2025: A Year in Review

ICTP Annual Report

The Abdus Salam International Centre for Theoretical Physics

IAEA International Atomic Energy Agency

unesco United Nations Educational, Scientific and Cultural Organization

The Abdus Salam
International Centre
for Theoretical Physics

2025:

A Year in Review

ICTP Annual Report

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Foreword

In 2025 ICTP announced its new strategic plan for the coming five years and beyond. ICTP's vision for the future must respond to new opportunities and realities of the 21st century while keeping true to the foundational inspiration that we share with ICTP's founders Abdus Salam and Paolo Budinich.

That vision must take into account a delicate balance between ICTP's need to emphasize the unity of pure and applied science and the growing need to ensure equitable opportunities with new technologies.

ICTP's Strategic Plan 2025 puts forth the vision of 'ICTP 2.0', with three strategic priorities:

- Create an **International Science Alliance** (ISA) to build collaborations with national agencies, foundations and private donors to engage with the ICTP global community in equal partnership for more effective delivery;
- Nurture the **International Consortium for Scientific Computing** (ICOMP), a global partnership created in 2024 to make computational sciences accessible to the broader scientific community, with ICTP as the central node;
- **Reinforce existing scientific competencies** of ICTP in the core areas of research and programmes, modernise both the scientific and physical infrastructure, and build upon these core strengths to attract the best talent to ICTP.

Through the implementation of this plan, ICTP will continue to serve as a lighthouse for global science, dedicated to advancing theoretical sciences and building scientific capacity to pursue new opportunities and tackle planetary- scale challenges together.

Important steps have already been taken towards ICTP's strategic goals, including new partnerships with major foundations like the Simons Foundation International, KFAS and the Arab Fund; with countries like South Africa and Brazil; with national and international agencies like CECAM or Cineca; and with corporations like IBM and Quantinuum.

ICTP 2.0 goes hand in hand with an active fundraising campaign to build resources and strengthen infrastructure to a caliber commensurate with the quality of the scientific research and programmes being practiced at the Centre in Trieste, and through its affiliates around the world. The new Euler-Lagrange Lecture Hall Complex has already been completed and the modernization of the Marie Curie Library has commenced thanks to a transformative public-private partnership. A major matching grant from the Simons Foundation International will assist ICTP in purchasing and renovating its Adriatico Guesthouse, transforming it into a world-class International Science Complex. Other resources are being sought for additional projects and an endowment to support research and programs.

ICTP visitors enjoying a light moment on the Centre's terrace during a poster session.

ICTP's Strategic Plan 2025 puts forth the vision of 'ICTP 2.0'

The Centre's three strategic pillars – core scientific excellence, open access, and global partnerships – are mutually reinforcing. By integrating theoretical physics with transdisciplinary applications, ICTP is redefining its orientation and also expanding its role as a scientific institution. Its inclusive philosophy reflects a deep appreciation of the unity of science and its creation coming from different civilizational backgrounds. This philosophy informs its strategic approach towards a structural and systemic change for access and representation whether it is geography or gender. ICTP thus strives to be not only a global hub of knowledge but a force for equity and an agent for social change.

ICTP's mission is as relevant today as it was at its founding more than six decades ago. In an era of climate crisis, AI ethics, and technological upheaval, the need for inclusive, cooperative, and open science has never been greater. Organizations like ICTP have a very critical role to play. ICTP's vision provides a model for how science can serve as a shared resource for humanity and not as a privilege of the powerful. Its continued commitment to foundational knowledge and scientific solidarity ensures that it remains a guiding light – illuminating not only what science can achieve, but who it can empower.

Atish Dabholkar
Director, ICTP

ICTP DIrector Atish Dabholkar and Alessandro Curioni, vice-president of IBM Europe and Africa and president of the IBM Research Laboratory in Zurich, signing a collaboration agreement.

Giorgio Parisi, the 2021 Nobel laureate, poses with participants and students at ICTP's international conference on "Quantum Physics: From Foundations to Emerging Technologies".

In September 2025 ICTP welcomed a delegation from India led by Abhay Karandikar (left), Secretary of India's Department of Science and Technology, shown here with ICTP Director Atish Dabholkar and ICTP scientific computing expert Ivan Girotto.

ICTP Celebrates Quantum Science and Technology

The week of 26 May 2025 was a momentous one at ICTP.

One hundred years after the first theoretical formulation of quantum mechanics, the Centre marked the occasion with a series of high-level events featuring world renowned experts on the topic.

From a major international conference with talks by Nobel laureates, to satellite events at the Centre's partner institute in Sao Paulo, the ICTP South American Institute for Fundamental Research, and an activity in Rome, organized by the Italian Accademia dei Lincei for high school students, ICTP's reputation as a beacon for science was once again affirmed.

This was evident in the appearance of nine Nobel laureates at ICTP's international conference on "Quantum Physics: From Foundations to Emerging Technologies", co-organized by the Lincei, which ran from 28 to 30 May. The event focused on the history of quantum science, its impact on society, and selected advances of quantum science and technology. It was a cornerstone event for the United Nations' International Year of Quantum Science and Technology, which was co-chaired by ICTP scientist Rosario Fazio. A summary of the conference follows.

Wednesday 28 May

Day 1 of the scientific conference began with a talk by the 2023 **Nobel laureate Anne L'Huillier** on applications of attosecond pulses in physics, a technology that she developed in order to look at the dynamics of electrons and deepen our understanding of the nature of matter as we know it.

2023 Nobel laureate Anne L'Huillier

"For me quantum mechanics is something that I have devoted all my life to, so I find it important to celebrate it," she said when asked what quantum physics represents for her.

2022 **Nobel laureate Alain Aspect** talked about the experiments that provided evidence for quantum entanglement, the ability of two quantum particles to continue to interact even at very long distances – one of the most puzzling paradigms of quantum physics. *"This is the story of how a fundamental question raised by Einstein in 1935 eventually brings us to quantum technology,"* he commented, adding, *"I was lucky to work on a fundamental subject 40 years ago, at a time when the question of entanglement was purely fundamental, and to see that this is now leading to many applications."*

2022 Nobel laureate Alain Aspect

The first morning ended with a talk by **Federico Capasso**, who connected online from Harvard University to talk about the interesting research and applications made possible by metasurfaces – sophisticated, carefully designed materials that Capasso and his group use to structure light, modifying its shape. He also touched upon some of the main applications of this technology, from polarization imaging to create the modern version of the old Polaroid photos, to quantum optics and flat lenses. *"We are using technology developed to build the modern microchips to create new optical materials,"* Capasso said, *"and this interaction between electronics and optics is already happening right now, in our cell phones."*

Maciej Lewenstein of the Institute of Photonic Science in Barcelona, Spain, provided an overview of fundamental discoveries in quantum physics, including many made by some of the speakers at the conference. **Nicolas Gisin** of the University of Geneva, Switzerland, explored various measurement settings, beyond those explored in the test of Bell's inequalities, to provide further perspectives on entanglement. **Guglielmo Tino** of the University of Florence, Italy, explained how, as an experimental physicist, he contributes to answering one of the most fundamental questions of modern physics, namely that of the compatibility between gravity and quantum mechanics, by using quantum sensors, built starting from cold atoms, to probe gravity. **Vanderlei Bagnato** of the University of Sao Paulo, Brazil, talked about his explorations of turbulence in atomic superfluids, special fluids that strikingly display no viscosity, and therefore can flow without energy loss.

The day was closed by **Peter Zoller** of the University of Innsbruck, Austria, one of the pioneers of quantum computing. He started with an overview on quantum information, from its birth in 1994, when American mathematician Peter Shor developed the first quantum algorithm, designed to find the prime factors of an integer. *"It is very interesting that the first ideas about how to implement quantum computers based on neutral atoms, photons or superconductors are still leading candidates for quantum computing today,"* he noted.

Thursday 29 May

Day 2 was inaugurated by a talk from **Serge Haroche, Nobel laureate**. Starting from the origins of quantum mechanics, Haroche gave a historical overview of the most important discoveries related to quantum physics, particularly lasers. *"Intense, direct, monochromatic and coherent,"* as Haroche called it, the laser is a *"wonderful light tamed by man"*, that is at the heart of his research using lasers to trap atoms, a technique that is the basis of quantum computers.

Haroche's talk was followed by a series of presentations focusing on some of the most exciting, cutting-edge applications of quantum physics. **Paola Cappellaro** of MIT talked about how diamond defects are utilized in various quantum technology applications, from quantum computers to communication, and from quantum simulations to quantum sensing. **Costanza Toninelli**, of the Italian National Research Council, discussed the interaction between single photons and single molecules, while **Artur Ekert** of the University of Oxford, UK and the CQT National University of Singapore, provided a historical overview of quantum cybersecurity, showing how purely curiosity-driven research on quantum physics by pioneers such as Planck, Einstein and Bell, intertwined with our quest for higher security in communications, has led to the most modern applications in cybersecurity.

The first part of the afternoon was marked by the talks of 2001 **Nobel laureates Wolgang Ketterle** and **Eric Cornell**, the protagonists of the first experimental realization of the Bose-Einstein condensate in 1995. As noted by **Sandro Stringari**, who chaired the session and is also an expert on the topic, 2025 also marked the 30-year anniversary of that discovery. However, both Ketterle and Cornell chose to talk about something different.

Ketterle went back to a foundational idea in quantum mechanics, notably the fact that two quantum particles are indistinguishable, a concept at the basis of his most recent research, while Cornell focused on applications of molecular spectroscopy in the search for new particle physics, *"But I managed to put some quantum physics into it,"* he said, *"as it seemed appropriate for this conference."*

Gabriele Beccaria, a science journalist who writes for the Italian national newspaper *La Stampa*, posed a series of questions to the quantum community to stimulate public interest and engagement in quantum science, from the type of transformations that will be made possible by the most recent advances in quantum science, to the best ways to effectively communicate about these changes.

Mikhail Lukin, of Harvard University, talked about recent progress in the development of quantum computers and started by clarifying that *"There are many open questions in this field. We do not know if and how large-scale quantum computers can be built, we certainly have no idea on how we will use them, but what I would like to convey is that, especially from the perspective of fundamental science, this is a very exciting field of research."*

Public Event with William Phillips and Vanderlei Bagnato

The evening of Thursday 29 May featured a science-based public performance at a theatre in Trieste, led by 1997 **Nobel laureate William Phillips** – who connected from the University of Maryland – and Vanderlei Bagnato, who was on stage and assisted by two collaborators. In an entertaining conversation that combined rigorous explanations with hands-on experiments performed live, the two researchers explained how quantum physics helped us redefine some of the most fundamental units in our metric system, such as the second, the metre and the kilogram. They also stressed how important and foundational this revolution was, as for centuries we have relied on definitions that would make our units change over time. Take the unit of time, for example. *"The second had always been understood as a fraction of a day,"* explained Phillips, adding, *"The problem is that since about 1900 we know that the duration of a day is changing over time."* Quantum physics has allowed us to find a new definition of the second, based on the time taken by a Cesium atom to decay when excited with a specific energy. *"Today we have atomic clocks, which are much better than the rotation of the Earth,"* explained Phillips, before Bagnato and his assistants were able to build a mechanical equivalent of the atomic clock, using just a bucket of water and a pendulum, in front of a full and amused theatre.

Vanderlei Bagnato performing an on-stage experiment during the quantum physics performance for the public.

Friday 30 May

Day 3 of the event opened with a talk by 2016 **Nobel laureate Duncan Haldane** who, in the introduction to his talk, stated, *"We all know the laws of quantum physics formulated 100 years ago by Heisenberg and Schroedinger, but just because we know the laws, it does not mean we know everything that they allow to happen,"* referring to the many developments of quantum mechanics and exciting discoveries that have followed the formulation of the theory. The first to provide a theoretical explanation of the fractional quantum Hall effect, a puzzling phenomenon made possible by the laws of quantum physics, Haldane focused on some key theoretical aspects related to topological quantum matter, of which the fractional quantum Hall effect is an important example.

Subir Sachdev of Harvard talked about a specific type of high-temperature superconductor containing copper, known as a cuprate superconductor, which scientists have not been able to fully understand yet – although, according to Sachdev, they are now pretty close.

A discussion on international cooperation featured panelists (from left) Anne L'Huillier, David Spergel, Atish Dabholkar, Robbert Dijkgraaf, and Alessandro Curioni.

Matthias Troyer of Microsoft began his talk by presenting the case for quantum computing. He stressed how even the fastest modern classical computers work according to exactly the same principles as the abacus. *"We have not changed the way we compute for over 4500 years,"* he said. Quantum algorithms are different though and hold the promise to help us go beyond the limitations in computing speed that are intrinsic in classical computers. Troyer and his colleagues at Microsoft have been looking for problems that will allow us to achieve a practical advantage over classical computers when using quantum ones.

Quantum simulators were also at the heart of **Giorgio Parisi's** talk. The 2021 Nobel laureate focused on the possibility to use quantum physics to solve some classical problems, particularly the so-called optimisation problem, which pervades physics and engineering and where one wants to find the minimum of a specific function.

The talks of the afternoon explored some applications of quantum mechanics. **Maurizio Prato** of the University of Trieste talked about how he and his team use light to produce hydrogen that can be used as a green fuel. **Silvia Pascoli** of the University of Bologna, Italy, moved the discussion to high energy physics by talking about neutrino oscillations.

Nobel laureate Giorgio Parisi.

These are particularly interesting to physicists trying to understand the elementary components of the universe and their interactions, because *"they are the only observation we have to prove that the Standard Model is incomplete,"* Pascoli said.

