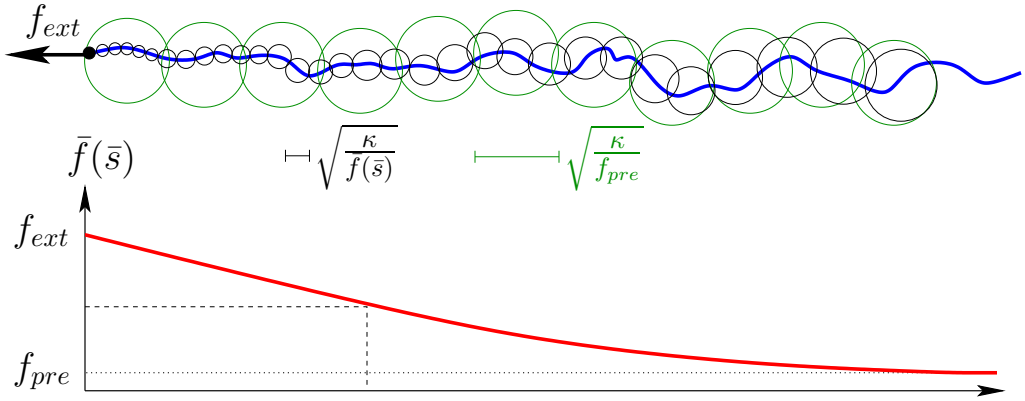
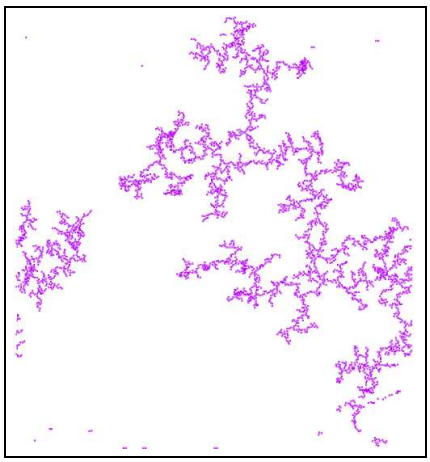
Progress Report 2005

SOFT CONDENSED MATTER THEORY GROUP

Institut für Theoretische Physik
Universität Leipzig





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2 Publications

Propagation and Relaxation of Tension in Stiff Polymers

Oskar Hallatschek, Erwin Frey, and Klaus Kroy

Phys. Rev. Lett. 94, 077804 (2005)

We present a unified theory for the longitudinal dynamic response of a stiff polymer in solution to various external perturbations (mechanical excitations, hydrodynamic flows, electrical fields, temperature quenches, etc.) that can be represented as sudden changes of ambient/boundary conditions. The theory relies on a comprehensive analysis of the nonequilibrium propagation and relaxation of backbone stresses in a wormlike chain. We recover and substantially extend previous results based on heuristic arguments. New experimental implications are pointed out.

Brownian motion: a paradigm of soft matter and biological physics

Erwin Frey and Klaus Kroy

Ann. Phys. (Leipzig) 14 (2005) p.20

This is a pedagogical introduction to Brownian motion on the occasion of the 100th anniversary of Einstein's 1905 paper on the subject. After briefly reviewing Einstein's work in a contemporary context, we pursue several lines of further developments and applications to soft condensed matter and biology. Over the last century Brownian motion has been promoted from an odd curiosity of marginal scientific interest to a guiding theme pervading all of the modern life sciences.

Im Zickzack zwischen Physik und Biologie

Erwin Frey und Klaus Kroy

Physik Journal 3/2005, p.61

Einsteins Interesse an statistischen Fluktuationen zieht sich als Leitmotiv durch seine Arbeiten. Aus seinen Ansätzen erwuchs eine unübersehbare Fülle an Forschungsgebieten, nicht nur innerhalb der Physik, sondern auch in anderen Disziplinen wie Biologie, Ökonomie oder Verkehrsforschung. Das Kapitel der Brownschen Bewegung umfasst noch viele ungeklärte Fragen. So fangen wir gerade erst an zu verstehen, in welchem Maße Fluktuationen die Prozesse des Lebens bestimmen.

