DY 61: Granular Matter / Contact Dynamics (joint session DY/CPP)

Time: Thursday 10:00–13:00 Location: BH-N 333

DY 61.1 Thu 10:00 BH-N 333

Predicting contact numbers in granular packings — •Matthias Schröter[1], Simon Weis[2], and Gerd Schröder-Turk[3] — [1]Institute for Multiscale Simulation, University Erlangen, Nägelsbachstrasse 49b, 91052 Erlangen, Germany — [2]Institut für Theoretische Physik I, Universität Erlangen-Nürnberg, Staudtstraße 7, 91058 Erlangen, Germany — [3]School of Engineering and Information Technology, Murdoch University, 90 South Street, Murdoch, WA 6150, Australia

The mechanical stability of granular packings depends on the number of contacts its individual particles form with their neighbors. While these contact numbers can be measured using X-ray tomography [1], there are very few theoretical results prediciting this crucial parameter. A major part of the reason why theory lacks behind here is the frictional nature of the contacts [2]; up to now no effective method has been found to handle the inequality given by Coulomb friction. On the other side there is an abundance of experimental data. This raises the question if training an artificial neural network might be more effective to predict contact numbers than asking human experts.

[1] Schaller, Neudecker, Saadatfar, Delaney, Schröder-Turk, and Schröter, Physical Review Letters **114**, 158001 (2015)
[2] Schröter, EPJ Web of Conferences **140**, 01008 (2017)

DY 61.2 Thu 10:15 BH-N 333

Rotator crystals in a granular monolayer — •Simeon Völkel and Kai Huang — Experimentalphysik V, Universität Bayreuth, 95440 Bayreuth, Germany

The collective behaviour of vertically vibrated hexagonal disks confined in a horizontal monolayer is investigated experimentally. The disks tend to rotate upon sufficiently strong driving. Additionally, they can arrange in a hexagonal structure, reminiscent of a rotator crystal in equilibrium systems. We investigate the transitions into and out of this non-equilibrium steady state and their dependence on the presence of a wetting liquid. Furthermore we characterize the rotator crystal state using the bond orientational order parameter, parameters coupled with set voronoi diagrams, as well as the distribution of particle orientations. Finally we explore the influence of the disk's shape by varying the number of corners systematically.

DY 61.3 Thu 10:30 BH-N 333

Collisional charging enhances aggregation in granular gases — •Chamkor Singh and Marco G. Mazza — Max Planck Institute for Dynamics and Self-Organization (MPIDS), 37077, Goettingen, Germany

Since classical antiquity lightnings have been associated with the ashes produced during volcanic activity. It has been long speculated that collisional charging may play a significant role in particle's aggregation in such natural processes, *e.g.*, in the formation of planetesimals during the early stages of the birth of a planet, charging in dust devils, lightnings in thunderclouds, and electric sparks in dunes. We perform molecular dynamic simulations in three dimensions for a dilute, freely-cooling granular gas of viscoelastic particles that exchange charges during collisions. Using percolation theory, we find a stronger power law growth of the average cluster size, $S(t) \sim t^z$, with $z \approx \frac{3}{2}$ in the *collisionally charged* gas than $z \approx \frac{6}{5}$ in the *neutral* case. Remarkably, z is found to be independent of the typical Bjerrum length, or equivalently, of the ratio of characteristic Coulomb to thermal energy. However, this ratio alters the crossover time of the growth. The velocity distribution of the charged viscoelastic particles does not show a relaxation towards Maxwellian within the early stages of aggregation.

DY 61.4 Thu 10:45 BH-N 333

Structural Evolution of Planar Granular Media — •Clara Wanjura[1], Takashi Matsushima[2], Othmar Marti[1], and Rafi Blumenfeld[3,4,5] — [1]Ulm University, Germany — [2]University of Tsukuba, Japan — [3]Inst. of Physics, Chinese Academy of Sciences, China — [4]Imperial College London, UK — [5]Cambridge University, UK

Granular materials are ubiquitous in nature, but continuum models of their macroscale behaviour and properties have proved to be difficult. Particle-scale properties and the structure affect strongly the large-scale behaviour.

Here we study a key characteristic of the structure in two dimensions: the cell-order distribution (COD). We first describe the evolution of the COD by a set of master equations and establish their validity by comparison to simulation data. The structure and the COD evolve mainly by contact making and breaking events. Of these, we identify and quantify 'non-clapping' events as the most relevant to the COD evolution and distinguish these from the less relevant 'clapping' events, which only add noise to the dynamics. The role of the cell order transition rates and their behaviour in the master equations are studied in detail analytically and numerically.

This formalism can be extended to the study of other structural characteristics.

