contact area in model experiments. The aim is to progressively introduce controlled disorders into a mesoscale interface to study its influence on the sliding transition.
To introduce a controlled disorder in our interfaces, two texturing techniques are used. The first is based on the deposition of different thin films by magnetron sputtering (physical vapor deposition method) through a mask on a glass substrate to locally modify the friction properties of the interface without modifying the topography. The second one is based on topographic modifications made by micro-milling to reproduce roughness with controlled geometry. Finally, we will show that it is possible to design patterned interfaces that favor the emergence and the detection of sliding precursors sufficiently in advance before the global macroscopic sliding of the interface.

Keywords: Precursors, Friction, Patterned interfaces, Disorder

*Speaker

Does inertia induce stick-slip in friction?

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Abstract

We study the nucleation of slip between two sliding solids, whereby we focus on a mesoscopic level where the disorder, introduced by the surface roughness, matters. It is at this scale that we can study how different contacts interact through the bulk's elasticity. A result of this interaction is that the detachment of one asperity can trigger that of other contacts in its vicinity. An interesting question is if such collective effects organise into depinning-like avalanches. Vice versa this system allows the clarification of the debated role of inertia on an avalanche-like response [1-3]. We argue that, due to the presence of rare weak sites, the response is smooth in the thermodynamic limit. At the same time we find this mechanism not to be efficient, leading to a stick-slip response in finite systems.

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J.M. Schwarz, D.S. Fisher (2003). Depinning with dynamic stress overshoots: A hybrid of critical and pseudohysteretic behavior. Physical Review E, 67(2), 021603.

K. Karimi, E.E. Ferrero, J.-L. Barrat (2017). Inertia and universality of avalanche statistics: The case of slowly deformed amorphous solids. Physical Review E, 95(1), 013003.

Keywords: Friction, Inertia, Hysteresis, Avalanches, Depinning

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Soil creep without gophers and other complications: Experiments probing sub-yield creep in the (near-)absence of disturbances

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Abstract

Soil and dirt are relentlessly dragged along hillslopes by gravity. We typically conceptualize transport as either being driven by agencies external to the grains themselves (eg. bioturbation, freeze-thaw) or as an excess of a critical friction criterion. The existence of sub-yield deformation violates both of these perspectives as well as non-local models of granular rheology, which require the invocation of a momentum source to capture creep. Recent DEM simulations demonstrate that grains creep without bound in the presence of structural disorder, boundaries and an applied stress. These observations have not been validated by physical experiments. Here, we render the problem of sediment transport on hillslopes via an interpretation of soil creep as the deformation of an amorphous solid and seek to probe this phenomenology with physical experiments.

A symmetric pile of grains is prepared below the angle of repose in an enclosed box at a fixed temperature and relative humidity. The system rests on a vibration-isolation table and is allowed to sit for 14 days. Although apparently static, the grains are slowly creeping. Measuring such exceedingly slow velocities presents a technical challenge, as particle-tracking and image cross-correlation techniques do not have the capabilities to resolve micron-scale displacements over reasonable experiment durations. Thus, we implement Diffusing Wave Spectroscopy (DWS), a technique that allows us to probe velocities on the order of the optical wavelength (10ˆ-7 m/s). By collecting the interference pattern produced by photons exiting a ensemble of grains, we map the value of the correlation function of subsequent speckle patterns to deformation of the grains. We begin by developing a model system of glass beads (d = 1mm) and find an exponential velocity decay with distance away from the free surface. We then proceed to test a suite of material sizes and shapes (beads, rods, assorted polygons) and find that rates of creep change with material properties, but the qualitative features and functional form of the velocity profile remain consistent with the model system.

This ubiquity of creep is intriguing and challenges how we conceptualize sub-yield sediment transport on hillslopes. Further work should seek to connect these insights to field-scale measurements.

Keywords: creep, sub, yield deformation

*Speaker

The Abelian Sandpile Model with fractal binary patterns of Non-conservative Sites

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Abstract

We considered the two-dimensional Abelian sandpile model and violated the local conservation of sand grains. The sandpile model has been investigated with a uniform distribution of non-conservative sites. But, we used fractal patterns to mark non-conservative sites and showed that the local violation of the conservation do not destroy the criticality but new scaling exponents appear so that the probability distribution of avalanche sizes have two scaling region with exponents and which are separated by a characteristic size . As expected both of and the exponents depend on the density of non-conservative sites and the lattice size. We calculated this dependence and showed that the new exponent clearly depends upon the fractal dimensions of the medium with a dominantly declining linear trend. Our result has been empirically illustrated in earthquake phenomena. It is shown that the local exponent of the Gutenberg-Richter law is associated with the local fractal dimensional of faults. Our implication is that in natural SOC phenomena, the catastrophic events change the media in which they are embedded. These quasi-static changes adjust the fractality of the media which influence the scaling exponents. Both the experimental observations and numerical results of our model confirm this view. We hope our work creates a paradigm for future studies of self-organized critical phenomena which have fractal structures.

