# DY 55: Poster: Turbulence; Complex Fluids; Microfluidics; Droplets and Wetting

Time: Thursday 15:00–18:00 Location: P1A

DY 55.1 Thu 15:00 P1A

**High Performance Free Surface LBM on GPUs** — •Moritz Lehmann, Fabian Häusl, and Stephan Gekle — Biofluid Simulation and Modeling, Theoretische Physik VI, Universität Bayreuth

By combining the lattice Boltzmann method (LBM) with the Volume-of-Fluid (VoF) model, free surfaces can be simulated. Besides the challenge of running VoF alongside LBM with massive parallelism on the GPU, the core difficulty of VoF is surface tension calculation using piecewise linear interface construction (PLIC), which until now had no complete analytic solution and so far was solved iteratively - thereby severely slowing down the simulation. We present the full analytic solution for PLIC and apply it to a GPU implementation of VoF-LBM. This excellent performance enables close to real-time simulations of complex free surface phenomena such as drop impacts with all the variety of emerging effects such as crown- and jet-formation or the Plateau-Rayleigh instability. The model is validated by comparison to analytic solutions and experimental data.

DY 55.2 Thu 15:00 P1A

**Dynamics of gel networks on different time and length scales** — •Matthias Gimperlein and Michael Schmiedeberg — Institut für Theoretische Physik 1, FAU Erlangen-Nürnberg, 91058 Erlangen, Germany

Gelation is connected to a slow-down in dynamics, the onset of percolation and an increasing number of neighboring particles. The slow-down occurs on different time scales depending on the studied length scales.

Using Brownian Dynamics simulation for a system of colloidal particles interacting due to a modified square well potential we investigate the properties of gel networks on different time and length scales.

The square well potential is modified by introducing an additional interaction range $\alpha$ to flatten the walls of the square well such that Brownian dynamics simulations are possible. The phase diagram was determined by fitting the gas-liquid coexistence binodal. In the square well limit ($\alpha \to 0$) the result shown in [1] is recovered.

Further research includes distinguishing dynamic regimes or structures on different length and time scales, investigating the history/protocol dependency of the development (*i. e.* starting from different initial configuration by varying particle density or system structure) and finding stable or metastable structures to describe the evolution of gel networks not on the particle level anymore, but on a coarse grained level.

[1] Speck *et al.*, J. Chem. Phys. **148**, 241101 (2018)

DY 55.3 Thu 15:00 P1A

**Defects and phasonic flips during the growth of soft quasicrystals** — •Stefan Wolf[1,2], Michael Engel[1], and Michael Schmiedeberg[2] — [1]Institute for Multiscale Simulation, Friedrich-Alexander-University Erlangen-Nuremberg, Erlangen, Germany — [2]Institut für Theoretische Physik I, Friedrich-Alexander-University Erlangen-Nuremberg, Erlangen, Germany

An important but not yet well-understood mechanism during the growth of defect-free quasicrystals is the repair of defects or excitations via phasonic flips. We simulate a one-component quasicrystals in order to study the growth and the influence of phasonic flips. We developed a Monte Carlo method to fathom the growth of quasicrystals without and with phasonic flips. To speed up the simulations, the possible directions of the growth are limited to positions given by fixed vectors. For the calculation of the energy, and therefore for the probability of occupation of a position, an oscillating pair potential is used. First results show the formation of structures with 10-fold rotational symmetry for low temperatures without phasonic flips. In the next step, phasonic flips are taken into account in order to reveal how they influence the growth of quasicrystals.

DY 55.4 Thu 15:00 P1A

**The parameter space of thermohaline stairs** — •Axel Rosenthal and Andreas Tilgner — Institute of Geophysics, Göttingen, Germany

Convection and diffusion in water can be observed when a gradient in temperature or in salinity takes effect on density in presence of gravity. Both gradients can force or stabilize the process. We conducted experiments where the salt gradient is the driving force and simultaneously the temperature gradient is stabilizing in opposite direction, observed by particle image velocimetry. The question is at which gradients, expressed by Rayleigh numbers, does the transport occure in stable so called "thermohaline stairs"? Thermohaline stairs are a sequence of two flow systems, a finger regime and a large scale circulation.