The shape of barchan dunes

Klaus Kroy, Sebastian Fischer and Benedikt Obermayer

J. Phys.: Condens. Matter 17 (2005) S1229-S1235

Barchans are crescent-shaped sand dunes forming in arid regions with unidirectional wind and limited sand supply. We report analytical and numerical results for dune shapes under different environmental conditions as obtained from the so-called 'minimal model' of aeolian sand dunes. The profiles of longitudinal vertical slices (i.e. along the wind direction) are analysed as a function of wind speed and sand supply. Shape transitions can be induced by changes of mass, wind speed and sand supply. Within a minimal extension of the model to the transverse direction the scale-invariant profile of transverse vertical cuts can be derived analytically.

Non-equilibrium behavior of sticky colloidal particles: beads, clusters and gels

Sedgwick H.; Kroy K.; Salonen A.; Robertson M.B.; Egelhaaf S.U.; Poon W.C.K.

European Physical Journal E 16 (2005), p.77-80

To understand the non-equilibrium behavior of colloidal particles with short-range attraction, we studied salt-induced aggregation of lysozyme. Optical microscopy revealed four regimes: bicontinuous texture, 'beads', large aggregates, and transient gelation. The interaction of a metastable liquid-liquid binodal and an ergodic to non-ergodic transition boundary inside the equilibrium crystallization region can explain our findings.

Elasticity, dynamics and relaxation in biopolymer networks

Klaus Kroy

Current Opinion in Colloid and Interface Science, *in the press* 2005

Our cells, muscles, and connective tissue owe their remarkable mechanical properties to biopolymer networks. Their incessant assembly, disassembly, restructuring, and active and passive mechanical deformation underlies the astounding robustness, adaptability, physical strength and motility of cells and of biological tissue in general. Unlike the flexible polymer networks discussed in standard texts on polymer physics, most biological macromolecular assemblies are predominantly made from (mixtures of) stiff polymers, however. The resulting local mechanical anisotropy and persistence entail

distinct mechanical and dynamic properties unlike those familiar from synthetic polymers, foams, or other cellular structures. At the same time they pose formidable difficulties to theoretical modeling efforts, which were so far unsuccessful in establishing a generally accepted view of the origin of the macroscopic elasticity and equilibrium dynamics, let alone the complex biological function of biopolymer networks.

3 Talks and Posters at Conferences and Workshops

- Mini-Symposium, 15/16 February 2005
  Hahn-Meitner-Institut Berlin, contributed talks by
  Benedikt Obermayer: *Tension Propagation in Semiflexible Polymers*
  Jens Glaser: *Molecular Force Microscopy on Graphite*
  Daniel Rings: *Atomic Force Microscopy: Soft Matter*

- DPG-Meeting, 4-9 March 2005, Berlin
  Benedikt Obermayer: *Non-linear dynamics of stiff polymers* (poster)

- Workshop Soft Matters in Biological Physics, 20./21. September 2005
  Universität Leipzig
  invited talk by Oskar Hallatschek: *Anisotropic semiflexible polymer dynamics*

- Workshop Brownian Motion: A Paradigm of Soft Matter and Biological Physics, 26-28 September 2005
  Arnold Sommerfeld Center for Theoretical Physics Munich
  invited talk by Klaus Kroy: *How a deterministic response emerges from Brownian polymer dynamics*

- Workshop on Dynamical Arrested State of Soft Matter and Colloids, 22-26 January 2005, Bad Gastein, contributed talk by Klaus Kroy: "Shear-driven flocculation of sticky spheres: crossover from kinetic aggregation to anisotropic percolation"

- Conference on "Traffic and Granular Flow" HU Berlin, 10-12 October 2005, contributed talk by Klaus Kroy: "On growth and form of desert dunes"

- Jülich Soft Matter Days 2005, 1-4 November 2005
  Gustav-Stresemann-Institut, Bonn, Germany
  Benedikt Obermayer: *Non-linear dynamics of semiflexible polymers* (poster)
  Jens Glaser: *Hydrodynamic interactions for stiff polymers* (poster)

4 Invited Talks at Academic Institutions

- Klaus Kroy "On growth and form of desert dunes", North Dakota State University
- Benedikt Obermayer "Nonlinear Dynamics of Stiff polymers", LMU München
- Sebastian Fischer "Modelling the evolution of aeolian sand dunes", TU München
- Klaus Kroy "Tension dynamics in stiff poymers", MPI Leipzig
- Klaus Kroy "On growth and form of desert dunes", Universität Bayreuth