In the final talk of the day, **David Gross** gave an overview of the developments of quantum mechanics that have tried to describe the fundamental particles and forces, leading to the development of quantum field theory, particularly to quantum chromodynamics, the theory that earned him the 2004 Nobel Prize, and to the Standard Model. He addressed one of the main open questions in fundamental physics: the need to combine quantum mechanics, which is extremely successful at describing matter at very small scales, with gravity, which instead decides how matter behaves on large scales, such as those of planets, galaxies and their aggregates.

Another highlight of the day was the panel discussion on international scientific collaboration. Members of the panel included **Nobel laureate Anne L'Huillier**, **David Spergel**, president of the Simons Foundation, **Robbert Dijkgraaf**, president-elect of the International Science Council, former director of the Institute for Advanced Study in Princeton and former Minister of Education, Culture and Science in the Netherlands, and **Alessandro Curioni**, vice-president of IBM Europe and Africa and president of the IBM Research Laboratory in Zurich, as well as ICTP director **Atish Dabholkar**.

The speakers in the panel shared many important messages, also in light of current urgent challenges. Dabholkar opened the discussion with a reflection on the crises that humanity is facing and the importance to tackle them at the global scale. *"We are at an unprecedented time in the history of humanity, when we have an amazing control on the quantum world, but we struggle to solve fundamental political problems. In this situation international scientific cooperation is going to be essential and I believe that organizations like ICTP have a very critical role to play,"* he said.

ICTP Research

ICTP is widely regarded as an extraordinary environment for advancing knowledge in the physical and mathematical sciences, with a permanent faculty of distinguished scientists who conduct rigorous, world-class, curiosity-driven research in frontier and interdisciplinary science ranging from string theory, cosmology, and black holes to quantum computing, climate science, and quantitative life sciences.

They teach and mentor hundreds of students and young researchers every year, equipping them to go on to study, teach, and conduct research in the world's finest universities, and to contribute to the development of science in their home countries. Research at ICTP has been linked, directly or indirectly, to five Nobel prizes.

Today, ICTP supports cutting-edge research on wide-ranging topics in physical science and mathematics, organised under the following main groups: High Energy, Cosmology and Astroparticle Physics; Condensed Matter and Statistical Physics; Mathematics; Earth System Physics; Quantitative Life Sciences; and Science, Technology and Innovation.

In addition, ICTP supports a growing research and education programme in medical physics. With support from its UN partner the IAEA, the centre holds an annual series of conferences and workshops on medical physics topics such as dosimetry and radiotherapy. ICTP and the IAEA also jointly coordinate a Master of Advanced Studies in Medical Physics that prepares students to be medical physicists in their home countries.

An emerging research initiative at ICTP involves an international effort to equalise access to scientific computing resources. Reflecting ICTP's commitment to Open Science, the centre's International Consortium for Scientific Computing (ICOMP) aims to coordinate global efforts to enhance the impact of scientific computing in addressing the scientific challenges that are at the core of a sustainable future for the Earth.

ICTP has been the anchor of the "Trieste Science System" – a network of institutes including the International School for Advanced Studies (SISSA), Elettra Synchrotron Facility, and the University of Trieste – which offers even broader opportunities for research collaboration within a short distance of our campus.

Read more about ICTP's research lines on the following pages.

ICTP SCIENTIFIC STAFF IN NUMBERS

NUMBER OF ICTP RESEARCHERS

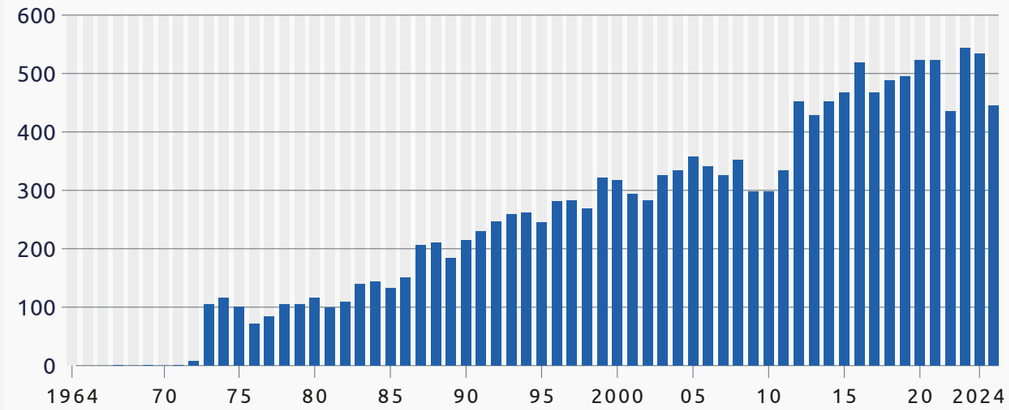
Staff, consultants, longterm visiting scientists, postdoctoral fellows

148

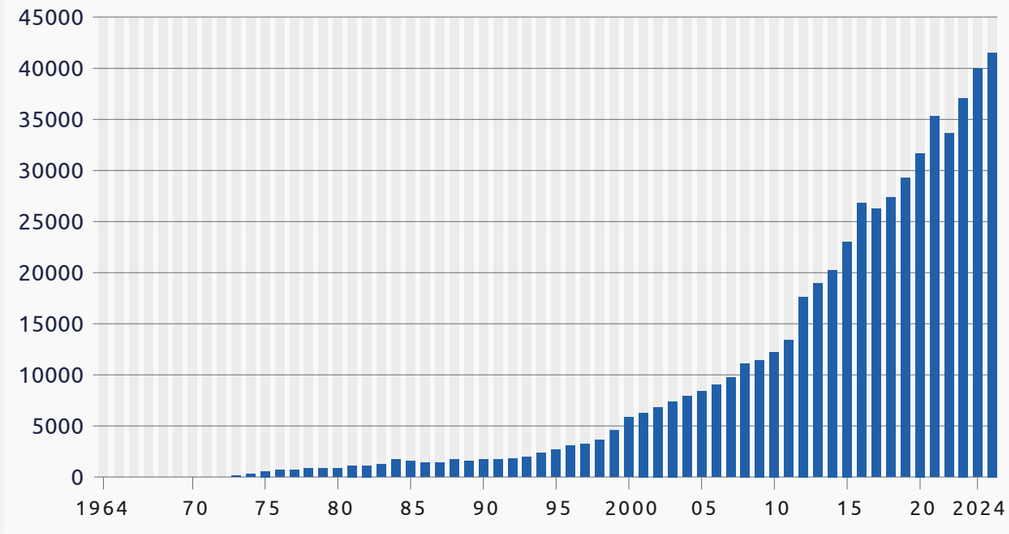
NUMBER OF COUNTRIES REPRESENTED BY ICTP RESEARCHERS

33

NUMBER OF ICTP PAPERS LISTED BY FINAL PUBLICATION YEAR



TOTAL NUMBER OF CITATIONS OF ICTP PAPERS



RESEARCH AREA:

High Energy, Cosmology and Astroparticle Physics (HECAP)

As a direct descendent of Abdus Salam's original research group at ICTP, the HECAP section tackles fundamental questions in physics to understand the basic laws governing the universe.

RESEARCH AREAS INCLUDE:

COSMOLOGY

New experimental results have driven fundamental changes in our understanding of the large-scale structure and evolution of the universe. HECAP cosmologists explore a variety of topics, such as dark energy, gravitational waves, black holes, and inflation.

PHENOMENOLOGY OF PARTICLE PHYSICS

HECAP researchers study the phenomenology of particle physics using an approach that combines modelling and data interpretation. Quantum Field Theory and experimental particle physics are bridged to investigate physics beyond the Standard Model, the phenomenology of high-energy colliders and precision experiments, dark matter, axions, neutrino and flavour physics.

STRING THEORY AND QUANTUM GRAVITY

String theory, which aims to unify general relativity and quantum mechanics, could be used to describe spacetime in extreme conditions, such as near a black hole or the big bang singularity, where quantum gravitational effects are significant. HECAP researchers study topological string theory and connections with new mathematics, the physics of quantum black holes, strongly coupled quantum field theories, string compactifications, and the fundamental principles of holographic correspondence.

EXPERIMENTAL PARTICLE PHYSICS

The joint HECAP/University of Udine ATLAS group collaborates with experimentalists working on CERN's Large Hadron Collider (LHC). HECAP researchers study the top quark and Higgs boson, and work on detector development, Monte Carlo simulation/validation, and computing performance.

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HECAP IN NUMBERS 2025

04	01	36	55
SCIENTIFIC ACTIVITIES ORGANISED AT ICTP	SCIENTIFIC ACTIVITIES ORGANISED ABROAD	SEMINARS ORGANISED	SHORT-TERM VISITORS

HECAP scientists study inflationary cosmology, black holes, physics beyond the Standard Model, general properties of Quantum Field Theory and string theory. Although HECAP has a mostly theoretical focus, with researchers using analytical methods to solve fundamental and sometimes purely mathematical problems, the ATLAS group at HECAP also collaborates with experimental scientists at CERN. This combination of experimental and theoretical groups in the section is key and it provides ongoing feedback between theory and experiments in the field.

Among their diverse research activities, HECAP scientists investigate the cosmological properties of primordial black holes, a compelling candidate for dark matter, and derive general constraints rooted in the fundamental principles of quantum mechanics and special relativity. This research line is generously supported by a prestigious ERC grant awarded to HECAP research scientist Joan Elias Miró.

Among the highlights of the activities organised by the HECAP section in Trieste in 2025, the traditional String Spring School and the Particle Physics School brought together many high-level, internationally renowned experts. Activities organised abroad included the 5th Joint ICTP-Trieste/ICTP-SAIFR School on Cosmology in São Paulo, Brazil.

HECAP also collaborates closely with the local community of high-energy physicists and cosmologists. It plays an important role in the Institute for Geometry and Physics (IGAP) – to be noted in 2025 the Workshop on String Field Theory and Related Aspects – and in the Institute for Fundamental Physics of the Universe (IFPU), which organised more than 20 focused workshops in 2025.

PUBLICATION HIGHLIGHTS

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Petrossian-Byrne, R., & Villadoro, G. (2025). Open string axiverse. Journal of High Energy Physics, 2025(7), 049. https://doi.org/10.1007/JHEP07(2025)049

RESEARCH AREA:

Condensed Matter and Statistical Physics (CMSP)

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Research at CMSP spans various key areas of theoretical condensed matter physics, including nanostructure properties and many-body quantum systems; quantum information processing; computer simulations of fluids and solids using atomistic, molecular, and electronic structure-based methods; new material design for sustainable energy applications; and synchrotron radiation-related physics. Unsupervised machine learning methods are also applied to complex quantum systems at CMSP.

RESEARCH AREAS INCLUDE:

PHYSICS OF NANOSTRUCTURES

Nano-device development has a fundamental impact on modern technology, and both quantum coherence and strong interactions play a key role in these systems. CMSP researchers study the quantum transport of energy, charge, and mass; examining anomalous transport in quantum and classical low-dimensional systems, energy transport through impurities and nanostructures, and the fundamental properties of quantum heat engines.

EQUILIBRIUM AND NON-EQUILIBRIUM MANY-BODY QUANTUM SYSTEMS

CMSP researchers investigate a wide spectrum of topics related to many-body quantum systems, such as superconductivity and magnetism in strongly-correlated systems, superfluids, cold atoms in optical lattices, localisation in disordered systems, many-body physics and light, dynamics and relaxation in complex systems, quantum simulators, and quantum computing.

ATOMISTIC, MOLECULAR, AND ELECTRONIC STRUCTURE SIMULATIONS

A wide range of systems and phenomena may be studied in-depth by modeling at the electronic structure, atomistic, and molecular levels. At CMSP, systems simulated using these approaches include surfaces and interfaces of transition metal systems; multiferroic materials; nanostructures and nanostructured phases of graphene on metal; ultra-high-pressure systems; the development of polarizable force-fields for oxides; acid-base chemistry in water and interfaces; hydrogen-bond networks in biological systems; and the chemical physics of solvation.

MATERIALS FOR SUSTAINABLE ENERGY APPLICATIONS

Advanced functional materials are required for the efficient collection and storage of sustainable forms of energy. At CMSP, quantum mechanical modelling is combined with machine learning to investigate the physics and chemistry of material interfaces, which are key to the development of catalysis, new kinds of batteries, and solar cells.

CMSP IN NUMBERS 2025

12 SCIENTIFIC ACTIVITIES ORGANISED AT ICTP

02 SCIENTIFIC ACTIVITIES ORGANISED ABROAD

51 SEMINARS ORGANISED

113 SHORT-TERM VISITORS

CMSP continues its strong involvement in sustainable energy research, employing computational atomistic modelling to investigate novel materials for next-generation batteries, solar energy harvesting, and advanced catalysts. The group also maintains close collaborations with experimentalists at the nearby Elettra synchrotron facility, focusing on the study of multiferroic materials and the behaviour of matter under extreme conditions.

In recent years, CMSP researchers have successfully secured several prestigious European Research Council (ERC) grants to advance quantum and materials science. The ERC Advanced Grant RAVE focuses on the collective dynamics of interacting particles by examining individual quantum trajectories, aiming to further the development of quantum technologies. Similarly advancing theoretical frontiers, the ERC Consolidator Grant WaveNets seeks to bridge the gap between experimental capabilities and theoretical understanding in quantum matter by applying network theory to many-body wave-functions.

Additionally, the ERC Consolidator Grant Hybop investigates the exotic optical properties of dense hydrogen-bond networks to harness them as non-invasive probes. Building upon this foundational work, the ERC Proof of Concept grant CUSHOP combines generative AI and laboratory experiments to design safer, environmentally friendly organic sunscreen molecules capable of capturing UVA and UVB radiation.