Keywords: Two, dimensional Abelian sandpile model, Local violation of conservation, Binary fractal patterns

*Speaker

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Dissipation in depinning systems: Universal aspects and crossovers

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Abstract

We study the statistics of the energy dissipated in individual avalanches at the depinning transition. In the regime dominated by the depinning phenomenology, a relation between the size of an avalanche and its energy can be derived using "naive" scaling arguments and verified in mean-field systems. This relation allows to design a method to determine the dynamic exponent from static information (using blocked and marginaly stable configurations only). The crossover to a regime where depinning scaling between size and energy breaks down (and the mentioned method fails to capture the depinning dynamic exponent) is briefly discussed.

Keywords: Depinning Transition, Scaling Relations, ABBM Model, Avalanche Energy

*Speaker

Intermittent dynamics in the unclogging of a granular silo

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Abstract

The emergence of arches spanning a narrow opening arrests the flow of discrete bodies through the outlet. Clogs are often undesired and may end up causing problems and economic loss. Vibration is widely used perturbation in order to avoid and destroy the arch formation. In this contribution, we present our experimental results regarding the evolution of arches in a granular silo submitted to a constant vibration [1]. For the first time, the intermittent dynamics of the unclogging process has been evidenced, even for long-lasted broken arches and unbroken arches. Both, breaking time distribution and quiescent time distributions exhibit heavy tails, compatible with power-laws. We have found that the standard deviation of all angles between consecutive beads is a variable suitable for describing the morphological evolution of the arch. The two-time autocorrelation and the mean squared displacement of our morphological variable unveil the aging intrinsic of the unclogging phenomenon. In addition, we have rationalized the evolution of the arch regularity as a stochastic variable. We have extended the study by applying a description based on a 1D continuous time random walk model, achieving good quantitative agreements with the experimental data. This approach can shed light on the complex avalanche process inherent in this unclogging phenomenon.

Guerrero, B. V., Pugnaloni, L. A., Lozano, C., Zuriguel, I., and Garcimartín, A. (2018). Phys. Rev. E, 97(4), 042904.

Keywords: clogging, granular, aging, intermittency

*Speaker

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Dynamics of microscale precursors establish brittle compressive failure as a critical phenomenon in Carrara marble

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Abstract

Microscale heterogeneities influence failure mechanisms in the crust. To track the microstructural changes in rock samples when loaded, we employed a novel experimental technique that couples dynamic X-ray microtomography imaging with a triaxial deformation apparatus, Hades. This technique provides three dimensional time series images of the microstructural evolution of centimeter sized rock samples as they are driven towards macroscopic failure. Here, we studied the brittle failure of Carrara marble under triaxial compression. Dynamic tomographic data reveals the spatial distribution and correlations of microfractures toward failure. We have observed the emergence of scaling relationships between microstructural parameters, including damage volume, and applied differential stress when failure was approached. The total volume of microfractures accumulated from the beginning of the experiment as well as their growth rate showed power law increase. The growth of largest connected microfracture is related to differential stress as a power-law with divergence at failure. The distribution of incremental volume of microfracture growth showed power-law behavior with an exponential cut-off. On approaching failure, cut-off size, which is same as the volume of largest fracture network, increased to the size of the system size. These characteristic features demonstrate that brittle failure in Carrara marble under compression behaves similarly to a critical phase transition, where the stress at failure is considered as a critical point. Scaling exponents computed from our data are in good agreement with predictions made in numerical models. Our results show that precursors of macroscopic brittle failure in Carrara marble follow predictable trends.

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Manipulating discharge size in submerged granular hoppers

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[3]Mikko Alava – Finland
[4]Douglas Durian – United States

Abstract

Discharging granular hopper is a system where discrete particles flow through a narrow opening, an orifice, due gravity. In a traditional dry hourglass type of hopper the dynamics of the system are dictated by the granular media and the effect of interstitial gas is considered negligible. However, this is not the case with submerged hoppers with fluid as an interstitial medium. In both cases, the flow actually consists on avalanches which are separated by a clog.

There exists no critical diameter for the orifice size and the clogging is always possible. However the measured average mass discharge rate grows rapidly with the hole diameter and the clogging becomes highly improbable for large orifices increasing dramatically the avalanche size. Although the scaling is the same in dry and submerged cases the dynamics leading to the clog are different. The dry case is underdampened while the submerged case is overdampened. The recently observed surge [1,2] effect creates a permeation flow which changes the prefactors in the clogging probability. The transition from clogging is sharper in the dry case as the fluid flow prevents some of the clogs from forming [3].

Even more surprisingly a re-entrant clogging transition is found when the interstitial fluid flow is controlled [4]. From the application point of view, understanding fluid-grain coupling provides the means to design uncloggable hoppers with low flow rates deep in the clogging region and achieving the maximum granular throughput.

J. Koivisto and D.J. Durian, Nat. Comm. 8, 15551 (2017).

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J. Koivisto and D.J. Durian, PRE 95, 032904 (2017).

