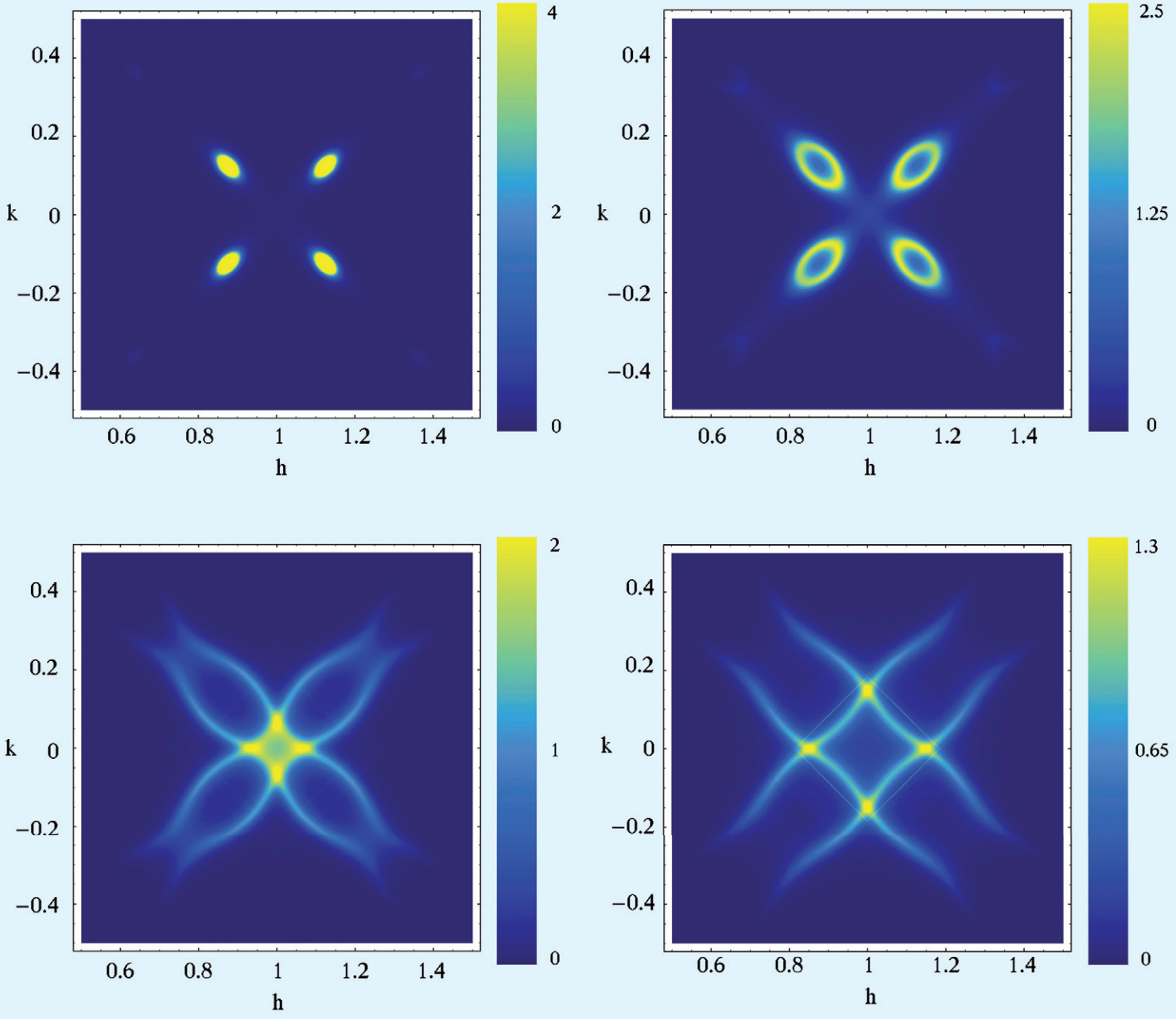
EUROPEAN SCIENCE FOUNDATION

SETTING SCIENCE AGENDAS FOR EUROPE

RESEARCH NETWORKING PROGRAMME

INTERDISCIPLINARY STATISTICAL AND FIELD THEORY APPROACHES TO NANOPHYSICS AND LOW DIMENSIONAL SYSTEMS (INSTANS)

