Dossier

Andrea Gambassi

October 9, 2008

Content:

Curriculum vitæ et studiorum

Name	Andrea Gambassi
Sex	Male
Place and date of birth	Montevarchi, AR (Italy), December 5th, 1976
Marital status	Single
Citizenship	Italian
Current Address	Max-Planck-Institut für Metallforschung, Heisenbergstrasse 3, D-70569 Stuttgart Office 5E13 Tel: +49-711-6891938 Fax: +49-711-6891922 e-mail: `gambassi@mf.mpg.de`

Studies

- 1995 - 1999: Undergraduate studies in Physics, University of Pisa and Scuola Normale Superiore of Pisa (Italy).
- August - September 1998: Summer Student at the Fermi National Accelerator Laboratory of Batavia, IL (USA).
- 26 October 1999: Laurea degree in Physics, 110/110 *cum laude*.
  Field: Nonequilibrium Statistical Mechanics, Field Theory
  Title of the Laurea Thesis: *"Analytic Determination of Finite Size Scaling Functions for Nonequilibrium Critical Phenomena"*, in Italian
  Advisors: Prof. Sergio Caracciolo (SNS); Prof. Andrea Pelissetto (University of Rome -"La Sapienza").
- 26 November 1999: Diploma in Physics of the Scuola Normale Superiore, 70/70 *cum laude*.
  Discussed Theme: *Phase Transitions in Driven Diffusive Systems.*
- 2000 - 2002: Ph. D. Student in Physics at the Scuola Normale Superiore, Pisa (Italy).
- 10 January 2003: Ph. D. degree in Physics, 70/70 *cum laude*.
  Title of the thesis: *"Dynamic Critical Behavior of Non-Equilibrium Systems"*
  Advisor: Prof. Sergio Caracciolo (University of Milano, Italy)
  Referees: Royce K. P. Zia, Leticia F. Cugliandolo.

Scientific Career:

- February 2003 - December 2004: Post-Doc in Prof. Dietrich's Group at the Max-Planck-Institut für Metallforschung, Stuttgart (Germany).
- December 2004 - November 2010: (non-tenure) Researcher at the Max-Planck-Institut für Metallforschung (Department of Prof. Dietrich), Stuttgart (Germany).
- 31 January 2007: "Qualification" as *Maître de conférence* (section 30-Milieux dilués et optique) granted by the French National Council of Universities (CNU).

Scientific visits:

- 30 July - 15 August 2002: Short-term visitor at the Department of Physics, Virginia Polytechnic Institute and State University, Blacksburg, VA (USA).
  Invited by Prof. R. K. P. Zia and Prof. B. Schmittmann.

- 25-30 August 2003: (Short-term) Visiting Scientist in the "Statistical Mechanics and Interdisciplinary Applications" Research Group within the Condensed Matter Section at the Abdus Salam International Centre for Theoretical Physics (ICTP), Trieste (Italy).
  Invited by Prof. L. F. Cugliandolo.

- 25 September - 5 October 2007: Invited lecturer at the Department of Physics, University of Milano (Italy). [details about the lectures are supplied at p. 12]
  Invited by Prof. S. Caracciolo.

- 19 November - 24 November 2007: Short-term visitor at the Laboratoire de Physique Théorique d'Orsay, Université de Paris-Sud, Orsay (France).
  Invited by Dr. G. Schehr.

- 26 November - 20 December 2007: Invited lecturer at the International School for Advanced Studies (SISSA), Trieste (Italy). [details about the lectures are supplied at p. 12]
  Invited by Prof. G. Mussardo.

- 24 February - 21 March 2008: Visitor at the Ian Wark Research Institute, University of South Australia, Adelaide (Australia).
  Invited by Prof. John Ralston, Director.

- 28 September - 4 October 2008: Short-term visitor at the Laboratoire de Physique Théorique d'Orsay, Université de Paris-Sud, Orsay (France).
  Invited by Dr. G. Schehr and Prof. H. Hilhorst.

- 27 October - 14 November 2008: Invited research stay within the program *The Theory and Practice of Fluctuation-Induced Interactions* at the Kavli Institute for Theoretical Physics, Santa Barbara (USA).

Academic Awards and Distinctions:

- 1995: Via a national entrance examination, admitted to the Scuola Normale Superiore, Pisa (Italy), as one of the 27 undergraduate fellows of the Classe di Scienze.

- 1999: *"Supremae Dignitatis" Medal* awarded by the University of Pisa for the graduation result achieved in the Laurea degree.

- 2000: Via a national entrance examination, admitted to the Scuola Normale Superiore, Pisa (Italy), as one of the 10 graduate fellows in Physics of the Classe di Scienze.

- 2003: *Premio di Operosità Scientifica* (prize for scientific activity) awarded by the Società Italiana di Fisica (Italian Physical Society).

Grants:

- 1995-1999: Undergraduate Fellowship at the Scuola Normale Superiore, Pisa (Italy).
- 1998: INFN (National Institute of Nuclear Physics) Scholarship for the participation to the INFN - Summer Student Program at the Fermi National Accelerator Laboratory, Batavia, IL (USA).
- 1999-2002: Financially supported by INFN within the Research Project PI11 (INFN Sezione di Pisa): *Quantum and Statistical Theory of Fields.*
- 2000-2002: Graduate Fellowship at the Scuola Normale Superiore, Pisa (Italy).
- 2003: Grant by the European Commission, contract HPCF-CT-2002-00362 COSYMA, covering half of the participation fee of the International School of Physics "Enrico Fermi", Course CLV, Varenna (Italy), 1-11 July 2003.

Teaching

[For additional details on the teaching activities see p. 11]

- Summer Semester 2005: Special lectures (*Spezialvorlesungen*) at the Department of Physics, University of Stuttgart (Germany): *Field Theory in Statistical Physics.*
- Summer Semester 2006: Exercise course for the MSc program in Physics of the University of Stuttgart (Germany): *Thermostatistics.*
- Winter Semester 2006: Exercise course for the MSc program in Physics of the University of Stuttgart (Germany): *Quantum Mechanics.*
- 25 September - 5 October 2007: Invited lectures for PhD students of the Department of Physics of the University of Milano (Italy): *Stochastic dynamics in Statistical Physics.*
- 26 November - 19 December 2007: Invited lectures for PhD students in Physics at SISSA (International School for Advanced Studies), Trieste (Italy): *Stochastic dynamics in Statistical Physics.*
- Summer Semester 2008: Exercise course for the Diplom un BSc courses at the University of Stuttgart (Germany): *Theoretische Physik I, Mechanik*

Student Supervision

- November 2004 - December 2006: co-supervision of the PhD project of Luca Alloatti.
- January 2005 - February 2008: co-supervision of the PhD work of Carlo Dotti.