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RESEARCH AREA:

Mathematics (MATH)

The MATH section covers a broad range of traditional themes in mathematics, such as algebraic geometry; harmonic analysis and PDEs; dynamical systems and ergodic theory; differential geometry, topology and geometric analysis, with a focus on general relativity and condensed matter physics; and both algebraic and analytic number theories.

RESEARCH AREAS INCLUDE:

HARMONIC ANALYSIS AND ANALYTIC NUMBER THEORY

Harmonic analysis is used to study various oscillatory phenomena in nature, while analytic number theory involves the analysis of structures related to integer numbers. MATH researchers explore a range of themes that lie at the interface between these two fields.

HIGH-DIMENSIONAL STATISTICS, INFERENCE AND THEORY OF MACHINE LEARNING

MATH and QLS researchers investigate fundamental questions related to inference and learning efficiency, data requirements, and performance. Their mathematically rigorous approach is rooted in statistical physics combined with information theory, random matrix theory, high-dimensional statistics, and the mathematical physics of spin glasses.

DIFFERENTIAL GEOMETRY AND GEOMETRIC ANALYSIS

Differential geometry is the mathematical theory describing the curvature of spaces with arbitrary dimension. MATH researchers combine techniques from the calculus of variations, PDEs, and algebraic geometry to investigate various aspects of differential geometry, and their connection to general relativity, cosmology, and condensed matter physics.

DYNAMICAL SYSTEMS AND ERGODIC THEORY

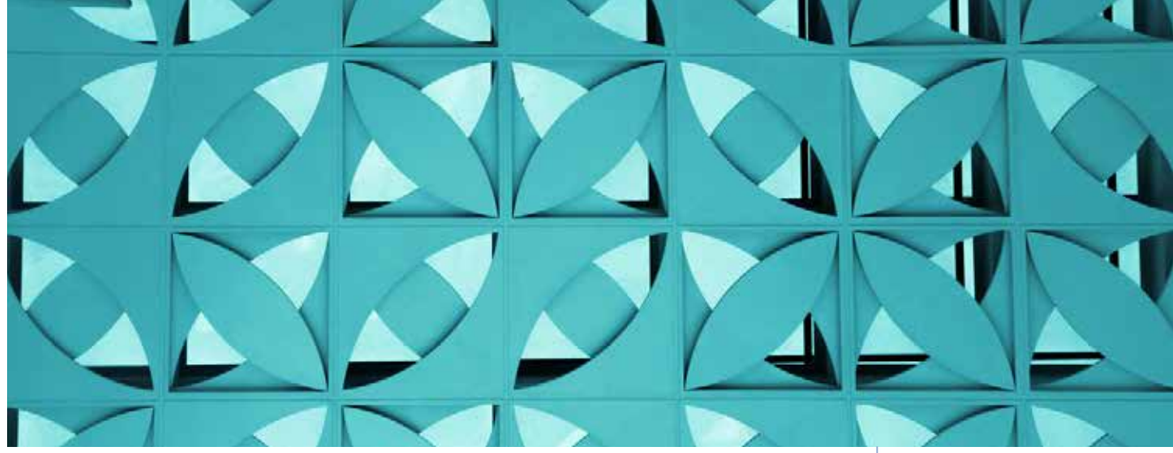
MATH researchers use (smooth) ergodic theory, and combine ideas from analysis, topology, geometry, probability theory, to understand and explain the phenomena of unpredictability and chaos in dynamical deterministic systems, and their statistical properties.

ALGEBRAIC GEOMETRY

Algebraic geometry is closely linked to algebra, complex analysis, differential geometry, topology, number theory, and mathematical physics, and utilises their methods and results. MATH researchers in this field focus on moduli spaces: algebraic varieties that parametrise interesting objects in algebraic geometry, such as curves, vector bundles, and sheaves on varieties.

MATHEMATICAL PHYSICS

MATH researchers explore mathematical concepts that are closely related to theoretical physics. Quantum field theory and string theory are mines for non-trivial mathematical conjectures and constructions such as topological quantum field theory, which incorporates topological invariants of manifolds and embeddings into convenient algebraic structures.



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MATH IN NUMBERS 2025

06 SCIENTIFIC ACTIVITIES ORGANISED AT ICTP

05 SCIENTIFIC ACTIVITIES ORGANISED ABROAD

27 SEMINARS ORGANISED

81 SHORT-TERM VISITORS

In 2025, MATH researchers obtained relations between Verlinde numbers expressed as Segre numbers of certain complexes over the moduli space of semistable vector bundles over complex projective curves with genus at least 2. New foundational results on pointed Gromov-Hausdorff convergence of sequences of Kähler submanifolds of a fixed Kähler ambient space were found. MATH researchers also proved strong statistical stability of a large class of one-dimensional maps which may have an arbitrary finite number of discontinuities and of non-degenerate critical points. They improved the current upper and lower bounds for the average value of Montgomery's function over long intervals by using a Fourier optimization framework. They also investigated the SU(r) Vafa-Witten partition function for surfaces with holomorphic 2-form.

In 2025, the MATH section organised eleven activities in Trieste and across the world, including Brazil, Rwanda and Vietnam. On top of schools and workshops on foundational topics such as geometric analysis, hyperbolic geometry, harmonic analysis and low dimensional topology, some of these activities also focused on interdisciplinary subjects of interest, with an eye towards applications and the use of new computational tools. Examples are the School and Workshop on Explicit Arithmetic Geometry, where modern techniques from high performance computing were implemented, and two meetings on number theory and physics. Other activities organised in Trieste in 2025 included a conference on moduli theory and two special lectures. MATH also collaborated with SISSA to give an advanced PhD course on modular forms.

The MATH section also strengthened crucial strategic partnerships, particularly with the International Mathematical Union (IMU), the Centre International de Mathématiques Pures et Appliquées (CIMPA), and with the Italian National Institute for Advanced Mathematics (INdAM). In particular, in 2025, 12 CIMPA-ICTP Fellows participated in the Research in Pairs Program and 26 grantees participated in the ICTP-INdAM Program. MATH collaborated with CIMPA to organise 4 courses and started a new collaboration with the Simons Laufer Mathematical Sciences Institute (SLMath) in Berkeley to co-organize a Summer Graduate School on Machine Learning in Trieste.

PUBLICATION HIGHLIGHTS

Alves, J. F., Gama, D., & Luzzatto, S. (2025). Statistical stability of interval maps with critical points and singularities. Journal of Dynamics and Differential Equations. https://doi.org/10.1007/s10884-025-10432-8

Arezzo, C., Li, C., & Loi, A. (2025). Gromov-Hausdorff limits and holomorphic isometries. Mathematical Research Letters, 32(3), 707-738.

Carneiro, E., Milinovich, M., & Ramos, A. P. (2025). Fourier optimization and Montgomery's pair correlation conjecture. Mathematics of Computation, 94(351), 409-424. https://doi.org/10.1090/mcom/3935

Göttsche, L., Kool, M., & Laarakker, T. (2025). SU(r) Vafa-Witten invariants, Ramanujan's continued fractions, and cosmic strings. Michigan Mathematical Journal, 75(1), 3-63. https://doi.org/10.1307/mmj/20255201

Marian, A. (2025). The Segre-Verlinde correspondence for the moduli space of stable bundles on a curve. Communications in Mathematical Physics, 406(1), Article 5. https://doi.org/10.1007/s00220-025-04877-6

RESEARCH AREA:

Earth System Physics (ESP)

The ESP section encompasses a range of research topics related to the solid (lithosphere) and fluid (atmosphere and oceans) components of the Earth System.

The solid-Earth geophysics research line investigates how continents deform and the way earthquake faults behave in a time span of interest to society. Global atmospheric and ocean models are used to study large-scale climate variability and change, whereas high-resolution regional models provide local scale climate information. ESP also studies the impact of anthropogenic climate change on water cycle, humans, ecosystems and vector-borne diseases.

RESEARCH AREAS INCLUDE:

SOLID EARTH GEOPHYSICS

ESP researchers use seismology, space geodesy, tectonics, and numerical experiments to conduct large-scale modelling of faults and cracks in the Earth's crust; examining active earthquake and volcanic regions, the physics of transient deformation, and earthquake hazard.

AI FOR CLIMATE APPLICATIONS

ESP researchers use AI-based climate emulators to complement their dynamical modelling and reach kilometre-scale climate projections.

CLIMATE APPLICATIONS

ESP applies analogue methods to understand the contribution of anthropogenic climate change to the recent exacerbation of extreme climate events all over the world. Dynamical and statistical modelling techniques are employed to assess the socio-economic impact of climate variability and change on human resources such as energy, water, and health. The ESP-developed VECTRI dynamical model is employed to describe malaria transmission, and determine its response to climate variability. ESP scientists use the CHyM hydrological model, coupled with the regional climate models, to describe the hydrological conditions of the river basins in a changing climate.

EARTH SYSTEM MODELING

A suite of Earth system models are developed to represent the key processes that determine the Earth's climate, such as atmospheric and ocean circulation, and land surface processes. ESP researchers use tools such as recent evolutions of the regional climate model RegCM, the intermediate complexity global model SPEEDY and the global ocean model MOM5 to understand our climate, its natural variability, and its response to anthropogenic forcing.

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CMSP IN NUMBERS 2025

03
SCIENTIFIC ACTIVITIES ORGANISED AT ICTP

04
SCIENTIFIC ACTIVITIES ORGANISED ABROAD

19
SHORT-TERM VISITORS

In 2025, ESP researchers developed and tested a new AI-based, high resolution regional climate emulator, GNN4CD, which was shown to correctly reproduce the climate change signal in the statistical distribution of the hourly precipitation over the Italian regions. The GNN4CD is based on graph neural networks and it implements a new training strategy. The emulator complements the regional climate model RegCM5 for high resolution km-scale projections.

ESP researchers showed that a record-breaking compound extreme rainfall event in April 2024 in West and East Asia was linked to anomalous heating in the Indian Ocean.

A 2025 paper from ESP examined an ensemble of eight ocean reanalysis (ORA) products, which are essential tools for monitoring and understanding tropical Atlantic interannual variability. The analysis revealed a significant spread in tropical Atlantic Ocean temperature anomalies and showed that this is caused by discrepancies among the atmospheric fields used to force ORAs.

ESP researchers also presented a new stochastic reaction-diffusion model for the tropics, which is able to simulate aggregated and random convective states.

PUBLICATION HIGHLIGHTS

Blasone, V., Coppola, E., Sanguinetti, G., Arora, V., Di Gioia, S., & Bortolussi, L. (2025). Graph neural networks for hourly precipitation projections at the convection permitting scale with a novel hybrid imperfect framework. Environmental Data Science, 4, e47. https://doi.org/10.1017/eds.2025.10022

Prigent, A., Richter, I., Storto, A., Farneti, R., Imbol Koungue, R. A., Okumura, Y., & Chang, P. (2025). Interannual variability of upper ocean temperature in the tropical Atlantic: An ocean reanalysis intercomparison. Climate Dynamics, 63, 339. https://doi.org/10.1007/s00382-025-07820-7

Tompkins, A. M., Casallas, A., & De Vera, M. V. (2025). Drivers of mesoscale convective aggregation and spatial humidity variability in the tropical Western Pacific. npj Climate and Atmospheric Science, 8(1). https://doi.org/10.1038/s41612-024-00848-2

He, C., & Kucharski, F. (2025). Tele-connected rainfall extremes over West and East Asia in April 2024 tied to Indian Ocean heating. Climate Dynamics, 63, 107. https://doi.org/10.1007/s00382-025-07593-z

RESEARCH AREA:

Quantitative Life Sciences (QLS)

The QLS section focuses on problems at the interface between statistical physics, biology, ecology, economics, neuroscience, information theory and artificial intelligence.

RESEARCH AREAS INCLUDE:

QUANTITATIVE ECOLOGY AND EVOLUTION

QLS researchers investigate how many species can coexist in highly-diverse communities, and what are the processes determining their dynamics and their evolution in uncertain environments, with a main focus on microbial ecology. This research line aims at building a robust quantitative phenomenology from observational and experimental data and integrating it with mathematical theory.

NEURAL COMPUTATION

QLS researchers use statistical physics and theoretical machine learning to study memory capacity in heterogeneous, biologically plausible neural networks and the mechanisms by which the brain encodes salience and surprise of stimuli for enhanced processing of important information.

STOCHASTIC THERMODYNAMICS

Nonequilibrium fluctuations in microscopic systems are studied at QLS using stochastic thermodynamics, and a combination of theory, numerical simulation, and experimental data analysis. QLS scientists investigate the relevance of the martingale theory of stochastic thermodynamics to biological, soft-matter, condensed and active matter systems, with applications extending to finance and game theory.

EMERGENT COLLECTIVE BEHAVIOUR IN INTERACTING AGENT SYSTEMS

Statistical mechanics-based methods are used to explore phenomena in economics and finance, such as loss of transparency in financial transformations and the unintended consequences of technological innovation, with particular emphasis on problems relevant to the human dimension of sustainable development.

PHYSICS OF BEHAVIOUR AND SENSING

QLS researchers study decision-making in several model systems such as chemotaxis in bacteria and cancer cells, olfactory search, and flight. Statistical physics, information theory, computer science, and biology are used to form an algorithmic understanding of animal search behaviour and decision-making guided by sensory information.

HIGH-DIMENSIONAL STATISTICS, INFERENCE, AND THEORY OF MACHINE LEARNING

QLS researchers study inference and learning efficiency using a quantitative approach based on statistical physics, addressing questions about the impact of data structure and the required amount of data on performance. An information-theoretic quantitative measure of relevance is employed to address fundamental questions such as the difference between learning and understanding and the emergence of abstraction in deep neural networks. In addition, QLS researchers are developing a novel statistical physics framework able to describe feature learning mechanisms in deep neural networks.