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*Speaker

Study of dislocation dynamics under cyclic Loading with Acoustic Emission

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Abstract

Two contradicting pictures of dislocation-mediated plastic flow are discussed in the literature. The classical paradigm assumes that correlations among individual dislocations are weak and fluctuations are roughly Gaussian, which makes the homogenized description adequate. A different point of view emerged from the analysis of high resolution Acoustic Emission (AE) data in plastically deforming hexagonal crystals, which showed that temporal fluctuations may be power-law distributed in size and energy. Indeed, past experiments performed under monotonic loading on both single- and poly-crystals of hexagonal metallic materials and ice showed that the plastic deformation processes are not smooth and homogenous in time and space but are governed by avalanches of dislocations moving through the material in a very heterogeneous and intermittent fashion.
Actually, the relevance of this intermittent dynamics in plasticity could depend at the same time on (i) the nature of the material (favoring or not the formation of complex dislocation structure) and (ii) the loading mode (monotonic versus cyclic, reinforcing or not the dislocation structure). In hexagonal crystals, the small number of easy slip planes favors long-range elastic interactions, hence collective effects prevailing the intermittency (signature of a *wild* plasticity). On the contrary, the multi-slip character of plastic deformation in fcc materials favors short-range interactions between dislocations. Hence, the build-up of a dislocation microstructure (walls, cells...), which reduces the dislocation mean-free path, inhibits the collective dislocation dynamics and avalanches, leading to a *mild* plasticity. Recently, we showed that this *mild* regime, made of numerous, small and uncorrelated dislocation glide events could coexist with *wild* fluctuations (correlated, power-law distributed) as rare but potentially very large cascades of unlocking events can take place, leading to brutal rearrangements of the dislocation substructure. Concerning the loading mode, cyclic loading is well known to progressively generate well-defined dislocation structures such as veins, labyrinths, cells, and walls separating persistent slip-bands (PSB). These strong dislocation structures would embed the avalanches motions hence the fraction of intermittent plasticity would decrease under cycling.

Here, we question the collective dislocation dynamics when driven by cyclic loading by studying the evolution of the plasticity of pure Cu single crystals during cyclic tests, monitored by AE and imaging of dislocations via ECCI (Electron Channeling Contrast Imaging). The

*Speaker

wildness degree of plasticity (the fraction of plastic deformation accommodated through dislocation avalanches) is explored over the loading cycles, while the dislocation sub-structure is evolving.

We choose to study single crystals (pure Cu single crystals, with different orientations favoring multiple glide) to reduce the AE to dislocations motion and micro cracking only. Uniaxial stress-controlled low-cycle fatigue tests are carried out (Rσ =0.1, at 0.1 Hz) and different stress steps are imposed. Two types of AE are considered: continuous (background noise associated with the mild plasticity) and discrete AE (above a given threshold, associated with avalanches). Dislocation structure is characterize before / during and after cyclic test using ECC-imaging, in a Supra-55VP SEM.
The firs results show that the amount of continuous AE energy increases with the imposed stress level. Almost no discrete emission is recorded before the macroscopic yield strength. Above the yield, discrete AE is observed, especially during the first cycles. Meanwhile, the continuous AE is observed at each cycle, but decreasing in intensity with the number of cycles. The plastic intermittency and dislocation avalanches rapidly decay over very few cycles, meaning that the dislocation structure evolves rapidly during the first cycles, through avalanches and single dislocation motion. After few cycles, as a structure is formed, the movement of single dislocation is made harder by the formation of dislocation junction. Consequently, the dislocation mean free path decreases and the elastic energy generated by their motions falls off simultaneously. Thus, continuous AE decreases until it becomes stationary, sign that the dislocation structure evolves less rapidly than at the beginning of the cycles. The evolution of the wildness is also studied in correlation with AE energy distributions along the cycles and according to the force applied and the dislocation structure formed.

Keywords: dislocation avalanches, dislocation dynamics, acoustic emission, power law distributions

Correlations between avalanches

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Abstract

We describe in detail the correlations between sizes, velocities, durations and shapes of successive avalanches in the theory of elastic depinning.

Keywords: disordered elastic systems, avalanche dynamics and geometry

*Speaker

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Critcality at finite deformation rates in sheared yield stress materials under external excitations

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Abstract

The flow properties of soft disordered solids such as emulsions, foams, granular materials and others are characterized by critical features at the yielding transition (limit of vanishing shear rates) and, under certain circumstances, by a regime of coexistence between regions flowing at different shear rates (bands). The emergence of critical dynamics at finite shear rate is however still poorly understood and has only been addressed in the case of vibrated frictional granular materials in a recent work [Wortel et al., PRL 2016] where an external mechanical vibration induces a transition from a non-monotonic to a monotonic flow curve, accompanied by critical-like fluctuations of the macroscopic shear rate. In this study we investigate the role of an external agitation in a mesoscale elasto-plastic model for the flow of dense disordered materials exhibiting a shear banding instability. We evidence a transition from phase separated to homogeneous flow accompanied by critical-like fluctuations of the macroscopic shear rate. The scaling of fluctuations is found to be consistent with the scaling of the macroscopic flow curve across the transition. We also find that some of the critical exponents characterising this dynamical phase transition seem to be in agreement with experimental observations. Altogether, this suggests a possible generic mechanism for the emergence of critical features when self-fluidization mechanisms associated to shear weakening compete with an external source of noise.