Professional Activities

- Referee for:
  1. Journal of Physics: Condensed Matter (2003-)
  2. Europhysics Letters (2004-)
  3. Journal of Physics A: Mathematical and Theoretical (2004-)
  4. European Physical Journal E (2004-)
  5. European Physical Journal B (2005-)
  6. Physical Review E (2006-)
  7. Journal of Statistical Mechanics: Theory and Experiments (2006-)
- Member:
  1. Società Italiana di Fisica (2002-)
  2. European Physical Society (2002-)
  3. Deutsche Physikalische Gesellschaft (2005-)

Invited talks at conferences, schools and workshops:

1. Workshop Progress in nonequilibrium statistical Physics and disordered systems - Atelier Nancy 2003, LPM, Nancy (France), 21-22 May 2003.
   Talk: *Aging in ferromagnetic systems at criticality.*

2. International Seminar on Non-Equilibrium Statistical Physics in Low Dimensions and Reaction Diffusion Systems, Max-Planck Institut für Physik Komplexer Systeme, Dresden (Germany), 22 September - 3 October 2003.
   Talk: *The Driven Lattice Gas: which Universlity Class?*

3. Meeting Soft Matter at Interfaces, Ringberg 2004, Ringberg Castle, Germany, 23 - 25 February 2004.
   Talk: *Critical Dynamics in Confined Systems*

4. Summerschool Ageing and the Glass Transition, University of Luxembourg (Luxembourg city), 18 - 24 September 2005.
   Invited lecture: *Slow dynamics at critical points: the field-theoretical perspective.*

5. 6th NTZ-Workshop on *Computational Physics* CompPhys05, Institut für Theoretische Physik, Universität Leipzig, Leipzig (Germany), 1-2 December 2005.
   Talk: *Critical behavior of the two-dimensional randomly driven lattice gas.*

6. *Statistical Physics and Low Dimensional Systems*, atelier des groupes Physique Statistique et Surfaces et Spectroscopies, LPM, Université Henri Poincaré, Nancy (France), 17-19 May 2006.
   Talk: *Finite-size scaling in the non-equilibrium critical behavior of the randomly driven lattice gas: The field-theoretical approach.*

7. XXIV Convegno *Fisica Teorica e Struttura della Materia* [Theoretical Physics and Structure of Matter], Levico Terme (Italy), 17 - 20 September 2006.
   Talk: *Fenomeni critici in stati stazionari di non-equilibrio: il caso della diffusione forzata* [Critical phenomena in non-equilibrium steady states: The case of driven diffusion]

8. XIII workshop on Statistical Mechanics and non perturbative Field Theory, Bari (Italy), 20-22 September 2006.
   Talk: *A closer look at Critical Points: Slow dynamics, aging and their universal features.*

9. *Statistical Physics and Low Dimensional Systems 2007*, atelier des groupes Physique Statistique et Surfaces et Spectroscopies, LPM, Université Henri Poincaré, Nancy (France), 23-25 May 2007.
   Talk: *Dynamic crossover in the persistence properties of critical systems.*

10. StatPhys23: XXIII IUPAP International Conference on Statistical Physics, Genova (Italy), 9-13 July 2007.
    Invited talk in the topical session "Phase transitions and critical phenomena": *Relaxation phenomena at criticality.*

11. Meco33: 33rd Conference of the Middle European Cooperation in Statistical Physics, Puchberg/Wels (Austria) 14-16 April 2008.
    Talk: *Thermodynamic Casimir effect: fluctuation-induced forces at work.*

12. International workshop 60 years of Casimir effect, ICCMP, University of Brasilia (Brazil), 23-27 June 2008.
    Talk: *The Casimir effect: from quantum to critical fluctuations.*

Invited seminars:

1. Institut für Theoretische Physik I, Universität Erlangen-Nürnberg, Erlangen (Germany), 26 June 2003.
   Talk: *Field-theoretical approach to Nonequilibrium Critical Dynamics of Ferromagnetic Spin Systems.*

2. The Abdus Salam International Centre for Theoretical Physics (Condensed Matter Section), Trieste (Italy), 27 August 2003.
   Talk: *The Fluctuation-Dissipation Ratio in Critical Dynamics.*

3. Fachbereich Physik, Universität Duisburg - Essen, Essen (Germany), 6 May 2004.
   Talk: *The Universality Class of the Driven Lattice Gas: A never-ending debate?*

4. King's College, London, 16th January 2006.
   Talk: *How does the Ising model age? A look at its universal features.*

5. Service de Physique Théorique, CEA, Saclay, 20 April 2006.
   Talk: *How does the Ising model age? A look at its universal features.*

6. Institut für Theoretische Physik I, Universität Erlangen-Nürnberg, Erlangen (Germany), 12-14 June 2006.
   Talk (tutorial): *The Casimir effect: From Quantum Electrodynamics to Statistical Physics.*

7. *SISSA – International School for Advanced Studies*, Trieste, Italy, 25 October 2006.
   Informal Talk: *A closer look at Critical Points: Slow dynamics, aging and their universal features.*

8. *ICTP – International Centre for Theoretical Physics*, Trieste, Italy, 26 October 2006.
   Joint Seminar SISSA-ICTP: *Non-equilibrium critical behaviors in Driven Diffusive Systems.*

9. *ICP – Institut für Computerphysik*, Stuttgart, Germany, 6 November 2006.
   Kolloquium: *Casimir effect in QED and statistical physics.*

10. Service de Physique Théorique, CEA, Saclay, 15 January 2007.
    Talk: *Aging and persistence in the non-equilibrium critical relaxation of the Ising model*

11. Laboratoire de Physique Théorique de l'Ecole Normale Supérieure (LPTENS), Paris, 16 January 2007.
    Talk: *Aging and persistence in the non-equilibrium critical relaxation of the Ising model*

12. Laboratoire de Physique Théorique d'Orsay, Orsay, France, 18 January 2007.
    Séminaire commun LPT/LPTMS (Physique Statistique des Systèmes Complexes): *Aging and persistence in the non-equilibrium critical relaxation of the Ising model*

13. *SISSA – International School for Advanced Studies*, Trieste, Italy, 10 December 2007.
    Lecture: *The Casimir effect: From quantum electrodynamics to statistical physics.*

14. *SISSA – International School for Advanced Studies*, Trieste, Italy, 12 December 2007.
    Talk: *A closer look at the non-equilibrium critical relaxation.*

15. *Ian Wark Research Institute*, Adelaide, Australia, 27 February 2008.
    Talk: *The critical Casimir effect: Measuring and tailoring femto-Newton forces.*

16. Laboratoire de Physique Théorique d'Orsay, Orsay, France, 2 October 2008.
Séminaire commun LPT/LPTMS (Physique Statistique des Systèmes Complexes): *The Casimir effect: from quantum to critical fluctuations.*

Contributions to Conferences, Schools, and Seminars:

- Research Workshop Self-Organized Criticality and Phase Transitions in Driven Systems, ICTP, Trieste (Italy), 1-4 March 2000.
  Poster contribution: *Finite–Size Scaling for the Driven Lattice Gas.*

- Tutorial activity during the XXIII Corso di Orientamento Universitario (XXIII University Guidance Course for High-School Italian students), Cortona (Italy), 2 - 8 September 2001.
  Tutorial lecture: *Meccanica Statistica* (Statistical Mechanics), for selected high-school students.