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QLS IN NUMBERS 2025

04
SCIENTIFIC ACTIVITIES ORGANISED AT ICTP

02
SCIENTIFIC ACTIVITIES ORGANISED ABROAD

26
SEMINARS ORGANISED

54
SHORT-TERM VISITORS

In 2025 QLS scientists organised several training activities – schools and conferences that took place both in Trieste and across the world. Besides the Spring College in the Physics of Complex Systems, a yearly school targeting master's and PhD students, the Hands-on Quantitative Biology School in Trieste, organized in collaboration with the International Centre for Genetic Engineering and Biotechnology (ICGEB), the Istituto Fondazione di Oncologia Molecolare (IFOM) and Institut Curie, exposed PhD students and postdocs from diverse backgrounds to interdisciplinary approaches in biology through theoretical lectures and hands-on experiments.

QLS is very active in the fields of AI and Machine Learning. The section organised two main events on these topics in 2025, including the 6th edition of Youth in High-Dimensions: Recent Progress in Machine Learning, High-Dimensional Statistics and Inference and a conference titled "How creative is Generative AI? Perspectives from Science and Philosophy". These were followed by the award ceremony of the first ICTP-IBM Brahmagupta AI Prize for Young Scientists.

QLS was a key organiser of the first ever Africa-hosted satellite event of the IUPAP International Conference on Statistical Physics at the ICTP East African Institute for Fundamental Research (ICTP-EAIFR). The event took place from 5 to 10 July in Kigali, Rwanda. It started with a two-day school gathering around 25 students from 10 African countries, followed by a workshop on cutting-edge topics in statistical physics and complex systems – very active research areas that are still underexplored by the African physics community. Nobel laureate Giorgio Parisi highlighted the challenges of engaging the African community in international events and research networks. Special attention was given to stirring cross-disciplinary dialogues on how to promote African research outside the continent. Half of the speakers of the workshop were women, which prompted in-depth discussions on the challenges of women in STEM in Africa.

PUBLICATION HIGHLIGHTS

Shoemaker, W. R., Sánchez, Á., & Grilli, J. (2025). Macroecological patterns in experimental microbial communities. PLOS Computational Biology, 21(5), e1013044. https://doi.org/10.1371/journal.pcbi.1013044

Barbier, J., Camilli, F., Ko, J., & Okajima, K. (2025). Phase diagram of extensive-rank symmetric matrix denoising beyond rotational invariance. Physical Review X, 15(2), 021085. https://doi.org/10.1103/PhysRevX.15.021085

de Mulatier, C., & Marsili, M. (2025). Bayesian inference of minimally complex models with interactions of arbitrary order. Physical Review E, 111(5), 054307. https://doi.org/10.1103/PhysRevE.111.054307

Bresque, L., Das, D., & Roldán, É. (2025). Run-and-tumble exact work statistics in a lazy quantum measurement engine: Stochastic information processing. Physical Review Letters, 134(20), 200402. https://doi.org/10.1103/PhysRevLett.134.200402

Heinonen, R. A., Biferale, L., Celani, A., & Vergassola, M. (2025). Optimal trajectories for Bayesian olfactory search in turbulent flows: The low information limit and beyond. Physical Review Fluids, 10(4), 044601. https://doi.org/10.1103/physreve.107.055105

RESEARCH AREA:

Science, Technology and Innovation (STI)

STI researchers develop technological solutions to critical scientific and societal challenges. The Unit bridges in-house innovation and collaborations with UN and international partners to tackle complex problems that impact humanity.

The STI Unit has a broad research scope, encompassing sustainable AI on embedded devices; advanced instrumentation for sensors, nuclear and particle physics, optics, cultural heritage, and supercomputing; cost-effective digital fabrication technologies for education and outreach, and ionospheric physics, modelling, and space weather.

RESEARCH AREAS INCLUDE:

WIRELESS ICT AND INTERNET OF THINGS

STI researchers develop high-impact technological solutions for the world's most pressing scientific and societal challenges. By deploying Delay Tolerant Networking to bridge the gap for the unconnected, they ensure that even the most remote Internet of Things (IoT) sensors can deliver critical data. Paired with advanced embedded AI, these innovations turn complex environmental and social hurdles into scalable human progress.

IONOSPHERIC PHYSICS, MODELLING AND SPACE WEATHER

STI researchers investigate the near-Earth plasma environment, advance the understanding of ionospheric physics, and develop ionospheric electron density models. Particular focus is placed on space weather phenomena and their impact on the performance of technological systems, such as the Global Navigation Satellite Systems (GNSS). Special emphasis is given to ionospheric monitoring, primarily through the analysis of total electron content data which is performed also using Machine Learning techniques.

ADVANCED SCIENTIFIC INSTRUMENTATION

STI researchers at the Multidisciplinary Laboratory (MLab) develop advanced instrumentation and innovative methods across a broad range of fields, including particle physics experiments, nuclear applications, heterogeneous computing, cultural heritage, and optics. By combining interdisciplinary expertise through internal and external collaborations, their work addresses diverse scientific challenges and enables the development of cutting-edge technologies and methodologies that advance both fundamental and applied research.

DIGITAL FABRICATION AND SCIENCE DISSEMINATION

The STI Unit's Scientific FabLab (SciFabLab) features cutting-edge manufacturing equipment for digital fabrication and rapid prototyping, operating within the global FabLab network. The laboratory is accessible to ICTP researchers and the public for projects focused on science, education, and sustainable development. Additionally, the SciFabLab engages in science outreach through laboratory tours and events like the Maker Faire Trieste.

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STI IN NUMBERS 2025

08
SCIENTIFIC ACTIVITIES ORGANISED AT ICTP
2 activities organized in Rome

02
SCIENTIFIC ACTIVITIES ORGANISED ABROAD

01
SEMINAR ORGANISED

55
SHORT-TERM VISITORS

The ionospheric modeling team at STI continues to actively engage in expanding the network of low-cost GNSS receivers developed by the group. This initiative aims to strengthen Africa's capacity in space weather and ionospheric monitoring, enhancing data collection and analysis for scientific research and technological applications.

In 2025 members of STI organized several activities, both in Italy and around the world, including workshops and conferences in Malawi, Guatemala, Macau, Ghana, Saudi Arabia.

STI researchers design robust, low-cost equipment for the specific needs of the Global South, with particular attention to sustainability. The Marconi Lab was a pioneer in adopting and developing Tiny Machine Learning (TinyML) – an energy-efficient technology that brings localized AI to the most resource-constrained regions. The group also leads the TinyML Academic Network, a global alliance of over 60 universities working to ensure that sustainable AI expertise is grown from within the developing world.

In 2025, the STI Unit's SciFabLab focused on research and training activities on the use of digital technologies for science and education, on developing science exhibits, and on designing and prototyping devices for the implementation of scientific experiments.

Researchers at the MLab have been working in ongoing collaboration with INFN to develop the readout system of a multichannel detector that will be used in 2026 at CERN's AMBER experiment to measure the proton radius. In partnership with the IAEA's Nuclear Science and Instrumentation Laboratory, in 2025 MLab researchers developed a mixed-radiation system with edge AI for real-time neutron and gamma discrimination, as well as a macro X-ray fluorescence scanner for cultural heritage and environmental studies. The team also collaborates with the University of Trieste on a cluster of heterogeneous devices based on field programmable gate array technology, with remote access for reconfigurable computing and edge AI applications.

PUBLICATION HIGHLIGHTS

Zennaro, M., Pietrosemoli, E., Soltobaev, A., Sultanov, T., & Moldobekov, B. (2025). From mountains to data: Low-cost weather stations in Kyrgyzstan's challenging terrain. Frontiers in Communications and Networks, 6, 1505375. https://doi.org/10.3389/frcmn.2025.1505375

Crespo, M. L., De Micco, L., Antonelli, M., Lopresti, R., Silva, A., Florian, W., Garcia, L., & Cicuttin, A. (2025). Experimental validation of true randomness and entropy generation leveraging asynchronous cellular automata. Nonlinear Dynamics, 113, 22943-22962. https://doi.org/10.1007/s11071-025-11370-2

Pignalberi, A., Nava, B., Prol, F., et al. (2025). Improving the NeQuick model in the plasmasphere through radio occultation and POD TEC observations. IEEE Transactions on Geoscience and Remote Sensing, 63, Article 4113719, 1-19. https://doi.org/10.1109/TGRS.2025.3635770

Momeni, M., & Migoya-Orué, Y. (2025). Solar activity and ionospheric variation: A comprehensive study using Hurst exponent and probability density functions analysis. Advances in Space Research, 75(10). https://doi.org/10.1016/j.asr.2025.02.060

Samayoa, W. F., Crespo, M. L., Carrato, S., Silva, A., Escobar, M. B., & Cicuttin, A. (2025). HyperFPGA: A scalable reconfigurable platform for computing paradigms research. IEEE Access, 13, 201377-201391. https://doi.org/10.1109/ACCESS.2025.3637300

EMERGING RESEARCH AREAS:

Medical Physics and Scientific Computing

Over the years, ICTP has realised the evolving importance of two research fields research that fall outside of its current established sections. Activities in both medical physics and scientific computing have existed at the centre for years; now, thanks to strong partnerships with its UN partners and institutional consortiums, the two fields are developing into spheres of research and educational activities in their own right. Read more about these efforts below.

Graduation ceremony 2025, Master of Advanced Studies in Medical Physics.

MEDICAL PHYSICS

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The Medical Physics group at ICTP investigates the computational and theoretical aspects of physical science applied to medicine. Focusing on radiation oncology, medical imaging, and radiation dosimetry, the group places a particular emphasis on addressing challenges critical to global health.

In 2025, the Medical Physics group organised five scientific activities. It also launched the GLOBEAM initiative to develop advanced AI models for automating and benchmarking radiation therapy treatment planning. This multicentric effort includes San Raffaele Hospital in Milan, Oncopole l'Espoir in Oran, the National Cancer Center in Benghazi, and the Salah Azaiez Institute in Tunis. In parallel, a major national dosimetry study was conducted with the Italian Association of Medical Physics to evaluate portal-image-based in vivo systems. The study was coordinated by ICTP and it involved 12 Italian institutes. Preliminary findings from both initiatives will be presented at the 2026 ESTRO Congress in Stockholm.

The Medical Physics group also coordinates the Master of Advanced Studies in Medical Physics, run jointly with the University of Trieste and in close collaboration with the IAEA.

In 2025, it organised five conferences and workshops, two of which were joint with the IAEA.

PUBLICATION HIGHLIGHTS

O'Daniel, J., Hernandez, V., Clark, C., Esposito, M., Lehmann, J., McNiven, A., Olaciregui-Ruiz, I., & Kry, S. (2025). Which failures do patient-specific quality assurance systems need to catch? Medical Physics, 52(1), 88-98. https://doi.org/10.1002/mp.17468

Esposito, M., Buono, R., Chand, S. B., Poudel, S., Castriconi, R., Tudda, A., Placidi, L., Cagni, E., Landoni, V., Mazzilli, A., & Moretti, E. (2025). Assessing the global transferability of knowledge-based planning models for breast radiotherapy: A case study in Nepal. Radiotherapy and Oncology, 206, S2219-S2221. https://doi.org/10.1016/S0167-8140(25)00340-8

SCIENTIFIC COMPUTING

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The Scientific Computing group at ICTP investigates critical aspects for advancing High-Performance Computing (HPC) and Artificial Intelligence (AI) through the development and application of computational methods across a range of topics in computational and theoretical physics, including fluid dynamics, climate science, and astrophysics.

In 2025 the Scientific Computing group organized four activities, two at ICTP and two abroad. Key contributions made by the group include advances in numerical modelling of dense emulsions; GPU porting of the RegCM5 climate model; development of new foundation models for scientific time-series data; development of new algorithms in the field of causal inference, explainable AI and equivariant deep learning for astrophysics; advancement of climate emulation techniques.

The group leads the Master in HPC, serves as a core component of ICTP's International Consortium for Scientific Computing (ICOMP), and manages access to leading HPC facilities for ICTP scientists and affiliated centres, while playing a central role in ICTP activities focused on scientific computing and AI.

PUBLICATION HIGHLIGHTS

Girotto, I., Scagliarini, A., Yi, L., Benzi, R., Sun, C., & Toschi, F. (2025). Non-reciprocal coalescence-breakup dynamics in concentrated emulsions. arXiv. https://arxiv.org/abs/2509.21347

Zivanovic, U., Di Gioia, S., Scaffidi, A., de los Rios, M., Contardo, G., & Trotta, R. (2025). Rotary masked autoencoders are versatile learners. In Advances in Neural Information Processing Systems (NeurIPS 2025). https://arxiv.org/abs/2505.20535

ICTP Prizes and International Chairs

ICTP has established a series of prizes and chairs to recognise major contributions to mathematics and physics by researchers from across the world and enhance global scientific collaboration.

The prize ceremonies, celebrated throughout the year, are occasions for esteemed scientists to visit ICTP, present their work, and interact with ICTP's community of scholars and students. The winners of the prizes awarded by ICTP become role models for young researchers around the world and active members of ICTP's global scientific network. ICTP also appoints distinguished scientists to international research chairs, enabling them to spend extended time at ICTP and work side-by-side with ICTP scientists, visitors, postdocs, and students from around the world.