DY 55.5 Thu 15:00 P1A

**Droplet evaporation/condensation in the lattice gas** — •Manuel Maeritz — Universität Tübingen, Institut für Angewandte Physik

We investigate the droplet evaporation/condensation of the lattice gas in two and three dimensions within the framework of density functional theory. First, we construct improved free energy functionals by mapping the lattice gas to the Asakura-Oosawa model and formulate a functional using a suggestion by Cuesta et al. (Highlander functional) [1]. Comparison to standard mean-field results shows a clear improvement of the phase diagram. Second, we apply the functional to droplets in finite boxes and extract droplet surface tensions. A comparison to recent simulation results by Tröster et al. is given [2].

[1] J. Cuesta, L. Lafuente and M. Schmidt, Phys. Rev. E 72, 031405 (2005).

[2] A. Tröster, F. Schmitz, P. Virnau, K. Binder, J. Phys. Chem. B 122, 3407-3417 (2018).

DY 55.6 Thu 15:00 P1A

**Characterizational Measurements of a Model Wind Turbine in a Variable Density Wind Tunnel** — •Birte Thiede[1], Christian Küchler[1], Julian Jüchter[2], Michael Hölling[2], Eberhard Bodenschatz[1], Joachim Peinke[2], and Michael Wilczek[1] — [1]Max Planck Institute for Dynamics and Self-Organization, Göttingen — [2]ForWind, Institute of Physics, University of Oldenburg, Oldenburg

Wind tunnel experiments with small-scale models are an essential part of wind turbine research as they offer a highly controllable environment for the investigation of various research questions. Due to the limited size of wind tunnels, the Reynolds numbers that can typically be achieved in such experiments are significantly smaller than those in actual wind turbine systems.

The Variable Density Turbulence Tunnel at the Max Planck Institute for Dynamics and Self-Organization can be filled with the dense gas SF6 and pressurized up to 15 bar, which leads to sufficiently high Reynolds numbers (up to $2 \cdot 10^7$) to perform wind turbine experiments at dynamic similarity.

In this tunnel, we study the power generation as well as the wake characteristics for different turbulent inflow conditions (generated by an active grid) and a range of Reynolds numbers of the MoWiTO 0.6, a model wind turbine built at the ForWind Center for Wind Energy Research Oldenburg, which is equipped with a pitch- and a load control.

DY 55.7 Thu 15:00 P1A

**Upscaling of dielectrophoretic continuous-flow separation in a microfluidic system** — •Jakob Derksen, Dario Anselmetti, and Martina Viefhues — Experimental Biophysics and Applied Nanoscience, Bielefeld University, Germany

High throughput analysis and separation of biomolecules or nanoparticles is an important task for many biological and medical applications such as separating DNA fragments and purification of gene vaccines. Thus, new separation techniques are requested. In this work, we present a sufficient microfluidic concept for upscaling of continuous-flow separation by means of dielectrophoresis (DEP).

DEP describes the movement of an electrically polarizable object in a non-uniform electric field. The advantages are that it is non-invasive, label-free and it provides selective manipulation of samples. A current disadvantage of this method is the limitation to small sample volumes and associated with that, the enormous purification time for reasonably sample volumes in the range of millilitre.

Here, we demonstrate the upscaling of a dielectrophoretic continuous-flow separation method in a microfluidic system. For that purpose, we created a system with two parallel separation channels in one device. We successfully demonstrated the separation of 100 nm and 40 nm beads and 10 kbp and 5 kbp DNA and harvesting in separate reservoirs. With these experiments, we firstly demonstrated an upscaling of separation throughput in a microfluidic device, paving the way to high-throughput applications.

DY 55.8 Thu 15:00 P1A

**Two-point velocity statistics from ocean surface drifter observations in the Benguela upwelling system: In search of the inverse energy cascade** — •Julia Draeger-Dietel[1], Alexa Griesel[1], and Dhruv Balwada[2] — [1]Institut für Meereskunde, Universität Hamburg, Hamburg, Germany — [2]Courant Institute of Mathematical Sciences, New York University, New York, NY, USA

