DY 22: Granular Matter/ Contact Dynamics

Time: Wednesday 14:00–18:00 Location: HÜL 186

DY 22.1 Wed 14:00 HÜL 186

Where to Dig for Gold? - Density Segregation inside Migrating Dunes — Christopher Groh[1], Ingo Rehberg[1], and •Christof A. Krülle[1,2] — [1]Experimentalphysik V, Universität Bayreuth, D-95440 Bayreuth, Germany — [2]Maschinenbau und Mechatronik, Hochschule Karlsruhe - Technik und Wirtschaft, D-76133 Karlsruhe, Germany

Spatiotemporal patterns in nature, such as ripples or dunes, formed by a fluid streaming over a sandy surface show complex behavior despite their simple forms. Below the surface, the granular structure of the sand particles is subject to self-organization processes, exhibiting such phenomena as reverse grading when larger particles are found on top of smaller ones. Here we report results of an experimental investigation with downscaled model dunes revealing that, if the particles differ not in size but in density, the heavier particles, surprisingly, accumulate at the crest of migrating dunes while lighter particles are buried at the bottom. As a side effect we show that the migration velocity of bi-dense dunes scales with the mean density of the grains as a power law function with an exponent of -3/2. This insight into the sedimentology of dunes composed of different types of sand has, loosely speaking, the implication, that in a ripple or dune mixed of gold and sand, the gold nuggets are likely to be found at the top, close to the surface at the crest.

DY 22.2 Wed 14:15 HÜL 186

Axial segregation and convection of a granular mixture in a quasi-2d rotating container — •Frank Rietz and Ralf Stannarius — Universität Magdeburg, Abt. Nichtlineare Phänomene

A bimodal mixture of glass spheres is filled into a long, flat rectangular container. The flatness of the container allows the particles to arrange only in a quasi 2d layer. The cell is slowly rotated along the horizontal axis. We observe in most cases demixing of the beads in lateral bands. In some cases the mixture does not segregate and the beads circulate in convection patterns. With this simple system we can reproduce well-known three-dimensional phenomena like axial segregation banding in half filled rotated cylinders[1] and convection rolls in flat rotated cells[2]. By reducing the complexity from 3d to 2d we show that models based on the angle of repose are not relevant for 2d cells and thus might be not relevant in general.

[1] K.M. Hill, A. Caprihan, and J. Kakalios, *Phys. Rev. Lett.* **78**, 50 (1997).
[2] F. Rietz and R. Stannarius, *Phys. Rev. Lett.* **100**, 078002 (2008).

DY 22.3 Wed 14:30 HÜL 186

Traffic jams, gliders, and bands in a simple lattice swarming model — •Fernando Peruani[1], Tobias Klauss[2], Andreas Deutsch[2], and Anja Voss-Boehme[2] — [1]Max Planck Institute for the Physics of Complex Systems, Dresden, Germany — [2]ZIH - Technische Universitaet Dresden, Dresden, Germany

In this talk, we will introduce a simple swarming model on a two-dimensional lattice where the self-propelled particles exhibit a tendency to align ferromagnetically. Volume exclusion effects are present: particles can only hop to a neighboring node if the node is empty. We will show that such effects lead to a surprisingly rich variety of self-organized spatial patterns. As particles exhibit an increasingly higher tendency to align to neighbors, they first self-segregate into disordered particle aggregates. Aggregates turn into traffic jams. Traffic jams evolve toward gliders, triangular high density regions that migrate in a well-defined direction. Maximum order is achieved by the formation of elongated high density regions - bands - that transverse the entire system. Numerical evidence suggests that below the percolation density the phase transition associated to orientational order is of first-order, while at full occupancy it is of second-order.

DY 22.4 Wed 14:45 HÜL 186

Amplitude-dependent phase-separation in vibrated dry granular matter — •Klaus Röller[1], James P.D. Clewett[2], Roger M. Bowley[2], Stephan Herminghaus[1], and Michael R. Swift[2] — [1]MPI for Dynamics and Self-Organization, Bunsenstr. 10, D-37073 Göttingen, Germany — [2]School of Physics and Astronomy, University of Nottingham, Nottingham, NG7 2RD, United Kingdom.