Some of the ICTP prizes and chairs are named to honour the scientific contributions from the global South. These include the Srinivasa Ramanujan International Chair in Mathematics, the Miguel Virasoro Visiting International Chair in Physics, the ICTP-IBM Brahmagupta AI Prize for Early Career Scientists, and the ICTP-IMU Ramanujan Prize in mathematics. This choice exemplifies ICTP's founding principle that scientific endeavours are the shared creation and heritage of all humankind.

Dirac Medallists 2025 Gary Horowitz (left) and Robert Wald (right) with ICTP Director Atish Dabholkar.

2025 Ramanujan Prize winner Claudio Muñoz.

Prizes

Dirac Medal

ICTP's Dirac Medal, given in honour of physicist and ICTP friend P.A.M. Dirac, is awarded annually to scientists who have made significant contributions to theoretical physics. It was first awarded in 1985. The 2025 Dirac Medal was attributed to Gary Gibbons of Cambridge University, UK, Gary Horowitz of the University of California Santa Barbara, USA, Roy Kerr of the University of Canterbury, New Zealand, and Robert Wald of the University of Chicago, USA, for their landmark contributions to our understanding of gravity.

Richard Feynman Prize in Quantum Computing

The ICTP-IBM Richard Feynman Prize in Quantum Computing is awarded jointly by ICTP and IBM to established researchers for their exceptional contributions to the field of quantum computing, including theory, algorithms, applications, or simulations. Launched in 2025 and named in honour of quantum mechanics pioneer Richard Feynman, it will be awarded for the first time in 2026.

Ramanujan Prize

The ICTP-IMU Ramanujan Prize is awarded jointly by ICTP and the International Mathematical Union (IMU) to young mathematicians from developing countries who have conducted outstanding research in mathematics in a developing country. The Prize was established In 2005. In 2025, it was awarded to Claudio Muñoz of the University of Chile for his fundamental contributions to dispersive partial differential equations.

Brahmagupta AI Prize

The ICTP-IBM Brahmagupta AI Prize for Early Career Scientists is awarded jointly by ICTP and IBM to outstanding researchers working in AI for Science/Science for AI. The award honours Indian mathematician and astronomer Brahmagupta, who is known for introducing zero and negative numbers. The prize was established in 2024 and awarded for the first time in 2025 to computer scientist Simon Olsson of Chalmers University of Technology, Sweden, for his pioneering work on the use of Artificial Intelligence methods in molecular simulations.

Simon Olsson delivering his lecture as first recipient of the ICTP-IBM Brahmagupta AI Prize for Early Career Scientists.

(From left to right) President of ICO Eric Rosas, winners Gustavo Grinblat and Omnia Hamdy, ICTP Director Atish Dabholkar.

Gallieno Denardo Award

The ICO-ICTP Gallieno Denardo Award is awarded jointly by ICTP and the International Commission for Optics (ICO) to recognise the work of young researchers from developing countries who are active in optics and photonics research and have contributed to the promotion of research activities in a developing country. The award was established in 2007. In 2025, the winners were Omnia Hamdy Abdelrahman Nematallah, from the National Institute of Laser Enhanced Sciences at Cairo University, Egypt, and Gustavo Grinblat, from the Faculty of Exact and Natural Sciences, University of Buenos Aires, and the Argentine Research Council – CONICET, Argentina.

Walter Kohn Prize

The Walter Kohn Prize for quantum-mechanical materials modelling was jointly instituted and co-funded by ICTP and the Quantum ESPRESSO Foundation. It is awarded biennially to a young scientist for their outstanding contributions in the field of quantum-mechanical materials and molecular modeling, performed in a developing country or emerging economy, with emphasis on first-principles techniques. The Walter Kohn Prize will be next awarded in 2026.

Spirit of Abdus Salam Award

The Spirit of Abdus Salam Award is given by the family of Abdus Salam to recognise tireless work to further Abdus Salam's humanitarian passion and vision for the cooperation, promotion and development of science and technology in the developing world. It can be attributed to members of the extended ICTP family of scientists and non-scientists alike. In 2025, the prize was awarded to Renato Padovani, for his efforts in setting up, organizing and managing the Advanced Master in Medical Physics, and Qaisar Shafi, for his longstanding commitment to Abdus Salam's vision as his colleague and doctoral student, and more recently as a supporter of the Qaiser and Monika Shafi Prize for Diploma students.

Qaisar Shafi and Renato Padovani at the Spirit of Salam Award ceremony.

International Chairs

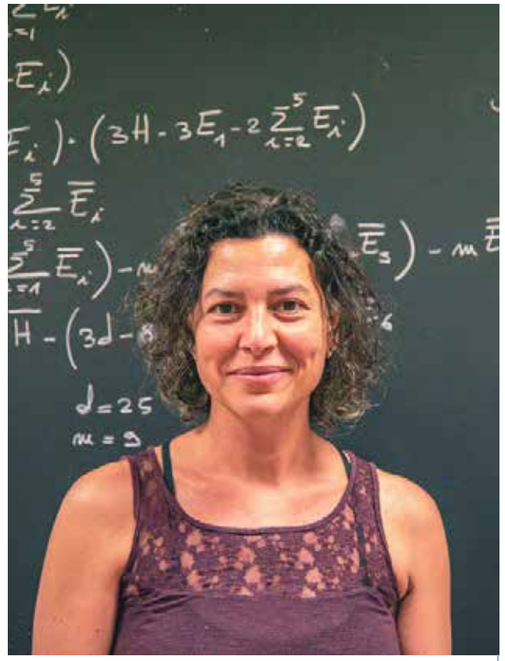
ICTP International Chairs are prestigious visiting positions allowing distinguished physicists and mathematicians to spend extended time at ICTP. While in Trieste, these high-level researchers deliver lectures, lead discussion groups, guide research, and mentor scientists from disadvantaged countries. They make an invaluable impact on ICTP's community by providing a unique opportunity for scientists in all stages of their careers and from all corners of the world to have direct exposure to the world's best scientific talent. Those scientists, in turn, share their knowledge with colleagues and students in their home countries.

Ramanujan International Chair

ICTP's Ramanujan Chair is hosted in the Mathematics section and named in honour of Indian mathematical genius Srinivasa Ramanujan (1887 – 1920). Since 2025, the chair has been held by Brazilian mathematician Carolina Araujo of the Institute for Pure and Applied Mathematics (IMPA) in Rio de Janeiro, Brazil. An algebraic geometer specializing in birational geometry and foliations, Araujo is a distinguished mathematician and a promoter of women in mathematics, with longstanding connections to ICTP.

Virasoro International Chair

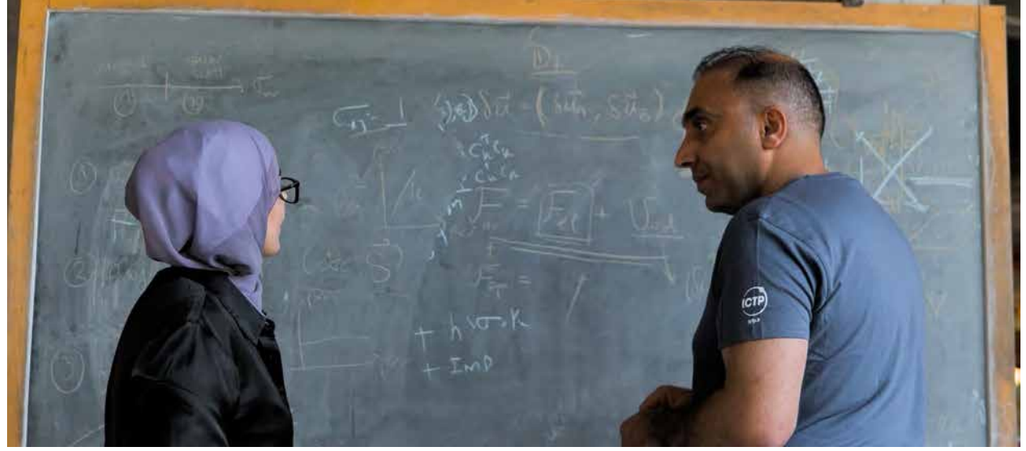
The Miguel Virasoro Visiting International Chair is hosted in ICTP's Condensed Matter and Statistical Physics section. It was launched in 2024 and has since been held by Subir Sachdev, a condensed matter physicist known for his important contributions to the understanding of entangled states of quantum matter.



Carolina Araujo, Ramanujan International Chair.

Subir Sachdev, Virasoro International Chair.

Higher Education and Career Development



Educational Programmes

Scientists at all stages of their careers can advance their knowledge in physics and mathematics through ICTP's education and training programmes. These include pre-PhD programmes that help prepare students for the rigors of doctorate study; joint masters and PhD degree programmes operated with Italian and European universities; and a sabbatical programme supporting visits of scientists who want to maintain their connection to ICTP.

Postgraduate Diploma Programme: Supporting its mission to promote advanced scientific research in developing countries, ICTP offers a Postgraduate Diploma Programme that prepares talented students for PhD studies. The intense, one-year course of study is competitive: from about 180 applicants to each of the five regular Diploma programmes, only 10 students are admitted in each. All are given full support, covering airfare and living costs. The focus is especially on those developing countries for which high-quality advanced scientific training is less accessible. In the 2025-2026 course that began in September 2025, the students came from 25 countries in Africa, Asia and Latin America.

After obtaining the ICTP Diploma, most students go on to do a PhD in Europe or North America, or return to jobs as college teachers, or register for PhD studies in their home countries. In the 2024-2025 batch of 43 students who received their Postgraduate Diplomas, the MSc/PhD placements included Kyoto University, University of Munich, University of Glasgow, Berlin Mathematical School, University of Houston, and the Okinawa Institute of Science and Technology, among others.

ICTP EDUCATION IN 2025

139
STUDENTS ENROLLED IN MASTERS, PHD, DIPLOMA AND STEP PROGRAMMES

58
COUNTRIES REPRESENTED (INCLUDING 10 LEAST-DEVELOPED COUNTRIES)

Masters' Programmes: ICTP, in collaboration with local universities, offers study opportunities to scientists from the developing world, helping them attain master's and doctoral degrees in physics and mathematics. Thanks to these collaborations, students from disadvantaged countries can pursue masters degrees in the following programmes:

- *Master of Advanced Studies in Medical Physics:* a two-year advanced training programme run jointly by the ICTP and the University of Trieste designed to provide young, promising graduates of physics or related fields (mainly from developing countries) with postgraduate theoretical and clinical training so that candidates may be recognised as clinical medical physicists in their home countries.

The programme comprises a year of basic and advanced courses (taught in English) prepared with the assistance of experts from the ICTP, the University of Trieste, the International Atomic Energy Agency (IAEA) and appointed external advisors. This is followed by a year of professional clinical training in a medical physics department of an Italian hospital in the programme's training network. The MMP is co-sponsored by the IAEA, and is supported by the International Organisation for Medical Physics (IOMP), the European Federation of Organizations in Medical Physics (EFOMP), the Italian Association of Medical Physics (AIFM), in collaboration with Trieste University Hospital. The Master's Programme is accredited by the International Organisation for Medical Physics (IOMP). In 2025, 17 students (7 female and 10 male) from 16 different countries were enrolled in the 2025-2026 academic year, while 19 students (7 female and 12 male) graduated from the programme.

- *Master in High Performance Computing:* an innovative degree programme that prepares students for exciting careers in the fast-growing field of high performance computing (HPC). Set in the stimulating research environment of ICTP and SISSA, the programme combines lectures with hands-on and applied projects to prepare future HPC specialists for academia and industry. Courses are delivered by an international faculty composed by local HPC experts complemented by international well-renowned experts in the field. Practical HPC experience allows students to work side-by-side with scientific groups and/or stimulating industrial environments.
In 2025, 12 students (3 female and 9 male) from 8 countries were registered in the MHPC with the ICTP Fellowship, while 4 students (2 female and 2 male) graduated.

In addition, ICTP offers a limited number of scholarships to students from developing countries selected to follow the training track in Condensed Matter Physics of the International Master in Physics of Complex Systems, offered through an international consortium of universities. Each scholarship includes a travel grant, insurance and tuition fees. In 2025, 2 students from Thailand and Iran were funded by ICTP.

