RESEARCH AREA

PHYSICS

RESEARCH AREA PHYSICS

COORDINATOR
Michele Fabrizio

AREA COMMITTEE
Cristian Micheletti
Matteo Bertolini
Stefano Liberati
Giuseppe Mussardo
Sandro Sorella
Alessandro Bressan
Andrea Romanino
Giovanni Pinamonti
Pietro Baratella

SISSA physicists are engaged in the fundamental problems of Theoretical Physics at all length scales.

Research topics cover a wide spectrum embracing Astroparticle Physics, Astrophysics, Elementary Particle Physics, Quantum Field Theory, Biophysics, Condensed Matter Theory and Statistical Physics.

Excellent educational and research opportunities are offered to the many talented students who enrol in **SISSA's Physics PhD programmes**.

RESEARCH AREA PHYSICS

ASTROPARTICLE PHYSICS

COORDINATOR STEFANO LIBERATI

Astroparticle Physics is a young and interdisciplinary field at the frontier between **Astrophysics**, **Cosmology**, and **Particle Physics**.
It addresses some of the most pressing and fundamental questions in science today, such as understanding the nature of gravity, explaining the origin and evolution of the Universe and identifying the nature of its constituents, including dark matter and dark energy. In recent years, the field has witnessed a rapid growth, also thanks to the wealth of new data and the rich experimental programmes in progress. The focus at SISSA is to connect the new insights offered by these exciting phenomenological developments to the forefront of theoretical research in the field.

A **PhD programme** entirely devoted to Astroparticle Physics has been in place since 2004, when it was established as a joint initiative of the Astrophysics and Particle Physics groups, and has now developed into an independent research and educational initiative. So far the programme has awarded 13 PhD degrees, and all graduates have gone on to complete postdoctoral fellowships in internationally renowned institutions.

The **curriculum** consists of 3-4 years of study and research. During the first year, students are offered a number of courses covering a wide spectrum of topics including quantum field theory, the standard model of particle physics and its extensions, cosmology and gravitation theory, particle and high-energy astrophysics. Students must then take an examination on a selection of these courses. By the beginning of the second year they start working on a research project under the supervision of one (or more) of the Astroparticle Physics SISSA staff members as well as scientists at the International Centre for Theoretical Physics (ICTP) and the Trieste Astronomical Observatory (OAT) participating in the initiative.

Students in the programme will be part of a fairly **large scientific community**. The **Astroparticle Physics group**, which currently consists of 16 graduate students, 4 postdoctoral fellows and 10 staff members, runs its activities in close contact and with support from the extensive Astrophysics and Particle Physics expertise available at SISSA and other important local institutions like **ICTP**, the **National Institute for Nuclear Physics (INFN)** and **OAT**. Such a stimulating environment makes a PhD in Astroparticle Physics at SISSA a very special opportunity for scientists looking to gain uncommonly broad knowledge which they will able to apply to the most daunting questions of modern physics.

The main research lines include:
- Classical and Quantum gravity
- Particle Astrophysics
- The Dark Universe
- Theoretical Cosmology

The most recent placements after PhD at SISSA:

Institute for Advanced Studies, Princeton, USA
Albert Einstein Institute, Germany
New York University, New York, USA
Deutsches Elektronen-Synchrotron, Germany
CENTRA/IST, Portugal
University of Mainz, Mainz, Germany

Additional information about the courses and the research activity can be found at: **www.sissa.it/app** Info: **phd@sissa.it**	Short fellowships may be awarded to candidates taking the entrance exam. These fellowships cover travel and accommodation expenses and entitle students to visit the school before the selection.

RESEARCH AREA PHYSICS

ASTROPHYSICS

COORDINATOR ALESSANDRO BRESSAN

There has never been a better time to work in **Astrophysics**, a vibrant and competitive discipline in frontier research.
Applicants to the PhD program in Astrophysics will first be assessed on the basis of their CV and reference letters. A number of candidates will be invited for an interview on one of the two announced dates.

The **PhD course** consists of 3 to 4 years of study and research. First-year students are required to attend several courses spanning a period from November to May and to take exams in a selection of those courses. At the beginning of the first year, students are assigned a tutor, a SISSA staff member who will advise them on selecting exams and will provide guidance on choosing a research project for their PhD thesis. After completion of the courses, students will start working on their research project under the supervision of one or more SISSA staff members.