Standing Committee for Physical and Engineering Sciences (PESC)



www.esf.org

The European Science Foundation (ESF) was established in 1974 to create a common European platform for cross-border cooperation in all aspects of scientific research.
With its emphasis on a multidisciplinary and pan-European approach, the Foundation provides the leadership necessary to open new frontiers in European science.
Its activities include providing science policy advice (Science Strategy); stimulating cooperation between researchers and organisations to explore new directions (Science Synergy); and the administration of externally funded programmes (Science Management). These take place in the following areas: Physical and engineering sciences; Medical sciences; Life, earth and environmental sciences; Humanities; Social sciences; Polar; Marine; Space; Radio astronomy frequencies; Nuclear physics.
Headquartered in Strasbourg with offices in Brussels and Ostend, the ESF's membership comprises 77 national funding agencies, research performing agencies and academies from 30 European countries.
The Foundation's independence allows the ESF to objectively represent the priorities of all these members.

Cover pictures:
Spin response for an array of coupled Hubbard ladders of alternating doping. The spin response has been computed so that it is directly comparable to neutron scattering measurements on the cuprate material, $L_{1.875}\ Ba_{0.125}\ Cu\ O_4$. This particular cuprate has static stripes, i.e. both spin and charge density order. The four figures give the spin response at four different energies.
[Figures courtesy F.H.L. Essler and R. Konik]

Introduction

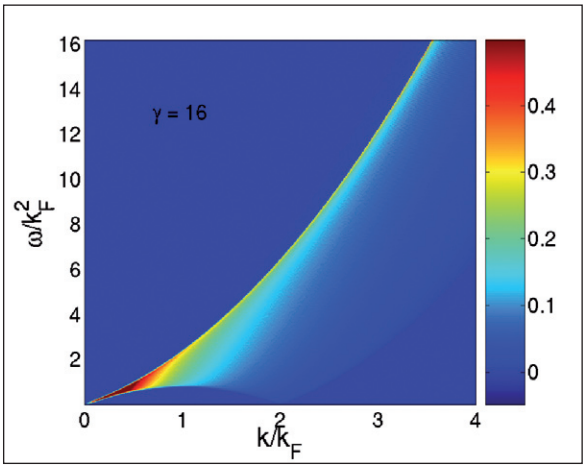
Interdisciplinary Statistical and Field Theory Approaches to Nanophysics and Low Dimensional Systems (INSTANS) is an interdisciplinary research activity. It brings together expertise in condensed matter, quantum field theory and statistical physics.
Its goal is to set up a new theoretical framework to answer the fundamental questions encountered in the modern physics of nanoscopic and low-dimensional systems of quantum matter.

The field of nanophysics has been triggered by technological progress in microelectronics, resulting in incredibly small components, below one micrometre down to a few nanometres. A very important part of the research in this area is naturally concerned with practical applications that have a considerable and widely publicised potential.

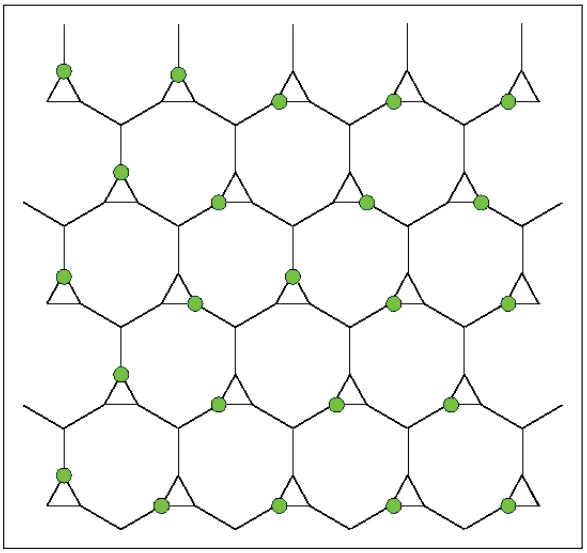
The INSTANS programme has its focus on electronic systems, such as nanotubes, quantum dots and quantum Hall effect devices, as well as specific devices featuring cold atoms. These systems are dominated by quantum effects and strong interactions that give rise to non-perturbative effects, such as spin-charge separation or fractionally charged excitations. Moreover, interesting transport effects as well as other experimental probes often require non-equilibrium descriptions. These aspects make the standard theoretical approaches developed for systems on larger scales rather inadequate. Considerable progress in statistical field theory, in which Europe has played a leading role, has provided a new set of powerful non-perturbative theoretical methods that are ideally suited for the challenges posed. The INSTANS programme aims at sharpening these tools and addressing the fundamental problems in this rapidly evolving domain of physics.

