Aitta Anneli

From tricritical phenomena describing symmetry breaking in fluid flow to tricritical phenomena in the iron melting curve: insights into planetary interior structure, core temperature and composition

Thirty years ago I studied experimentally, with Guenther Ahlers and David S. Cannell, how symmetry breaking in a Taylor vortex pair can be described in terms of tricritical phenomena. About 10 years ago I started to investigate if there is a tricritical point in the iron melting curve. The consequence would be that the melting temperature, and density at that temperature, depend on pressure quadratically, allowing a more robust extrapolation to pressures beyond experimental data. This waits for experimental verification.

The theory leads to strong predictions for planetary core structure and temperature as well as planet core composition. It gives an equation for the maximal concentration of light impurities in the iron-rich core melt, and also the density and temperature of such a melt. The results have been published for the Earth and Venus. This theory can also be applied to other planetary bodies that have melt in their iron-rich cores if the planetary mass and radius are known, or, in the case of exoplanets, estimated. In addition, one needs to make assumptions about crust thickness and density if these are not known.

Aronson Igor S.

Living Liquid Crystals

We propose a class of active matter, the living liquid crystal (LLC), representing motile rod-shaped bacteria placed in water-based nontoxic liquid crystal. Long-range orientational order of the liquid crystal and the swimming activity of bacteria demonstrate a strong coupling that dramatically alters individual and collective bacterial dynamics. For example, swimming bacteria perturb the orientational order of the liquid crystal or even cause its local melting, making the flagella motion optically visible. Second, self-organized textures emerge from the initial uniform LLC alignment with a characteristic length controlled by a balance between bacteria activity and anisotropic viscoelasticity of liquid crystal. Third, the local liquid crystal orientation controls the direction of motion of bacteria.
Granular Dynamics and Statistical Mechanics

It is fitting to focus on Dynamics and Statistical Mechanics in any meeting that honors Guenter Ahlers. In fact, the granular world is replete with phenomena that connect to these two broad topics. I will briefly discuss dynamical instabilities for granular systems and then focus particularly on the statistical and dynamical properties of granular materials near jamming. Heuristically, density is a key control parameter that can tune a granular system from a low-density fluid-like state to a high-density solid-like state. This insight underlies recent scenarios of jamming that depend strictly on density, where all states above a critical density, corresponding to random dense packing, are jammed, and all those below are 'un jammed', i.e. fluid-like. This scenario likely applies if grains are frictionless. However, we have recently shown that for 'real' granular systems where the grains have friction, jamming has a much richer structure. Below the critical density for the frictionless case, it is possible to create jammed states that have non-zero shear stress -- shear jammed states. The lowest density for which these shear states exist corresponds to random loose packing. Dynamics in the shear jamming regime connect to novel statistical ensembles and exhibit activated dynamics, in analogy to thermal materials.

On the degeneration of turbulence at high Reynolds numbers

Exploding dissipative solitons in the cubic-quintic complex Ginzburg-Landau equation and in reaction-diffusion systems

We review the properties of exploding dissipative solitons in the cubic-quintic complex Ginzburg-Landau equation in one and two spatial dimensions including the influence of noise. Then we show that the concept of exploding dissipative solitons is also important for models of reaction-diffusion type. Similarities and differences between exploding dissipative solitons in the two different types of equations are characterized and analyzed. As an example we mention that in RD models explosive dissipative solitons can propagate for a long time over large distances in contrast to the case of the cubic-quintic complex Ginzburg-Landau equation.
Large-scale coherent flow structures in turbulence

Many turbulent astrophysical and geophysical flows are dominated by robust coherent structures on the largest scales, such as convection rolls in the atmosphere. One of the challenges in understanding such flows is that these structures have different shapes and dynamics depending on boundary conditions. I will present an approach to solvable models that can be applied to different geometries by using empirically-known flow structures as approximate solutions to the Navier-Stokes equations, which leads to low dimensional dynamical systems models. As an example, I will present results of Rayleigh-Bénard convection experiments, in which a container is filled with water and heated from below. Buoyancy drives a flow which organizes into a roll-shaped circulation which spontaneously breaks the symmetry of the system. As a consequence, this roll exhibits a wide range of dynamics including erratic meandering, spontaneous flow cessations, and several oscillation modes. A simple model consisting of stochastic ordinary differential equations quantitatively reproduces these observed flow dynamics, including the different dynamical modes observed in experiments with different boundary shapes. These results suggest that we may be able to develop general and relatively easy to solve models for a wide range of turbulent flows dominated by large-scale modes.

The effect of regulatory proteins on the nucleation and growth of bone minerals

Biomineralization is the process by which living organisms produce the minerals that make up hard tissues such as shell, bone, and teeth. This process is regulated in vivo by several proteins, some of which inhibit the growth of biominerals, while others nucleate mineralization. We have used dynamic light scattering to study the effects of isoforms of the regulatory proteins osteopontin (OPN) and matrix gla protein (MGP), and peptides derived from them, on the nucleation and growth of hydroxyapatite crystals from supersaturated calcium phosphate solutions. Dynamic light scattering allows us to monitor the size of the precipitating particles in real time, and provides information about their concentration. Both OPN and MGP inhibit mineralization. We find that native OPN delays the onset of precipitation, while recombinant OPN, which lacks the phosphorylations of the native protein, inhibits growth but has no apparent effect on nucleation. Measurements on peptides of OPN and MGP similarly show the importance of phosphorylations in the inhibition of nucleation, and suggest that the growth rate of the crystals is controlled by strongly acidic regions of the polypeptides. This work also demonstrates that dynamic light scattering can be a powerful tool for delineating the mechanism of protein modulation of mineral formation.
Patterns driven by superposed AC and DC electric fields