- Max-Planck Institut für Metallforschung, Department Dietrich, Stuttgart (Germany), 21 February 2002.
  Talk: *Finite-Size Critical Behaviour of the Driven Lattice Gas.*

- 5th International Conference Renormalization Group 2002, Tatranska Strba (Slovakia), 10 - 16 March 2002.
  Short Talk: *Aging in ferromagnetic systems at criticality near four dimensions.*

- XI workshop on Statistical Mechanics and non perturbative Field Theory, Bari (Italy), 26-28 September 2002.
  Short Talk: *Aging in ferromagnetic systems at criticality: field-theoretical approach.*

- Department of Physics "E. Fermi", Università degli Studi di Pisa (Italy), 24 January 2003.
  Informal seminar: *Aging e violazioni del teorema di fluttuazione-dissipazione in sistemi con dinamica lenta: dai vetri ai ferromagneti* (Aging and violation of the fluctuation-dissipation theorem in systems with slow dynamics: From glasses to ferromagnets).

- Selected as a Student of the International School of Physics "Enrico Fermi", *The Physics of Complex Systems (New Advances and Perspectives)*, Course CLV, Varenna (Italy), 1-11 July 2003.
  Poster contribution: *Aging Properties of Ferromagnets: a Field-Theoretical Approach.*

- IX Convegno Nazionale di Fisica Statistica e dei Sistemi Complessi (IX Italian National Congress on Statistical Physics and Complex Systems), University of Parma (Italy), 22-24 June 2004.
  Short Talk: *Aging and Critical Dynamics: what can we learn from Field Theory?.*

- 69. Jahrestagung der Deutschen Physikalischen Gesellschaft (69th annual meeting of the German Physical Society), Berlin (Germany), 4-9 March 2005.
  Contributed talk: *Aging Properties of Critical Systems: the Renormalization-Group Approach.*

- 71. Jahrestagung der Deutschen Physikalischen Gesellschaft (71th annual meeting of the German Physical Society), Regensburg (Germany), 26-30 March 2007.
  Contributed talk: *Nonequilibrium relaxation and critical Casimir forces.*

- Laboratoire Matière et Systèmes Complexes, Université de Paris VII – Denis Diderot, Paris (France), 10 May 2007.
  Lunch-talk: *Aging, persistence, and criticality.*

Participation to Conferences and Schools:

- International Conference New Trends in Statistical Mechanics, Certosa di Pontignano, Siena (Italy), 21 - 25 May 2000.
- VI Convegno Nazionale di Fisica Statistica e dei Sistemi Complessi (VI Italian National Congress on Statistical Physics and Complex Systems), University of Parma (Italy), 29-31 May 2001.
- N.A.T.O. Advanced Research Workshop on Statistical Field Theories, Villa Olmo, Como (Italy), 18 - 23 June 2001.
- International Summer School Fundamental Problems in Statistical Physics X, Altenberg (Germany), 20 August - 1 September 2001. (Selected participant.)
- DIMACS Meeting on Computational Complexity, Entropy and Statistical Physics, DIMACS Center, Rutgers University (USA), 14 December 2001.
- 86th Statistical Mechanics Conference, Rutgers University (USA), 16 - 18 December 2001.
- International Conference Field Theory and Statistical Mechanics, Rome (Italy), 10 - 15 June 2002.
- Meeting Soft Matter at Interfaces 2003, Ringberg castle (Germany), 28-30 July 2003.
- Opening of the LXXXIX Congresso Nazionale (89th general meeting) of the Società Italiana di Fisica (Italian Physical Society), Parma (Italy), 17 September 2003.
- Workshop Lengthscales and Heterogeneous Dynamics in Glassy Materials, New College, Oxford (UK), 22-25 September 2004.
- Meeting Soft Matter at Interfaces 2005, Ringberg castle (Germany), 23-25 May 2005.
- International Summer School Fundamental Problems in Statistical Physics XI, Leuven (Belgium), 4 - 17 September 2005. (Selected participant.)
- Workshop Relaxation Dynamics of Macroscopic Systems, Isaac Newton Institute for Mathematical Sciences, University of Cambridge, Cambridge (UK), 9-13 January 2006. (Selected participant.)
- Meeting Soft Matter at Interfaces 2006, Ringberg castle (Germany), 6-8 March 2006.
- School Non-Equilibrium Dynamics of Interacting Particle Systems, Isaac Newton Institute for Mathematical Sciences, University of Cambridge, Cambridge (UK), 27 March - 7 April 2006. (Selected participant.)
- International Workshop Dynamics and Relaxation in Complex Quantum and Classical Systems and Nanostructures, Max-Planck-Institut für Physik komplexer Systeme, Dresden (Germany), 24 July - 3 August 2006. (Selected participant.)
- Informal meeting on Statistical Physics, SISSA, Trieste (Italy), 14-15 December 2006.
- Meeting Soft Matter at Interfaces 2007, Ringberg castle (Germany), 2-4 April 2007.
- Meeting Soft Matter at Interfaces 2008, Ringberg castle (Germany), 31 March - 2 April 2008.

Summary of teaching activities

Summer semester 2005:
Course "Field Theory in Statistical Physics: From seawaves to elementary particles" for PhD students in Physics of the university of Stuttgart (Germany). Lectures and tutorials in collaboration with Dr. Martin Oettel:
<u>Duration:</u> 26 hours of theory + 8 hour of exercises and tutorials (of which I taught about 14 hours of theory + 5 hours of exercises).
Theory:
General introduction (relevance of field theory for the physics of solids, fluids etc.; foundations of quantum mechanics). Propagator in quantum mechanics: the case of a free quantum particle. Feynman-Kac formula (path integral, functional integral). Harmonic oscillator and its propagator (detailed calculation on the lattice and in the continuum). Calculation of quantum-mechanical energy levels from the propagator. Path integral with topological constraints (cylinder and segment). Semiclassical approximation for the propagator within the Euclidean formalism. Tunneling processes. Instantons. Brownian motion and Wiener integral. Relation with the diffusion equation. Random walk in one dimension. Wiener's path integral. Application: first-passage problem. The Casimir effect in statistical mechanics: Path integral in the presence of spatial boundaries, surface waves in liquids and Casimir effect in quantum electrodynamics. Basics of perturbation theory for the functional integral.
Tutorials:
Solution of the exercises and problems assigned during the theoretical lectures.

Summer Semester 2006:
Course "Thermostatistics", for Master students (MSc) of the "international master program" of the University of Stuttgart:
Tutorials: I collaborated with Dr. Mihail Popescu in preparing the assignments (12 exercise sheets, with 2 or 3 exercises each) and the solutions for the theoretical course (approx. 40 hours, one semester) held by Prof. Siegfried Dietrich at the University of Stuttgart.
Content of the exercises: temperature and heat, mechanical work, first and second principles of thermodynamics. Thermodynamic processes, perfect gas. Internal energy etc. quasi-static transformations. Phase equilibria. Phase transitions.

Winter Semester 2006/2007:
Course "Quantum Theory", for Master students (MSc) of the "international master program" of the University of Stuttgart:
Tutorials (approx. 30 hours): I prepared the exercises (15 exercise sheets, with 2 or 3 exercises each) for the theoretical course (approx. 45 hours) held by Prof. Siegfried Dietrich at the University of Stuttgart. I met the students once a week for approx. 90 minutes, discussing the solutions of the assignments.
Content of the exercises: Waves, differential equations, Compton scattering, Bohr-Sommerfeld atomic model, material waves, delta distribution, Ehrenfest theorem, wave function, propagator, Schrödinger equation, two-level systems, uncertainty relations, eigenvalues and eigenvectors, dynamics of two-level systems, one-dimensional problems (square well, harmonic oscillator, semi-infinite harmonic oscillator, tunneling of potential barriers, bound states, scattering states, scattering and transfer matrix). Operators, commutators, coherent states, Baker-Campbell-Hausdorff formula. Kronig-Penney model (band structure of solid). Rotations and angular momentum.