PhD and Sandwich Programmes: ICTP, in collaboration with local universities, offers study opportunities and fellowships to scientists from the developing world, helping them attain master's and doctoral degrees in physics and mathematics. Thanks to these collaborations, students from disadvantaged countries can pursue doctoral degrees in the following programmes:

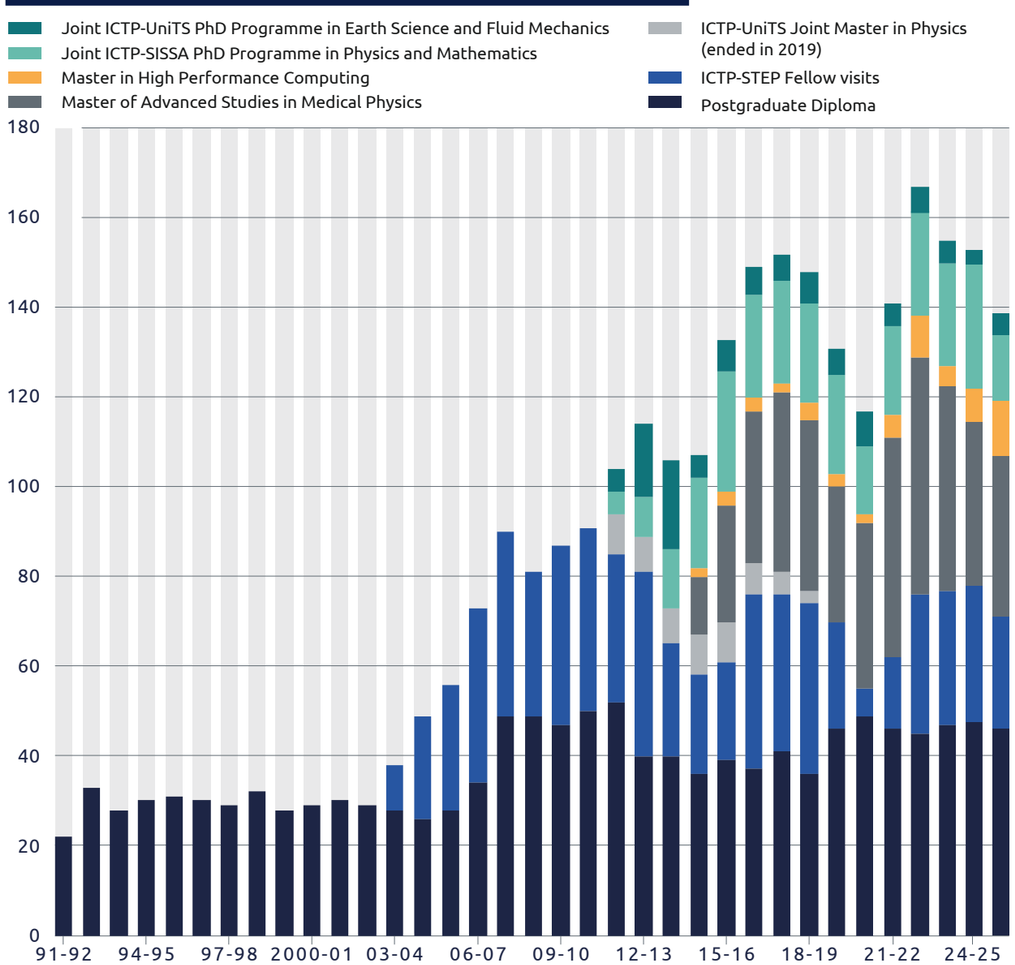
- *Physics PhD Programme, University of Trieste:* ICTP offers a scholarship for students from developing countries who want to do research in areas of interest to ICTP to enroll in this PhD programme. In 2025, 2 female students from Tunisia and Rwanda were enrolled in the programme with an ICTP scholarship.

- *Joint ICTP/SISSA PhD Programme in Physics and Mathematics:* ICTP partners with SISSA to offer students who have successfully completed ICTP's Postgraduate Diploma Programme the opportunity to enroll in a PhD programme in Trieste. The Programme offers courses in: applied mathematics, mathematical analysis, geometry, mathematical physics; astroparticle physics, astrophysics; elementary particles; physics and chemistry of biological systems; statistical physics; condensed matter theory and numerical simulation. During 2025, 15 students (3 female and 12 male) from 11 countries were enrolled in this PhD programme; 6 students graduated in 2025.

- *Joint PhD Programme, Earth Science, Fluid-Dynamics, and Mathematics. Interactions and Methods:* Co-sponsored by ICTP, the University of Trieste and the Italian National Institute of Oceanography and Experimental Geophysics (OGS), this programme aims at the interdisciplinary training of students in the field of the Earth system science, with special attention to the interactions between Earth science, fluid-dynamics and applied mathematics, as well as to the interplay of methodological aspects, modeling and applications. In 2025, 5 students (2 female and 3 male) from 5 countries were enrolled in the Programme, and 1 female student from Kuwait graduated.
- *PhD Programme, Industrial and Information Engineering, University of Trieste*: ICTP provides fellowships to students from developing countries to enroll in this programme that prepares researchers in design methods, theoretical analysis, soft-computing and advanced experimentation. During 2025, 1 male student from Guatemala was enrolled in the programme with an ICTP fellowship.

In addition, through its **Sandwich Training Educational Programme** (STEP), ICTP and its UN partner, the International Atomic Energy Agency (IAEA), offer fellowships to PhD students from developing countries in the fields of physics, mathematics and related fields. PhD students study at their home universities but have the financial support to visit ICTP or a collaborating institute for a three- to six-month stay each year for up to three successive years. Fellows work on their PhD theses with their advisors at their home institutes and co-advisors at the hosting institutes. Their PhD is awarded at their home institutes. During 2025, 25 fellows (13 female and 12 male) from 17 countries participated in the STEP programme.

TREND IN ICTP PROGRAMMES AND ENROLLMENT, 1991-2025



Career Development Programmes

In addition to its educational programmes, ICTP provides sabbatical, postdoctoral and laboratory opportunities through the following schemes.

Associates Programme: ICTP's Associates Programme supports regular visits to ICTP, where ICTP Associates have the opportunity to remain in touch with the experts and also with the most modern aspects of their scientific fields. To a large extent, this helps to eliminate the brain-drain in their home countries and the sense of isolation.

ICTP Associates are active scientists in their countries, and they are expected to play a major role in the process of building their scientific communities, enhancing physics and mathematics education at all levels, and planning research projects related to the specific needs of their region. During 2025, 119 Associates (30 female and 89 male) from 39 countries visited ICTP.

In 2025, the Associates Programme launched a new scheme, called Institute Associates, to recognise long-time ICTP collaborators from the global South who have been strongly committed to ICTP's mission and programmes. Imrana Ashraf of Pakistan, Karen Hallberg of Argentina, Swadesh Mahajan of India and the US, and Narayan Adhikari of Nepal were chosen as the first Institute Associates in recognition of their commitment to advancing science in their countries and to making advanced knowledge available to scientists from across the world.

Postdoctoral Opportunities: ICTP Postdoctoral Fellowships are intended for young scientists or mathematicians with a strong research record. Fellows must have completed a PhD in a related field prior to the start of their Fellowship. The Fellowships typically have a two-year duration with a possible extension for a further period of 12 months. The starting date can be negotiated. Preference is given to candidates who will benefit most from the time spent at ICTP in pursuit of their own research, using the ICTP facilities and participating in ICTP activities, and who will interact with local scientists and visitors and will contribute to the intellectual vitality of the Centre. In 2025, ICTP supported 81 postdoctoral students (22 female and 59 male) from 25 countries.

Laboratory Opportunities: Access to modern, well-equipped research laboratories can be a challenge for scientists working in the developing world. ICTP helps by supporting visits to its on-site laboratories as well as to those located elsewhere in Trieste and throughout Italy. Laboratory programmes include ICTP's Training and Research in Italian Laboratories (TRIL), which offers scientists from developing countries the opportunity to undertake training and research in an Italian laboratory in different branches of the physical sciences. In 2025, 81 scientists (34 female and 47 male) from 25 countries participated in the TRIL programme.

Further laboratory opportunities are available through the ICTP-ELETTRA Users Programme, offering access to Trieste's Elettra synchrotron radiation facility for scientists from developing countries who work in those countries. Support includes a limited number of grants to cover travel and living expenses of individuals and small groups who participate in the beamtime at Elettra. During 2025, 10 scientists (4 female and 6 male) from 3 countries benefited from the Elettra Users Programme.

ICTP cooperates with its UN partner, the IAEA, in placing scientists from developing countries in Italian laboratories. In 2025, this IAEA Fellowship Training and Scientific Visits Programme placed 40 researchers (13 female and 27 male) from 22 countries in hospitals and research institutes around Italy.

In addition, ICTP has partnered with the American Physical Society (APS), the European Physical Society (EPS), and the APS Forum on Early Career Scientists (FECS) to support research visits to laboratories in Europe (excluding Italy) and North America, or to a more advanced developing country. In 2025, this APS-EPS-ICTP Travel Award Fellowship Programme (ATAP) supported 5 female scientists from 4 countries.

CAREER DEVELOPMENT IN 2025

255
SCIENTISTS ENGAGED IN CAREER DEVELOPMENT PROGRAMMES: ASSOCIATES, TRIL, ELETTRA AND ATAP

55
COUNTRIES REPRESENTED (INCLUDING 14 LEAST-DEVELOPED COUNTRIES)

ICTP Conferences, Schools and Workshops

ICTP's work at the very frontiers of research makes it a destination of choice for leading physicists and mathematicians from all over the world. Each year, ICTP brings together thousands of world-leading and early career scientists from more than 150 countries to participate in advanced workshops and conferences that explore topics at the cutting edge of physics and mathematics. This rich intellectual atmosphere is enhanced by resources such as our Library – one of Europe's finest research libraries – our high-performance computing facilities, and residential and community facilities that promote informal social and intellectual interactions.

Over the years, more than 100 Nobel laureates, 20 Fields medallists, and members of our distinguished Scientific Council have spent time at ICTP, offering unparalleled opportunities for the brightest minds in the world, whether established or early-career scientists, to learn from each other

In 2025 ICTP focussed several conferences and schools on quantum science and technology in line with the United Nation's International Year of Quantum Science and Technology. This included its major international conference "Quantum Physics: From Foundations to Emerging Technologies", held in May, that featured 9 physics Nobel Laureates as speakers, along with world renowned experts on the topic (see highlights of the conference on page 6).

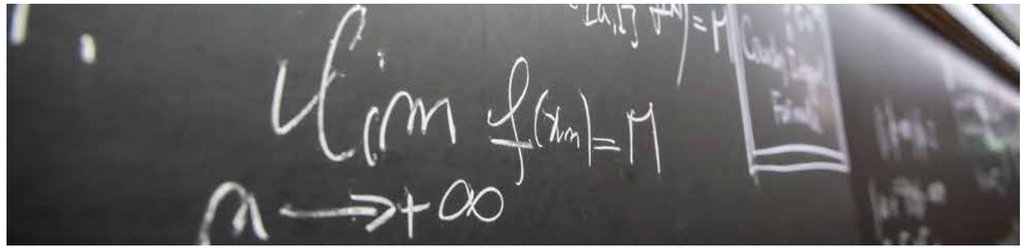
ICTP ACTIVITIES IN NUMBERS, 2025

4963
PARTICIPANTS, INCLUDING THOSE WHO PARTICIPATED REMOTELY

144
NATIONS REPRESENTED

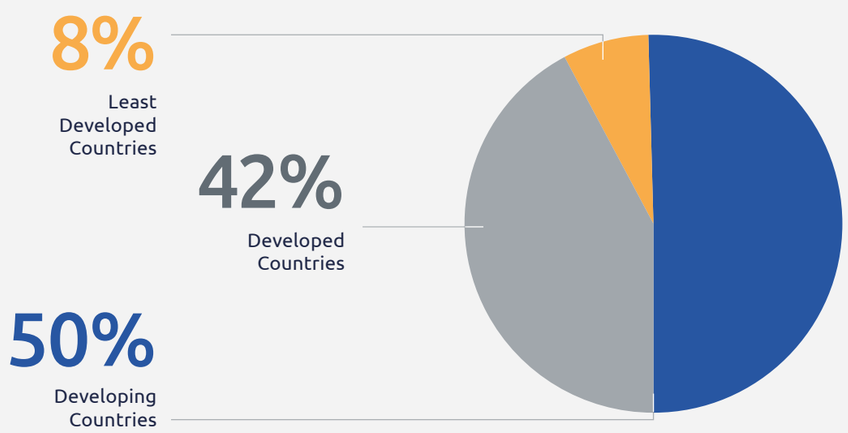
54
CONFERENCES, SCHOOLS AND WORKSHOPS

31%
OF PARTICIPANTS WERE WOMEN



Attendees of ICTP's Dirac Ceremony, April 2025.

DEVELOPING STATUS OF PARTICIPANTS' COUNTRIES, 2025



Global Science Outreach

04 ICTP Partner Institutes

Brazil: ICTP South American Institute for Fundamental Research
China: International Center for Theoretical Physics-Asia Pacific
Mexico: Meso-American Institute for Sciences
Rwanda: East African Institute of Fundamental Research

14 ICTP Schools, Workshops and Conferences

05 ICTP-EAU Affiliated Centres

03 ICTP-EAU Networks

13 ICTP-EAU Scientific Meetings

25 Physics Without Frontiers Activities

Science Outreach: ICTP Building Science Capacity in the Global South

ICTP has a long tradition of scientific capacity building in developing countries. Over the last few decades, ICTP has supported numerous activities throughout the developing world, including training programmes, networks, and science road shows. ICTP also conducts high-level conferences, schools and workshops in the global South as part of its annual Scientific Calendar of events.

Activities are initiated by scientists and scientific institutions in the developing world and are carried out at sites located within the region.

The purpose is threefold:

- To initiate, stimulate or make applicable research and training in the fields of physics and/or mathematics related to locally available resources or local problems of specific relevance to the development of the region.
- To form and strengthen national and regional communities and research groups by supporting institutions or national societies for physicists and mathematicians at all levels.
- To enhance physics and mathematics teaching.

ICTP achieves these goals through a number of science outreach programmes:

- **External Activities Unit:** ICTP supports research and training activities of physicists and mathematicians living and working in developing countries, primarily by providing assistance for regional activities. Such support complements the training and research that is provided to developing-country scientists at ICTP. The goal is to boost the scientific level of individuals, groups or institutes in developing countries to an international level through North-South collaboration, and to stimulate networking of scientists in the developing regions to reach a critical mass of researchers through South-South collaboration. Assistance is coordinated by ICTP's External Activities Unit, through which ICTP directly supports postgraduate courses and students as well as early career scientists in Affiliated Centres, research group networks, scientific meetings, and visiting scholars and consultants. In 2025, ICTP's External Activities Unit promoted 5 Affiliated Centres, 3 Scientific Networks and 13 Scientific Meetings, involving a total of 33 countries from Africa, Asia, Europe and Latin America.
- **Physics Without Frontiers:** Physics Without Frontiers (PWF) targets the far reaches of the developing world to inspire and engage undergraduate and master's-level physics students. ICTP's international outreach programme, run by working groups comprising volunteer young PhD students and postdoctoral researchers, brings advanced physics training and international collaboration to places where opportunities are limited. Outreach is also extended to high school students, the general public, and policy makers via events throughout a country. Most PWF activities are co-organized with local and international partners, strengthening collaboration and local capacity. For example, the LHC Open Data Workshop held at the University of Lomé (Togo) was organized in collaboration with partners including the University of Sussex and the University of Notre Dame, among others. In 2025, PWF organized a total of 25 activities – including schools, workshops, courses, seminars, and symposia – in 22 countries, reaching a total of more than 1,200 participants.