Nonequilibrium structures induced in a nematic by an AC field have different time symmetry depending on the frequency (f) of the applied voltage (U). Moreover the transition f -> 0 is not smooth, thus the DC solution falls into another category. This is our main motivation to enlighten the interplay among the different morphologies corresponding to the distinct solutions. Looking at the onset of patterns on the U_AC - U_DC plane one expects a patternless region, the boundary line of which can be calculated by the standard model of electroconvection. There is satisfactory agreement for low frequencies, but for the dielectric mode the superposition of voltages inhibits the pattern forming mechanism; therefore the patternless region extends to much higher voltages than the individual AC or DC thresholds. Instead of a smooth boundary line one detects a long, patternless channel up to very high voltages.

Convection in Rotating Systems and its Dynamo Action

Convection in rotating spherical fluid shells is characterized by the relative orientation of gravity and rotation vector. Outside the virtual cylinder touching the inner boundary at its equator convection assumes the form of thermal Rossby waves which are particularly suitable for the generation of magnetic fields. Without magnetic field the shear generated by the thermal Rossby waves tends to destroy them. Only localized convection or intermittent convection may survive the shearing action. Dipolar, quadrupolar and hemispherical dynamos can be realized. Lorentz forces counteract the shearing action of the differential rotation and thus permit an efficient heat transport. Of particular interest are regimes of bistability where depending on initial conditions either dynamos with strong mean magnetic fields or dynamos with highly fluctuating magnetic fields are realized. In systems like the Earth’s core aperiodic reversals of the poloidal field may occur in connection with periodic toroidal dynamo waves.

Particle tracking experiments in (rotating) turbulent convection

We are currently working on an extension of our experimental diagnostics for rotating Rayleigh-Bénard convection: 3D particle tracking velocimetry (PTV). This volumetric measurement technique has been successfully applied to non-rotating convection. In a water-filled cylindrical tank of equal height and diameter 200 mm, we have employed PTV in a central volume of about 50 x 50 x 50 mm^3 at a Rayleigh number \( Ra = 1.4e9 \) and Prandtl number \( Pr = 6.4 \). We have measured velocity and acceleration pdfs consisting of about 60 million samples total. The velocity has a Gaussian distribution, with slightly more
prominent tails for the vertical component. Acceleration pdfs are of stretched-exponential shape, as is customary in turbulent flows. We are currently extending PTV to rotating convection.

by: Hadi Rajaei, Rudie Kunnen & Herman Clercx

Cross Michael

Synchronization, Pattern Formation, and Improving the Precision of Frequency References and Clocks

The synchronized state of oscillators in the usual Winfree-Kuramoto model is rather featureless, and the often assumed improvement of the precision of the rhythmicity by a factor of the number of synchronized oscillators* is indeed correct. However, adding propagation effects to the model, as will often be relevant to actual physical systems, leads to more interesting synchronized states that may consist of phase waves propagating from target or spiral sources as in other pattern forming systems. I will discuss how the nature of the sources impacts the improvement in frequency precision in these situations.

* "It is often stated in research papers (it is even alleged that I proved this in 1967, which I did not) that mutual synchronization disciplines each oscillator to much improved regularity of oscillation at the common frequency" - A.T. Winfree in "The Geometry of Biological Time" (1980)

Work done with John-Mark A. Allen

Dohm Volker

Thermodynamic Casimir force in 4He films: analytic theory

Thermodynamic Casimir forces arise from long-range fluctuations in confined condensed matter systems. Such fluctuations exist both near criticality and well below criticality due to Goldstone modes. Both types of Casimir forces exist in ^4He films. We present analytic results based on the phi^4 model that is in the same universality class as ^4He. For the case of periodic boundary conditions, our theory describes the entire crossover from the Goldstone regime in the low-temperature region up to the region far above criticality including the critical regime with a minimum of the Casimir force scaling function [1]. For the case of realistic (Dirichlet) boundary conditions, our theory essentially resolves the longstanding problem of the pronounced minimum in the regime between the Kosterlitz-Thouless transition and bulk $T_{\lambda}$ [2] that was observed experimentally in ^4He films by R. Garcia and M.H.W. Chan.

Dynamical Effects and Self-Organized Criticality near the Superfluid Transition in 4He

When a heat flux is applied to a column of liquid helium, the temperature at which the isothermal transport of heat by superfluid counterflow abruptly fails is depressed below the static critical temperature $T_{\lambda}$. When this heat flux is applied from above, the helium column forms a state where the thermal gradient across the helium is equal and opposite to the hydrostatically-induced pressure gradient in $T_{\lambda}$, and where the distance of the helium temperature from $T_{\lambda}$ as a function of pressure (and hence column height) across the column is constant. This is an example of self-organized criticality (SOC). This thermally-resistive SOC state is actually colder than the isothermal superfluid state, and it supports a new anisotropic temperature wave that travels only against the vector direction of the heat flux that self-organizes the column. We measured the heat capacity of the helium in this SOC state, and we found it to be equal to the static gravity-free heat capacity of helium as measured by John Lipa in space over a wide temperature range of reduced temperatures. The heat capacity on this dynamical SOC state diverged at the static $T_{\lambda}$, while the effective thermal conductivity diverged below $T_{\lambda}$ at the depressed temperature induced by the heat flux. These results suggest that the static critical temperature $T_{\lambda}$ is not destroyed by the heat flux, but that it is difficult to observe this except on the SOC state. This work has been supported by NASA’s prior Microgravity Fundamental Physics Program, and has been conducted by many collaborators and co-authors over the years.