25 September - 5 October 2007:
Invited lectures "Stochastic dynamics in Statistical Physics", for PhD students at the Department of Physics, University of Milano (Italy):
Duration: 13 hours.
Content:
(A) *Basics:* General introduction; Stochastic processes; Markov processes and chains; Brownian motion; Master equation; Detailed balance; Equilibrium and non-equilibrium steady states; Kramers-Moyal expansion and Fokker-Planck equation; Pawula's theorem. Some examples of stochastic processes: (i) one-dimensional random walk (ii) branching and decay process, non-equilibrium phase transitions, methods of characteristics; Langevin equation for the Brownian motion; Einstein's relation; Ito and Stratonovich calculus. From the Langevin to the Fokker-Planck equation; Purely dissipative dynamics; Fluctuation-dissipation theorem.
Functional methods (from stochastic systems to field theory): Fluctuations, correlations and field-theoretical methods; Lotka-Volterra model; Discrete stochastic interacting particle systems; Fock-space representation of the Master Equation; Coherent states and their properties: Field-theoretical action associated with the stochastic dynamics of discrete interacting particle systems; Examples of reaction-diffusion systems. Langevin equation from the Master equation and problems with imaginary noise.
(B) Some examples of field-theoretical actions: brancing and decay with coaugulation; mean-field approximation and power counting. Field-theoretical representation of Langevin equations (response function formalism); response field; consequences of causality; the role of the determinant.

26 November - 19 December 2007:
Invited lectures "Stochastic dynamics in Statistical Physics", for PhD students in Physics at SISSA (International School for Advanced Studies), Trieste (Italy):
Duration: 17 hours.
Content:
(A) In this part I presented the same topics as in part (A) of the lectures I gave in Milano (see above).
(B) Some examples of field-theoretical actions: brancing and decay with coaugulation and its relation with directed percolation (heuristic); Mean-field approximation and power counting; Renormalization at one loop in the dimensional expansion; Callan-Symanzik equation for the propagator and its solution via the method of characteristics; Scaling behaviour, (non-equilibrium) critical exponents, and physical meaning of the propagator. Field-theoretical representation of Langevin equations (response function formalism): From stochastic equations to dynamic functionals; Response fields; consequences of causality; the role of the Jacobian determinant. Use of Grassmann variables to account for the determinant. Superfields, superspace, and BRS symmetry of the dynamic functional. The case of purely dissipative Langevin equation: Supersymmetry (SUSY) of the associated dynamic functional and fluctuation-dissipation theorem as a consequence of SUSY.

Summer Semester 2008:
Course "Theoretische Physik I, Mechanik", for Diplom un BSc students the University of Stuttgart:
Tutorials (approx. 25 hours): I reviewed the solution of the exercises (12 exercise sheets, with 4 or 5 exercises each) for the theoretical course (approx. 45 hours) held by Prof. Siegfried Dietrich at the University of Stuttgart. I met the students once a week for approx. 120 minutes, discussing the solutions of the assignments.
Content of the exercises: Review of differential equations, vector calculus; transformations between co-

ordinate systems, inertial forces; equations of motion and various applications; non-conservative/conservative fields, potential of the forces, gravitational field; action; relativistic equation of motion for a particle; two-body problem; variational calculus and Euler-Lagrange equation; central potentials and Kepler's problem; scattering cross-sections.

Publications

Authors, if listed in alphabetical order, have equally contributed to the research presented in the publication. A non-alphabetical order, instead, reflects a difference in the authors' contributions.

Preprints/in preparation

1. A. Gambassi and P. Calabrese,
Quantum quench close to a critical point: Landau-Ginzburg evolution of the order parameter (2008).

2. O. Vasilyev, A. Gambassi, A. Maciołek, and S. Dietrich,
Universal scaling functions of critical Casimir forces obtained by Monte Carlo simulations (2008).

3. A. Gambassi, A. Maciołek, C. Hertlein, U. Nellen, L. Helden, C. Bechinger, and S. Dietrich,
Critical Casimir effect in binary liquid mixtures: femtonewton forces at work (2008).

4. R. Paul, A. Gambassi, and G. Schehr,
Dynamic crossover in the persistence of manifolds at criticality (2008).

5. C. Dotti, A. Gambassi, M. N. Popescu, and S. Dietrich,
Driven lattice gas model for fluid transport through a slit-like narrow pore (2008).

6. A. Gambassi,
The Casimir effect: from quantum to critical fluctuations (2008),
(Contribution to the proceedings of the conference "60 Years of Casimir Effect", ICCMP, Brasilia, June 2008).

Regular articles

1. S. Caracciolo, A. Gambassi, M. Gubinelli, and A. Pelissetto,
Finite-size correlation length and violations of finite-size scaling,
Eur. Phys. J. B **20**, 255-265 (2001) (published 21.12.2000)
[e-print `cond-mat/0010479`].

2. R. Contino, A. Gambassi,
On Dimensional Regularization of Sums,
J. Math. Phys. **44**, 570-587 (2003) (published February 2003)
[e-print `hep-th/0112161`].

3. P. Calabrese and A. Gambassi,
Aging in ferromagnetic systems at criticality near four dimensions,
Phys. Rev. E **65**, 066120 (2002) (6 pages) (published 25.06.2002)
[e-print `cond-mat/0203096`].

4. P. Calabrese and A. Gambassi,
Two-loop Critical Fluctuation-Dissipation Ratio for the Relaxational Dynamics of the $O(N)$ Landau-Ginzburg Hamiltonian,
Phys. Rev. E **66**, 066101 (2002) (12 pages) (published 04.12.2002)
[e-print `cond-mat/0207452`].

5. P. Calabrese and A. Gambassi,
Aging and fluctuation-dissipation ratio for the diluted Ising Model,
Phys. Rev. B **66**, 212407 (2002) (4 pages) (published 20.12.2002)
[e-print `cond-mat/0207487`].

6. P. Calabrese and A. Gambassi,
Aging at criticality in Model C dynamics,
Phys. Rev. E **67**, 036111 (2003) (7 pages) (published 20.03.2003)
[e-print `cond-mat/0211062`].

7. S. Caracciolo, A. Gambassi, M. Gubinelli, and A. Pelissetto,
Transverse Fluctuations in the Driven Lattice Gas,
J. Phys. A: Math. Gen. **36** (2003) L315-L320 (published 13.05.2003)
[e-print `cond-mat/0211669`].

8. S. Caracciolo, A. Gambassi, M. Gubinelli, and A. Pelissetto,
Shape dependence of the finite-size scaling limit in a strongly anisotropic $O(\infty)$ model,
Eur. Phys. J. B **34**, 205-217 (2003) (published 04.08.2003)
[e-print `cond-mat/0304297`].