Building an International Science Community

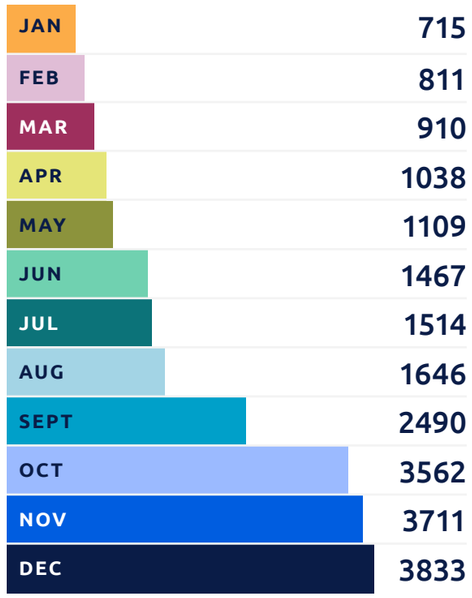
The ICTP Global Science Portal is an online community platform that allows ICTP's past and present staff, associates, visitors, students and affiliates to connect with the institute and each other.

The Portal supports global science equality and cooperation by providing an online space for researchers to promote their work, network, form collaborations, access and share resources and opportunities, and develop regional and research-based communities.

A Growing Community

The Portal community grew from 700 members to almost 4000 in 2025. Portal membership represents a diverse global network of researchers. Members range from masters students at the beginning of their career to retired senior associates wishing to maintain a link with the ICTP community. Portal membership now spans every physics and maths research area represented at ICTP.

PORTAL MEMBERS



REACH IN THE GLOBAL SOUTH

157

Portal membership spans 157 countries across the world.

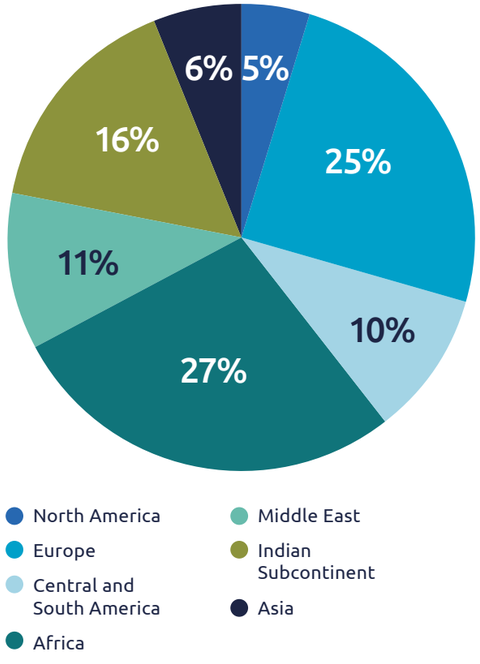
12%

of the portal population reside in Least Developed Countries (LDCs), and 79 % of all LDCs are represented on the Portal. Our largest LDC communities are in Bangladesh, Ethiopia, Nepal, Rwanda, Sudan, and Uganda.

11%

Past and present members of the ICTP Associates programme are well-represented on the Portal, comprising 11 % of the userbase.

GLOBAL REACH



ICTP's Global Science Portal celebrated its one-year anniversary with an in-person, speed-networking party ... and cake!

Exclusive tailored events:

The Portal organises and promotes events for the global ICTP community. The following Portal events took place in 2025:

- In-person speed networking event for students, associates and faculty.
- Online lecture on navigating science careers.
- Q&A on careers in scientific publishing.
- Online streaming of the documentary “Brief Tender Light” about African students at MIT, and a Q&A with the director.
- “Outreach on a budget” online panel on in-person science outreach activities in remote locations.
- Talk by UNESCO’s Amal Kasry on "Strengthening Basic Sciences and Engineering Through Institutional and Human Capacity Building".

New features:

The Portal team rolled out various new features in 2025, including:

- **User Portfolios:** This feature allows users to upload their lectures, papers, TEDTalks, and links to their websites to promote their research.
- **Media Centre:** This is a repository to store and organise videos, photos and documents of interest to the global community. The following media were added to the Portal in 2025: 4 Portal highlight seminar videos, 15 interviews, 5 career shorts from our in-person networking event, 4 explainers on new features on the Portal, 26 Portal News articles, 114 seminar listings, 15 networking and social events.
- **Opportunities listings:** where members can both view and upload job adverts, calls for funding, and collaboration requests. In 2025, the Portal team posted 41 opportunities, and 11 users posted opportunities at their institutes.
- **App:** A fully integrated mobile App, to facilitate member access on mobile devices and in regions with unstable internet coverage.
- **Mentoring Group:** To provide additional career support to the global ICTP community, we onboarded the 2025 cohort of String Theory Mentoring (a project aimed at providing tailored career guidance to young researchers in String Theory). There are currently 222 members of the String Theory Mentoring group, which provides a space for mentors/mentees to share experiences and stay in contact.

Public Outreach

Throughout the year, ICTP engages with the public through numerous outreach activities aimed at spreading the joy of science to all ages. Some events are highlighted here.

Educational Programmes

ICTP's Public Information Unit coordinates a visiting programme for school-age students and university undergraduates to meet ICTP scientists and tour facilities such as the ICTP Library and the Centre's SciFabLab. During 2025, 18 such visits to ICTP took place, introducing almost 500 visitors, from Italy and abroad, to the magic of ICTP physics and mathematics. The organized visits are designed to inspire students, introduce them to cutting-edge topics in physics and mathematics, and to offer first-hand experiences at a leading research institute that brings together scientists from around the globe.

Students from Germany and Italy participating in the Physics Exchange Program (GIPE), September 2025.

Trieste Maker Faire

ICTP, together with the municipality of Trieste, organises the Trieste Maker Faire, a celebration of ingenuity and makers, providing a showcase of creativity and technology by featuring inventors, creatives, attractions, experiments, and technological and scientific workshops for all ages. The 2025 free event was held over two days in Trieste's grand Piazza Unità, attracting thousands of attendees.

TriesteNext Science Festival

ICTP participated in Trieste's yearly public celebration of science, TriesteNext, which took place at the end of September. For the 2025 edition, ICTP teamed up with The World Academy of Sciences (TWAS), the Organization for Women in Science for the Developing World (OWSD), and the InterAcademy Partnership (IAP) for an exhibit titled "Global Science for a Sustainable Future". The display and related activities highlighted the organisations' shared missions and combined impact on science in the global South. The institutes showcased their UN connection by displaying SDG-related achievements. In addition to the exhibit space, ICTP coordinated a panel discussion titled Thinking About the Quantum Future: The Italian Strategy.

ICTP Social Media

ICTP maintains a robust presence on major social media platforms including Facebook, Instagram and LinkedIn, keeping its global audience of scientists, students and supporters up to date on its programmes and successes. During 2025, ICTP social media followers responded enthusiastically to content, as witnessed by the platforms' extraordinary engagement rates: 54% for Facebook, 64% for Instagram, and 44% for LinkedIn.

Throughout 2025, ICTP ran multiple social media campaigns. Two of the most successful ones promoted the Centre's major international conference on quantum science and technology held in May and supported the Centre's first fundraising challenge campaign. For the May event, a series of multimedia posts – some featuring the Nobel laureates who attended the conference – ran during the week of the conference, generating an engagement rate of 38% and attracting nearly 300 new followers that week.

The fundraising social media campaign, titled "the Butterfly Effect", was more extensive, with multimedia content posted for the month-long duration of the campaign generating nearly a half a million views. Thanks to the support of the social media content, the fundraising campaign was able to reach its financial goal.

ICTP HECAP postdoc Valentin Benedetti (left) explaining the properties of black holes to a visitor of the ICTP booth at the 2025 TriesteNext science festival.

2025 Timeline

January

2025 SALAM'S DISTINGUISHED LECTURES

The 2025 edition of ICTP's Distinguished Lecture Series featured Aleksandra Walczak, a professor at the Ecole Normale Superieure in Paris, who gave a series of three talks entitled "Prediction in Immune Repertoires: Learning Rules in a Self-organised Mess". The lectures focussed on immune repertoires, which provide a unique fingerprint reflecting the immune history of individuals, with potential applications in precision medicine.

INTERNATIONAL MATHEMATICS MASTER IN ALGERIA LAUNCHED

The 2025 edition of ICTP's Distinguished Lecture Series featured Aleksandra Walczak, a professor at the Ecole Normale Superieure in Paris, who gave a series of three talks entitled "Prediction in Immune Repertoires: Learning Rules in a Self-organised Mess". The lectures focussed on immune repertoires, which provide a unique fingerprint reflecting the immune history of individuals, with potential applications in precision medicine.

February

CELEBRATING WOMEN IN SCIENCE

On the International Day of Women and Girls in Science, ICTP and the Trieste section of the Italian National Institute of Nuclear Physics (INFN) organised a public event based on the play "The Hidden Force", offering an overview of 20th-century physics through the eyes of four female protagonists. More than two hundred people attended the event, which was held in Trieste's Teatro Miele.

March

ICTP COLLOQUIUM

"Joseph-Louis Lagrange:
A Glimpse into His Life and Contributions"

Alberto Cogliati, University of Padua, Italy

View the talk online at:
https://www.youtube.com
watch?v=PHQYXbpLBpY&pp=0gcJCcUKAYcqIYzv

April

NEW ICTP LECTURE HALL INAUGURATED

ICTP inaugurated a new lecture hall and a suite of classrooms after a major renovation of space used by its Postgraduate Diploma Programme. The newly refurbished lecture hall, housed in the Centre's Leonardo Building, has been named "Euler-Lagrange" in honour of the two renowned scientists whose collaborative work has had a lasting impact on both physics and mathematics.

DIRAC MEDAL 2024 CEREMONY

ICTP honoured the four recipients of its 2024 Dirac Medal at a ceremony on 2 April. Horacio Casini, CONICET and Bariloche Atomic Centre, Argentina; Marina Huerta, CONICET and Bariloche Atomic Centre, Argentina; Shinsei Ryu, Princeton University, United States; and Tadashi Takayanagi, Kyoto University, Japan, received the medal for their pioneering contributions to the understanding of quantum entropy in gravity and quantum field theory. The photo shows them after the ceremony talking with ICTP Diploma students.

May

FOUR SCHOLARS NAMED ICTP INSTITUTE ASSOCIATES

Four researchers with longtime connections to ICTP were appointed Institute Associates in recognition of their long-time service and commitment to ICTP's mission. Imrana Ashraf of Pakistan, Karen Hallberg of Argentina, Swadesh Mahajan of India and the US, and Narayan Adhikari of Nepal have long been associated with ICTP and have contributed to its mission in multiple ways – from mentoring students to organizing conferences and training scientists working in the developing world. The appointments recognize their commitment to advancing science in their countries and to making advanced knowledge available to scientists from across the world.

ICTP AT THE UN

© UNESCO-New York

On Friday 9 May, ICTP's 60th anniversary was celebrated at the United Nations' headquarters in New York. Some 200 representatives of the UN's member countries attended the event "Advancing Global Scientific Cooperation for Sustainable Development: Leveraging Quantum Science for a Resilient Future" organised by the Permanent Mission of Italy to the UN and by UNESCO. The event also marked the 70th anniversary of Italy's membership in the United Nations.

ICTP AND IBM ANNOUNCE PLANS FOR NEW PRIZE FOR QUANTUM COMPUTING

In the spirit of the UN's 2025 International Year of Quantum Science and Technology (IYQ), ICTP and IBM announced a new prize to recognize excellence in quantum computing. The intended prize, the ICTP-IBM Richard Feynman Prize in Quantum Computing, named in honor of quantum mechanics pioneer Richard Feynman, will be open to anyone who has made significant contributions to the field of quantum computing. It is intended to be awarded annually at a yearly conference co-sponsored by ICTP and IBM.

ICTP DIrector Atish Dabholkar (left) and IBM's Alessandro Curioni at the announcement of the new prize.

June

ICTP COLLOQUIUM

"Choosing to Collide"

Nathaniel Craig, University of California, Santa Barbara

View the talk online at:
https://www.youtube.com/watch?v=jlv2wU9pn0I

ICTP SUCCESS STORY

Firas Shuaib, one of the first students to graduate from the master's programme at ICTP's partner institute in Rwanda, the East African Institute of Fundamental Research, is now the first such graduate to receive his PhD. He received his doctoral degree from the University of Limoges, France, after completing a PhD project on sustainable energy storage technologies.

July

FIRST WINNER OF THE ICTP-IBM BRAHMAGUPTA AI PRIZE FOR EARLY CAREER SCIENTISTS

ICTP and IBM announced the inaugural winner of their joint ICTP-IBM Brahmagupta Artificial Intelligence Prize for Early Career Scientists: Simon Olsson of Chalmers University of Technology, Sweden. The citation reads, "for his pioneering work on the use of Artificial Intelligence methods in molecular simulations, overcoming long-standing computational problems in statistical mechanics, with translational impact on drug discovery and vaccine design."