The **Astrophysics group** consists of 8 staff members, 7 postdoctoral fellows and 20 PhD students. All the principal investigators have recognized expertise in the fields of analysis and interpretation of cosmic microwave background and sub-millimetre surveys, large-scale structure surveys, cluster physics, galaxy formation and evolution, dark energy, dark matter, galactic and extragalactic black holes, stellar structure and evolution, high-energy astrophysics, relativistic astrophysics, early Universe physics and gravitation theory. Students will also benefit from close contact with other SISSA groups, such as the **Astroparticle Physics** and the **Theoretical Particle Physics groups**, and from connections with the **International Centre for Theoretical Physics (ICTP)** and the **Trieste Astronomical Observatory (OAT)**.

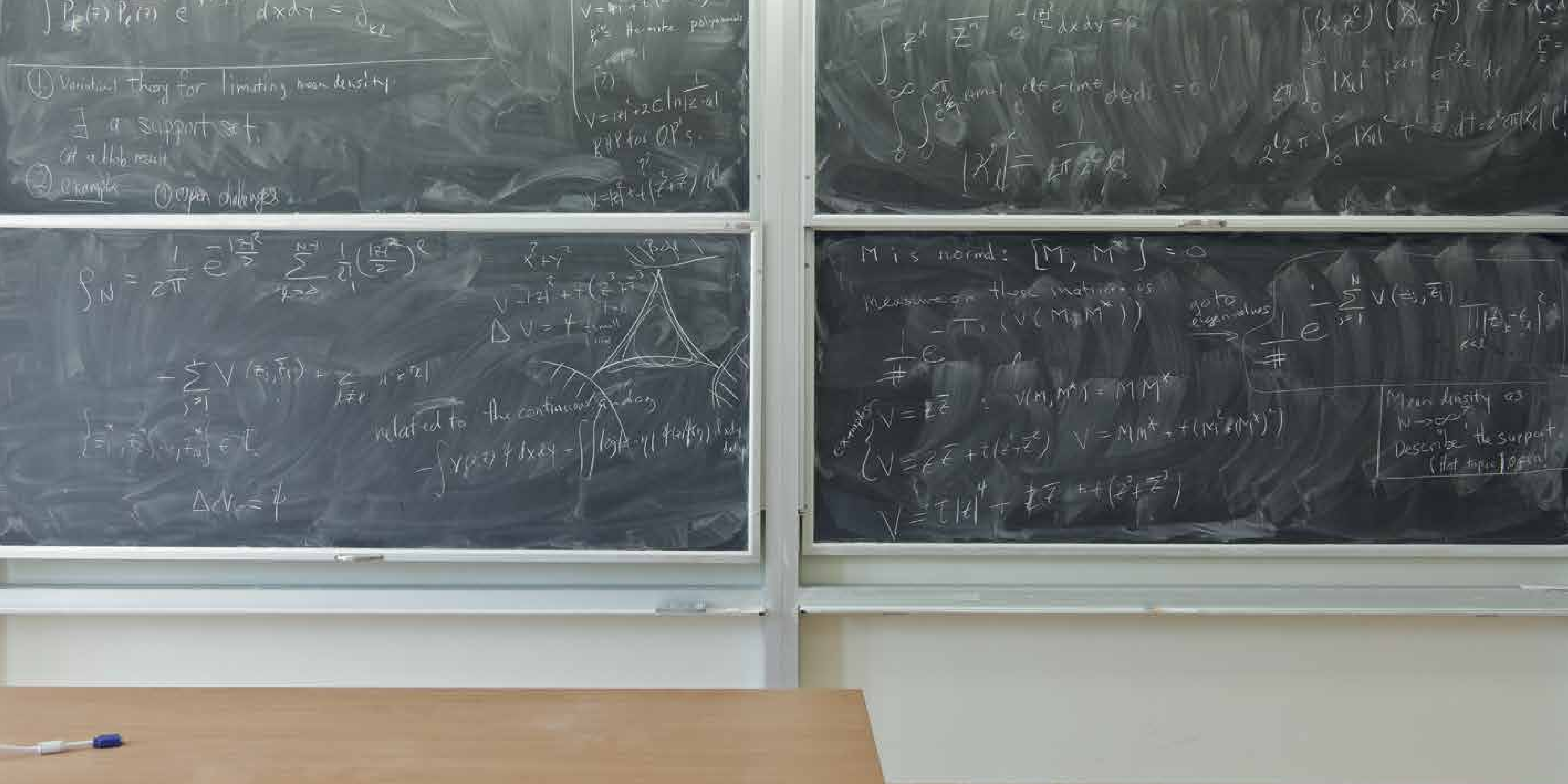
The main research interests are:
- Cosmic microwave background
- Large scale structure
- Dark matter and dark energy
- Galaxy formation and evolution
- High energy astrophysics and AGN
- Stellar structure and evolution
- General relativity and quantum gravity phenomenology
- Black holes and compact stars

The most recent placements after PhD at SISSA:

Keele University, UK
Harvard-Smithsonian Center for Astrophysics, Cambridge, USA
University of California Berkeley, USA
Albert Einstein Institute, Germany
Max Planck Institute for Gravitational Physics, Potsdam, Germany
Yale University, New Haven, USA
Australia Telescope National Facility, Australia

Additional information about the courses and the research activity can be found at:
www.sissa.it/ap/index.php
Info: **phd@sissa.it**

Short fellowships may be awarded to candidates taking the entrance exam.
These fellowships cover travel and accommodation expenses and entitle students to visit the school before the selection.