Broken symmetries and phase diffusion in convection

The large scale circulation in cylindrical Rayleigh-Bénard cells breaks the azimuthal symmetry of the container. The time evolution of the state consists of internal changes, and of rotations in azimuthal direction. Using the recently developed method of comoving frames (http://arxiv.org/abs/1309.4590) we separate the rotations and study properties of the phase diffusion in direct numerical studies up to $Ra=10^8$. 
Fisher Michael E.

Effects of Proximity and Connectivity: Superfluid Helium in Boxes with Films and Layered Ising Models


Funfschilling Denis

Temperature field in a Rayleigh-Bénard turbulent convection cell by 2 colors Laser Induced Fluorescence

The temperature field in a Rayleigh-Bénard convection cell is an important information for the understanding of the physical mechanism of the convection. By use of the 2 colors LIF (Laser Induced Fluorescence) technique, the temperature field is first measured around a single rising plume in a quasi-infinite media, then in a cylindrical cell of aspect ratio one. Plumes are not emitted regularly in a turbulent Rayleigh-Bénard convection cell and statistics on plumes have been completed.

Goldenfeld Nigel

Emergence of large-scale circulation in convection and the transition to turbulence

Results are presented on the probability distribution of cessations in stationary and rotating turbulent convection, with excellent comparison to the experiments of Ahlers and co-workers. I also describe the significance of the large-scale circulation as an example of a general epiphenomenon associated with the transition to turbulence. Finally, I present predictions related to our recent detailed proposal about the evidence for the directed percolation universality class of the transition from the laminar to turbulent state.

Großmann Siegfried

The law of the wall and beyond

By Siegfried Grossmann and Detlef Lohse
He Xiaozhou

High-Ra thermal convection in compressed gas

Hohenberg Pierre

The Ginzburg-Landau equation and its many generalizations.

The well-known Ginzburg-Landau equation, suitably generalized, can be considered as a language in which to describe many important properties of matter near continuous phase transitions, as well as macroscopic pattern formation and dynamics of systems far from equilibrium. The career of Guenter Ahlers has spanned both areas and many of his achievements can be described using the language of the generalized Ginzburg-Landau equation.

Li Ning

Power to Change the World - Search for Safe, Clean and Competitive Energy

Lohse Detlef

The phase space of turbulent Taylor-Couette flow: from pattern formation to ultimate turbulence

Lücke Manfred

Collisions of localized convection structures in binary fluid mixtures

Collisions of a localized traveling wave structure with a localized stationary structure are investigated. In ethanol-water mixtures with appropriately chosen negative separation ratios, both exist bistably in the unstable quiescent surrounding for a range of supercritical heating rates. Depending on the Rayleigh number, we observe different evolution scenarios of the convection structures that appear as a result of the collision. The incident localized traveling wave can be absorbed by the stationary structure and then the latter expands: either both of its fronts get unpinned and propagate into the quiescent fluid or only
the one that is hit propagates while the opposing one remains pinned. For smaller Rayleigh numbers, the stationary structure is destroyed while the incident localized traveling wave survives and a second one is created that moves ahead of the incoming one, both being coupled together. The mechanisms involved in these scenarios are analyzed and elucidated with the help of finite difference numerical simulations that are carried out subject to realistic boundary conditions.

Morris Stephen W.

On the origin of ripples on icicles

Natural icicles often exhibit ripples about their circumference which are due to a morphological instability. We present an experimental study that explores the origin of the instability, using laboratory-grown icicles. Contrary to theoretical expectations, icicles grown from pure water do not exhibit growing ripples. The addition of a non-ionic surfactant, which reduces the surface tension, does not produce ripples. Instead, ripples emerge on icicles grown from water with dissolved ionic impurities. We find that even very small levels of impurity are sufficient to trigger ripples, and that the growth speed of the ripples increases only approximately logarithmically with impurity concentration. With impurities present, the ripple wavelength remains constant under all other variations of the growth conditions. Ripples are observed to travel during their growth. For low impurity concentrations, they travel upward at speeds of mm/hr. For higher impurity concentrations, some ripples moved nonlinearly and different ripples on the same icicle sometimes traveled in opposite directions. Existing theories of ripple formation do not account for the effect of impurities and cannot be easily generalized to include them. Thus, while our experiments have provided much new information on the origin of icicle ripples, this elegant example of natural pattern formation remains theoretically unexplained.

Pesch Werner

Inclined-layer convection in binary fluid

The numerous new facets of Rayleigh-Bénard convection in binary fluids have motivated intense experimental and theoretical investigations during the past decades. In this contribution we address some new effects characteristic for inclined fluid layers. Our study is based on the standard hydrodynamic equations for binary mixtures. It includes the characterization of the various roll solutions by Galerkin methods but makes also use of direct numerical solutions to access weakly turbulent patterns.

