DY 31: Particulate Matter I: From microscopic interactions to collective motion (Focus session)

Particulate systems, such as colloids, foams, granular as well as active matter, share common features such as jamming, non-locality and intermittency. However, the daily life experience of building a sand sculpture tells us that tuning slightly the particle-particle interactions may lead to a dramatically different collective behaviour. This focus session shall discuss how properties at the microscopic particle level, such as form, softness and interactions, influence the collective behaviour of particulate systems: From static problems such as jamming and glass transition to dynamic ones such as pattern formation and phase transitions, from thermally driven colloids to granular and self-propelled particles driven far from thermodynamic equilibrium. The goal is to identify universal laws for a better understanding, controlling and eventually designing the collective behaviour of particulate systems that widely spread in nature, industry and our daily lives.

Organized by K. Huang and S. Herminghaus

Time: Wednesday 9:30–13:00 Location: ZEU 118

Invited Talk DY 31.1 Wed 9:30 ZEU 118

Magnetocapillary interactions for self-assembling dynamical systems — •Nicolas Vandewalle, Galien Grosjean, and Maxime Hubert — GRASP, Institute of Physics B5a, Sart Tilman, University of Liege, B4000 Liege, Belgium

When soft ferromagnetic particles are suspended at air-water interfaces in the presence of a vertical magnetic field, dipole-dipole repulsion competes with capillary attraction such that 2d structures are self-assembling. The complex arrangements of such floating bodies are emphasized. The equilibrium distance between particles exhibits hysteresis when the applied magnetic field is modified. Irreversible processes are evidenced. By adding a horizontal and oscillating magnetic field, periodic deformations of the assembly are induced. We show herein that collective particle motions induce locomotion at low Reynolds number. The physical mechanisms and geometrical ingredients behind this cooperative locomotion are identified. These physical mechanisms can be exploited to much smaller scales, offering the possibility to create artificial and versatile microscopic swimmers. Moreover, we show that it is possible to generate complex structures that are able to capture particles, perform cargo transport, fluid mixing, etc...

Invited Talk DY 31.2 Wed 10:00 ZEU 118

Influences of fluxes in nonequilibrium soft matter — •Marco G. Mazza — Max Planck Institute for Dynamics and Self-Organization, Göttingen

The world contains structures at every scale that are produced by nonequilibrium processes. We investigate how fluxes of matter or energy can create states with structural and dynamical properties completely absent in equilibrium systems. We will discuss two recent results in soft matter systems. Firstly, we will show with computer simulations and theory how deformations in the liquid crystals' orientational fields lead to colloidal self-assembly. Secondly, we discuss by means of experiments and simulations how to rationalize an intriguing nonequilibrium phase separation in driven granular materials without invoking *ad hoc* equilibrium-like assumptions.

DY 31.3 Wed 10:30 ZEU 118

How does a magnetic snake swim in a pool billiard? — Florian Johannes Maier, Markus Sesselmann, Ingo Rehberg, and •Reinhard Richter — Experimentalphysik 5, Universität Bayreuth, 95440 Bayreuth, Germany

We experimentally investigate magnetic surface swimmers on water. Those are moving objects, which self-assemble from ferromagnetic micro-particles, floating on the liquid surface due to interface tension, under the influence of an harmonically oscillating homogeneous magnetic field oriented vertically and a non-magnetic disc. The magnetic field is distinguished by its amplitude and frequency. The speed of the surface swimmers strongly depends on these parameters. We observe the swimmers by means of a camera from above. Via object-tracking, the position of the disc can be protocolled as a function of time, allowing us to reproduce trajectories and to calculate the speed.

The functional dependencies between speed and amplitude and between speed and frequency are investigated by independently varying both control parameters. In the first case, the data obtained are in good agreement with the predicted scaling whilst there are some deviations in the latter case.

Moreover, due to the interplay between the surface bound swimmers and the liquid meniscus at the edge of the experimental vessel different dynamics can be realized. We observe periodic and quasiperiodic trajectories in a circular vessel and aperiodic trajectories in a vessel shaped like a Bunimovich-stadium.