5 Miscellaneous

- "Symposium: Naturwissenschaftliche und technische Systeme im Fokus von Fremd- und Selbstorganisation" der Arnold Sommerfeld Gesellschaft, 10/11 November 2005, Leipzig
  invited after-dinner-lecture by Klaus Kroy: "Im Zickzack zwischen Physik und Biologie"

6 Lectures

6.1 SOSE 2005

Fluctuations and Response of Polymers

Wahlfach, Vorlesung, Universität Leipzig

Many soft materials are built from a mixture of low dimensional structures such as linear or branched polymers and membranes. Due to their low dimensionality these meso-structures are affected (crumpled, shaken, ...) by thermal forces. Their conformations and stochastic dynamics determine the mechanical and dynamical properties of many materials encountered in everyday life, in particular of our own bodies. The lecture will give a predominantly theoretical perspective on polymers, but not too technical.

Scaling concepts in polymer physics

Mitteldeutsche Physikcombo in Jena

Chemically, a polymer simply is a long chain of identical small molecules. Yet, the question how this chain arranges itself and moves in its embedding space, has provided formidable challenges to statistical physicists. The dull structure calls for renormalization and scaling concepts, which have indeed been very successful in predicting the universal conformational and dynamical properties of flexible polymers. The lecture also addresses some not so well known delicate aspects of this story.

The Physics of DNA

Mitteldeutsche Physikcombo in Leipzig

DNA is arguably one of the most important polymers we know of, and it is by now well established that its mechanical properties play a key role in many of its biological functions. Although its overall appearance is certainly that of a flexible polymer, most relevant interactions act on scales where it is rather rod-like, so that the whole theory of flexible polymers, outlined in the first Combo lecture, is of very limited use. We discuss a more suitable minimal model, the so-called wormlike chain, along with some more refined descritions of DNA, in order to disentangle the universal and specific aspects of DNA mechanics.

Antrittsvorlesung: Physik der Wanderdünen

Die spontane Entstehung von Sanddünen ist ein verbreitetes und spektakuläres Naturphänomen, das gleichermaßen als ästhetisch faszinierend und ökonomisch

bzw. ökologisch bedrohlich wahrgenommen wird. Um die zugrunde liegenden physikalischen Mechanismen zu erhellen, werde ich ein einfaches, sogenanntes Minimalmodell vorstellen. Daraus lassen sich nichttriviale Ähnlichkeitsrelationen für die Gestalt und Dynamik von Wanderdünen unter verschiedenen Strömungs- und Einflußbedingungen ableiten. Sie sind Manifestationen eines versteckten universellen Formgesetzes hinter der Vielfalt der beobachteten Dünengestalten in den ariden Zonen der Erde sowie auf Flußsohlen, Meeresböden und auf dem Mars. Es basiert auf einem subtilen Wechselspiel der Selbstähnlichkeit und spontanen Symmetriebrechung der turbulenten Strömung mit der durch die Sandkorngröße vorgegebenen charakteristischen Längenskala.

6.2 WISE 2005/2006

Statistische Mechanik

Kursvorlesung, Universität Leipzig

Entgegen dem Titel wird die Vorlesung Leipziger Tradition folgend mit Grundelementen der Thermodynamik beginnen und dann erst die Statistische Mechanik klassischer und quantenmechanischer Systeme einführen. Nützliches Vorwissen: Mechanik, Quantenmechanik, elementare Thermodynamik und Statistik.

Introduction to Hydrodynamics and Elasticity

Wahlfach, Vorlesung, Universität Leipzig

In many active research activities in soft matter physics, biological physics, and the environmental sciences one meets problems that are characterized by a combination of elasticity, hydrodynamics, and statistical mechanics. Yet, the former two disciplines have essentially vanished from the physics curriculum and were delegated to mathematicians, engineers and other applied scientists, meaning that physicists usually regard their general structure as "established" and their solution as "too complicated". However, there are still some funny surprises that make the subject exiting for physicists looking for fundamental problems, apart from the mentioned interdisciplinary applications. I will try to convey some idea about where the basic equations of hydrodynamics and elasticity come from, what is amazing about them, and how they can be solved in some of the simplest cases. Some topics might be: diffusion eq., Euler eq., Navier-Stokes eq., hydrodynamic interactions, turbulent boundary layers, non-linear elasticity, rubber elasticity, beams, shells, viscoelasticity, viscoelastic tension propagation.