One goal is a systematic study of the resulting interplay between buoyancy-driven and shear-flow driven pattern-forming mechanism. The latter become in particular dominant at small Prandtl numbers of the order $O(0.2)$, which can be easily realized in binary gas mixtures like $\text{H}_2-\text{Xe}$ [1]. In addition to inclination we discuss also the impact of a spatially periodic temperature modulation [2], which leads often to complex patterns characterized by interesting wave vector resonances. Quantitative tests of our results with the use of the existing gas convection apparatus should be possible without major difficulty.
Pobell        Frank

Strong paramagnetism of Au nanoparticles fabricated on a highly ordered biological matrix

Magnetic properties of Au nanoparticles fabricated on a highly ordered surface protein of an archeon were studied by element-selective XANES and XMCD as well as by SQUID magnetometry. The results demonstrate that the particles are strongly paramagnetic, without indication of magnetic blocking down to 16 mK. The average magnetic moment per particle is 2.4 mB. This moment originates at the particle’s Au 5d band, in which an increased number of holes with respect to bulk Au is observed by XMCD. The magnetic moment per Au atom is at least 25 times larger than values measured for Au nanoparticles fabricated on non-biological matrices.

du Puits      Ronald

Near-wall heat transport in turbulent Rayleigh-Bénard convection in air

Simultaneous measurements of velocity and temperature in a convective boundary layer have been undertaken to characterize the near-wall heat transport in turbulent thermal convection. In a large-scale Rayleigh-Bénard experiment, known as the ‘Barrel of Ilmenau’, Laser Doppler Velocimetry (LDV) was used in combination with an ultra-small microthermistor of 125µm size to measure the diffusive and the convective fraction of the near-wall heat flux. Time series of the wall-normal velocity component and the temperature have been measured at various distances from the wall and the profile of the wall-normal heat flux component q(y) has been analyzed. The measurements clearly show that, even at a very moderate Ra numbers as low as Ra=3×10^10, convection significantly contributes to the heat transport throughout the boundary layer.


Particle motion and irreversibility of turbulent flows

In three-dimensional turbulent flows, the flux of energy from large to small scales breaks time-reversal symmetry. I will discuss how this irreversibility can be observed by following the trajectories of tracers, moving with the fluid.

For two particles (or more), I will show that irreversibility manifests itself by a slower relative separation forward in time, than backward, an effect which can be explained using directly the Navier-Stokes equations. For one particle only, a more surprising manifestation of irreversibility is that a tracer particle needs more time to build up large kinetic energy, than to dissipate it. This leads to a statistical signature, which allows us to quantify irreversibility.

Packing patterns of polar particles

The self-assembly of magnetic particles into a simple cubic lattice [1,2,3] triggers questions like: i) What is the overall magnetization of those clusters? ii) How susceptible are they to external magnetic fields? iii) What is the arrangement of the individual magnets within those clusters?

The minimal model to attack these problems consists of 8 dipoles arranged in the corners of a cube. The magnetic configuration is discussed in a 16-dimensional configuration space formed by the polar and azimuthal angles of the 8 dipole orientations. Using symmetry constraints, the dimensionality of the problem can further be reduced.

The binding energy per particle as a function of the azimuthal and polar angles of one of the dipoles shows an elongated valley corresponding to the lowest energy, i.e. a continuum of frustrated states, which seems to be unique for this particular magnetic cluster.

Reppy, John D.

In pursuit of the elusive Supersolid; Is it real?

One of the most exciting events in the last decade of condensed matter physics was the possible observation of the Supersolid state of solid 4He in the torsional oscillator experiments by Kim and Chan. Unfortunately recent work has shown that, many if not all, of the early experiments were actually observing effects due to the interplay between the anomalous elastic properties of the solid and the mechanical properties of the oscillators. Our recent approach to this problem is to employ double or triple frequency oscillators where one can distinguish between dynamic elastic effects and frequency independent contributions such as would be expected for a super solid.

Scheel, Janet

Onset of Rayleigh-Bénard convection in cylindrical containers

Onset patterns in cylindrical Rayleigh-Bénard Convection cells are determined as a function of aspect ratio from direct numerical simulations. Both insulating and conducting thermal sidewall boundary conditions are studied. The results are compared to the theory (Buell and Catton) as well as the experiments (Herbert et. al). The focus here is on the existence of a transition from the azimuthal Fourier modes found in smaller aspect ratios to patterns of straight parallel rolls found in moderate to large aspect ratios.

Schröter, Matthias

Granular media and the Jamming paradigm

Shishkina, Olga

Influence of the angle between the wind and the isothermal surfaces on the boundary layer structures in turbulent thermal convection

We derive the asymptotes for the ratio of the thermal to viscous boundary layer thicknesses for infinite and infinitesimal Prandtl numbers Pr as functions of the angle between the large-scale circulation and an isothermal heated or cooled surface for the case of turbulent thermal convection with laminar-like boundary layers. For this purpose, we apply the Falkner-Skan ansatz, which is a generalization of the Prandtl-Blasius one to a nonhorizontal free-stream flow above the viscous boundary layer. Our
theoretical predictions for the boundary layer thicknesses are in good agreement with our DNS results.

References:

Co-authors: Susanne Horn and Sebastian Wagner

Schumacher  Jörg

Small-scale universality in turbulence

Three turbulent flows of systematically increasing complexity, homogeneous and isotropic turbulence in a periodic box, flow between two parallel walls and thermal convection in a closed cylindrical container are computed by highly-resolved direct numerical simulations of the governing dynamical equations. Here we use these simulations to establish two fundamental results. First, at Reynolds numbers of the order of 100 the fluctuations of the velocity derivatives pass through a transition from Gaussian or slightly sub-Gaussian to intermittent behavior. Second, beyond the transition point, the statistics of the rate of energy dissipation in all three flows obey the same Reynolds number power laws which have been derived for homogeneous isotropic turbulence. These results allow us to claim universality of small scales even at low Reynolds numbers. This is a joint work with Janet D. Scheel, Dmitry Krasnov, Diego A. Donzis, Katepalli R. Sreenivasan and Victor Yakhot.