Hermite polynomials
Variational Theory for limiting mean density
a support set
example
open challenges
M is normal: [M, M*] = 0
Measure on these matrices
goto eigenvalues
related to the
examples
Mean density as
Describe the support

RESEARCH AREA PHYSICS

PHYSICS AND CHEMISTRY OF BIOLOGICAL SYSTEMS

COORDINATOR CRISTIAN MICHELETTI

Understanding the working principles of living organisms and soft matter systems from the basic equations ruling the dynamics of atoms and molecules was considered science fiction until a few years ago, and biophysics was almost unanimously considered a battlefield for phenomenologists. Nowadays, applying rigorous physics to biological processes is no longer a dream. What's more, it is becoming clear that the next few decades will be the golden age for the "theory of life", which is expected to undergo the same accelerating growth experienced by other physics disciplines in the past century.
Young scientists attracted by the opportunity to develop and apply concepts, models and methods to explore the still uncharted territory of quantitative biology can take up this challenge in our PhD programme in **Physics and Chemistry of Biological Systems**.
This **PhD programme** has a highly **interdisciplinary character** and offers advanced, research-oriented training in theoretical and computational topics at the interface of Physics, Chemistry and Biology. The faculty includes members from the **SISSA Physics and Mathematics areas**, the **CNR-IOM Democritos centre** and ICTP, the **International Centre for Theoretical Physics**.
Students are typically admitted to the PhD programme after taking a written and oral exam, though non-EU applicants may be pre-selected based exclusively on academic qualifications.

During the November-April period of the first year, students attend a set of advanced courses, which include:

- Statistical Mechanics, Numerical Methods in Computational Physics
- System Biology, Statistics and Probability
- Introduction to Biochemistry, Computational Biochemistry
- Advanced Sampling Techniques
- Molecular Dynamics
- Statistical Mechanics of Polymers
- Mechanical Aspects of Cell Biology and Bioinformatics
- Introduction to Quantum Chemistry
- Simulations in Molecular Medicine

At the end of the courses, each first year student takes on a **supervised research project**. The choice of research topic and supervisor is arranged with the PhD faculty. The PhD programme is typically completed in about **4 years**. The progress of each PhD student is monitored with an official annual assessment (progress report), and the final PhD exam is based on a written dissertation that is defended orally in front of a board of international experts.

The most recent placements after PhD at SISSA:

Centre for Genomic Regulation, Barcelona, Spain
Massachusetts Institute of Technology, Boston, USA
Max Planck Institute for Biophysics, Frankfurt, Germany
Max Planck Institute for Polymer Research, Mainz, Germany
National Institute of Health, Bethesda, USA
Temple University, Philadelphia, USA
University of Edinburgh, UK
University of Illinois, Urbana-Champaign, USA
University of Vienna, Austria

Additional information about the courses and the research activity can be found at:
www.sissa.it/sbp
Info: **phd@sissa.it**

Short fellowships may be awarded to candidates taking the entrance exam.
These fellowships cover travel and accommodation expenses and entitle students to visit the school before the selection.

RESEARCH AREA PHYSICS

STATISTICAL PHYSICS

COORDINATOR GIUSEPPE MUSSARDO

Statistical Physics, together with Quantum Mechanics, is the pillar of our understanding of many physical phenomena, from the simplest to the most sophisticated. The field has recently witnessed a significant and impressive outpouring of experimental and theoretical results, which have created an ideal physicist's playground.

Statistical Physics addresses, for instance, crucial questions about the nature of phase transitions and predicts the possibility to forge new states of matter, such as Bose-Einstein condensation in ultra-cold gases. At the same time, it provides a vital source of fresh ideas and inspiration for those who work in more theoretical directions. Its attraction lies in its ability to produce an array of sophisticated analytical and conceptual tools with far-reaching applications. The remarkable blend of mathematical and physical ideas is at the root of the outstanding scientific elegance and extraordinary efficiency characterizing this scientific area.

