

ICTP:  
A Year  
in Review

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The Abdus Salam  
International Centre  
for Theoretical Physics



The Abdus Salam  
**International Centre  
for Theoretical Physics**

2022:

# A Year in Review

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In Memoriam

2022: A Year in Review

The Abdus Salam International Centre for Theoretical Physics

Compiled by the ICTP Public Information Office  
Designed by 400 Communications

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# Foreword

By the summer of 2022, life was returning to pre-pandemic normalcy at ICTP: the Centre was bustling with scientists from around the globe as always. The year saw many other positive developments.

Four ICTP scientists won prestigious ERC grants to conduct advanced research in topics ranging from biological fluorescence (Ali Hassanali), machine learning and neural networks (Jean Barbier), quantum field theory and high energy physics (Joan Elias Miró) and quantum information (Rosario Fazio). Success in attracting these highly competitive grants is a welcome independent recognition of the quality and diversity of science at ICTP.

ICTP has been pursuing a proactive gender strategy which is slowly but surely moving ICTP in the right direction. ICTP recognises that the gender imbalances in the sciences need to be addressed at multiple levels to effectively bring about change. The incoming class of postgraduate diploma students in 2022 had almost equal numbers of men and women. The percentage of women among the professional staff at ICTP has increased to 28% from 15% during the past three years. There is also a growing trend of female participants in ICTP activities. Barriers of gender, ethnicity, geography or class often stand in the way of the full realization of the potential of many talented scientists. Overcoming these barriers is fundamental to the mission of ICTP.

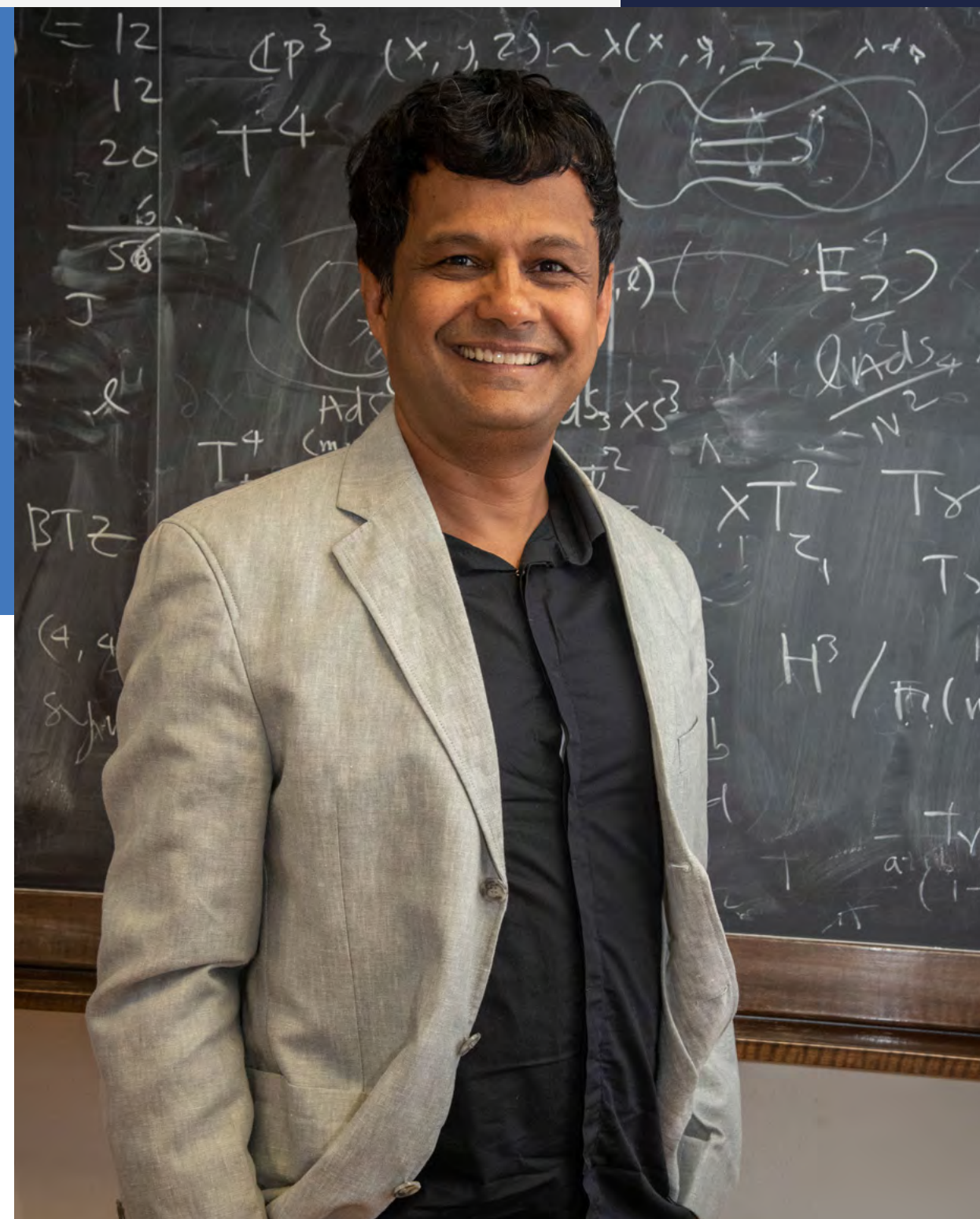
There is a growing trend at ICTP in activities for quantum and high performance computing. The need for an International Consortium for Scientific Computing was clearly identified in our strategic plan so that the latest developments in machine learning or quantum computing could become broadly accessible to the global scientific community. Our efforts in this direction are also shaping up well. We signed an MoU with South Africa's National Institute for Theoretical

and Computational Sciences (NITheCS) for scientific collaborations, in the presence of that country's Minister of Research and the Director General of the Department of Science and Innovation. Given ICTP's strength in various domains of computational science such as climate modelling and quantum materials, this initiative holds great promise.