9. S. Caracciolo, A. Gambassi, M. Gubinelli, and A. Pelissetto,
Finite-Size Scaling in the Driven Lattice Gas,
J. Stat. Phys. **115**, 281-322 (2004) (published April 2004)
[e-print `cond-mat/0312175`].

10. S. Caracciolo, A. Gambassi, M. Gubinelli, and A. Pelissetto,
Comment on "Dynamic behavior of anisotropic non-equilibrium driving lattice gases",
Phys. Rev. Lett. **92**, 029601 (2004) (1 page) (published 14.01.2004)
[e-print `cond-mat/0305213`].

11. S. Caracciolo, A. Gambassi, M. Gubinelli, and A. Pelissetto,
Reply to "Comments to the letter Transverse fluctuations in the driven lattice gas*" by E. V. Albano*,
J. Phys. A: Math. Gen. **37** (2004) 8193-8195. (published 04.08.2004)

12. P. Calabrese and A. Gambassi,
On the definition of a unique effective temperature for non-equilibrium critical systems,
J. Stat. Mech.: Theor. Exp. P07013 (2004) (31 pages) (published 30.07.2004)
[e-print `cond-mat/0406289`].

13. P. Calabrese and A. Gambassi,
Ageing Properties of Critical Systems, (**invited topical review**)
J. Phys. A: Math. Gen. **38** (2005) R133-R193 (published 18.04.2005)
[e-print `cond-mat/0410357`].

14. M. Pleimling and A. Gambassi,
Corrections to local scale invariance in the non-equilibrium dynamics of critical systems: numerical evidences,
Phys. Rev. B **71**, 180401(R) (2005) (4 pages) (published 02.05.2005)
[e-print `cond-mat/0501483`].

15. S. Caracciolo, A. Gambassi, M. Gubinelli, and A. Pelissetto,
Critical Behavior of the Two-Dimensional Randomly Driven Lattice Gas,
Phys. Rev. E **72**, 066111 (2005) (4 pages) (published 09.11.2005)
[e-print `cond-mat/0507614`].

16. A. Gambassi and S. Dietrich,
Critical dynamics in thin films,
J. Stat. Phys. **123**(5), 929-1005 (published 31.05.2006)
[e-print `cond-mat/0509770`].

17. A. Gambassi and S. Dietrich,
Relation between the thermodynamic Casimir effect in Bose-gas slabs and critical Casimir forces,
Europhys. Lett. **74**(4), 754-755 (2006) (published 07.04.2006)
[e-print `cond-mat/0602630`].

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Research activity

I am currently interested in the static and dynamic properties of statistical systems, especially under non-equilibrium conditions.

In particular I am working on the precise characterization of [**A**] collective behaviors emerging in the non-equilibrium stationary state of some driven lattice-gas models and [**B**] of slow dynamics (aging and persistence) in statistical systems. The action of external forces [A] and a slow dynamics [B] are indeed the two major causes for non-equilibrium behavior and are currently under intensive theoretical and experimental investigation.

Confined systems (e.g., thin films of magnetic materials or wetting layers of fluids) allow the experimental study of the combined effect of surfaces and confinement on the collective behavior of statistical systems. I am interested in providing theoretical predictions for the experimentally accessible quantities which characterize this effect and in particular in the equilibrium and non-equilibrium dynamics of the thermodynamic Casimir effect [**C**].

The dynamics of fluids at the micro- and nano-meter scale is the subject of current theoretical interest in view of its applications in microreactors and chemical sensors. Kinetic lattice-gas models and generalized hydrodynamic approaches are useful tools for understanding some qualitative features of the spreading dynamics of fluid monolayers. I am currently working on generalizations of these models [**D**].

Keywords: Phase Transitions, Renormalization Group, Field Theory, Stochastic Dynamics, Dynamic Critical Phenomena, Coarsening, Finite-Size Scaling, Lattice-Gas Models, Surface Critical Phenomena, Non-equilibrium Behavior, Aging, Persistence, Classical Spin Models, Reaction-diffusion Systems, Fluctuation-Dissipation Relations, Effective Temperature, Quantum Phase Transitions, Critical Casimir Effect, Wetting Films, Microfluidics

A. Driven lattice gases and their phase transitions

In collaboration with: S. Caracciolo (University of Milan), A. Pelissetto (University of Rome), M. Gubinelli (Département de Mathématiques - Université de Paris-Sud).

In our research activity we focus on some of the simplest non-trivial lattice models (in more than one spatial dimension) reaching a non-equilibrium stationary state, i.e., the driven lattice gas (DLG) and the randomly driven lattice gas (RDLG). The DLG is a natural non-equilibrium generalization of the Ising (lattice gas) model and thus it is expected to provide a paradigm of non-equilibrium critical behavior. In spite of its simplicity, there has been a long-standing controversy about the universality class of the DLG phase transition. This was mainly due to some discrepancies observed between field-theoretical predictions and Monte Carlo simulations (MCs), related to subtleties in the Finite-Size Scaling (FSS) for such a system. On this basis, some authors criticized the field theory used to describe the critical properties of the DLG, proposing an alternative field-theoretical description which eventually turned out to be the same as the one capturing the critical properties of the RDLG. To tackle the crucial problem of FSS we adopted, for the first time in non-equilibrium critical phenomena, an alternative approach, which is more constrained (no tunable parameters) than the methods previously and usually used to characterize the critical behavior. For this purpose we need to determine a suitable finite-volume correlation length ξ_L of the system. Previous studies in this direction failed because of the generic power-law decay of two-point correlations in the stationary state of the DLG. (As opposed to the Ising model in which these correlations decay algebraically *at* the critical point and otherwise exponentially.) Thanks to some preliminary studies of equilibrium models [A1] we were able to give a proper definition of ξ_L [A2] and then we tested its properties by means of MCs of the two-dimensional DLG [A3]. This allowed us to discriminate between the predictions coming from the different proposed field theories, by looking at qualitative features of the critical fluctuations in the model. We confirmed the standard picture on the basis of a more quantitative analysis and of a comparison with the predictions for the universal FSS functions that we worked out from the field theory [A4]. In spite of our results, recent findings still show a surprising agreement between MCs of the DLG and the predictions of the field theory for the RDLG universality class. Although we have not yet been able to account completely for these findings (partly questioned in [A5]), we think that they can be reconciled with the standard picture taking into account peculiarities of the FSS in strongly anisotropic systems (which we have investigated in [A6] for equilibrium models). In this respect, we are probably very close to obtaining a consistent and clear picture of the critical properties of the DLG, solving a ten-year old puzzle on an important model.

Recently we have adopted our approach to FSS in order to study the critical properties of the two-dimensional RDLG and to test also the sensitivity of the method. Comparing the MC results for the DLG and the RDLG we have indeed found that in finite volume and particular lattice geometries they are barely distinguishable. This might partly explain the puzzling findings mentioned above about the DLG universality class. Nevertheless our analysis is able to detect qualitative differences between them [A7]. Within the field-theoretical approach we have worked out (taking advantage of a suitable regularization method devised in [A8]) the one-loop predictions for the universal FSS functions of some of the quantities we measured in MCs. The qualitative agreement is remarkable and provides a rather stringent test of the field-theoretical model used to describe the universal critical properties of the RDLG [A9], going beyond the sole comparison between infinite-volume quantities (such as critical exponents).