Keywords: Yielding transition, shear banding, soft disordered solids, criticality in soft materials

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Effect of long-ranged elasticity on avalanches at the depinning

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Abstract

Interfaces with long-ranged elasticity are important to understand crack propagation in brittle materials and the dynamics of wetting lines. In presence of disorder the interface displays an intermittent motion caracterized by large reorganisations called avalanches. At variance with the short-range case where avalanches are spatially connex, in presence of long-range interactions avanlanches are split in multiple connex components called "clusters". We introduce a cellular automaton for the avalanche dynamcis and study the statistical and geometrical properties of the clusters. We distinguish several phases depending on the range of the elasticity and find universal power-law distributions whose exponents are related to the standard avalanche exponents.

Keywords: depinning, long, range elasticity, clustering

*Speaker

Athermal creep dynamics of yield-stress fluids: a mesoscopic elastoplastic modeling approach

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Abstract

We develop a spacially resolved mesoscopic elastoplastic description and a corresponding mean-field model to study the transient dynamics prior to steady flow of amorphous solids[1, 2]. These elastoplastic models not only reproduce the experimentally observed non-linear time dependence of the strain response to an external stress[3], but also allow for the determination of the different physical processes involved in the onset of the re-acceleration phase after the initial slowing down and a distinct fluidization phase. The fluidization time displays a power-law dependence on the distance of the applied stress to an age dependent yield stress, which is not universal but strongly dependent on initial conditions.

C. Liu, K. Martens and J-L. Barrat, Mean-field scenario for the athermal creep dynamics of yield-stress fluids, Phys.Rev.Lett 120.028004 (2018)

C. Liu, E. Ferrero, K. Martens and J-L. Barrat, Athermal creep dynamics of yield-stress fluids: a mesoscopic elastoplastic modeling approach, Soft Matter 14 8306-8316 (2018)

P. Coussot, H. Tabuteau, X. Chateau, L. Tocquer, and G. Ovarlez, Aging and solid or liquid behavior in pastes, Journal of Rheology 50, 975 (2006).

Keywords: Yielding, Creep dynamics, Stress control, Amorphous, non, linear

*Speaker

The role of the system size scaling of non-affine displacement in glasses in yielding

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Abstract

Non-affine displacements play an important role to define yielding in glasses, hence in the mechanical failure. We study the distribution of non-affine displacements after shearing a Lennard-Jones glass close to zero temperature. The exponential tail of the distribution scales with the system size, and the scaling exponent depends on the energy of the initial configuration and strain. On the other hand the largest size mobile cluster as a function of system size exhibits a power law behaviour. Interestingly, the power law exponent as a function of strain for a given initial energy has the same form as the scaling exponent except for a constant shift. We can close this gap by increasing the cutoff used to define the mobile particles. At some strain the largest cluster percolate. A recent work[1] from Peter Schall's group showed that the strain of percolation in glasses is the same as the yield strain. We are trying to understand how the strain of percolation changes with the cutoff and what is special at the cutoff where the power law exponent and the scaling exponent are almost the same. [1] Ghosh et al., Phys. Rev. Lett. 118, 148001 (2017).

Keywords: Glass, Yielding, Percolation

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Wood avalanches in fast tomography

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Abstract

Under compression wood deforms with fast avalanche-like dynamics overlayed on top of the slow dynamics due to the fundamental material response. This is known to produce power-law statistics in the acoustic emission of the sample and the periods of high acoustic activity correlate with the localization of deformation into the softwood layers. We have performed in situ tomography imaging of wood compression experiments on the ID15A beamline at the European Synchrotron Radiation Facility (ESRF) to study the intermittent avalanches in the deformation of wood. The 3D reconstructions obtained from the tomography are used to calculate 3D strain fields by Digital Volume Correlation (DVC). The simultaneous acquisition of the global stress-strain response of the sample as well as acoustic emission data enables us to study the correlations between these different signals of avalanche activity.

Keywords: wood compression, tomography, acoustic emission, digital volume correlation

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Global and local characterization of avalanches during the compressive failure of elasto-damageable materials

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Abstract

Failure in structural materials such as wood, rock and concrete involves multiple cracks that interact with each other and with microstructural disorder. However, deciphering damage at the macro-scale is cumbersome and is indirectly measured through deterioration of effective properties. The macroscopic behavior of such materials subjected to compression loading involves three stages – linear elasticity at small displacements followed by local bursts of micro-rupture during which material property degrades and the final failure resulting from the coalescence of damage to form a macroscopic crack that runs through the sample. Characterizing the intermittent dynamics of damage occurring prior to localization is therefore, relevant to structural health monitoring and estimation of residual life.

