DY 44: Droplets, Wetting, Complex Fluids, and Soft Matter (joint session DY/CPP)

Time: Friday 9:30–12:45 Location: H47

Invited Talk DY 44.1 Fri 9:30 H47

From Cavitation in Soft Matter to Erosion on Hard Matter — •Claus-Dieter Ohl — Institute of Physics, Otto-von-Guericke University, Magdeburg, Germany

Cavitation is the technical term for the formation of empty spaces in a liquid. These unstable voids eventually implode and focus energy on small volumes. Shock wave emission, light emission, erosion, and even nuclear reactions are the consequence of this near singular energy focusing. Here, I will present recent research related to cavitation not only in liquids but also in elastic solids and particularly at the interface of both materials. Singularities developing on the axis of symmetry in non-spherical collapses near boundaries are able to amplify shock waves through self focusing. We think that this mechanism is the primary cause for erosion. In contrast, the non-spherical collapse and shock wave focusing near a tissue allows for the penetration of the tissue with liquid jets at 1000m/s and above. The mechanism at play may be relevant in sports and battle zones, as they could lead to traumatic brain injuries.

DY 44.2 Fri 10:00 H47

Shape switching and tunable oscillations in adaptive droplets — •Tim Dullweber[1,2], Roman Belousov[1], Camilla Autorino[1,4], Nicoletta Petridou[1], and Anna Erzberger[1,3] — [1]European Molecular Biology Laboratory, Heidelberg, Germany — [2]University Heidelberg, Heidelberg, Germany — [3]Institute for Theoretical Physics, Heidelberg University, Heidelberg, Germany — [4]Faculty of Biosciences, Heidelberg University, Heidelberg, Germany

Soft materials can undergo irreversible shape changes when driven out of equilibrium. When shape changes are triggered by processes at the surface, geometry-dependent feedback can arise. Motivated by the mechanochemical feedback observed in multicellular systems, we study incompressible droplets that adjust their interfacial tensions in response to shape-dependent signals. We derive a minimal set of equations governing the mesoscopic droplet states, controlled by just two dimensionless feedback parameters. We find that interacting droplets exhibit bistability, symmetry-breaking, excitability and tunable shape oscillations ranging from near-sinusoidal to relaxation-type. We apply our framework to model shape measurements in zebrafish embryos and identify a shape-switching mechanism promoting boundary formation. The underlying critical points reveal novel mechanisms for physical signal processing through shape adaptation in soft active materials, and suggest new modes of self-organization at the collective scale.

DY 44.3 Fri 10:15 H47

Impact of the history force on the motion of droplets in shaken liquids — •Frederik Gareis and Walter Zimmermann — Theoretical Physics, University of Bayreuth

The Basset-Boussinesq history (BBH) force acts on droplets and solid particles in flows, alongside stationary viscous friction, inertia, and gravitational forces. This force arises from vortex shedding around objects undergoing unsteady acceleration. In this study, we analytically calculate the BBH force for spherical, sedimenting heavy particles in horizontally shaken (periodically accelerated) fluids at low Reynolds numbers and identify the parameter ranges where BBH effects are significant. Our results reveal that BBH can increase particle displacement amplitude by over 60 percent, particularly in the transition region between the low-frequency viscous Stokes regime and the high-frequency inertia-dominated regime. Additionally, we derive a power law for the oscillatory displacement amplitude of a particle around its mean position in a horizontally shaken fluid, facilitating clear experimental identification of BBH effects.

DY 44.4 Fri 10:30 H47

Bubble Dynamics and Transport in Porous Structures: Insights from Mesoscale Simulations — •Qingguang Xie[1], Othmane Aouane[1], and Jens Harting[1,2] — [1]Forschungszentrum Jülich GmbH, Helmholtz-Institut Erlangen-Nürnberg (IET-2), Erlangen, Germany — [2]Friedrich-Alexander-Universität Erlangen-Nürnberg, Erlangen, Germany

Bubble formation, detachment, and transport within porous structures are critical phenomena in various applications, including electrolyzers and chemical reactors. We numerically investigate the dynamics of bubble growth and detachment at a catalytic surface using the lattice Boltzmann method. The departure radius of a bubble, growing with either a pinned or moving contact line, shows good agreement with theoretical predictions. Beyond detachment, we examine the subsequent transport of bubbles through a porous transport layer, systematically evaluating transport efficiency by considering factors such as pressure gradients, reaction rates, and pore wettability. Our findings provide valuable insights for optimizing the design of porous structures, potentially resulting in enhanced performance in electrolyzers and other gas-evolving devices.

DY 44.5 Fri 10:45 H47

Displacements in thin fluid and elastic films — •Andreas M. Menzel — Otto von Guericke University Magdeburg, Germany

We address the displacements of comparatively small objects in flat thin fluid films under low-Reynolds-number conditions or in flat thin elastic sheets under linear elasticity.