Steinberg  Victor

Turbulent drag reduction in von Karman swirling flow

A short review of our recent results on turbulent drag reduction (TDR) in von Karman swirling flow of water and water-sucrose polymer solutions, where Re and Wi as well as polymer concentration ϕ are varied, is presented. First, we show experimental quantitative results on the transition to early turbulence in water- and water-sugar-based polymer solutions than the transition to turbulence in their Newtonian solvents. The transition values of Re^turb_c to fully developed turbulence as well as Re^TDR_c to TDR regime are obtained by measurements of only global quantities as torque Γ(t) and pressure p(t) as functions of Re and elasticity El = Wi/Re as well as polymer concentration ϕ. Two scaling regions for fundamental turbulent characteristics are identified and they correspond to the turbulent and TDR regimes. The both Re^turb_c and Re^TDR_c are found via the dependence of the friction coefficients C_f and C_p defined through average torque <Γ> and rms pressure fluctuations p_rms for different El and ϕ and via the limits of the two scaling regions. The friction coefficients C_f and C_p for different elasticity El = Wi/Re and ϕ vs. Re/Re_c collapse onto universal curves in accord with theory, where Re_c is Re at the TDR onset. Power spectra for Γ and p at Re/Re_c >1 show a drastic reduction of low-frequency noise and the emergence of a peak corresponding to the main vortex frequency in accord with TDR.
Finally, we report rather unexpected results on drastic difference in the transition to the turbulent regimes and their properties in von Karman swirling flow of water-based polymer solutions for viscous (by smooth disks) and inertial (by disks with blades) forcing and by tracking torque $\Gamma(t)$ and pressure $p(t)$. For the viscous forcing, only single turbulent regime is found with the transition value $Re^{\text{turb}}_c = Re^{\text{TDR}}_c \sim 4.8 \times 10^5$ independent of $\phi$, while for the inertial forcing, two turbulent regimes are revealed: first transition is to fully developed turbulence and the second one is to the TDR regime with the both onset values $Re^{\text{turb}}_c$ and $Re^{\text{TDR}}_c$ depending on $\phi$. The both regimes differ by the scaling exponents of the fundamental turbulent characteristics, the dependence of skewness and flatness of probability density functions of $p$ on $Re$, and the different frequency power spectra of $p$ with the different dependencies of the peaks in the power spectra on $\phi$.

Sun Chao

*Multiple states in highly turbulent Taylor–Couette flow*

Verzicco Roberto

*The effects of the sidewall in Rayleigh-Bénard convection*

The influence of the temperature boundary conditions at the sidewall on the heat transport in Rayleigh-Bénard convection is investigated using direct numerical simulations. Both, adiabatic and isothermal sidewalls are considered showing that the latter are responsible for a parasite heat current that increases the Nusselt number up to Rayleigh numbers (Ra) of the order of $10^{10}$. When Ra exceeds this threshold the bulk of the flow becomes more isothermal and the sidewall effect is negligible. However, if the sidewall doesn't have the same temperature as the mean plate temperature $((T_h+T_c)/2)$ the heat flux from the lateral boundary interferes with that of the plates and the effect does not decrease for increasing Ra.

Sidewalls with finite thickness and thermal properties different from the fluid are also considered showing that they can change not only the Nusselt number but also the turbulence statistics and even the mean flow structure. Some cases are investigated by separating the effects of the sidewall thermal conductivity, density and specific heat.

Finally, taking inspiration from a recent study (Ahlers et al., New J. Phys., 14, 103012 (2012)), more complex set-ups are simulated by accounting for the porous convection within the insulating foam layers and the thermal shields that are placed outside of the container. Although each result is peculiar of the particular setup it has been found that the joining of the sidewall with the isothermal horizontal plates is a very critical issue that should be carefully designed in experiments.
Weiß  Stephan

*On the coupling of spatio-temporal patterns in a chemical system*

We use experiments and numerical simulations of the spatially extended light-sensitive Belousov-Zhabotinsky (BZ) reaction as a model to study the behavior of coupled pattern forming systems. We find various kinds of synchronisations as a function of the coupling strength, the initial conditions and the initial chemical concentrations. In a system of two coupled BZ-cells, we observe synchronised motion of the spiral cores for weak and complete synchronisation for strong coupling. In a system of three coupled BZ-cells, we find the interesting situation that typical spiral patterns can only be completely synchronised for weak coupling. For stronger coupling, we found a novel state consisting of spirals, whose amplitudes oscillate in space and time.

Wu  Mingming

*Pattern formation in biological systems*

In this talk, I will give two examples of pattern forming systems in biology. This work is inspired by the beautiful hexagonal patterns that I created in a gas convection system in Guenter’s lab in 1993. The first example describes the emergence of a periodic convection pattern observed in a bacteria suspension when subjected to oxygen gradients. Using a hydrodynamic model, I will show that chemotaxis is required for the hydrodynamic instability that leads to the pattern formation. A second example is the observation of a directed swimming pattern of a bull sperm suspension when subjected to a fluid flow. In the absence of a flow, bull sperm swim randomly. In the presence of a flow, bull sperm swim against the flow. I will show that this directional disorder-order transition can be described by a supercritical transition fully governed by hydrodynamic forces, similar to the one observed in gas convection experiments in 1993.