DY 31.4 Wed 10:45 ZEU 118

Shear-induced dynamics in colloidal nanoclutches — •Sascha Gerloff and Sabine H. L. Klapp — Institut für Theoretische Physik, Technische Universität Berlin, Hardenbergstraße 36, 10623 Berlin, Germany

Dense colloidal suspensions in strong spatial confinement under shear display complex non-equilibrium dynamics [1-3]. Understanding the shear stress response of these soft materials at the nanoscale is key from a fundamental point of view as well as for applications [3,4].

Here, we discuss results from Brownian dynamic (BD) simulations of strongly confined suspensions of charged colloids under shear in two different set-ups. First, the colloids are confined to a narrow slitpore, which induces the formation of well-defined layers with crystalline inplane structure [2]. We find that the response of this system is dictated by the frictional dynamics between the crystalline layers. In the second set-up, we consider a system consisting of two individually driven rings, confining additional particles between the inner- and the outer ring (Taylor-Couette geometry). We focus on the impact of hydrodynamic interactions on the dynamics and the shear stress response. The overall goal is to identify the dominating transport mechanisms, determining the rheological response.

[1] W. Fornari et al., Phys. Rev. Lett. 116, 018301 (2016).
[2] S. Gerloff and S. H. L. Klapp, Phys. Rev. E (2016) in press.
[3] I. Williams et al., Nat. Phys. 12, 98-U134 (2016).
[4] F. M. Pedrero et al., Phys. Rev. Lett. 115, 138301 (2015).

DY 31.5 Wed 11:00 ZEU 118

Dynamics of particles in self-generated flow — Ran Niu, Thomas Palberg, and •Thomas Speck — Institut für Physik, Johannes Gutenberg-Universität Mainz

Colloidal particles are an established model system for a range of microscopic processes in condensed matter. While interactions can be tuned, truly long-range attractions so far have not been possible. Here we report on experiments using ion exchange particles, whereby the release of ions generates a flow above a substrate. We show that this flow leads to effective forces over hundreds of microns and discuss ramifications.

15 min. break

DY 31.6 Wed 11:30 ZEU 118

Shear-driven segregation of dry granular materials with different friction coefficients — •Tamás Börzsönyi, Katalin Gillemot, and Ellák Somfai — Wigner Research Centre for Physics, Budapest, Hungary

We present experimental and numerical results about bulk segregation in a shear-driven dry granular mixture, where the particles only differ in their surface friction coefficients. We show that the smoother particles tend to sink to the bottom of the shear zone, while rough particles migrate to the top of the sample. This phenomenon is similar to the well known kinetic sieving in particle mixtures with size heterogeneity. In the present case the smooth particles have a higher probability to penetrate into voids created by the shearing than the rough ones. The experimentally observed patterns were reproduced by discrete element simulations. Moreover, simulations performed in the absence of gravity revealed, that rough particles tend to stay in the shear zone, while the smooth particles are being expelled from it. We propose a mechanism, in which the smooth particles are driven towards regions of lower shear rate.

[1] K. A. Gillemot, E. Somfai, T. Börzsönyi, Soft Matter, 2016, DOI: 10.1039/C6SM01946C

DY 31.7 Wed 11:45 ZEU 118

Outflow and clogging of shape-anisotropic grains in hoppers with small apertures — •Ahmed Ashour[1], Tamás Börzsönyi[2], and Ralf Stannarius[1] — [1]Institute of Experimental Physics, Otto von Guericke University, Magdeburg, Germany — [2]Institute for Solid State Physics and Optics, Wigner Research Center for Physics, Hungarian Academy of Sciences, Budapest, Hungary

Outflow of granular material through a small orifice is a fundamental process in many industrial fields, for example in silo discharge, and in everyday's life. Most experimental studies of the dynamics have been performed so far with monodisperse disks in two-dimensional (2D) hoppers or spherical grains in 3D. We investigate this process for shape-anisotropic grains in 3D hoppers and discuss the influence of size and shape parameters on avalanche statistics, clogging states, and mean flow velocities. Increasing the aspect ratio of the grains leads to lower flow rates and higher clogging probabilities compared to spherical grains. The number of grains forming the clog is larger for elongated grains of comparable volumes, and the long axis of these blocking grains is preferentially aligned towards the center of the orifice. At still higher aspect ratio, the outflowing material leaves long vertical rat-holes in the hopper that can even reach the surface of the granular bed.