Recently, the damage localization in weakly disordered solids during compressive failure was shown to result from the interactions of damaged clusters through the elastic field, similar to depinning of an elastic interface driven in a disordered media [1,2]. In the present work, we examine the precursors to localization during compression of a 2D cellular elasto-damageable solid. Avalanches during compression failure are analyzed at the global scale in terms of size and duration from the characteristic features of macroscopic force-displacement plots and energy balance. Further, spatial characterization of avalanches at the scale of the unit cells is performed using the continuous image acquisition during the experiments. Comparing the results from global and local analyses allows for examination of local load re-distribution of elastic energy during progressive damage before localization and testing the suitability of the depinning model.

- E. Berthier, V. Demery and L. Ponson, Damage spreading in quasi-brittle heterogeneous materials: I. Localization and failure, J. Mech. Phys. Solids 102, 101-124 (2017).
- E. Berthier et al. Damage spreading in quasi-brittle heterogeneous materials: II. Statistics of precursors to failure (in preparation).

Keywords: Compressive failure, avalanches, damage localisation, precursors

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Transient normal and shear strain localization in Etna basalt

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Abstract

To examine how preexisting weaknesses influence the propagation, arrest, and coalescence of fractures in deforming volcanic edifices, we triaxially compressed Etna basalt while acquiring *in situ* tomograms. Through segmentation of the tomograms into solid rock and fractures/pores, we directly observed the evolving geometry of fracture networks, including their preferred orientation. Through digital volume correlation (DVC), we tracked the magnitude and spatial localization of the volumetric and distortional strain components. These data provide *in situ* observations of the geometry and orientation of developing fractures throughout triaxial compression, their interaction with preexisting pores, and the magnitude and localization of strain they accommodate that previous experimental studies could only infer. These observations provide insights into potential precursors to volcanic edifice rupture: the transition from contraction-dominated to dilation-dominated deformation. The DVC data shows that contraction localization preceded dilation and shear strain localization into the protofault zone. This onset of strain localization preceded macroscopic yielding and coincided with increases in the magnitude and volume of rock experiencing dilation, and spatial clustering of the strain populations. The exploitation of weaknesses by propagating fractures enabled the dominant shear strain to switch senses as propagating fractures lengthened along 30-60∘ from the maximum compression direction. Scanning electron microscopy images reveal pore-emanated fractures, and fractures linking pores. These experiments provide the first *in situ* evidence of internal contraction preceding dilation and shear, consistent with inferences from field and laboratory observations. The transition from contraction to dilation may signal imminent volcanic flank eruption.

Keywords: precursors, preexisting weaknesses, fractures, yielding, basalt, tomography, digital volume correlation

*Speaker

Depinning, Avalanche Dynamics and Coagulation Processes

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[3]University of Southern California – United States

Abstract

We consider a one-dimensional exactly solvable model that describes the depinning of an elastic string of particles in a strongly pinning, random-periodic environment under a slowly increasing force [1,2]. The evolution towards depinning occurs by the triggering of avalanches, which are at first isolated, but later grow and merge. For large system sizes the dynamically critical behavior is dominated by the coagulation of active regions, i.e. regions in which avalanche activity has occurred before. Our analysis and numerical simulations show that the evolution of the active region sizes is well described by a Smoluchowski coagulation equation with an additive kernel. This allow us to capture the critical behavior of the correlation lengths and avalanche sizes in terms of certain moments of the size distributions of active regions [3]. Interestingly, the coagulation process emerges as a description of the avalanche dynamics at the mesoscopic scale at which only some of the microscopical features of the underlying model are relevant. This furnishes an example for how universal features at larger length scales might emerge from an underlying microscopic dynamics.

D.C. Kaspar and M. Mungan, "Subthreshold behavior and avalanches in an exactly solvable charge density wave system," EPL, 103 (2013) 46002.

D.C. Kaspar and M. Mungan, "Exact Results for a Toy Model Exhibiting Dynamic Criticality," Ann. Henri Poincare, 16 (2015), 2837.

M. Iseri, D.C. Kaspar and M. Mungan, "Depinning as a Coagulation Process,", EPL 115 (2016), 46003.

Keywords: Depinning, Dynamic Criticality, Coagulation Process

*Speaker

Ionic Control of Magnetism

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[3]King Abdullah University of Science and Technology – Saudi Arabia
[4]Georgetown University [Washington] – United States

Abstract

Methods for electrically controlling magnetic materials have generated significant interest in recent years, promising to form the basis of a new generation of ultrafast low-dissipation technologies. Here, an approach to controlling magnetism which leverages electrically-induced ionic motion is presented. Consisting of both a chemically-induced redox reaction as well as electro-thermal treatment, this two-step approach is shown to significantly and irreversibly alter the hysteretic behavior of a thin film bilayer system. The changes to the magnetism, observed via via magnetometry and electron microscopy, arise from dislocations along grain boundaries, which are disrupted as a result of the ionic migration. While these changes appear to be irreversible under further electrical conditioning, thermal cycling resets the magnetic behavior. These results highlight the viability of this approach for controlling interfacial magnetism, and suggest new pathways towards improved ionic devices.