Xi  Heng-Dong

*The Fourier modes of the flow in turbulent Rayleigh-Bénard Convection*

We present experimental studies of different Fourier modes of the flow in turbulent thermal convection in cells of aspect ratio 1 and 1/2. We found that overall the first Fourier mode, which corresponds to the so-called large-scale Circulation (LSC), dominates the flow. The second and the remaining higher modes are very weak; the time-averaged amplitude of the second mode is only about 46% of that of the first mode. We further found that during the cessation/reversal of the LSC the amplitude of the second mode is higher than that of the first mode. In addition, it is found that during a reversal/cessation the amplitude of the second mode experiences a rapid increase to a maximum then a decrease, which is opposite to the behavior of the amplitude of the first mode --- it decreases to almost zero then re-
bounds. The experiment reveals that the second mode plays an important role in the dynamics of the reversal/cessation of the LSC.

**Xia Ke-Qing**

*Some recent non-traditional thermal convection experiments*

In this talk we will present results from three experimental and numerical studies conducted recently in our group. Two are related to Rayleigh-Bénard convection (RBC), but with polymer additives and the other in confined geometries. The third one is on horizontal convection. Enhanced heat transports are observed in the first two cases, which have a common feature that is related to the coherence of thermal plumes, i.e. enhanced heat transport can be achieved through the increased coherence of thermal plumes, even in the expense of slower flow that is either due to the increased viscosity or frictional drag from confinement. In the third experiment, the horizontal convection --- a simple conceptual model for oceanic circulation, we found that a returning flow can be achieved without penetrating the strongly stratified thermal boundary layer.

We acknowledge support of this work by the Hong Kong Research Council through GRF Grants CUHK403811 and CUHK403712.

By Ke-Qing Xia, S. D. Huang, Y. C. Xie, K.L. Chong, M. Kaczorowski, P. Wei, and R. Ni

**Xu Haitao**

*Experimental observation of energy cascade in fully developed turbulence*

**Zhong Jin-Qiang**

*Influence of modulated rotations on the large-scale circulation of turbulent Rayleigh-Bénard convection*

We present measurements of the large-scale circulation (LSC) in turbulent Rayleigh-Bénard convection with modulated rotations. We use a cylindrical cell of aspect ratio one that rotates about a vertical axis at a prescribed angular speed: $\Omega(t) = \Omega_1 \cos(\omega t) + \Omega_0$. The azimuthal orientation of the LSC $\theta(t)$ undergoes net retrograde rotation with an average speed $v$; whilst the detrended angular velocity $d\theta/dt = d\theta/dt - v$ reveals harmonic oscillations $d\theta/dt = A_{\theta} \cos(\omega t + \phi_{\theta})$. The thermal amplitude $\delta(t)$ of the LSC also exhibits oscillations at the same frequency $\delta(t) = A_{\delta} \cos(\omega t + \phi_{\delta}) + \delta_0$. 
The frequency of modulation is expressed in dimensionless form by the Strouhal number $Sr=\omega/(2\Omega_0 \text{Ro})$ (Ro being the Rossby number). When the Strouhal number is close to zero, we find negative correlation between the retrograde rotation speed $-d\theta_d/dt$ and $\delta(t)$. Furthermore, we find that the magnitudes of both $\phi_{\theta}$ and of the phase difference $d\phi=\phi_{\theta}-\phi_{\delta}$ increase when the Strouhal number increases, and that the LSC retrograde rotation speed always leads the amplitude, both lag behind $\Omega$. These are interpreted as due to the influence of the inertia of the LSC on its azimuthal rotations.

Zhou Quan

Partition-Plates-Induced Heat Transport Enhancement in Turbulent Thermal Convection

Enhancing heat transfer from a hot surface to a fluid is of fundamental interest as well as of great technological importance. Turbulent Rayleigh-Bénard (RB) convection, i.e. a fluid layer between horizontal parallel plates and heated from below, has become a paradigm for the study of convective heat transport in closed systems in the past several decades and how to improve its global heat-transfer efficiency is still an open issue. In this study, we report an experimental and numerical study which reveals a novel mechanism leading to dramatically enhanced heat transport of RB convection. When partition plates are inserted into the convection sample with thin slits of width $d$ comparable with the thermal boundary layer thickness from the top and bottom plates, it is found that the heat-transfer efficiency can be enhanced up to 230% for the number of plates reaching 28. Detailed studies show that the spontaneous symmetry breaking of the system leads the upwelling hot lighter fluid and the downwelling cold heavier fluid to be at two sides of each partition plate, and thus the alternating pressure difference between neighboring cells, which generates the intense horizontal motion of the fluid within thin slits that can take the hot/cold fluids out of the thermal boundary layers more efficiently and sustain the bifurcation flow around the partition plate. This study suggests a new technique to enhance heat transport in micro-devices and other applications.

Zhou Sheng-Qi

The convective pattern in the Arctic Ocean
Magnetic control of flexoelectric domains in a nematic liquid crystal

N. Éber, P. Salamon, Á. Buka, T. Ostapenko, S. Dölle, and R. Stannarius

1 Institute for Solid State Physics and Optics, Wigner Research Centre for Physics, Hungarian Academy of Sciences, Budapest, Hungary
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Flexoelectricity-induced stripe patterns (flexodomains [1-4]) were studied under the influence of superposed electric and magnetic fields in the rod-like nematic liquid crystal 4-n-octyloxyphenyl 4-n-methyloxybenzoate (1O08). Experiments were carried out using a planar cell in three different geometries: applying the magnetic field parallel with, oblique to, and perpendicular to the rubbing direction.