A new phase transition is observed experimentally and by simulation in a dry granular gas subject to vertical vibration between two horizontal plates. Molecular dynamics simulations allow to investigate the observed phase separation in detail. We find a high-density, low temperature gas, coexisting with a low-density, high temperature gas moving coherently. A simple scaling argument approximately gives the amplitude dependence of the temperature in each phase. The characteristic dependence of the phase separation on the vibration amplitude distinguishes this phase separation from other known transitions in driven granular media.

DY 22.5 Wed 15:00 HÜL 186

Phase transitions of two dimensional wet granular matter under swirling motion — •Christopher May, Kai Huang, and Ingo Rehberg — Experimentalphysik V, Universität Bayreuth, D-95440 Bayreuth, Germany

Wetting triggered phase transitions of granular matter may lead to natural disasters such as landslide. To shed light on phase transitions of wet granular matter in general, we study experimentally the dynamical behavior of two dimensional wet glass beads under horizontal swirling motion. The cohesion induced by capillary bridges formed between adjacent particles tends to keep wet granular clusters rigid against 2D swirling motion. How the rigidity varies with wetting liquid added and how the change of rigidity in turn influences the phase transitions of the 2D system are going to be addressed. The structures of the clusters are investigated by particle tracking techniques and their solid-, fluid- and gaslike states are characterized by means of bond-orientational order parameters.

DY 22.6 Wed 15:15 HÜL 186

Spiral Patterns in Vertically Vibrated Wet Granular Matter — •Kai Huang and Ingo Rehberg — Experimentalphysik V, Universität Bayreuth, D-95440, Germany

Spiral patterns widely exist in nature and have been extensively studied in various non-equilibrium systems. As a peculiar example, we report here spiral patterns in a few layers of cohesive glass beads driven by vertical vibrations. The cohesion is introduced by adding few percent of wetting liquid into the sample so that the particles are bonded with each other by liquid bridges. As the vibration amplitude reaches a certain threshold, traveling waves or rotating spiral patterns start to appear. These spiral patterns have typically a meandering core and three rotating arms which are associated with the three phases of a parametrically driven oscillation with period 3. The phase diagram for the pattern forming system will be presented and the mechanism for the spiral patterns will be discussed.

DY 22.7 Wed 15:30 HÜL 186

Fluidization of wet granulates under hydrodynamic stresses — •Ilenia Battiato and Jürgen Vollmer — Max Planck Institute for Dynamics and Self-Organization, 37073, Göttingen

We investigate the fluidization threshold of three-dimensional wet granulates under hydrodynamic drag exerted by a creeping flow. A continuum model of flow through porous media provides a closed form expression for the average drag force on a single grain. The balance equation for the forces and a force propagation model are then used to investigate the effects of porosity and different packing structures (e.g. Face Centered and Hexagonal Close Packing) on the stability of the pile.

DY 22.8 Wed 15:45 HÜL 186

Temperature-sensitive wet granular matter — •Christoph Gögelein, Martin Brinkmann, Matthias Schröter, and Stephan Herminghaus — MPI für Dynamik und Selbstorganisation, Bunsenstr. 10, 37073 Göttingen

We present our recent experimental studies on the temperature-induced formation of capillary bridges in granular matter. We will demonstrate that we can precisely tune the bridge size and force by immersing our glass spheres in a binary liquid mixture [1]. Furthermore, we will discuss the effect of capillary bridges on random sphere packing's using a fluidized bed setup.

[1] C. Gögelein, M. Brinkmann, M. Schröter, and S. Herminghaus, Langmuir 26 (2010) 22, 17184.