Lagrangian trajectories from surface drifters in the ocean constitute a time evolving, highly non-uniform spatial grid. The corresponding drifter velocity observations can be treated as scattered point Eulerian measurements, which can help in deducing the turbulent properties of the flow. Here we examine the probability distribution $P(\Delta u_\ell|s)$ of relative longitudinal velocity $\Delta u_\ell$, as a function of spatial separation $s$, from surface drifters deployed in the upwelling region off Namibia. We find the $P(\Delta u_\ell|s)$ to be positively skewed for relative separations $s$ of 10 km - 80 km. The rescaled 3rd order structure function, $\langle \Delta u_\ell^3 \rangle /s$, reveals a (positive) plateau, supporting an inverse energy cascade with energy transfer rate $\epsilon \simeq 2.4 \cdot 10^{-8} m^3/s^2$. The combination with former findings of Richardson scaling of pair separations, $\langle s^2(t) \rangle = g\epsilon t^3$, yield a reduced Obhukov constant $g$ close to the finding in laboratory experiments. The reduced Obhukov constant can be traced back to an algebraic decay $s^{-\alpha}$ with $\alpha \simeq -5/3$ in the central regime of the corresponding probability distribution $P(s|t)$ of relative separations $s$ for fixed time $t$. An algebraic decay with $1 < \alpha < 2$ points to the relevance of Levy walk models in the stochastic description of the turbulent transport process in the ocean.

DY 55.9 Thu 15:00 P1A

**Charged Liquid Bridges** — •Klaus Morawetz — Münster University of Applied Sciences,Stegerwaldstrasse 39, 48565 Steinfurt, Germany — International Institute of Physics- UFRN,Campus Universitário Lagoa nova,59078-970 Natal, Brazil

A new solution of a charged catenary is presented which allows to determine the static and dynamical stability conditions where charged liquid bridges are possible. The creeping height, the bridge radius and length as well as the shape of the bridge is calculated showing an asymmetric profile in agreement with observations. The flow profile is calculated from the Navier Stokes equation leading to a mean velocity which combines charge transport with neutral mass flow and which describes recent experiments on water bridges. The velocity profile in a water bridge is reanalyzed. Assuming hypothetically that the bulk charge has a radial distribution, a surface potential is formed that is analogous to the Zeta potential. The Navier*Stokes equation is solved, neglecting the convective term; then, analytically and for special field and potential ranges, a sign change of the total mass flow is reported caused by the radial charge distribution. [Water 9 (2017) 353, Phys. Rev. E 86 (2012) 026302, errata Phys. Rev. 86 (2013) 069904]

DY 55.10 Thu 15:00 P1A

**Small-scale simulations of high Reynolds number turbulence** — •Niklas Schnierstein[1,2] and Michael Wilczek[1] — [1]Max Planck Institute for Dynamics and Self-Organization, Göttingen, Germany — [2]Georg-August University, Göttingen, Germany

Three-dimensional turbulence is a multi-scale problem, in which energy is transferred from the largest, energy-containing scales to the smallest, dissipative scales. The separation of these scales increases with the Reynolds number. Thus, resolving all scales of a turbulent flow in direct numerical simulations (DNS) is for many realistic problems computationally prohibitive. However, in some problems, one is only interested in certain scales of the flow. One example is the formation of microdroplets in clouds, for which small-scale turbulence is of crucial importance. For this reason, we explore the possibility of generating a realistic small-scale turbulent flow while adequately modeling the larger scales using stochastic processes. By controlling the parameters of these processes, we can precisely impose key statistical quantities on the flow, such as the energy spectrum and the correlation time. We investigate different methods of coupling the modeled and the resolved scales, characterize the generated flow field, and compare it to fully resolved DNS to analyze the advantages and limitations of this approach.

DY 55.11 Thu 15:00 P1A

**Effect of disorder on dispersive transport in porous media** — •Felix Jonathan Meigel[1,4], Thomas Darwent[3], Lucas Goehring[3], and Karen Alim[1,2] — [1]Max Planck Institute for Dynamics and Self-Organization, Goettingen, Germany — [2]Physics Department, Technical University Munich, Germany — [3]School of Science and Technology, Nottingham Trent University, Nottingham, United Kingdom — [4]Max Planck Institute for the Physics of Complex Systems, Dresden, Germany

Transport by the means of fluid flow through porous media is central for many processes in our daily life. Porous media show a large variety of morphologies that may change over time. How does the morphology interplay with the transport of solute particles through the medium? Here, we show how changing the disorder in a medium affects transport through the porous medium. We connect the dynamics on the level of single pores with the macroscopic transport through the whole medium. Using a first passage time formalism, we describe how macroscopic transport statistics emerge from the interplay of individual pores. We find dynamics that deviate from Fickian descriptions and cannot be explained using an effective advection diffusion equation. Using a two-dimensional model porous medium in which we can control the disorder, we focus on the variance of the dispersive front of a medium being filled up to saturation with solute particles. We find that the variance changes non-monotonically as either the disorder or the Peclet number is altered. We find these results both in simulation and experiments and give a theoretical explanation of our findings.