DY 61.5 Thu 11:00 BH-N 333

Optical Properties of Granular Matter — Dominik Kiese, Koray Önder, Sebastian Pitikaris, Matthias Sperl, and •Philip Born — Institut für Materialphysik im Weltraum, Deutsches Zentrum für Luft- und Raumfahrt, 51147 Köln, Deutschland

Dense packings of hard spheres exhibit strong local ordering, even with lacking long-range order. The point pattern associated with the short-range order of hard sphere packings are shown to exhibit a photonic band-gap, i.e. a complete suppression of wave propagation for wavelengths similar to the center-to-center particle distance [1]. Common center-to-center distances in real granular media are millimetric, and suppression of THz waves reminiscent of development of a photonic bandgap have been observed [2]. We present an experimental study on the evolution of this bandgap with manipulating the structural order in granular packings. Local order in sedimented particle packings is controlled by mixing ratio and size ratio in binary packings. The relation among the bandgap and the structure offers a tool quickly quantify local order and to track structural changes in agitated granular media. We give an outline how to compute the band structure of hard-sphere packings taking into account the full spatial distribution of the dielectric constant.

[1]L. S. Froufe-Pérez et al., Physical Review Letters 117, 053902 (2016).
[2] P. Born. K. Holldack, Review of Scientific Instruments 88, 051802 (2017).

15 min. break

DY 61.6 Thu 11:30 BH-N 333

Aeolian sand sorting and megaripple formation — Marc Lämmel[1], Anne Meiwald[1], Hezi Yizhaq[2], Haim Tsoar[3], Itzhak Katra[3], and •Klaus Kroy[1] — [1]Institut für Theoretische Physik, Universität Leipzig, Leipzig, Germany — [2]Dpt. of Solar Energy and Environmental Physics, Blaustein Inst. for Desert Research, Ben-Gurion University of the Negev, Israel — [3]Dpt. of Geography and Environmental Development, Ben-Gurion University of the Negev, Israel

Sand is blown across beaches and deserts by turbulent winds. The seemingly chaotic process creates two dominant bedforms: decametre-scale dunes and centimetre-scale ripples, but hardly anything in between. By the very same process, grains are constantly sorted. Smaller grains advance faster, while heavier grains trail behind. Here, we argue that, under erosive conditions, sand sorting and structure formation can conspire to create distinct bedforms in the forbidden wavelength gap between aeolian ripples and dunes. These so-called megaripples are shown to co-evolve with an unusual, predominantly bimodal grain-size distribution. Combining theory and field measurements, we generate a mechanistic understanding of their shape and migration speed, as well as their cyclic aging, renewal, and sedimentary memory, in terms of the intermittent wind statistics. Our results demonstrate that megaripples exhibit close similarities to dunes and can indeed be mechanistically characterised as a special type of ("reptation") dunes.

DY 61.7 Thu 11:45 BH-N 333

Rheology of 3D frictionless spherocylinders — •Dániel B. Nagy[1], Tamás Börzsönyi[1], Philippe Claudin[2], and Ellák Somfai[1] — [1]Institute for Solid State Physics and Optics, Wigner Research Center for Physics, Hungarian Academy of Sciences, Budapest, Hungary — [2]Physique et Mécanique des Milieux Hétérogènes, PMMH

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The rheology of dense granular matter is an active domain of research and important both from the fundamental and the applied point of view. In the absence of large gradients, a successful approach formulates the constitutive equation as an effective friction μ, dependent only on the dimensionless inertial number I. In our work we used 3D numerical simulations to extend this formalism to frictionless spherocylinders. As in the case of spherical particles, the effective friction is an increasing function of the inertial number. We systematically investigated the dependence of μ on the particle aspect ratio Q, as well as that of the normal stress differences, the volume fraction and the coordination number. We found an interesting non-monotonic behavior of the quasistatic friction coefficient with Q: from the spherical case $Q = 1$, it first sharply increases, reaches a maximum around $Q \approx 1.05$, and then gently decreases until $Q = 3$, passing its initial value at $Q \approx 2$. We provided a microscopic interpretation for this through the analysis of the distribution of dissipative contacts around the particles. For slightly elongated grains the dissipation density is highest in their central cylindrical band, whereas at larger Q this moves to their caps.

DY 61.8 Thu 12:00 BH-N 333

Controlling Segregation and Convection in Vibrofluidised Granular Media — •Christopher Windows-Yule[1,3], Anthony Rosato[2], and David Parker[3] — [1]Friedrich-Alexander-Universität Erlangen-Nürnberg, Erlangen, Germany — [2]New Jersey Institute of Technology, Newark, NJ, USA — [3]University of Birmingham, Edgbaston, Birmingham, UK

The convective and segregative behaviours of granular materials are of great relevance to myriad industrial and natural processes, yet - despite significant research - remain incompletely understood and infamously difficult to control. In this talk, we detail a series of combined experimental and simulational studies in which we elucidate a deep interrelation between these two important phenomena, and novel manners in which this interrelation may be exploited. In particular, we demonstrate manners in which careful manipulation of the geometry and excitation method of a vibrofluidised system may be used to augment, reduce, induce, suppress and otherwise control both convective and segregative phenomena.