15 min. break

DY 22.9 Wed 16:15 HÜL 186

Refraction, exclusion and reflection of shear zones in layered granular materials — •Balázs Szabó[1], Sandra Wegner[2], Tamás Unger[3], Frank Angenstein[4], Ralf Stannarius[2], and Tamás Börzsönyi[1] — [1]Research Institute for Solid State Physics and Optics, H-1525 Budapest, PoB. 49, Hungary — [2]Otto-von-Guericke-University, D-39106 Magdeburg, Germany — [3]HAS-BUTE Condensed Matter Research Group, Budapest University of Technology and Economics H-1111 Budapest, Hungary — [4]Leibniz Institute for Neurobiology, D-39118 Magdeburg, Germany

When granular materials deform under external stress the deformation is often localized into narrow regions. These shear zones develop along the most optimal path (weakest bonds break), thus, in an inhomogeneous material the shear zone tries to escape the high friction regions. In a layered system the zone can change direction when crossing the layer boundaries, which is very similar to the refraction of light beams in geometric optics [1]. We show experimentally and numerically, that for the case of shear zones the refraction law is in striking analogy with geometric optics, but here the frictional properties of the materials take the role of the optical index of refraction [2]. We also explore other configurations, where the zone is refracted from the layer boundary. Visualization of the zone inside the material was achieved by two independent techniques: (i) excavating the system layer by layer and (ii) Magnetic Resonance Imaging.

[1] T. Unger, Phys. Rev. Lett. 98, 018301 (2007). [2] T. Börzsönyi et al., Phys. Rev. E 80, 060302(R) (2009).

DY 22.10 Wed 16:30 HÜL 186

Tailoring the frictional properties of granular media — •Sonia Utermann[1,2], Philipp Aurin[1], Markus Benderoth[1], and Matthias Schröter[1] — [1]Max Planck Institute for Dynamics and Self-organization — [2]Georg-August-Universität Göttingen

Where the theorist often neglects friction, this most intriguing of granular interactions, the experimentalist cannot, and instead must embrace it. Here, we go a step further and develop a protocol which allows us to use friction between grains as an experimental control parameter. We present two simple chemical etching procedures which alter the roughness of soda-lime glass spheres: a procedure to smoothen the surface and one to roughen it. The roughness has an influence on the frictional properties of the grains because it alters the topology and size of the microscopic contacts between grains. We characterise the spheres using white light interferometry. Additional underwater angle-of-repose measurements on our etched samples give us a measure of frictional properties in the bulk.

DY 22.11 Wed 16:45 HÜL 186

Nanoindentation on sedimented colloids — •Marcel Roth[1], Carsten Schilde[2], Philipp Lellig[1], Arno Kwade[2], and Günter K. Auernhammer[1] — [1]MPI for Polymer Research, Mainz, Germany — [2]Institute for Particle Technology, TU Braunschweig, Germany

The mechanical properties of colloidal and granular matter depend on the mutual interplay of inter-particle forces as well as structural and material properties. While attractive forces are directly connected to the mechanical strength of the sample, particle rearrangements under gravity or external loads are critically affected by the particle density and surface properties.

In the present paper we investigate the mechanical properties of dense amorphous and semi-crystalline colloidal sediments made from monodisperse PMMA particles (diameter: $1.6\,\mu m$) via nanoindentation in combination with confocal microscopy. In doing so the bare mechanical data are complemented by three-dimensional trajectories of all particles during the indentation. Reorganization processes are identified and the average deformation field is calculated. Although the indent extension is only ten times larger than the particle size the deformation field of the amorphous structure is in reasonable agreement with the predictions from the continuum theory. In semi-crystalline assemblies heterogeneities and generation of dislocation defects are observed. As a consequence measured force-depth curves can be quantitatively analyzed with the theory of Oliver and Pharr to extract average values for hardness and effective elastic modulus characteristic for the tested structure.

DY 22.12 Wed 17:00 HÜL 186

Length scales of volume correlations in disk packings — •SongChuan Zhao and Matthias Schröter — Max-Planck-Institut für Dynamik und Selbstorganisation, Göttingen

In a static granular packing particles influence their nearest neighbors e.g by force chains [1]. More recently, building on the ideas of Edwards and co-workers [2], experiments on the distribution of Voronoi volumes in 2D granular packing have found that the logarithm of the free volume distribution scales in a non-extensive way with the cluster size. This implies the existence of the correlation between Voronoi cells [3]. We present experimental data how the length of this correlation depends on packing fraction. We vary the packing fraction in the range 0.820~0.838. Three length scales related to the correlation are identified. Two of them only appear for denser packing (> 0.826). They characterize anti-correlation between Voronoi volumes. One of them increases strongly with packing fraction.