The critical voltage and wave vector of the flexoelectric instability were determined as the function of magnetic field in all geometries. It has turned out that, depending on the geometry, the magnetic field not only alters the thresholds, but may realign the flexodomains. In contrast to the parallel and oblique geometries, in the perpendicular arrangement the critical voltage has a non-monotonic dependence on the magnetic field; the behaviour below and above the twist Freedericksz transition is significantly different.

In addition to the experiments, a theoretical modeling of the field-induced deformations was carried out using the continuum description, assuming anisotropic elasticity. Performing a linear stability analysis the onset parameters (the threshold voltage and the critical wave vector) were calculated numerically as the function of the magnetic field for the parallel as well as for the perpendicular geometries. The experimental data showed quantitative matching with the numerical results.

References:
Heat transport in rotating Rayleigh-Bénard convection

We report global heat transport measurements in cryogenic helium with Prandtl number 0.7 over a broad range of Ra and Ek numbers. The phase diagram for the onsets of rotationally-influenced and rotationally-dominated states are elucidated. We also report local heat transport measurements in water for Ra \( \approx 10^8 \).

Experiments on Rayleigh-Bénard convection

Toroidal and poloidal energy in rotating Rayleigh-Bénard convection

Local wall heat flux at various aspect ratios

In the past, a lot of effort has been made to investigate the global heat flux inside a Rayleigh-Bénard convection cell resulting in a multitude of scaling laws in the shape of \( \text{Nu} \sim \text{Ra}^a \text{Pr}^b \text{G}^c \) (G - aspect ratio) with the scaling exponents a, b and c. In order to understand the dominating mechanisms, local measurements of the wall heat flux were performed on the heating plate of the Barrel of Ilmenau. A set of data was measured at various aspect ratios between 1.13 and 6 while the Rayleigh number was kept constant at Ra=4e9.

First of all, the data reveal a strong variation of the local wall heat flux distribution of up to 130% of its mean value at smallest aspect ratio (G=1.13) where a single convection roll is present. This global flow structure will split into two smaller convection rolls if the aspect ratio is increased. As a consequence of this splitting, the local wall heat flux is distributed more uniformly.
Boiling Rayleigh-Bénard flow

We report on heat transport due to controlled boiling of Novec7000 (heptafluoro-1-methoxypropane) at the bottom plate of a cylindrical turbulent Rayleigh-Bénard sample of height and diameter equal to 9 cm. The top surface of the bottom plate was a thin silicon wafer. Over a $2.5$ cm diameter central area a triangular lattice of cavities, each of 30 $\mu$m diameter and 100 $\mu$m deep, was etched into the wafer. Only this etched area was heated from below. Except for small vapor bubbles when boiling took place, the sample was filled with liquid. Wafers with lattice spacings of $0.13$ mm and $1.02$ mm were used. When the cavities were activated (deactivated) by assuring that they were filled by vapor (liquid), then they nucleated (did not nucleate) bubbles even when the wafer temperature was below the bulk boiling point. Results of the heat transport as a function of the mean temperature with a fixed applied temperature difference $\Delta T = 20$ K (corresponding to a Rayleigh number $Ra \approx 2 \cdot 10^{10}$), as well as visualizations of bubble formation, are reported.

Ultimate Rayleigh-Bénard and Taylor-Couette turbulence

The scaling properties of Nu are expected to change to an asymptotic regime at a critical driving magnitude. Most of the geo- and astrophysical applications of RB and TC flows are at very high Ra and Ta of more than $1e20$. These values are inaccessible by experiments and direct numerical simulations and lie within this asymptotic, or ‘ultimate’ regime. The search for the ultimate regime and its corresponding scaling is very important as this scaling can be extrapolated towards arbitrary high Ra and Ta, facilitating estimation of the heat- and angular velocity fluxes in geo- and astrophysical systems.

Excitability dependent pattern formation in Dictyostelium discoideum

On starvation, the amoebae Dictyostelium discoideum emit the chemo-attractant cyclic adenosine monophosphate (cAMP) at specific frequencies. The neighboring amoebae sense cAMP through membrane receptors and produce their own cAMP. Soon the cells synchronize and move via chemotaxis along the gradient of cAMP. The response of the amoebae to the emission of cAMP is seen as spiral waves or target patterns under a dark field microscope. The causal reasons for the selection of one or the other patterns are still unclear. Here we present a possible explanation based on excitability. The excitability of the amoebae depends on the starvation time because the gene expression changes with starvation. Cells starved for longer times are more excitable. In this work, we mix cells of different excitabilities to study the dependence of the emergent patterns on the excitability. Preliminary results show a transition from spirals to target patterns for specific excitabilities. A phase map of the patterns
for different combinations of excitability and number densities is obtained. We compare our findings with numerical simulations of existing theoretical models.

Rehberg Ingo

Packing patterns of polar particles

The self-assembly of magnetic particles into a simple cubic lattice [1,2,3] triggers questions like: i) What is the overall magnetization of those clusters? ii) How susceptible are they to external magnetic fields? iii) What is the arrangement of the individual magnets within those clusters?