It is well-known that the fundamental solution of the corresponding continuum equations for forced in-plane displacements diverges logarithmically in strictly two-dimensional systems, the so-called Stokes paradox. We provide an illustrative way of interpretation and demonstrate how the divergence cancels under pairwise interactions and confinement [1,2]. Interestingly, logarithmic spatial dependencies prevail under rectangular clamping of elastic membranes [3]. Moreover, the divergence is still present in free-standing sheets of finite thickness, unless they are stabilized, for instance, by substrates [4,5].

We are confident that our analytical results will prove useful in corresponding quantitative experimental evaluations.

[1] S. K. Richter, A. M. Menzel, Phys. Rev. E **105**, 014609 (2022).
[2] T. Lutz, S. K. Richter, A. M. Menzel, Phys. Rev. E **106**, 054609 (2022).
[3] A. R. Sprenger, H. Reinken, T. Richter, A. M. Menzel, EPL (Europhys. Lett.) **147**, 17002 (2024).
[4] T. Lutz, A. M. Menzel, A. Daddi-Moussa-Ider, Phys. Rev. E **109**, 054802 (2024).
[5] A. Daddi-Moussa-Ider, E. Tjhung, T. Richter, A. M. Menzel, J. Phys.: Condens. Matter **36**, 445101 (2024).

DY 44.6 Fri 11:00 H47

Magnetic dynamics in ferromagnetic liquid crystal emulsions — •Christoph Klopp[1], Hajnalka Nádasi[1], Darja Lisjak[2], and Alexey Eremin[1] — [1]Otto von Guericke University, Institute of Physics, 39106 Magdeburg, Germany — [2]Jozef Stefan Institute, Department for Materials Synthesis, 1000 Ljubljana, Slovenia

We explore magnetic liquid crystal (LC) emulsions for applications as manipulatable chemical sensors in giant cells of Characean algae. Such emulsions can be controlled by magnetic fields and provide targeted drug delivery or sensing [1]. The investigated emulsions consist of a ferromagnetic liquid crystal [2] dispersed in an aqueous solution. We investigate the dynamic magnetic response using AC-susceptometry [3] as a function of the carrier medium viscosity and the particle or droplet size distribution. The emulsions' magnetic spectra differ drastically from those in the bulk of the hybrid liquid crystal mixture. We demonstrate the influence of the liquid crystal director configuration at the water-droplet interface by analyzing the effect of different surfactants (mainly SDS and PVA) in the aqueous phase.

[1] F. von Rüling et al., Liquid Crystals, 2024, 51, 1546
[2] A. Mertelj, et al., Nature, 2013, 504, 237-241
[3] M. Küster et al., J. Magn. Magn. Mater., 2023, 588, 171368

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15 min. break

DY 44.7 Fri 11:30 H47

Drying effects in soft colloidal monolayers — •Kai Luca Spanheimer[1], Matthias Karg[2], Nicolas Vogel[3], Liesbeth Janssen[4], and Hartmut Löwen[1] — [1]Institut für Theoretische Physik II: Weiche Materie Heinrich-Heine-Universität, 40225 Düsseldorf, Germany — [2]Physikalische Chemie I: Kolloide und Nanooptik Heinrich-Heine-Universität, 40225 Düsseldorf, Germany — [3]Lehrstuhl für Partikelsynthese Friedrich-Alexander-Universität,91058 Erlangen,

Germany — [4]Soft Matter and Biological Physics Eindhoven University of Technology, 5600 MB Eindhoven, The Netherlands

Langmuir-Blodgett deposition is a staple of colloidal monolayer research. It is used in sample preparation for imaging techniques, that spatially resolve colloid patterns. Recent experimental observations have shown that drying can strongly rearrange micron sized microgel patterns after their deposition. The usual dictum that these drying effects do not play a role for colloidal deposition can thus not be held up as a general rule. While capillary effects are well known to be strong at microscopic length scales and play a significant role in drying processes they have been mostly neglected concerning Langmuir-Blodgett deposition. In order to better understand the mechanism of drying we propose a model based on capillary attraction as well as hard core and soft shell repulsion. This model reproduces colloid patterns observed at interfaces as well as ones that occur after drying in the corresponding parameter regimes. From here we are able to derive parameter ranges where drying can play a role in rearranging patterns of colloids and where it can't.

DY 44.8 Fri 11:45 H47

Interplay of Elasticity and Capillarity in Droplets on Flexible Sheets — •Salik Sultan and Holger Stark — Technische Universität Berlin, Institute of Theoretical Physics, Hardenbergstr. 36, 10623 Berlin, Germany

Droplets resting on flexible sheets deform into lens-like shapes, offering promising applications in areas like tunable liquid lenses. We have extended and employ our fully three-dimensional Boundary Element Method (BEM) simulation framework [1] to investigate dynamic wetting on thin flexible sheets. Our study focuses on the intricate interplay between the mechanical properties of the sheet and droplet behavior, particularly emphasizing contact angle and droplet shape. By varying the tension and mechanical properties of the sheet, our model demonstrates how we can control and tune the shape of the droplet. Additionally, by introducing stiffness gradients, we aim to explore the potential to steer droplets along the sheet via durotaxis. The versatility of our model suggests potential extensions to other soft material and droplet interactions, such as capillary origami. This work sheds light on the complex interactions between soft substrates and liquid interfaces, leading the way for advancements in material science and interfacial biology.