It provides the basis for interdisciplinary training and collaboration. Activities of the programme include the organisation and support of research conferences, workshops and schools, a visitor programme (Short Visit Grants) and a programme for long-term scientific exchanges (Exchange Grants).

The running period of the ESF INSTANS Research Networking Programme is for five years from October 2005 to October 2010.



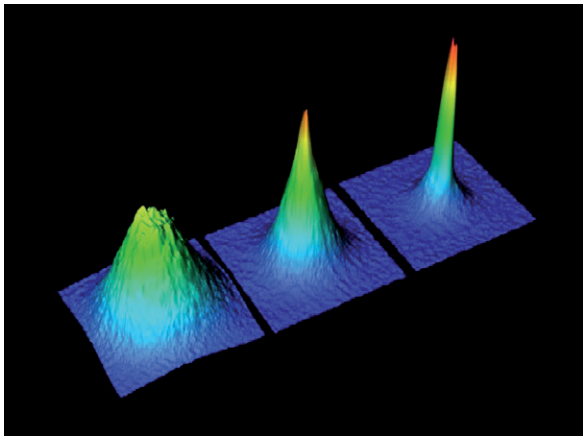
Dynamical density-density correlation function of the Lieb-Liniger interacting Bose gas in one dimension, computed using the ABACUS method, for a system of 200 particles. The horizontal and vertical axes are respectively momentum and energy transfer, and the coloring scheme follows the correlation intensity. Advanced analytical and numerical techniques for the analysis of low-dimensional quantum matter are central to the INSTANS programme. [Figure courtesy J.S. Caux]



Charge frustration for strongly correlated fermions on a 2-dimensional lattice. The interactions are such that the particles prefer to be 3 sites away from one another; the many ways to achieve this lead to frustration. Electronic properties of this system are investigated within the INSTANS programme.
[Figure courtesy L. Huijse]

Scientific Aims of INSTANS

The main objective of INSTANS is to develop new methods to tackle the above strongly correlated problems, with a particular emphasis on the study of out-of-equilibrium and non-perturbative features. The interesting new phenomena at the nanoscale occur in particular because of the low dimensionality of the systems. This invalidates many of the standard approaches of solid state physics, such as the Fermi liquid paradigm. At the same time it opens the way to the use of other techniques that have been pioneered in different fields, such as mathematical physics and string theory, and that can now find applications of experimental relevance. The success of this kind of interdisciplinary approach has been demonstrated over the last decade, for example several problems involving transport and strong interactions have been tackled by a combination of field theory and Bethe ansatz techniques, supplemented by generalisations of the Landauer-Buettiker approach. Yet numerous experimental results await theoretical explanation, sometimes even at a qualitative level. To address those, the INSTANS programme has the following specific aims.



Momentum distribution of ultracold bosonic atoms as the gas is cooled through the critical temperature for Bose-Einstein condensation. The spectacular experimental control of ultracold atoms is one of many recent experimental advances that inspire the theoretical work done in the context of the INSTANS programme. [Figure courtesy ETH-Quantum Optics Group]

A. Methodological and fundamental developments in transport

An important aim is to connect exact solvability with experiments involving transport out of equilibrium. On the INSTANS agenda are:

- general issues such as the renormalisation group, universality and fixed points,
- integrability in the context of the Keldysh formalism,
- generalisation of the Landauer-Buettiker formalism,
- study of quantum field theories at finite temperature or in finite volume, in the presence of chemical potentials, and, in particular, to develop further the form-factors approach in this situation,
- dynamics of fractionalisation on contact between Fermi liquid and, for example, a fractional quantum Hall medium.