[1] T.S. Majmudar, R.P. Behringer Nature (2005) 435:1079-1082
[2] S.F. Edwards and R.B.S. Oakeshott, Physica A, 157 1080 (1989)
[3] F. Lechenault, F. da Cruz, O. Dauchot and E. Bertin. J. Stat. Mech. (2006) P07009

DY 22.13 Wed 17:15 HÜL 186

Tagged particle dynamics close to the glass transition of a driven dissipative system — •Till Kranz[1,2], Matthias Sperl[3], and Annette Zippelius[1,2] — [1]Institut für Theoretische Physik, Göttingen — [2]MPI für Dynamik und Selbstorganisation, Göttingen — [3]Institut für Materialphysik im Weltraum, DLR Köln

In order to reach a steady state, granular (dissipative) systems need an external driving. One of the many possible methods is to fluidize the system by a fluctuating driving force. We have been able recently to establish the existence of a granular glass transition by extending mode coupling theory to nonequilibrium systems [1]. A similar extension of the mode coupling formalism for the incoherent scattering function $\phi_s(q,t)$ of a granular fluid shall be discussed in this contribution. Close to the critical density $\varphi_c(\epsilon)$, that depends on the coefficient of restitution ϵ, the incoherent scattering function $\phi_s(q,t)$ as well as the mean square displacement $\delta r^2(t)$ are found to exhibit a plateau for intermediate times. Related observables that are also meaningful for the nonequilibrium steady state of a granular fluid are the long time diffusion coefficient $D_\infty = \lim_{t\to\infty} \delta r^2(t)/t$ close to the glass transition and the localization length r_c at the glass transition. Evidence for a granular glass transition as indicated by the tagged particle dynamics has been found both in experiments and in simulations [2,3]. We will discuss our theoretical findings in relation to the experimental data.

[1] W. T. Kranz, M. Sperl and A. Zippelius, PRL **104**, 225701 (2010)
[2] A. R. Abate and D. J. Durian, PRE **74**, 031308 (2006)
[3] A. Fiege *et al.*, PRL **102**, 098001 (2009)

DY 22.14 Wed 17:30 HÜL 186

Superdiffusive, heterogeneous, and collective particle motion near the jamming transition in athermal disordered materials — •Claus Heussinger[1], Ludovic Berthier[2], and Jean-Louis Barrat[3] — [1]Institute for Theoretical Physics, University of Goettingen, Germany — [2]LCVN, Univ. Montpellier 2, France — [3]LPMCN, Univ. Lyon I, France

Many materials, from emulsions and suspensions to foams and granular materials are dense assemblies of non-Brownian particles. In these systems a fluid-to-solid "jamming" transition can be observed when the particle volume fraction is increased beyond a critical value. In this contribution, we use computer simulations to study the microscopic dynamics of an assembly of soft, frictionless particles near their jamming transition. We observe superdiffusive, spatially heterogeneous, and collective particle motion over a characteristic scale which displays a surprising non-monotonic behavior across the transition. Establishing a connection between single particle dynamics and collective particle motion, we develop an intuitive and appealing picture of jamming as the consequence of the diverging size of rigid particle clusters.

DY 22.15 Wed 17:45 HÜL 186

Jamming of frictional tetrahedra — •Max Neudecker[1], Stephan Ulrich[2], Stephan Herminghaus[1], and Matthias Schröter[1] — [1]Max-Planck-Institut für Dynamik und Selbstorganisation, Bunsenstr. 10, 37073 Göttingen — [2]Universität Göttingen, Institut für theoretische Physik, Friedrich-Hund-Platz 1, 37077 Göttingen

We present experimental results on the packing of polypropylene tetrahedra with 7mm side length. Analysis via X-ray-tomography allows for a detailed analysis of the radial distribution function and the number and type of geometrical contacts. We focus particularly on the dependence of these packing properties on the bulk packing fraction.