The minimal model to attack these problems consists of 8 dipoles arranged in the corners of a cube. The magnetic configuration is discussed in a 16-dimensional con-figuration space formed by the polar and azimuthal angles of the 8 dipole orientations. Using symmetry constraints, the dimensionality of the problem can further be reduced.

The binding energy per particle as a function of the azimuthal and polar angles of one of the dipoles shows an elongated valley corresponding to the lowest energy, i.e. a continuum of frustrated states, which seems to be unique for this particular magnetic cluster.


Schemet Natalie

Novel tracer particles for large-scale 3d-particle tracking velocimetry in air

The effects of thermal convection are present around us in the atmosphere, in indoor flows in large buildings, in passenger compartments and in many other situations. All these flows are highly turbulent, very complex and strongly three dimensional. One of the most powerful available methods that are used for visualization of air flows is the particle image velocimetry (PIV). However PIV cannot satisfy all requirements of investigation large-scale air flows, due to its limited spatial resolution even in stereoscopic arrangements.

The detection and observation of large scale flow structures by using of the three-dimensional particle tracking velocimetry (3D-PTV) is a promising method for determine of velocity fields in air flows in large scale experiments like the “Barrel of Ilmenau” (BOI) as presented by Lobutova[1].

The experimental study focusses on the application of Helium filled-soap bubbles (HFSB) and Helium filled-balloons (HFB) as tracer particles to visualize the flow motion. The much larger HLB have larger
Stokes number and can only be used for the characterization of large-scale circulations. The HFSB can provide a high temporal and spatial resolution of the velocity field due to their relatively small size, but their lifetime is too short for long-term measurements.

The idea is to use a new type of stable bubbles – so called stubbles. As the bubble solution is a rather viscous liquid commercial bubble generators are not suited. We report on a new bubble generator based on a laboratory prototype being suited to generate stubbles of size between 3 and 5 mm. The stubbles will be used to measure the large-scale flow in the convection cell “Barrel of Ilmenau”.


Schneider Tobias M.

Title TBA

With Priya Subramanian

Schröter Matthias

How wet is wet? An answer with Liquid $^4$Helium

By Kai Huang, Masoud Sohaili, Matthias Schröter, and Stephan Herminghaus

- no abstract given –

Wagner Sebastian

Numerical study of turbulent thermal convection with obstacles

We present numerical results on turbulent Rayleigh-Bénard convection in a box-shaped domain with rough heating and cooling plates. Regular roughness is realized by four parallelepiped obstacles of constant temperature attached to the bottom and top plates. By varying the obstacles height and width and the Rayleigh number we investigate the roughness induced heat transfer enhancement and changes in the kinetic energy.

Temperature distribution in the bulk of turbulent Rayleigh-Bénard convection for a Prandtl number of 12.3 with and without rotation

We report measurements of logarithmic temperature profiles \( \Theta(z,r) = A(r) \times \ln(z/L) + B(r) \) in the bulk of turbulent Rayleigh-Bénard convection (\( \Theta \) is a properly scaled and time averaged local temperature in the fluid, \( z \) the vertical and \( r \) the radial position, and \( L \) the sample height). The cylindrical sample had an aspect ratio \( \Gamma \equiv D/L = 1.00 \) (\( D \) is the diameter), and a Prandtl number \( \Pr = 12.3 \). The measurements covered the Rayleigh-number range \( 2 \times 10^{10} \leq \text{Ra} \leq 2 \times 10^{11} \). In contradistinction to what had been found\(^1\) for \( \Gamma = 0.50 \) and \( \text{Pr} = 0.78 \), the amplitude \( A(r) \) of the logarithmic term was independent of \( \text{Ra} \). The amplitude varied with \( r \) in a manner consistent with the function \( A(\xi) = A_1/\sqrt{2\xi - \xi^2} \) with \( \xi = (R-r)/L \) and \( A_1 \simeq 0.0016D \) (\( D \) is the sample radius). The results for \( A(r) \) are smaller than those\(^1\) at similar values of \( \text{Ra} \) for \( \Gamma = 0.50 \) and \( \text{Pr} = 0.78 \) by a factor of about 4.5.

When the sample was rotated about a vertical axis, the logarithmic vertical temperature profiles gradually evolved into linear profiles as the rotation rate increased.


Cross-stream migration of asymmetric bead spring models in oscillating shear flows

The cross-stream migration of asymmetric bead-spring polymers in time-dependent linear shear flows is investigated in the limit of small Reynolds numbers. Soft asymmetric dumbbells and ring-polymers are base models that show cross-stream migration in time-dependent linear shear flows. For a given asymmetry of a particle, the migration efficiency can be controlled by adjusting the amplitude and the period of the oscillating shear gradient. Our findings suggest that small deformable particles of different asymmetry and elasticity may be separated by switched shear flows via the process of cross-streamline migration. Asymmetric capsules show the same effects.
Zykov Vladimir

*Kinematic theory of spirals and wave segments*

Spiral waves and wave segments represent typical examples of self-organized pattern observed in excitable media. We demonstrate that at least two dimensionless medium’s parameters should be taken into account in order to determine the spatio-temporal characteristics of these patterns. The findings should be applicable to a wide class of systems, such as the propagation of electrical waves in the cardiac muscle or wave propagation in autocatalytic chemical reactions, due to the generality of the free boundary approach used. The predictions of the free-boundary approach are in good quantitative agreement with the results from numerical reaction-diffusion simulations.

By Vladimir Zykov and Eberhard Bodenschatz