Keywords: Magnetism, Granularity, Irreversibility, Ionic Migration

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Increasing power-law range for avalanche observables

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Abstract

Power-law–type probability density functions spanning several orders of magnitude are found for different avalanche properties and represent a hallmark of scale invariance. However, experiments only report a limited range of events, making it difficult to measure the exponents accurately. We propose a methodology to try to beat this limitations by combining different datasets with rigorous statistical tools with the aim of finding a broader fitting range. This methodology is applied to acoustic emission avalanches during failure-under-compression experiments of a nanoporous silica glass [1] and to the Gutenberg-Richter law for earthquakes [2].

V.Navas-Portella, I.Serra, A.Corral, and E.Vives, "Increasing power-law range in avalanche amplitude and energy distributions" , Physical Review E 97, 022134 (2018).

V.Navas-Portella, A.Corral,and A.Gonzalez "Testing the fitting range of the Gutenberg-Richter Law", unpublised (2018)

Keywords: Scale, invariance, fit, exponents, universality

*Speaker

Observation of the avalanche precursors under cycling or wet conditions

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Abstract

The observation of some precursors before avalanches is a quite recent discovery but understanding the physical characteristics which impulses the apparition of these precursors of granular avalanches is important for the prediction of some critical events. As pan of the dynamics leading to the avalanche, precursors are identified as collective motions of grains visible on the free surface. When a granular pile is tilted at a constant angular velocity, precursors appear quasi-periodically.

In one hand, our experiments conducted with monodisperse glass beads packings submitted to an automatic symmetric oscillation show well defined periodic precursors along the successive cycles. We simultaneously characterize precursors on the free surface with an optical method(surface 2D probe) and in the bulk with acoustic methods with and amplitude modulated pulse(3D volumetric probe).

In other hand, experiments with glass beads of $0.2, 0.5$ and 0.75 mm diameter, and polystyrene beads of 0.14 mm diameter inside an ambient relative humidity ranging between 40 and $94

Keywords: precursors, wet conditions, cycling, acoustic

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Effect of fault particle friction on the characteristics of seismic cycles and precursory activities of earthquakes

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Abstract

Earthquake, avalanche and landslide are among natural catastrophes that are accompanied by sudden release of stored energy. While the nucleation of these events may take up to tens of years, the rupture process is fast and often takes place in a few seconds to minutes. The nucleation and rupture of these catastrophes can be simplified to frictional stick-slip dynamics, where during the stick phase, the stored energy increases and the system reaches a critical state. In this critical state, micro-slips also called precursors precede the major slip event. In this work, using a three dimensional discrete element model, we simulate frictional stick-slip dynamics in a sheared granular layer and study the effect of grain friction on the characteristics of seismic cycles. We show that, the particle friction can systematically change the timing and size of slip events as well as the properties of the critical state: a fault gouge with high particle friction shows a more complex nucleation phase containing many small slip events that precede the major event. These complexities are also observable in the kinetic energy signal. The fault gouge with higher grain friction stores more elastic strain (potential) energy and releases this energy more often. The acoustic emission analysis based on monitoring of the particle velocity signals also confirms this observation and demonstrates higher temporal and more spatially distributed emissions. We discuss that our observations are similar to the numerical and experimental works studding the fault roughness. We show that, the particle roughness that is approximated in our model with grain friction plays a significant role in the earthquake (and other frictional processes in the earth including avalanche and landslide) nucleation altering the characteristics of critical state and precursory activities.

Keywords: precursor, friction, stick, slip dynamics, catastrophe, fault mechanics

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An effective implicit method for discrete dislocation dynamics simulations

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Abstract

Crystalline materials deform plastically due to the movement of linear dislocations in the crystal. The way how these dislocations move or get stuck explains work hardening, size effects, creep and several other technologically important phenomena, hence this is an actively investigated and developed subfield of materials science.
Dislocations exhibit complex spatiotemporal dynamics due to their long-range mutual interactions via their induced stress fields. The mathematical description of this system leads to stiff differential equations. Solving them with explicit methods on long time scales is computationally rather demanding. Nonetheless, all the currently applied algorithms are based on different explicit methods both in 2 and 3 dimensions. Although implicit methods are generally more suitable for such problems, because of the long-range interactions, the computing cost can be even higher for a large number of simulated dislocations.

We developed a new implicit method, which decreases the simulation runtime efficiently in 2 dimensions by reducing the complexity of the mathematical system using physical principles. Our in-depth analysis showed that, while achieving better precision, the runtime decreased with several orders of magnitude.
This numerical scheme makes it possible to study the precursors of avalanches and the avalanches as well in great depth, making it possible to understand better the behavior of dislocation systems during plastic deformation.