DY 61.9 Thu 12:15 BH-N 333

Rheology of Dense Granular Fluids: Theory & Experiment — •Till Kranz[1,2], Olfa Lopez[1], Annette Zippelius[3], Matthias Fuchs[4], and Matthias Sperl[1,2] — [1]Institut für Materialphysik im Weltraum, DLR Köln — [2]Institut für Theoretische Physik, Uni Köln — [3]Institut für Theoretische Physik, Uni Göttingen — [4]Theorie der Weichen Materie, Uni Konstanz

Granular fluids have been found to display a complicated rheology including Newtonian, shear thinning as well as shear thickening regimes. For a continuum description of granular flows, a constitutive equation is required that captures high densities and high shear rates.

We will introduce simple arguments regarding the time and energy scales in the system to explain the different flow behaviors. Newtonian rheology is expected at the lowest densities and shear rates only, shear thinning is related to the granular glass transition [1], and Bagnold scaling [2] is a consequence of hard-core interactions and shear heating. We will show how these constraints can be made quantitative in the framework of *Granular ITT* (Integration Through Transients) [3]. We will present experimental results for the flow behavior measured in a fluidized bed Couette cell that are well described by our theoretical approach.

[1] W. T. Kranz, M. Sperl and A. Zippelius, Phys. Rev. Lett. **104**, 225701 (2010)
[2] R. A. Bagnold, Proc. Royal Soc. A **225**, 49 (1954)
[3] W. T. Kranz, F. Frahsa, A. Zippelius, M. Fuchs and M. Sperl, arXiv:1710.04452, arXiv:1710.04475

DY 61.10 Thu 12:30 BH-N 333

Simulation and modeling of the frustrated packing in a granular system — •Sára Lévay[1], David Fischer[2], Ralf Stannarius[2], Balázs Szabó[3], Tamás Börzsönyi[3], and János Török[1] — [1]Department of Theoretical Physics, BME, Budafoki út 8., H-1111 Budapest, Hungary — [2]Institute of Experimental Physics, Otto von Guericke University, Universitätsplatz 2., D-39106 Magdeburg, Germany — [3]Wigner Research Centre for Physics, Hungarian Academy of Sciences, P.O. Box 49., H-1525 Budapest, Hungary

Optimal packings of uniform spheres is a solved problem in two and three dimensions. The two-dimensional ground state can be easily achieved by simple dynamical processes while in three dimensions this is almost impossible.

In a recent work we have shown that in $2+\varepsilon$ dimensions, achieved by a container in one dimension slightly wider than the spheres, the particles organize themselves in a triangular lattice touching either of the sides of the container. When the system is agitated, it evolves slowly towards the potential energy minimum through metastable states.

We show results of DEM simulations and Monte Carlo models which fit the experiments: The dynamics is local and is driven by the optimization of the volumes of 7-particle configurations and by the vertical interaction between touching spheres. Defects in the triangular lattice play an important role in the dynamics as they act as an activation source and help the compaction. The system behaves neither as a 2D nor as a 3D system. Geometric frustration hinders the global optimum.

DY 61.11 Thu 12:45 BH-N 333

Frustrated packing in a granular system confined in a $2+\varepsilon$ dimensional box — •David Fischer[1], Sára Lévay[2], János Török[2], and Ralf Stannarius[1] — [1]Institute of Experimental Physics, Otto von Guericke University, Universitätsplatz 2, D-39106 Magdeburg, Germany — [2]Department of Theoretical Physics, BME, Budafoki út 8., H-1111 Budapest, Hungary

Packing of spheres in three dimensions necessarily involves geometrical frustration. The locally optimal tetrahedral packing is not space-filling. In contrast, the close-packed equilateral triangular lattice optimizes the packing of disks in a two-dimensional plane both globally and locally.

We show experimentally that inside a container of a width only slightly wider than the diameter of the spheres, the particles organize themselves in a quasi-triangular lattice touching either the front or back wall of the container. Under appropriate agitation (harmonic vertical vibrations) the system can be driven remarkably close to its ground state. Nevertheless, perfect order is practically never reached.

We demonstrate that the system can be described by 13 local 7-particle configurations and that the volume occupied by those configurations plays a key role in the redistribution dynamics of the system. Our studies offer insights into both the influence of geometrical constraints on random granular packing and a descriptive example of frustrated ordering, comparable to order in antiferromagnetic Ising spin models.