B. Applications to recently observed phenomena

Specific challenges include the following:

- the Kondo effect in gapped systems in general, with specific application to the Josephson and quasiparticle current through a correlated nanotube dot, where experimental data are readily available for comparison,
- the proximity-induced current through a single-wall nanotube, which has experimentally been found to exceed the non-interacting value by two orders of magnitude,
- intrinsic superconductivity in nanotube ropes,
- theory for nanoscopic devices for cold atoms (such as atom chips).

C. Fundamental developments in field theories for disordered systems

There is at the present time no clear idea about the type of conformal field theory that may describe critical disordered electronic systems, such as the transitions between plateaus in the integer quantum Hall effect. Guided by exact solutions of non-compact conformal field theories coming from string theory, the INSTANS programme wishes to re-examine the possible theories describing critical disordered electronic systems. The INSTANS agenda in this field includes:

- a focus on logarithmic current theories and their relevance for the description of disorder,
- an exact S matrix approach for obtaining non-perturbative solutions of sigma models at intermediate couplings,
- the study of network models and the related quantum spin chains.

INSTANS Activities

Research Conferences
The First INSTANS Summer Conference has been held in Como, July 2006. A second meeting, to be organised along similar lines, has been scheduled to take place in Florence in September 2008. INSTANS also co-funded a Conference on Transport in Nanoscopic Systems, held at Freiburg in November 2007.

Workshops
INSTANS has supported small-scale focused workshops in Anacapri (March 2007), Amsterdam (July 2007), and Perugia (July 2007).

Summer Schools
A first INSTANS Summer School has been held in Oxford in August 2007. It was attended by some 60 PhD students and young post-docs who enjoyed an intense week of introductory lectures on topics central to the INSTANS programme. A second School will be organised in 2009.

Short Visit Grants
INSTANS Short Visit Grants are an increasingly popular instrument to facilitate visits between scientists involved in the INSTANS programme. The scheme funds visits for up to 15 days. Applications are evaluated by a sub-committee of the INSTANS Steering Committee.

Exchange Grants
INSTANS Exchange Grants facilitate exchange visits lasting from 15 days to up to six months. Applications are evaluated by a sub-committee of the INSTANS Steering Committee.

Coordination by Steering Committee through annual meetings
The INSTANS Steering Committee is responsible for the implementation of the programme. It has convened in Strasbourg (2005), Como (June 2006) and in Oxford (August 2007).

Funding

ESF Research Networking Programmes are principally financed by the Foundation's Member Organisations on an *à la carte* basis. INSTANS is supported by:

- **Fonds zur Förderung der wissenschaftlichen Forschung in Österreich (FWF)**
  Austrian Science Research Fund, Austria
- **Fonds voor Wetenschappelijk Onderzoek-Vlaanderen (FWO)**
  Research Foundation Flanders, Belgium
- **Commissariat à l'Énergie Atomique/Direction des Sciences de la Matière (CEA/DSM)**
  Materials Sciences Division of the Atomic Energy Commission, France
- **Deutsche Forschungsgemeinschaft (DFG)**
  German Research Foundation, Germany
- **Istituto Nazionale di Fisica Nucleare (INFN)**
  National Institute for Nuclear Physics, Italy
- **Nederlandse Organisatie voor Wetenschappelijk Onderzoek (NWO)**
  Netherlands Organisation for Scientific Research, The Netherlands
- **Fundação para a Ciência e a Tecnologia (FCT)**
  Foundation for Science and Technology, Portugal
- **Consejo Superior de Investigaciones Científicas (CSIC)**
  Council for Scientific Research, Spain
- **Ministerio de Educación y Ciencia (MEC)**
  Ministry of Education and Science, Spain
- **Vetenskapsrådet (VR)**
  Swedish Research Council, Sweden
- **Schweizerischer Nationalfonds (SNF)**
  Swiss National Science Foundation, Switzerland
- **Engineering and Physical Sciences Research Council (EPSRC),** United Kingdom