We are currently investigating the critical behavior of the DLG using short-time dynamic MCs (also in view of some of the recent findings mentioned above) and the possible crossover between DLG and RDLG due to biases in the external field.

B. Slow dynamics at critical points

In collaboration with: P. Calabrese (University of Pisa), F. Corberi (University of Salerno, Italy), L. F. Cugliandolo (Université de Paris VI), E. Lippiello (University of Salerno, Italy), M. Pleimling (Virginia Polytechnic Institute, USA), F. Baumann (Université de Nancy), F. Krzakala (ESPCI, Paris), Grégory Schehr (Université de Paris-Sud), R. Paul (University of Heidelberg), M. Zannetti (University of Salerno)

Systems with slow dynamics (e.g., glasses, granular matter etc.) are currently under intensive experimental and theoretical investigation. In some circumstances their dynamics becomes so slow that they can not equilibrate in finite time. As a consequence, they evolve always in non-equilibrium conditions, displaying novel dynamic phenomena such as *aging*. Quite recently it has been realized that this may also happen in non-complex systems: Simple models such as classical non-disordered ferromagnets quenched at or below their *critical point* (where the relaxation time diverges) have become very useful toy models to test some of the key ideas put forward in the context of complex systems. The fluctuation-dissipation ratio (FDR) has been introduced as a sort of measure of the "distance" from an equilibrium evolution. It has also been shown that, at least for some mean-field models of glasses, the FDR can be used to define a non-equilibrium temperature with a related "non-equilibrium thermodynamics". The interesting question is whether this can be done (and how) for non mean-field models as well. In view of these issues, in the past six years, there has been a lot of activity around the aging dynamics of ferromagnetic systems, with particular efforts to determine the FDR at criticality, by means of MCs and exact solutions of specific models. *Universality* of critical phenomena, on the other hand, can be exploited to provide analytical predictions for the quantities (such as two-time response and correlation functions of the order parameter) which characterize the non-equilibrium dynamics following a quench to the critical point. In a collaboration with P. Calabrese we adopted the field-theoretical renormalization-group approach [B1] to investigate the relevant aging properties of the non-equilibrium dynamics following a quench from the *high-temperature phase* to the *critical point*. We considered the non-equilibrium purely relaxational dynamics (Model A) of: (i) the d-dimensional $O(N)$ vector model at criticality (ϕ^4 Landau-Ginzburg Hamiltonian) in ϵ-expansion ($\epsilon = 4-d$) up to $O(\epsilon^2)$ [B2, B3, B4] (the N-vector model without $O(N)$-symmetry has been studied only up to $O(\epsilon)$ [B5]), (ii) the weakly dilute Ising model at first order in $\epsilon^{1/2}$ [B6], (iii) the d-dimensional $O(N)$ vector model at the tricritical point (ϕ^6 model) up to $O(\epsilon = 3-d)$ [B5], (iv) the ϕ^3 model at the critical point up to $O(\epsilon = 6-d)$ [B7]. Motivated by recent MCs we have also investigated the effects of planar surfaces (belonging to the Ordinary and Special surface universality classes) on the aging properties of Model A, providing general scaling forms and computing specific quantities within the Gaussian model [B7]. (In a collaboration with F. Baumann and M. Pleimling I am currently extending this investigation to the ϕ^4 model.) Up to one-loop we studied also the conserved dynamics (Model B) for the d-dimensional $O(N)$ vector model [B7] and the dynamics of a non-conserved order parameter coupled to a conserved density (Model C) [B8]. For all the models just mentioned we computed and analyzed the scaling behaviors of the two-time response and correlation functions of the order parameter, the associated universal scaling functions, and the long-time limit of the FDR. This analysis allowed us to provide the first analytical predictions (in the form of an expansion in the dimensionality d) for the FDR of non-exactly solvable models. (The only analytical results available in the literature were about a restricted number of exactly solvable models such as the Ising-Glauber chain and the Spherical Model.) Some of our predictions have been nicely confirmed by MCs. In addition, we provided also estimates for quantities which have not yet been measured, but which might be determined by experiments or MCs. We have summarized all these findings and the state of the art (up to mid-2005) in our topical review article on the aging properties of critical systems [B7].

We addressed also the problem of the definition – on the basis of the FDR – of a non-equilibrium *effective temperature* T_{eff} in systems undergoing critical aging. Indeed, some numerical findings seemingly indicate that this quantity is independent of the observable used to define it (this is the first requirement that a bona fide temperature should meet). Motivated by these results we have studied the general scaling properties of response and correlation functions for a generic observable of the $O(N)$ vector-model in the ϕ^4 universality class. It turned out that, within the mean-field (MF) approximation, the FDR (and therefore T_{eff}) is actually independent of the specific observable, whereas this is no longer the case beyond MF, as we checked explicitly in a one-loop calculation [B9].

The theory of Local Scale Invariance (LSI) has been proposed by M. Henkel and collaborators as an extension of Conformal Invariance to systems in which different spatial directions scale with different powers of the scaling factor in a scale transformation (strong anisotropy). Although some predictions based on LSI apparently agree with MCs, we have been able to show analytically that they disagree with our findings, at least at the critical point [B4, B6]. Thanks to a more careful analysis of numerical data, M. Pleimling and me [B10] have been able to detect such tiny discrepancies. As a consequence of these criticisms, the derivation of LSI has been revised, yielding, compared with the original proposal, more general predictions for the scaling properties of the non-equilibrium response function. Surprisingly, the available numerical data for some integrated response functions of the two-dimensional Ising-Glauber model (found to disagree with the previous version of LSI) surprisingly agree with the new predictions. This would imply that the quasi-equilibrium regime expected at short time differences in two-time response functions does not exist. Stimulated by this puzzling findings we have carried out a systematic and detailed numerical study [B11] of integrated (in time and space) and non-integrated response functions of this model in order to clarify whether this agreement is biased by the particular choice of the measured quantity or it actually supports the existence of the local dynamical symmetry predicted by LSI. Our numerical analysis clearly shows that the agreement is coincidental.

In collaboration with P. Calabrese and F. Krzakala we have investigated the case which is somehow complementary to the one previously considered: A ferromagnet (or, in general, a system with a second-order phase transition) is prepared in its *low-temperature phase* (i.e., with non-vanishing value of the order parameter and short-range correlations) and then suddenly *heated* to its *critical point* (where slow dynamics is expected). The aim of this study was to understand if (and how) a finite initial value of the order parameter affects the aging properties (such as scaling forms, scaling exponents, and FDRs) of the ensuing non-equilibrium critical relaxation, beyond the mean-field approximation and the case of lattice spin models with continuous symmetry which were already investigated in the literature. In particular, we focused on the Ising universality class with purely relaxational dynamics (Model A) and we studied the general scaling properties of the two-time response and correlation functions both by means of renormalization-group methods and by MCs [B12]. Interestingly enough, we found that: (i) the scaling behaviors of two-time quantities are characterized by a scaling exponent which – at variance with the case of a quench from the disordered state – is related to known critical exponents by a quite general scaling relation, confirmed both by MCs and field-theoretical calculations, (ii) the FDR is affected by the initial value of the magnetization and its long-time limit differs from that one in the absence of magnetization. As a consequence, an effective temperature $T_{\rm eff}$ defined on the basis of the FDR would be dependent on the thermal history of the model (a quite unconvenient property). In this study we have highlighted the crossover in the scaling properties of two-time quantities which is due to the initial value m_0 of the magnetization and which connects the behavior for $m_0 = 0$ (initially disordered state, extensively studied [B7]) to the one for $m_0 \neq 0$. We have recently extended these investigations to the case in which the model has a continuous symmetry and the initial state breaks this symmetry while having order parameter fluctuations with short range correlations. In particular we have analytically investigated the N-component vector model in the $O(N)$-symmetric universality class with purely dissipative dynamics (Model A) [B13]. We have found, as expected, that the aging properties of the order parameter components which are transverse to the decaying magnetization differ from those of the component which is parallel to it.