Thanks to an intense activity of postgraduate courses, weekly seminars, colloquia and journal club meetings, the PhD programme aims at providing students with aims at training students to a complete mastery of the scientific methods of **Statistical Physics** and exposing them to research topics which are currently at the frontier of this field, such as:

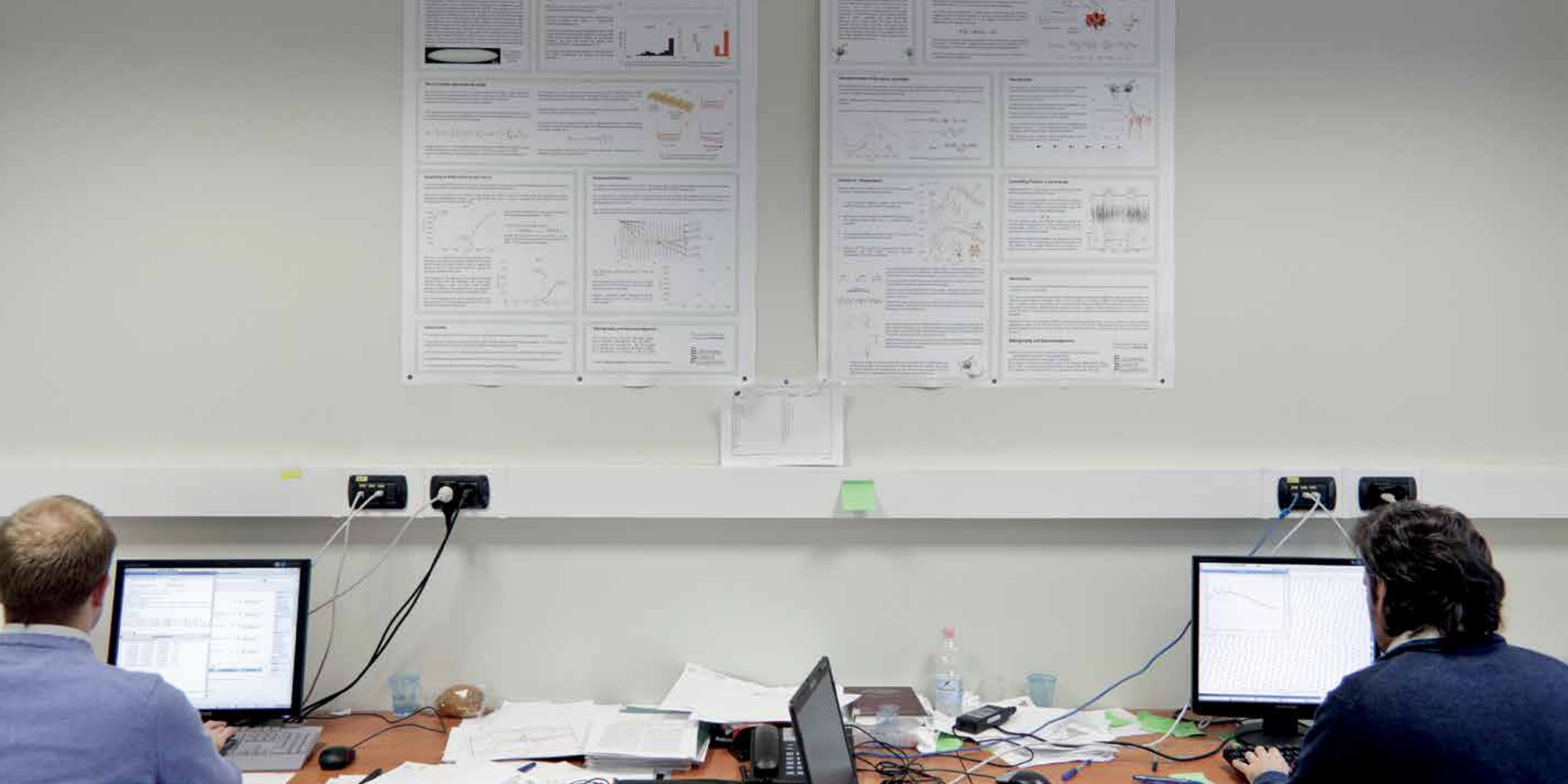
- Quantum Field Theory
- Exactly Solvable Models
- Ultra-cold atomic gases
- Quantum spin chains
- Physics out of equilibrium and thermalization properties
- Quantum quench and entanglement
- AdS/CFT correspondence
- Conformal Field Theory
- Stochastic methods
- Casimir effect
- Random matrices

The most recent placements after PhD at SISSA:

Rockfeller Foundation, New York, USA
Rutgers University, Rutgers, USA
Nordita, Stockholm, Sweden
Max Planck Institute, Munich, Germany
Institute of Complex Systems, Santa Fe, USA
Ecole Normale Superieure, Paris, France
Max Planck Institute, Dresden, Germany
Institute of Quantum Optics, Barcelona, Spain
CEA, Saclay, France
C.N. Yang Institute for Theoretical Physics, Stony Brook, USA

Additional information about the courses and the research activity can be found at:
www.sissa.it/statistical
Info: **phd@sissa.it**

Short fellowships may be awarded to candidates taking the entrance exam.
These fellowships cover travel and accommodation expenses and entitle students to visit the school before the selection.