DY 31.8 Wed 12:00 ZEU 118

Dancing screw nuts: collective behaviour under vertical vibrations — •Simeon Völkel, Manuel Baur, 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. Unlike spheres or circular disks, hexagonal disks prefer to rotate upon sufficiently strong driving due to the broken circular symmetry. As wetting liquid is added, the rotating disks self-organize into a hexagonal structure, reminiscent of a rotator crystal in equilibrium systems. The bond length of the ordered structure is slightly smaller than the circumdiameter of a hexagon, indicating geometric frustration. At the "microscopic" level, we propose an analytical model to predict the rotation speed of individual disks. At the "macroscopic" level, we quantify the influence of cohesive particle-particle interactions on the collective behaviour through characterizing the pair correlation and angular distribution functions in the ordered state. Finally we explore the transitions into and out of the rotator crystal state.

DY 31.9 Wed 12:15 ZEU 118

The effect of particle shape on the flow field in a quasi-2D hopper — •Balázs Szabó[1], Zsolt Kovács[1], Sandra Wegner[2], Ahmed Ashour[2], David Fischer[2], Ralf Stannarius[2], and Tamás Börzsönyi[1] — [1]Wigner Research Centre for Physics, Hungarian Academy of Sciences, H-1525 Budapest, Hungary — [2]Otto-von-Guericke-University, D-39106 Magdeburg, Germany

We study the outflow and the clogged states of spherical and non-spherical particles in a quasi-2D hopper setup by means of optical measurements. For spherical grains, the vertical velocity profile along a horizontal line is close to Gaussian, as suggested by most of the existing theories. However, for prolate particles, this curve clearly deviates from a Gaussian profile, indicating that the alignment of the grains has a strong effect on the velocity field. The plug-like flow profile suggests a fitting function that is the sum of two error functions, with two characteristic length scales instead of one. One parameter is the displacement of the two error functions, which appears to be related to the geometry of the setup. The other parameter is the width of the error functions, which is more sensitive to the particle shape.

DY 31.10 Wed 12:30 ZEU 118

Pattern formation on the brink of granular liquid-gas-like transition — •Andreas Zippelius and Kai Huang — Universität Bayreuth, 95440 Bayreuth, Germany

Granular materials driven far from thermodynamic equilibrium are a rich pattern forming system. For instance, a thin layer of sand grains under vertical vibrations yields Faraday's crispations (stripes, squares, circular rings, etc.). If the particles are slightly wet, so that cohesive particle-particle interactions start to play a role, a different pattern forming scenario arises: Propagating kink-wave fronts and rotating spirals emerge as the granular layer is fluidized.

Here, we report a new class of patterns observed in the vicinity of the liquid-gas-like transition in a cohesive granular layer. It is composed of ordered density-wave fronts propagating continuously along the rim of the container. We quantify the rotation speed and the shape of the fronts by means of high speed photography and discuss the influence of particle-particle interactions and driving parameters on the pattern selection. Finally, we analyze the dynamics of the propagating fronts from the mobility of individual particles to shed light on the pattern forming mechanism.

DY 31.11 Wed 12:45 ZEU 118

Particle-based model for the coating of complex-shaped, cohesive powder particles in additive manufacturing — •Eric Parteli[1] and Thorsten Pöschel[2] — [1]University of Cologne — [2]Friedrich-Alexander-University of Erlangen-Nuremberg

The development of reliable strategies to optimize part production in additive manufacturing technologies hinges, to a large extent, on the quantitative understanding of the mechanical behavior of the powder particles during the application process. In the present work, we develop a numerical tool for the particle-based simulations of powder application in additive manufacturing devices. Our simulations take into account an accurate description for the attractive particle interaction forces as well as the complex geometric shapes of the applied powder particles. To verify our numerical tool, we compute packing density of polydisperse powder systems of different materials, covering a broad range of size distributions, thereby finding excellent quantitative agreement with measurements. From simulations of powder coating in additive manufacturing, we find that the mechanical behavior of the bulk is fundamentally influenced by the dynamics of the powder at the microscopic level, in particular the formation of complex-shaped particle agglomerates and the concatenated suppression of pore filling by smallest particles in the distribution. We show that this behavior is responsible for one surprising result, namely that broader size distributions lead to coated powder beds of lower solid fractions. Moreover, an increase in surface roughness of the powder bed with process speed is found, thus suggesting decrease in part quality with production speed.