August

DIPLOMA 2025 GRADUATION CEREMONY

Forty-three students from 27 countries successfully completed ICTP's Postgraduate Diploma Programme and celebrated their achievement at a graduation ceremony held on 27 August 2025. As of that date, 28 of them have been accepted to PhD or masters' programmes at universities in Europe, Asia and the United States.

MEET THE DIPLOMA GRADUATES

YASSINE EL MOHTADI

Morocco

Diploma in High Energy, Cosmology, and Astroparticle Physics; accepted to a PhD programme in theoretical physics at the International Center for Theoretical Physics-Asia Pacific (ICTP-AP) in China

"In just one year, you need to cover many topics, which can sometimes become overwhelming. It's more a marathon than a sprint, and you really need to persevere. It has been an extremely fulfilling and eye-opening experience."

KOMAL RUBAB

Pakistan

Diploma in condensed matter physics; accepted to a PhD programme at SISSA

"I got interested in physics and maths because I like to learn how nature actually works. Then when we studied quantum mechanics and statistical mechanics, I immediately got very interested and I started studying books in addition to the course. That's how I decided that I wanted to study condensed matter."

LAURA CABRERA

Colombia

Diploma in Earth System Physics; accepted to a PhD programme in Tallin, Estonia

"I wanted to understand the behaviour of the world, but whenever I asked questions to my parents or to any member of my family, they never had the answers. My mom always encouraged me to study and I knew that was the only way for me to give my family and myself a better future."

ABDILAZIZ KOMILOV

Uzbekistan

Diploma in mathematics; accepted to a PhD programme at SISSA

"During university, I started to understand what maths was really about. It is about abstraction, about conceptual understanding, not just about calculations, like most people think."

SOLAFA FADLALLAH

Sudan

Diploma in quantitative life sciences; accepted to a PhD programme at the University of Trieste

"[Here at ICTP] you never see a problem from just one point of view. You always have students with diffverent backgrounds and people from different countries. Whenever we had an assignment or a project, it was always really nice to see how different people had different approaches and perspectives."

TWO DIPLOMA STUDENTS SHARE 2025 SHAFI PRIZE

ICTP Diploma students William Hendarto and Komal Rubab were awarded the Qaisar and Monika Shafi Prize, an annual award given to the most outstanding scholars in the programme. William Hendarto, of Indonesia, completed a Diploma in mathematics, while Komal Rubab, of Pakistan, earned a Diploma in condensed matter physics.

AI IN THE SPOTLIGHT

AI was celebrated at ICTP on Thursday 10 July, with two events that highlighted its transformative impact on both cutting-edge research and society at large. The day began with a ceremony marking the first ICTP-IBM Brahmagupta AI Prize for Early Career Scientists, and continued with an AI Alliance Meetup, Italy's first ever event of this kind, organized in collaboration with the International School for Advanced Studies (SISSA).

ICTP scientist Jean Barbier speaking at the AI Alliance Meetup.

August

UNITING AFRICAN PHYSICISTS

The African School for Electronic Structure Methods and Applications (ASESMA) is a biannual summer school that has been taking place since 2008, with ICTP's Sandro Scandolo among its founders. With the support of ICTP, the International Union of Pure and Applied Physics (IUPAP), and many other institutions and associations all over the world, the school combines lectures on the theoretical aspects of condensed matter physics, in particular electronic structure, with tutorials on the computational aspects of the subject. In 2025, the School took place at the University of Ghana, with 51 participants from 17 African countries.

HARMONIC ANALYSIS IN EASTERN AFRICA

Every year, ICTP and the Eastern African Universities Mathematics Programme (EAUMP) come together to organize a summer school on important mathematical topics. The EAUMP, which is supported by Sweden's International Science Programme (ISP), comprises universities from six Eastern African countries: Kenya, Rwanda, Tanzania, Uganda, Zambia, and Ethiopia. The 2025 ICTP-EAUMP Summer School in Real and Harmonic Analysis took place in Kigali, Rwanda, offering MSc and PhD students lectures on fundamental topics.

FROM SAUDI ARABIA TO TRIESTE

ICTP welcomed undergraduate students from the King Abdullah University of Science and Technology for summer hands-on research projects. ICTP's Science, Technology and Innovation (STI) unit hosted the 18 university students to conduct applied research and enhance their training experience over the summer, working in ICTP's three laboratories: the Marconi Lab, the Multidisciplinary Laboratory (MLab), and the Scientific Fabrication Laboratory (SciFabLab).

ICTP COLLOQUIUM

"Topological Physics as Censor, and as Microscope"

Roderich Moessner, Max Planck Institute for the Physics of Complex Systems, Dresden

View the colloquium online at: https://www.youtube.com/watch?v=H8X_B7uuE6k

September

ICTP ANNOUNCES A NEW, FIVE-YEAR STRATEGIC PLAN

ICTP Director Atish Dabholkar unveiled an ambitious strategic plan for the Centre, mapping out strategic priorities for the next five years and beyond. See details of the plan in the director's Foreword on page 4.

ICTP COLLOQUIUM

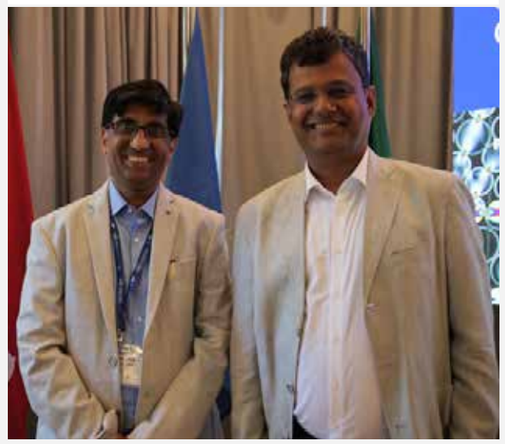
"The Weird and Wonderful World of Catalysis and How I Got There"

Michele Parrinello, Italian Institute of Technology, Genoa

View the talk online at: https://www.youtube.com/watch?v=WO1ItcHPQ2U

ICTP WELCOMES DELEGATION FROM INDIA

Science, technology and future alliances were the topics of discussion during a visit to ICTP on 4 September by a high-level delegation from India led by Abhay Karandikar, Secretary of that country's Department of Science and Technology (DST). Almost 15,000 scientists from India, from early-career researchers to some of the leaders in the field, have visited ICTP for extended periods for collaborations.



October

ARTIFICIAL INTELLIGENCE FOR AFGHAN STUDENTS

ICTP's flagship outreach programme, Physics Without Frontiers (PWF), held a workshop on "Machine Learning and Artificial Intelligence for Afghan Students". It was organised in partnership with the European Brain Research Institute Rita Levi Montalcini (EBRI). Participants met online over three days between 28 September and 1 October, despite a two-day nationwide internet shutdown that affected Afghanistan on 29 and 30 September.

November

THE ICTP SCIFABLAB MEETS KUWAIT

A new collaboration between ICTP and the Kuwait Foundation for the Advancement of Sciences (KFAS) aims to create a Scientific Fabrication Laboratory (FabLab) in The Scientific Center of Kuwait (TSCK). As part of the collaboration, eight people, including science communicators and outreach programme managers working at The Scientific Center of Kuwait, visited ICTP's SciFabLab from 24 to 27 November for a four-day training on topics such as managing and operating a FabLab and community engagement.

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ICTP COLLOQUIUM

"Noise and Climate Dynamics"

Angelo Vulpiani,
University of La Sapienza
in Rome

View the talk online at:
https://www.youtube.com/watch?v=YWknGTZPifg

December

GRADUATION CEREMONY, MASTER IN MEDICAL PHYSICS

Twenty students from 18 countries across Africa, Asia and South America graduated from the Master of Advanced Studies in Medical Physics (MMP), a two-year advanced training programme run jointly by ICTP and the University of Trieste, and co-funded by the International Atomic Energy Agency (IAEA). Graduates of the programme, most of whom come from developing countries, gain the advanced theoretical and clinical training needed to be recognised as clinical medical physicists in their home countries.

In Memoriam

ICTP lost a number of scientists from its global community in 2025; they are remembered below.

KARIM AOUDIA

In October, ICTP mourned the sudden passing of staff scientist Abdelkrim (Karim) Aoudia, a geophysicist and seismologist in the Centre's Earth System Physics (ESP) section. He was acting head of ESP and coordinator of that section's Solid-Earth Geophysics Research Group, leading a team of researchers using seismology, space geodesy, tectonics and numerical experiments to understand such topics as the mechanics of earthquakes and faulting and the structure and fluid dynamics of the Earth's crust and upper mantle in active earthquake and volcanic regions. He founded the ICTP Earth System Physics pre-PhD Diploma, a one-year educational programme for students from developing countries. Over the years he supervised and co-supervised more than 20 PhD students and organised more than 40 international summer schools, conferences and advanced workshops at ICTP and in developing countries.

ANDRE-MARIE HAMENDE

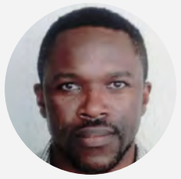
André-Marie Hamende served as ICTP's senior administrative and scientific information officer from 1964 to 1990.

LÊ DŨNG TRÁNG

Lê Dũng Tráng was the former head of the ICTP's Mathematics section; his most recent affiliation was as an emeritus professor at the University of Aix-Marseille, France.

JACOB PALIS

Jacob Palis was a former member and Chair of the ICTP Scientific Council and former President of The World Academy of Sciences for the developing world (TWAS).



TONY EZOME

Tony Ezome was a mathematics Regular Associate from 2018 to 2023 who worked closely with ICTP emeritus mathematician Fernando Villegas.

LINDA MEARNS

Linda Mearns had long-lasting scientific collaborations with members of the ICTP Earth System Physics section (ESP), including with Filippo Giorgi, former head of ESP.

Governance

ICTP operates under a tripartite agreement between the Italian Government, the International Atomic Energy Agency (IAEA), and the United Nations Educational, Scientific and Cultural Organization (UNESCO). Each party has a representative on the Centre's Steering Committee, which sets general guidelines for the Centre's activities, determines budgeting levels, and considers proposals from the Director for the programme, work plans, financial plans, and budget.

ICTP also has a Scientific Council that comprises distinguished specialists in disciplines relevant to the Centre's activities who represent a broad geographical range. The Council advises ICTP on its programmes of activities, taking into consideration major academic, scientific, educational and cultural trends relevant to the Centre's objectives. ICTP is a UNESCO Category 1 Institute.

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ICTP 2.0 Update

ICTP's first major fundraising campaign – ICTP 2.0 – formally launched on October 21, 2025 during a special event at the Simons Foundation International's New York offices.

Prof. David Spergel, president of SFI along with Marilyn Simons, Prof. Edward Witten, ICTP Director Atish Dabholkar and Development Advisory Board Chair Ashvin B. Chhabra led the presentation on ICTP's 2025 Strategic Plan and fundraising strategy. In addition to raising funds to support its International Science Alliance and International Consortium for Scientific Computing, plus scholarships, fellowships and associateships for students and scientists, a key priority and the catalyst for the campaign is the Simons Foundation International's $15 million challenge grant to acquire the Adriatico Guest House and transform it into a world-class International Science Complex.

Since the launch of the campaign, several things have happened to give ICTP an incredible amount of momentum to meet not only the $15 million match, but to reach our overall goal of €60 million.

KEY EVENTS

- Ashvin B. Chhabra and Daniela Bonafede-Chhabra make a leadership donation to complete the ICTP Library Renovations
- Fondazione Compagna di San Paolo joins in a three way partnership with ICTP and Simons Foundation International to acquire the Adriatico Guest House
- Jagadish Shukla – meteorologist and long-time friend of ICTP – issues a $25,000 challenge to inspire support from ICTP's community and alumni to make year-end donations to the International Science Complex. This generous act creates ICTP's first annual fund called "The Butterfly Effect" and the challenge is met before the end of 2025, making a $100,000 impact on the International Science Complex project.
- Inspired by their former professor's support of the International Science Complex, Stephen and Vincent Della Pietra, along with their wives Pamela Hurst-Della Pietra and Barbara Amonson, pledge a collective $4 million to the project in honor of Prof. Edward Witten, becoming the first anchor donors to ICTP 2.0 and the International Science Complex project. This generous pledge inspires others to give, allowing the possibility that ICTP will meet the Simons Foundation International's challenge by the end of 2026.

ICTP is a lighthouse for global science, a beacon of scientific inquiry and knowledge that attracts the brightest minds from all corners of the globe. The ICTP 2.0 fundraising campaign seeks to ensure that the foundations of this unique research centre are strengthened for generations of scientists to come. A cornerstone of the campaign is the Simons Foundation International's $15 Million Challenge Grant, which will transform the Adriatico Guest House into a world-class International Science Complex, providing a stable foundation for the programs that increase scientific capacity in the global South.

HELP US SHINE A LIGHT FOR SCIENCE!

If you'd like to learn more or support us, please scan this code.

Supporters listed on the following pages who have a butterfly icon are those who participated in ICTP's year-end Butterfly Effect Challenge.

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ICTP would like to express its deep gratitude to all who supported us in 2025.

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Vincent Della Pietra and Barbara Amonson in honor of Prof. Edward Witten

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SYMMETRY FORUM: BRINGING BALANCE TO GLOBAL SCIENCE

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Qaisar and Monika Shafi
Adnan Shihab-Eldin
Jagadish Shukla
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The Vafa Family

ATOMIC CIRCLE: THE BUILDING BLOCKS OF OUR MISSION

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The Romita Shetty and Nasser Ahmad Foundation
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Gong Xingao

QUANTUM PARTNERS: SMALL ACTIONS WITH BIG POTENTIAL

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