RESEARCH AREA PHYSICS

THEORETICAL PARTICLE PHYSICS

COORDINATOR MATTEO BERTOLINI

The PhD in **Theoretical Particle Physics** has always been part of the postgraduate programmes on offer at SISSA. More than a hundred students have obtained a PhD qualification in Theoretical Particle Physics since SISSA started offering the course.
Every year, five students are selected to attend this 3-year programme (plus an extra year, if needed) of study and research.
During the first year students attend about **450 hours of postgraduate courses** covering a wide spectrum of topics, ranging from phenomenology to the more formal aspects of theoretical particle physics.
By the beginning of the second year, students undertake **a research project** under the supervision of a SISSA staff member or a scientist working at a partner research institution (such as ICTP and INFN). The PhD degree is typically obtained 3 to 4 years after the beginning of the programme.

During their stay in Trieste, students have the opportunity to interact with about 20 other students from the same PhD curriculum plus hundreds of other international students from the different SISSA groups. In addition, the international environment of the Trieste area includes the **International Centre for Theoretical Physics (ICTP)** and other international institutions, which makes a PhD in Theoretical Particle Physics at SISSA an unprecedented opportunity for a highly challenging and stimulating experience.

The most recent placements after PhD at SISSA:

Utrecht University, Utrecht, The Netherlands
Weizmann Institute of Science, Rehovot, Israel
Princeton University, Princeton, USA
Technische Universität München, Munich, Germany
Harvard University, Cambridge, USA

Additional information about the courses and the research activity can be found at:
www.sissa.it/tpp
Info: **phd@sissa.it**

Short fellowships may be awarded to candidates taking the entrance exam.
These fellowships cover travel and accommodation expenses and entitle students to visit the school before the selection.

RESEARCH AREA PHYSICS

THEORY AND NUMERICAL SIMULATION OF CONDENSED MATTER

COORDINATOR SANDRO SORELLA

The PhD curriculum in **Theory and Simulation of Condensed Matter** is suited to highly motivated students interested in learning how the microscopic constituents of matters self-assemble to bring about the whole complexity of the states of matter, from molecules to complex solids, and in learning how to model fascinating macroscopic phenomena, from friction to superconductivity and superfluidity, emerging from the collective behaviour of those microscopic agents.

During **the first year of their PhD course**, students acquire the most advanced tools for modelling and studying states of matter, from ab-initio simulation of real materials and molecules to quantum simulation of lattice models, from the classical statistical theory of many-body systems to its quantum counterpart, and acquaint themselves with the broad research activity carried out at SISSA through more focused and topical courses. This preliminary stage provides students with a common background and all the information they need to decide on the research topic they intend to pursue in their PhD thesis.

The following 2 or 3 years of the PhD programme are devoted to individual research under the guidance of supervisors. Annual progress reports will ensure the timely detection and solution of possible difficulties.

The **DEMOCRITOS** Simulation Centre belonging to the Istituto Officina dei Materiali (IOM) part of the National Council for Research (CNR), and hosted by SISSA, is fully integrated in the research activity of the Condensed Matter group. Strong links are also maintained with scientists of the nearby Abdus Salam International Centre for Theoretical Physics (ICTP) and Elettra Synchrotron Radiation Facility.

The most recent placements after PhD at SISSA:

ETH Zürich, Switzerland
École Polytechnique, Palaiseau, France
Riken AICS, Tokyo, Japan
Cantoblanco University, Madrid, Spain
KITP, Santa Barbara, USA
Rutgers University, USA
École Polytechnique Fédérale, Lausanne, Switzerland

Additional information about the courses and the research activity can be found at:
www.sissa.it/cm
Info: **phd@sissa.it**

Short fellowships may be awarded to candidates taking the entrance exam.
These fellowships cover travel and accommodation expenses and entitle students to visit the school before the selection.

More information www.sissa.it

SISSA | via Bonomea 265 | 34136 Trieste - Italy | T +39 040 3787111 | info@sissa.it