Keywords: avalanches, dislocations, numerical scheme, plastic defomation, simulation, implicit

*Speaker

Machine learning plastic deformation of crystals

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[2]Department of Applied Physics, Aalto University – Finland
[3]Tampere University of Technology [Tampere] – Finland

Abstract

The irreversible changes in crystalline materials during plastic deformation are governed by the motion of dislocations – the line defects of the crystal structure. Experiments have shown that plastic deformation progresses through bursty events and in micron-scale samples these avalanches cause the stress response to fluctuate drastically from sample to sample. Here our aim was to study if the stress response of such sample could be predicted from the initial dislocation configuration. We simulated a crystalline solid with a two-dimensional discrete dislocation dynamics (2D DDD) model. The initial systems were then characterized with a set of inputs that we fed to a regression neural network predicting the stress for certain strain. Although the predictability vs strain evolved in a non-monotonic fashion as it was affected by the dislocation avalanches, the performance of the network with large strains was promising. Additionally, the predictability improved when the system size was increased.

Keywords: crystal plasticity, dislocations, neural networks, discrete dislocation dynamics simulations

*Speaker

Dislocation dynamics and separation of timescales in the Phase Field crystal

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Abstract

We study the elastic behavior and the motion of edge dislocations in the phase field crystal (PFC). After deriving an expression for the stress of a particular out-of-equilibrium state, we are able to prove that edge dislocations move according to the Peach-Koehler force. However, the PFC in its usual formulation lacks the proper separation of elastic and plastic timescales common in realistic materials. To alleviate this, we develop an efficient method of smoothly distorting the PFC lattice in order to satisfy mechanical equilibrium during PFC evolution.

Keywords: Phase Field Crystal, Plasticity, Dislocations

*Speaker

Depinning and Sandpiles: From Theory to Experiment

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Abstract

I will discuss key ingredients of the theory of depinning, and its relation to both Manna and Abelian sandpiles. This is confronted to experimental results on RNA peeling.

Keywords: depinning, field theory, sandpiles, unzipping

*Speaker

Acoustic probing and triggering of shear instability in dense granular media

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Abstract

Laboratory studies of granular friction have emerged as a powerful tool for investigating dynamics of seismic faults [1], including dynamic triggering of earthquakes and landslides [2]. Advancesingranularphysics havepavedtheway forunderstandinghowelastic waves trigger fault slips. Theemergingviewisthatdynamicperturbationofshearedgougematerialscausesan elastic softening up to a material failure, which could beseen as unjamming transition bythe acousticfluidization [3]. Here we report a series of experiments conducted in granular solids. First, we investigate the shear instability inconfined granularmediaby acoustic*probing*. Decrease of the shear wave velocity and development of the fabric anisotropy are observed prior to failure. We also find that the correlation function of the multiply scattered coda waves is very sensitive to the stick-slip like rearrangements of granular networks during shear banding [4]. Next, we study thefluidization of a granular solidby the nonlinear acoustic*pumping.*Two regimes are found whenthe amplitude of vibration increases: in the first we observe a significant shear modulus weakening but without visible grain rearrangement, while in the second there is a plastic rearrangement of grains accompanied with the modulus decrease up to 85% [5]. Finally, we show that such mechanisms could explain the triggering of granular avalanches by small-amplitudeultrasound that acoustically*lubricates*the contact area and reduce the apparent inter-particle friction [5,6] without causing rearrangement of grains via shear dilatancy.

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Y. KhidasandXJia, Probing the shear-band formation in granular media with sound waves-Phys. Rev. E**85**,051302 (2012)

J. Brum, J.-L Gennisson, M. Fink, A. Tourin, and X. Jia, Drastic slowdown of shear waves in unjammed granular suspensions, arXiv: 1810.08555

*Speaker

J.Léopoldès, G. Conrad, and X. Jia, Onset of sliding in amorphous films triggered by high-frequency oscillatory shear, Phys. Rev. Lett.**110**,248301 (2013)

Keywords: granular media, shear instability, avalanche triggering, sound waves

Asperity controls percursory slips and giant events in laboratory eathquakes

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Abstract

It is believed that asperity contact plays an essential role in fricton, especially in onset of dynamic slip or stick-slip motions. However, there remains very few studies controling asperities and observing their effects on frictional constitutive laws or mascoscopic stick-slip behaviors. Here we perform stick-slip friction experiments between compliant gels with well-controlled asperity shape/size/configurations by molding technique [1]. We find that, as curvature radius of the asperity becomes larger and the normal stress becomes smaller, the velocity dependence turns from rate-strengthening to rate-weakening and accordingly, frictional behavior transitions from steady sliding, slow slip to fast slip. Moreover, abnormal precursory slip behavior exhibiting periodically synchronized microslips is observed just before a giant event. In this talk, we discuss the relationship between asperity size and the frictional constitutive behavior, and then introduce our experimental results with in-situ visualization of a variety of precursory slips and giant events. [1] T. Yamaguchi, S. Takeuchi and Y. Sawae, in preparation.