7 Diplomarbeiten

- Sebastian Fischer, Diplomarbeit "Aeolian Sand Transport and Dune Formation", FU Berlin
- Benedikt Obermayer, Diplomarbeit "Non-equilibrium Dynamics of semi-flexible polymers", FU Berlin

8 NTZ-Workshop

Soft Matters in Biological Physics

Universität Leipzig, 20.-21. September 2005

Schedule:

20. September 2005

Sackmann	**Membranes and Vesicles**
9:15-9:30	*Welcome*
9:30-10:05	*Crystalline Domains in Fluid Vesicles: Shapes, Defects, and Budding* G. Gompper (Jülich)
10:05-10:30	*Lipid Membranes* V. Gordon (Edinburgh)
10:30-10:55	*Coarse-grained fluid membranes without solvent: Why? How? Wow!* M. Deserno (Mainz)
10:55-11:20	*Ordered domains control diffusion in model membranes* C. Selle (Leipzig)
11:20-11:50	**Coffee break**
Frey	**Stick and Creep**
11:50-12:15	*Force induced unbinding of specifically adhered vesicles* A. Smith (Stuttgart)
12:15-12:50	*Stochastic dynamics of adhesion clusters* U. Schwarz (Heidelberg)
12:50-13:15	*Three-ball animals: a family of biomimetic colloidal machines* W. Lobaskin (Mainz)
13:15-14:15	**Lunch break**

20. September 2005 (continued)

Liverpool	**Single Polymers I**
14:15-14:50	*Relating the viscoelasticity of complex actin networks to single filament dynamics* A. Bausch (München)
14:50-15:15	*Bimodality in the fluctuations of a grafted semiflexible polymer and the diffusion-convection analogy* P. Benetatos (Berlin/Göttingen)
15:15-15:40	*Actin Filaments Confined in Microchannels* P. Levi (Erlangen)
15:40-16:10	**Coffee break**
Kroy	**Single Polymers II**
16:10-16:35	*Anisotropic semiflexible polymer dynamics* O. Hallatschek (Berlin/Harvard)
16:35-17:00	*t.b.a.* T. Fraps (München)
17:00-19:30	**Posters and Coffee**
20:00	**Dinner**

21. September 2005

Gompper	**Complexes ...**
9:00-9:35	*Microscopic modelling of DNA: From Chromatin to Nanomachines* R. Netz (München)
9:35-10:10	*Optical tweezers to study the acting of DNA-binding proteins on single chains of DNA* F. Kremer (Leipzig)
10:10-10:45	*The nucleosome: A transparent, slippery, sticky and yet stable DNA-protein complex* H. Schiessel (Leiden)
10:45-11:15	**Coffee break**

21. September 2005 (continued)

Käs	**... and Bundles**
11:15-11:40	*Depletion-induced bundling of actin filaments* T. Gisler (Konstanz)
11:40-12:05	*Discontinuous unbinding transitions of filament bundles* J. Kierfeld (Potsdam)
Netz	**Mikado and Tensegrity**
12:05-12:40	*Intracellular space as active viscoplastic body: Do cells behave as Tensegrity Structures?* E. Sackmann (München)
12:40-13:15	*Stiff Polymers, Foams and Fiber Networks* E. Frey (München)
13:15-14:15	**Lunch break**
Schwarz	**Gels, Dead and Alive I**
14:15-14:50	*Dynamics of Gelation* A. Zippelius (Göttingen)
14:50-15:25	*Intracellular Molecular Machines Formed by Polymeric Films and Active Nanoelements* J. Käs (Leipzig)
15:25-15:55	**Coffee break**
Bausch	**Gels, Dead and Alive II**
15:55-16:30	*Order and Flow in Active Filament Solutions* T.B. Liverpool (Leeds)
16:30-16:55	*Hydrodynamic theory of active polar gels* K. Kruse (Dresden)
16:55-17:20	*Spontaneous flows and instabilities in active gels : applications to cytoskeleton dynamics* R. Voituriez (Paris)
17:20-17:50	**Coffee break**
Schiessel	**Light at the End of the Tunnel**
17:50-18:15	*Probing slow dynamics in time and space with multiple light scattering* F. Scheffold (Fribourg)
18:15-18:40	*Living Optical Fibers in the Retina* J. Guck (Leipzig)
18:40-19:05	*Fundamentals of Thermophoresis for Bioanalysis* D. Braun (München)