INSTANS Steering Committee

Professor Giuseppe Mussardo (Chair)
SISSA
International School for Advanced Studies
Faculty of Physics
Via Beirut 2-4
34014 Trieste • Italy
Tel: +39 040 378 7411
Email: mussardo@sissa.it

Professor Jose Carmelo
University of Minho
Centre of Physics
GCEP
Campus of Gualtar
4710 Braga • Portugal
Email: carmelo@fisica.uminho.pt

Professor Reinhold Egger
Heinrich-Heine Universität
Institut für Theoretische Physik IV
Universitätsstr. 1
40225 Düsseldorf • Germany
Tel: +49 211 811 4286
Fax: +49 211 811 5630
Email: egger@thphy.uni-duesseldorf.de

Professor Fabian Essler
Oxford University
Rudolf Peierls Centre for Theoretical Physics
Department of Physics
1 Keble Road
Oxford • United Kingdom
Tel: +44 1865 273 970
Email: f.essler1@physics.ox.ac.uk

Professor Thierry Giamarchi
University of Geneva
DPMC
24 Quai Ernest Ansermet
1211 Geneva • Switzerland
Tel: +41 227 026 363
Fax: +41 227 026 869
Email: thierry.giamarchi@physics.unige.ch

Professor Henrik Johannesson
Göteborg University
Department of Physics
Fysikgården 1
412 96 Göteborg • Sweden
Tel: +46-31-7723185
Fax: +46-31-7722092
Email: henrik.johannesson@physics.gu.se

Professor François Peeters
University of Antwerp
Condensed Matter Physics
Department of Physics
Groenenborgerlaan 171
2020 Antwerpen • Belgium
Tel: +32 3 265 36 64
Fax: +32 3 265 35 42
Email: francois.peeters@ua.ac.be

Professor Hubert Saleur
CEA Saclay
Service de Physique Théorique
CEA/Saclay - Orme des Merisiers
91191 Gif-sur-Yvette • France
Tel: +33 1 69 08 30 02
Email: Hubert.Saleur@cea.fr

Professor Kareljan Schoutens
University of Amsterdam
Institute for Theoretical Physics
Faculty of Science
Valckenierstraat 65
1018 XE Amsterdam • The Netherlands
Tel: +31 20 525 56 64
Fax: +31 20 525 57 78
Email: kjs@science.uva.nl

Professor German Sierra
Instituto de Física Teórica CSIC/UAM
Universidad Autónoma de Madrid
Cantoblanco
28049 Madrid • Spain
Email: german.sierra@uam.es

Professor Jakob Yngvason
University of Vienna
Faculty of Physics
Boltzmanngasse 5
1090 Wien • Austria
Tel: +43 1 4277 14100
Fax: +43 1 4277 95 15
Email: yngvason@thor.thp.univie.ac.at

Guest members:

Professor Daniel Cabra
Université Louis Pasteur de Strasbourg
Département de Physique
3-5 rue de de l'Université
67084 Strasbourg • France
Tel: + 33 3 90 24 06 56
Fax: + 33 3 90 24 06 54
Email: cabra@lpt1.u-strasbg.fr

Professor Gergely Zarand
Budapest University of Technology
and Economics
Department of Theoretical Physics
Budafoki ut 8
1521 Budapest • Hungary
Tel: +36 1 463 14 82
Fax: +36 1 463 35 67
Email: zarand@neumann.phy.bme.hu

ESF Liaison

Dr. Patrick Bressler
Science
Ms. Chantal Durant
Administration

Physical and Engineering Sciences Unit (PESC)
European Science Foundation
1 quai Lezay-Marnésia
BP 90015
67080 Strasbourg cedex • France
Tel: +33 (0)3 88 76 71 27
Fax: +33 (0)3 88 37 05 32
Email: cdurant@esf.org

For the latest information
on this Research Networking Programme
consult the INSTANS website:
www.esf.org/instans

EUROPEAN SCIENCE FOUNDATION
SETTING SCIENCE AGENDAS FOR EUROPE

1 quai Lezay-Marnésia | BP 90015
67080 Strasbourg cedex | France
Tel: +33 (0)3 88 76 71 00 | Fax: +33 (0)3 88 37 05 32
www.esf.org

Print run: 1000 – March 2008