DY 55.12 Thu 15:00 P1A

**Rheology and self-assembly of mixtures of magnetic and nonmagnetic liquid crystals under shear and external field** — •Ferdinand Schönerstedt, Nima H. Siboni, and Sabine H. L. Klapp — Institut für Theoretische Physik, Technische Universität Berlin, Hardenbergstraße 36, 10623 Berlin

Doping liquid crystals (LC) with magnetic nanoparticles (MNP) has proven a successful strategy to obtain magnetic field responsive materials. In this work, motivated by recent advances in MNP manufacturing technology [1], we investigate the effect of the external field on rheology and self-assembly of LC-MNP mixtures where the MNPs have the same shape and the same size of the LC particles.

It is noteworthy that even in the absence of the magnetic dipole-dipole interactions, such mixtures show an interesting demixing at strong fields, and as a consequence, an intriguing non-monotonic field dependence of the shear stress emerges [2]. By considering a finite dipole-dipole interaction in a non-equilibrium molecular dynamics simulation setup, we explore the interplay between the self-assembly of MNPs (under the influence of the external field [3]), and the shear- and magnetic field-induced orderings.

[1] A. Mertelj, D. Lisjak, M. Drofenik, and M. Čopič, Nature **504**, 237 (2013).

[2] N. H. Siboni, G. P. Shrivastav, and S. H. L. Klapp, arXiv:1908.10815 (2019).

[3] C. E. Alvarez, and S. H. L. Klapp, Soft Matter **8**, 7480 (2012).

DY 55.13 Thu 15:00 P1A

**Experimental Study of the Bottleneck in Fully Developed Turbulence using LDV** — •Torben Neumann[1,2], Gholamhossein Bagheri[2], and Eberhard Bodenschatz[1,2] — [1]Georg-August-University, Goettingen, Germany — [2]Max Planck Institute for Dynamics and Self-Organization, Goettingen, Germany

Turbulence plays an important role in many flows. The bottleneck effect is the phenomena of energy pileup in the energy spectrum of incompressible turbulence where viscous dissipation begins to act. Previous hotwire measurements in the Variable Density Turbulence Tunnel (VDTT) have shown a decrease of the bottleneck strength for high frequencies. However, the high frequencies cannot be fully explored by hotwire measurements. Therefore, the Laser Doppler Velocimetry technique (LDV) will be used to bypass the biases the hotwires might have. In order to do that, the first challenge is to design a particle dispersion system that is capable of working in a high pressure windtunnel and of dispersing particles in an optimal concentration for LDV measurements. The preliminary results of the LDV measurements conducted in the VDTT will be presented.

DY 55.14 Thu 15:00 P1A

**Manipulation of thermo-osmotic flows in thin liquid films** — •Nicola Andreas Söker and Frank Cichos — Universität Leipzig, Peter-Debey-Institut für Physik der weichen Materie

We study the creation and manipulation of flows in a micrometer sized film of water by thermo-osmotic surface flows along the confining walls.

A local temperature profile is created by optically heating a gold film inducing osmotic flows along the confining walls. Chemically patterning the gold surfaces creates asymmetric flows. The progammable directed flow might be used to position sub micrometer diffusing objects e.g. to position single biopolymers in a thermo phoretic trap structure presently developed [1] in our group. To characterize the emerging flow fields metal nano particles are used as tracers [2]. We also study the interference of the thermo-osmotic flows originating from multiple heating spots at the gold film.

[1] Fränzl, Martin., Thalheim, Tobias., Adler, Juliane. et al. Thermophoretic trap for single amyloid fibril and protein aggregation studies. Nat Methods 16, 611-614 (2019)

[2] Andreas P. Bregulla, Alois Würger, Katrin Günther, Michael Mertig, and Frank Cichos Phys. Rev. Lett. 116, 188303 * Published 5 May 2016

DY 55.15 Thu 15:00 P1A

**A study of metastability in hydrophobic surfaces** — •Marion Silvestrini[1,2], Alberto Giacomello[2], and Carolina Brito[1] — [1]Physics department, Federal University of Rio Grande do Sul, Porto Alegre, Brazi — [2]Dipartimento di Ingegneria Meccanica e Aerospaziale, Università di Roma "La Sapienza"

The study of wetting phenomena in solids is of great interest due to the possible technological applications of hydrophobic and hydrophilic surfaces. Besides these applications, there are some fundamental open questions concerning the transition between these two wetting states. For instance, it is known that metastability is a common feature in experiments and that these metastable states are, in general, hydrophobic states. It is then important to understand what are the properties of the substrates that leads to this effect. In previous works, we have studied such phenomena using the analytical global energy approach and Monte Carlo simulations of the Cellular Potts model.