[1] J. Grawitter and H. Stark, Steering droplets on substrates with plane-wave wettability patterns and deformations, Soft Matter 20, 3161 (2024).

DY 44.9 Fri 12:00 H47

Cluster quasicrystals composed of ultrasoft particles vs. soft quasicrystals built of colloids with hard cores — Robert F.B. Weigel and •Michael Schmiedeberg — Theoretical Physics: Lab for Emergent Phenomena, Friedrich-Alexander-Universität Erlangen-Nürnberg, 91058 Erlangen, Germany

We study and compare two different approaches for the stabilization of quasicrystals:

First, we consider a Phase Field Crystal model of complex patterns that self-assemble in systems consisting of ultrasoft colloids. Quasicrystals can be either stabilized by interactions with multiple length scales [1,2] or by preferred binding angles as in patchy colloids [3].

Second, we study a system with patchy colloids with a hard core with a Density Functional Theory. The hard-core is implemented by using a variant of the Fundamental Meassure Theory [4] that probably is the best mean field approach to hard particles.

While the ultrasoft particles assemble in cluster quasicrystals where the particles can completely overlap, in case of hard cores we observe structures that are rather dominated by the tiles that occur on a local level. Our results explain the differences between quasicrystlas that occur in different systems.

[1] Lifshitz, Petrich, PRL 79, 1261 (1997).
[2] Achim et al., PRL 112, 255501 (2014).
[3] Weigel, Schmiedeberg, Modelling Simul. Mater. Sci. Eng. 30, 074003 (2022).
[4] Rosenfeld, PRL 63, 980 (1989).

DY 44.10 Fri 12:15 H47

Beyond rings and chains: exploring porous crystals and flexible networks with magnetic colloids — •Carina Karner — Technische Universität Wien

We report on the self-assembly of magnetic colloids engineered with two distinct magnetic patches positioned at their poles, an advancement from traditional Janus particles with a single magnetic dipole. While Janus particles are known to form a variety of superstructures including chains, rings, and close-packed arrangements [1], the two-patch design significantly expands the range of achievable structures. Our simulation study reveals the formation of porous networks with adjustable flexibility, variable pore sizes, and controllable crystalline order. Notably, we observe the formation of a porous Kagome lattice, reminiscent of the experimental Kagome lattice observed colloids with two hydrophobic patches, the well known Janus-triblock system [2]. This enhanced self-assembly behavior in two-patch magnetic particles opens up further possibilities for creating fully tunable, field-responsive ferrofluids. Such systems could useful for applications requiring externally modulated viscosity, such as adaptive damping systems in automotive and aerospace engineering. [1] Vega-Bellido, G. I., DeLaCruz-Araujo, R. A., Kretzschmar, I., & Córdova-Figueroa, U. M. (2019). Self-assembly of magnetic colloids with shifted dipoles. Soft Matter, 15(20), 4078-4086. [2] Chen, Q., Bae, S. C., & Granick, S. (2011). Directed self-assembly of a colloidal kagome lattice.Nature,469(7330), 381-384.

DY 44.11 Fri 12:30 H47

Effect of geometrical confinement on friction in soft solids — •Aashna Chawla and Deepak Kumar — Department of Physics, Indian Institute of Technology Delhi, New Delhi 110016, India

Soft and biological materials come in a variety of shapes and geometries. When two soft surfaces with mismatched Gaussian curvatures are forced to fit together, beautiful patterns emerge at the interface due to geometry-induced stress. In this study, we explore the effect of geometrically incompatible confinement of a thin sheet on a soft hydrogel substrate on friction. We use a novel experimental setup to measure the friction between a thin flat elastic sheet placed on a low-friction hydrogel substrate. We show that the frictional force at the interface strongly depends on the geometry and is significantly larger for the geometrically incompatible configuration of a flat sheet on a spherical substrate compared to the other two geometrically compatible configurations: flat sheet on a flat substrate and flat sheet on a cylindrical substrate. Furthermore, for the incompatible configuration of the flat sheet on a spherical substrate, we observe that the frictional force increases monotonically with the sheet radius, with a transition in the behavior at an intermediate radius. We show that these effects arise from the coupling of the stress developed in the sheet due to its geometrically incompatible confinement with the curvature of the interface, resulting in an increased normal force, thereby increasing friction. The insights gained from this study could have significant implications for our understanding of friction in various biological, nanoscale, and other soft systems.