Keywords: friction, gel, precursory slip, earthquake, constitutive law

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PRACTICAL INFORMATION

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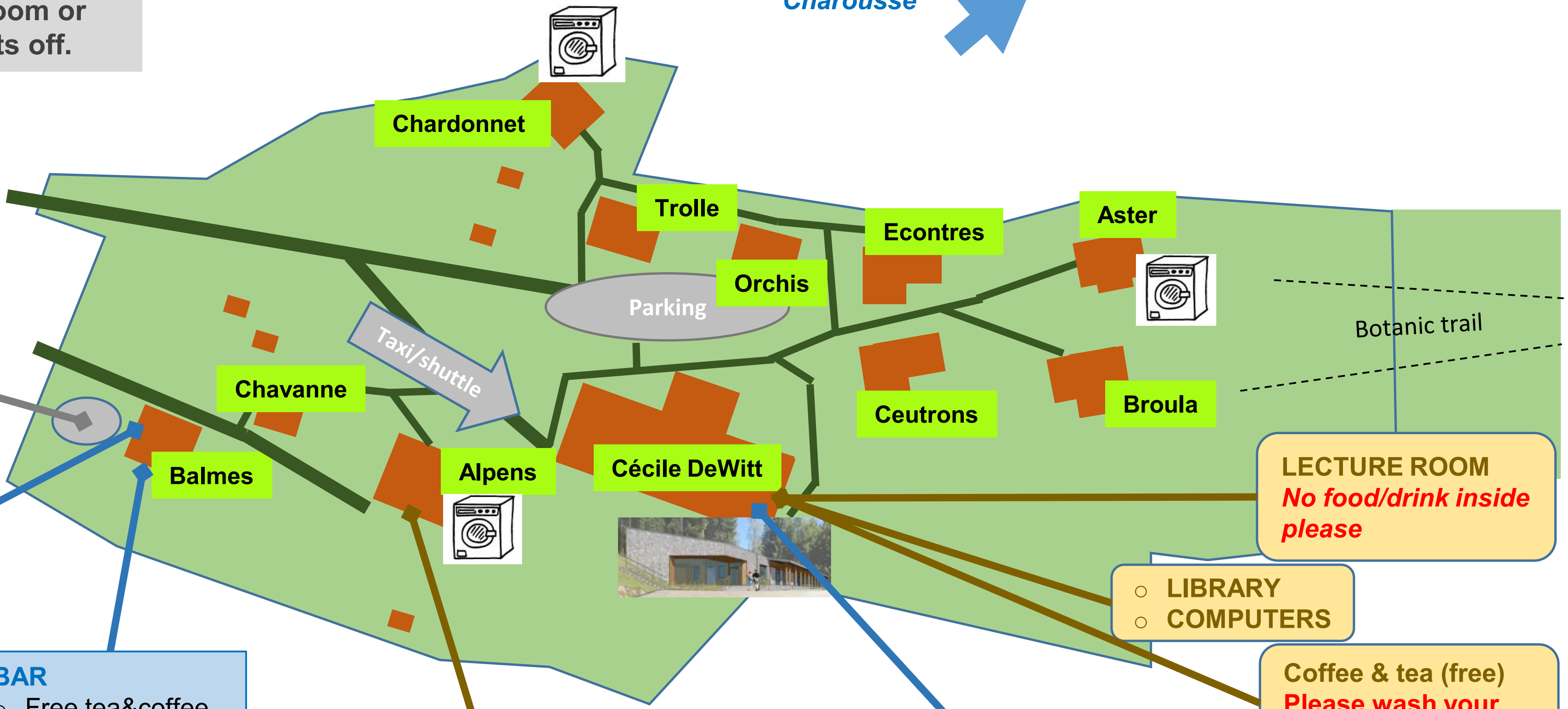

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  Dinner : 19:30 pm
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- **Drinks** (not included) can be bought on individual basis and paid here

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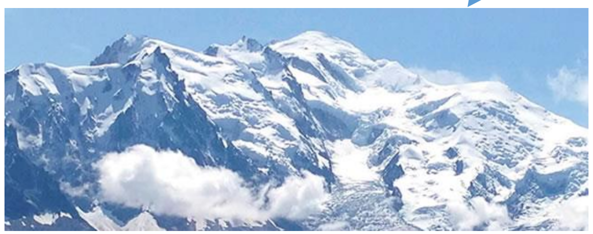
- To be paid : - school fee : 1st day
  - cold drink : last day

LECTURE ROOM
No food/drink inside please

- LIBRARY
- COMPUTERS

Coffee & tea (free)
Please wash your cups & glasses

Direction of Mont Blanc



Mountain activities are at your own risk

Before any hike or climb, please put a note on the special book provided and include the name of the participants, approximate itinerary, schedule and phone number. We draw your attention to the fact we only hold a collective insurance for accidents occurring on the school campus.

Washing Machines & dryers Free use & washing powder

Supporting institutions

cecam
Centre Européen de Calcul Atomique et Moléculaire

cnrs

ÉCOLE DE PHYSIQUE DES HOUCHES

DE LA RECHERCHE À L'INDUSTRIE
cea

UNIVERSITÉ Grenoble Alpes

Grenoble INP

La Région Auvergne-Rhône-Alpes

OSUG

A! Aalto University School of Science

Observatoire des Sciences de l'Univers de Grenoble

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