It has been shown that the final configuration depends strongly on the choice of initial wetting state of the droplet, which suggests the existence of a metastable regime in the system. To analyze systematically and understand this effect, in this work we apply a technique called Umbrella Sampling, that consist on adding a constraining term to the Hamiltonian, which drives the system to visit several specific configurations. We then use the results to calculate the free energy profile. This allows us to relate the energy barriers that lead to metastable states to the topology of the surface, which is a key point to understand the transition between CB and W states.

DY 55.16 Thu 15:00 P1A

**Topological modes in hydrodynamics** — •Richard Green — Institute for Theoretical Physics, University of Amsterdam, Science Park 904, 1098 XH Amsterdam, The Netherlands — Instituut-Lorentz, Universiteit Leiden, 2300 RA Leiden, The Netherlands

Topological band theory has been applied in recent work to classical fluids such as geophysical waves on the Earth's surface, and flocks on curved surfaces. I review these problems and consider what general features enable topologically protected modes to be supported in such classical systems.

DY 55.17 Thu 15:00 P1A

**Nonlocal interactions in strongly correlated systems** — •Daria Medvedeva — Institute of Physics of the Czech Academy of Sciences, Prague 8, Czech Republic — Ural Federal University, Yekaterinburg, Russian Federation

Systems with strong electron correlations can be perfectly described by quantum lattice models, e.g. by the Hubbard model. If coordination number or spatial dimension tend to infinity, this model can be solved by the Dynamical Mean-Field Theory taking into account only local correlations. However according to recent studies [1] we can't neglect nonlocal (between lattice sites) interactions in some materials. Moreover it was found that there are strong electron correlations in the systems with *sp*- electrons [2]. Theoretical description of such systems can be obtained making use the Extended Dynamical Mean-Field Theory (EDMFT). This research was devoted to development of a numerical algorithm to solve EDMFT equations. We have developed the numerical complex based on the exact diagonalization approach. The minimal parameterization of the effective impurity model was determined for different types of interactions. Using this scheme, we considered charge and exchange nonlocal interactions influence on the electronic properties of the model system and screening of the local Coulomb interaction by nonlocal one. We described functionalized graphene structures with adsorbed F and H atom, which can be really synthesized. [1] PRB 94, 214411 (2016). PRB 94, 224418 (2016). PRL 111, 036601 (2013). PRB 74, 212507 (2006). [2] PRL 110, 166401 (2013). PRB 88, 081405(R) (2013).

DY 55.18 Thu 15:00 P1A

**Acoustogalvanic rectification in Dirac and Weyl semimetals** — •Habib Rostami and Pavlo Sukhachov — Nordita, KTH Royal Institute of Technology and Stockholm University, Roslagstullsbacken 23, SE-106 91 Stockholm, Sweden

In this talk, I will discuss a nonlinear mechanism to generate a direct electric current by passing acoustic wave in inversion-symmetric Dirac and Weyl semimetals. According to the similarity with the photogalvanic rectification, where a direct current is produced in a second order response to light, we called this phenomenon the acoustogalvanic effect [1]. It relies on pseudo-electromagnetic fields [2] originating from sound-induced strain. Unlike the standard acoustoelectric effect [3], which relies on the sound-induced deformation potential and the corresponding electric field, the acoustogalvanic one originates from the pseudo-electromagnetic fields, which are not subject to screening. Due to an interplay of the pseudoelectric and pseudomagnetic fields, the acoustogalvanic current shows a nontrivial dependence on the direction of the sound wave propagation. Being within the experimental reach, the effect can be utilized to explore dynamical deformations and probe the pseudo-electromagnetic fields, which are yet to be experimentally observed in Weyl and Dirac semimetals.

[1] P. O. Sukhachov and H. Rostami, arXiv:1911.04526 (2019).

[2] A. Cortijo et al. Phys. Rev. Lett. 115, 177202 (2015).

[3] R. H. Parmenter, Phys. Rev. 89, 990 (1953).