In collaboration with P. Calabrese and L. F. Cugliandolo we are trying to extend part of the previously mentioned investigations to the aging behavior in quantum systems (and quantum phase transitions) where the interplay between slow critical thermal and quantum fluctuations opens up a very rich scenario which is largely unexplored even though of possible experimental relevance.

The various instances of systems with slow dynamics mentioned above are characterized by the fact that their dynamics satisfy the *detailed balance condition* and therefore, out of the critical point, these models relax into *equilibrium* steady states characterized by dynamics which are invariant both under time translations and time reversal (no aging). On the other hand, there is a wide class of systems – such as the driven lattice gases discussed at point [A] above or the directed percolation – which do not satisfy this condition and therefore they eventually reach non-equilibrium stationary states. The dynamics in such states is not invariant under time-reversal symmetry although (generically) invariant under time translations. Very recently it has been pointed out that slowly relaxing fluctuation modes may emerge also in these cases, leading to a (spontaneous) breaking of the time-translational invariance and to aging phenomena. This naturally occurs when the system is quenched to its (non-equilibrium) critical point. Recent numerical investigations of the contact process (quenched from the active phase to the critical point) in one and two spatial dimensions have provided evidences of this fact. On the other hand, several questions remained unanswered, mainly concerning the general scaling properties of two-time response and correlation functions, the possibility of defining a quantity analogous to the FDR, and the degree of universality of them. In collaboration with F. Baumann we have investigated this problem by taking a field-theoretical approach [B14]: As in the case of the critical properties of equilibrium systems, the scale-invariant behavior at non-equilibrium critical points is characterized by a certain degree of universality and therefore it can be suitably studied by means of simplified minimal (field-theoretical) models of dynamics. In particular we have been able to explain, beyond the known numerical evidences, the relation between some exponents which characterize the scaling behavior of two-time response and correlation functions. In addition we have provided analytical estimates of some of the quantities which were measured in numerical studies, finding a quite good agreement with them.

In collaboration with G. Schehr and R. Paul we investigated another interesting property of non-equilibrium dynamics: The *persistence* of the total order parameter (magnetization) during the non-equilibrium relaxation which follows a quench to the critical point. In the past, the global persistence probability (i.e., the probability $P(t)$ that the magnetization has not reversed its sign up to time t after the quench) has been studied mainly for the case in which the system (typically the Ising model) is quenched to the critical point from a state with very small (ideally vanishing) average order parameter m_0. It is also well-known that the persistence probability (and particularly the power of its asymptotic algebraic decay for large time) is connected to the two-time correlation function of the order parameter. By exploiting some of the prediction for this correlation function (especially those reported in [B12] and [B13]), we have pointed out the presence of a crossover in $P(t)$, between two regimes with different power-law decay in time. We have verified the occurrence of such a crossover by means of MCs of the two-dimensional Ising model, finding also quite good agreement with our theoretical predictions for the power of the algebraic decay of $P(t)$ expected and observed at very large times [B15]. The behaviour of the persistence probability of the total magnetization of a d'-dimensional submanifold of a d-dimensional system actually depends on d', being exponential for small enough d', algebraic for $d = d'$ and stretched exponential at a critical dimensionality d'_c. These results have been established for the persistence probability after a quench from an initial state with very small (ideally vanishing) average order parameter m_0. Motivated by our previous results for $d' = d$ we are currently investigating both numerically and analytically how this picture is modified when the initial state has a finite non-negligible value of m_0 and $d' < d$ [B16].

The research activity described above focusses on the case in which a *classical* system is prepared in an equilibrium state and then it is perturbed by a sudden change (quench) in a thermodynamic control parameter, e.g., the temperature. One might instead consider the case of *quantum* (many-body) interacting systems, i.e., prepare the system in the ground state of some Hamiltonian H_0 and then let it evolve unitarily at time $t > 0$ according to a different Hamiltonian H which might be related to H_0 by the change in a control parameter (quantum quench). In passing we note that this kind of quenches can actually be realized in intercating particle systems within optical lattices, where the decoherence time can be made long enough to observe the actual quantum evolution of the system (decoupled from the environment). Quite recently it has been shown that the "non-equilibrium" dynamics (at zero temperature) following a quantum quench can be studied by mapping the d-dimensional quantum problem into a $d + 1$-dimensional classical one in *confined* geometry with suitable boundary conditions. This mapping turned out to be very fruitful in order to characterized the evolution of several observable of experimental relevance and in order to explore the existence of a thermal-like asymptotic long-time state. In collaboration with P. Calabrese we are extending previous investigations of the evolution of a quantum system which can be described by a Landau-Ginzburg action to the case in which the quench occurs across the critical point from different starting configurations. The preliminary mean-field analysis of the dynamics of the order parameter already reveals a rich structure [B17].

C. Effective forces and collective dynamics in confined systems: The critical Casimir effect

In collaboration with:
Theory: S. Dietrich (MPI-MF, Stuttgart), A. Maciołek (MPI-MF, Stuttgart), B. M. Mognetti (University of Mainz), O. Vasilyev (MPI-MF, Stuttgart)
Experiments: C. Bechinger, C. Hertlein, L. Helden (University of Stuttgart).

It is a well-known theoretical and experimental fact that the static and dynamic critical behavior of statistical systems is sensitive to the presence of surfaces and indeed it is locally altered by them. In the last twenty years a rather deep understanding of this phenomenon has been achieved by extending the renormalization-group approach to the case of systems which are bounded by surfaces. Moreover, confining a system may result in a drastic change in its phase diagram, e.g., causing a shift in the coexistence curve and giving rise to fluctuation-induced forces. The theory of finite-size scaling (FSS) provides a framework to understand the effects of confinement on the static and dynamic critical behavior. Although thin films of magnetic materials and wetting layers of fluids are currently allowing the experimental investigation of many of these collective phenomena, their systematic theoretical analysis is still lacking, especially as far as dynamical properties are concerned.

In collaboration with S. Dietrich I am studying some aspects of the critical dynamics in confined systems (especially thin films of fluids), within a field-theoretical renormalization-group approach (combined with numerical methods). In particular we have recently analyzed the purely relaxational dynamics (Model A) in a thin-film geometry whose confining surfaces belong to the Ordinary surface universality class. We determined the general scaling properties of equilibrium dynamical quantities, providing explicit expressions for the associated universal quantities within the Gaussian approximation [C1]. To make contact with experiments it is important to extend these investigation to more realistic dynamic universality classes (such as Model H, describing binary liquid mixtures close to the demixing point).

A consequence of confinement is the onset of fluctuation-induced forces. As in the case of the Casimir effect in quantum electrodynamics, whenever the fluctuation spectrum of a field is affected by boundaries (such as confining walls or immersed bodies), long-range forces result on the boundaries themselves. In the case of quantum electrodynamics the fluctuating fields is the electromagnetic one, whereas in the case I am presently interested in – usually referred to as the *thermodynamic Casimir effect* [C2]– the fluctuating field is the order parameter of a second-order phase transition and its fluctuations, of thermal nature, becomes relevant upon approaching the critical point. Interestingly enough, this critical effect can be characterized by means of universal scaling function which depends only on the gross features of the system under investigation (i.e., on its bulk and surface universality class) allowing for a quite constrained comparison with experiments. In fact, beyond the theoretical interest, this effect is experimentally relevant because it generates effective interactions between particles in addition to dispersion forces (van der Waals) and thus it influences, e.g., the phase diagram of colloidal suspensions near the critical point of the solvent and the thickness of wetting layers of fluids at surfaces. Experimental studies of the static aspects of this effect are going on since some years especially in fluid films of pure ^{4}He close to the normal-to-superfluid transition, of ^{3}He/^{4}He and classical binary mixtures close to the tricritical and the demixing critical points, respectively. In these cases indirect evidence of the presence of such an additional force close to critical points is typically obtained by monitoring the anomalous temperature dependence of the equilibrium thickness of such wetting layers within which the fluctuating order parameter is actually confined. In collaboration with S. Dietrich, A. Maciołek, and O. Vasilyev I have investigated the Casimir effect within the field-theoretical approach, and via the mean-field analytic solution and Monte Carlo (MC) simulations of suitable lattice models, in order to provide predictions for the scaling behaviour of the Casimir force within the bulk and surface universality classes which are relevant for the experiments mentioned above (bulk XY for ^{4}He and ^{3}He/^{4}He, bulk Ising for classical binary mixtures; in each of these cases suitable surface universality classes have been considered). For tricritical points (^{3}He/^{4}He mixtures) our results [C3] properly capture the qualitative features observed in experiments upon varying the relative concentration of the two components. The agreement is actually improved by accounting for the logarithmic corrections which are expected at the upper critical dimensionality $d_{\rm ucd} = 3$. In the case of pure ^{4}He our results, even though derived within the mean-field approximation, properly predict the presence of the pronounced dip observed experimentally in the scaling function of the Casimir force. To be able to provide quantitative predictions (beyond the mean-field approximation) also for the amplitude of this dip and within the bulk Ising universality class, which is relevant for classical binary mixtures, we have developed a numerical scheme in order to determine via MC simulation the scaling function of the Casimir force [C4]. Although finite-size effects still affect our determination of these functions, our numerical results compare very well also at the quantitative level with the available experimental data for ^{4}He and classical binary mixtures at their critical points.

Most of the experimental studies of the critical Casimir effect exploit indirect evidences coming from the thinning or thickening of wetting films of fluids (an in the experiments mentioned above). In a collaboration with the experimental group of Prof. Bechinger (University of Stuttgart) we have provided the first direct measurment of the critical Casimir force (actually the associated potential) acting on a colloidal particle suspended in a critical binary mixture, when it comes close to a planar wall [C5] (sphere-plane geometry as opposed to the previously investigated film geometry). Also in this case the spectrum of fluctations in the surrouding critical medium, its average concentration profile, and therefore the associated free energy changes upon changing the distance between the particle and the wall, resulting in a Casimir-like force. (This geometrycal setting is actually also the one mostly used in experimental investigation of the elecrodynamic Casimir effect.) By determining the probability distribution function of the vertical Brownian motion of the particle via the total internal reflection microscopy (TIRM) it is possible to determine the associate potential and therefore the force with the required resolution of tens of fN. As expected on theoretical grounds, by varying the adsorption properties of the colloidal particle and the surface we have measured both attractive and repulsive Casimir forces which build up reversibly upon approaching the demixing point of the binary mixture. The experimental data turns out to be in very good agreement with the theoretical predictions based on our previous numerical results [C4] and on the Derjaguin approximation (required in order to convert the sphere-plate geometry in a film geometry).

Due to the rapid developments in the experimental techniques we expect the non-equilibrium dynamics of the Casimir effect to become experimentally accessible in the near future. Actually the experiment we performed in Stuttgart already provides such an information via the time-dependent position of the fluctating colloid. It is highly desirable to understand how to extract the signature of the critical slowing down in the Casimir force starting from the experimentally available raw data (which, in addition, are surely affected by hydrodynamical effects). Even the dynamics in simple cases has not been studied so far. In collaboration with B. M. Mognetti and S. Dietrich I am investigating the non-equilibrium behavior of the Casimir force in the field-theoretical Gaussian and Spherical models with Model A dynamics, confined by boundaries belonging to various universality classes (i.e., different boundary conditions). In particular we are focusing on the relaxation of this force towards its equilibrium value when the system is perturbed by an external field and then relaxes [C1] to equilibrium and when it is suddenly quenched from the disordered phase to the critical point [C6,C7]. (This kind of protocol might be of easier realization in experiments than studies of equilibrium dynamics.)

D. Kinetic lattice-gas models for microfluidics

In collaboration with M. N. Popescu (University of South Australia), C. Dotti, S. Dietrich (MPI-MF Stuttgart).

In recent years substantial efforts have been invested in developing miniaturized microfluidics devices operating as “on chip” chemical labs. Chemically patterned and heterogeneous substrates are used to drive and manipulate very small amount of liquids at the micro- and nano-meter scale. To build reliable devices it is therefore very important to have a clear understanding of the static and dynamic behavior of fluids at such scales, where the hydrodynamic description is usually inadequate.

A first step in this direction is the understanding of the spreading of ultra-thin films (i.e., having a thickness comparable to the molecular size) on heterogeneous substrates. Quite recently the problem of spreading of fluid monolayers (thickness $\sim$ *one* molecule) on an two-dimensional homogeneous substrate has been studied by means of kinetic Monte Carlo simulations of a simplified microscopic lattice-gas model of interacting particles. The results of the simulations and of a mean-field-like continuum limit agree qualitatively with some of the available experimental results.

We are currently studying an extension of the previous model in which the thickness of the film can be *few* molecular sizes, allowing for the formation of bulges. Moreover, in the case of thick layers the particle-substrate interaction becomes an additional relevant variable of the problem. In particular we have studied so far both the spreading properties and the stationary ones of the fluid film on a one-dimensional substrate (mimicking a two-dimensional narrow channel) in the presence of reservoirs. We have considered in detail the case in which the fluid-fluid interaction is negligible compared to the fluid-substrate interaction, both via kinetic Monte Carlo simulations and a simple mean-field approach which actually describes quite well what we have observed in the simulations [D1]. As a second necessary step we are currently studying the model in which the fluid-fluid interaction acts in addition to the fluid-substrate one. We also plan to study the effects of chemically patterned substrates (where the particle-substrate potential varies along the substrate) and of external driving forces on the dynamics of the fluid film.

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