ICTP was a founding member of the International Year of Basic Sciences for Sustainable Development (IYBSSD) 2022 and participated in the launch of the year at the UNESCO head-quarters in Paris and in the organisation at ICTP of many important activities linked to IYBSSD. The Secretariat of the International Union of Pure and Applied Physics has moved to Trieste in recognition of the scientific ambience offered by the Trieste Science System. The celebrations of the 100th anniversary of IUPAP were hosted at ICTP with seminars and panel discussions by many distinguished scientists.

ICTP was invited to the World Science Forum in Cape Town, and participated in a panel discussion on "Physics and Accelerators for Science and Social Justice" together with colleagues from SESAME, EAFIR and LAAAMP. Also in 2022, ICTP's successful Physics Without Frontiers (PWF) initiative celebrated its 10th Anniversary. More than 10,000 students from 35 countries have benefitted from this unique programme, launching the careers of many young scientists from less advantageous backgrounds and sometimes from countries in conflict.

**Atish Dabholkar**  
ICTP Director





# 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. Read more about these research lines on the following pages.

**NUMBER OF ICTP RESEARCHERS**

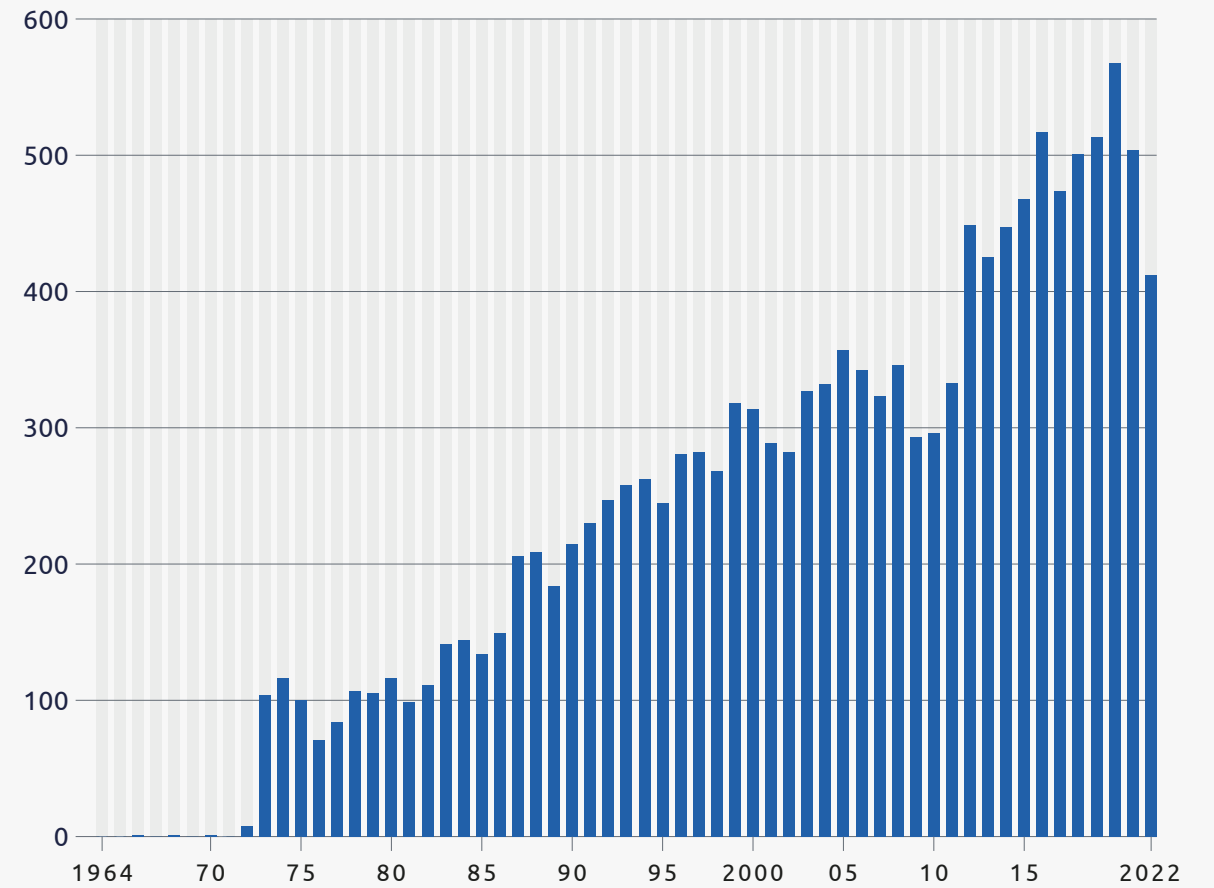
Staff, consultants, longterm visiting scientists, postdoctoral fellows

**174**

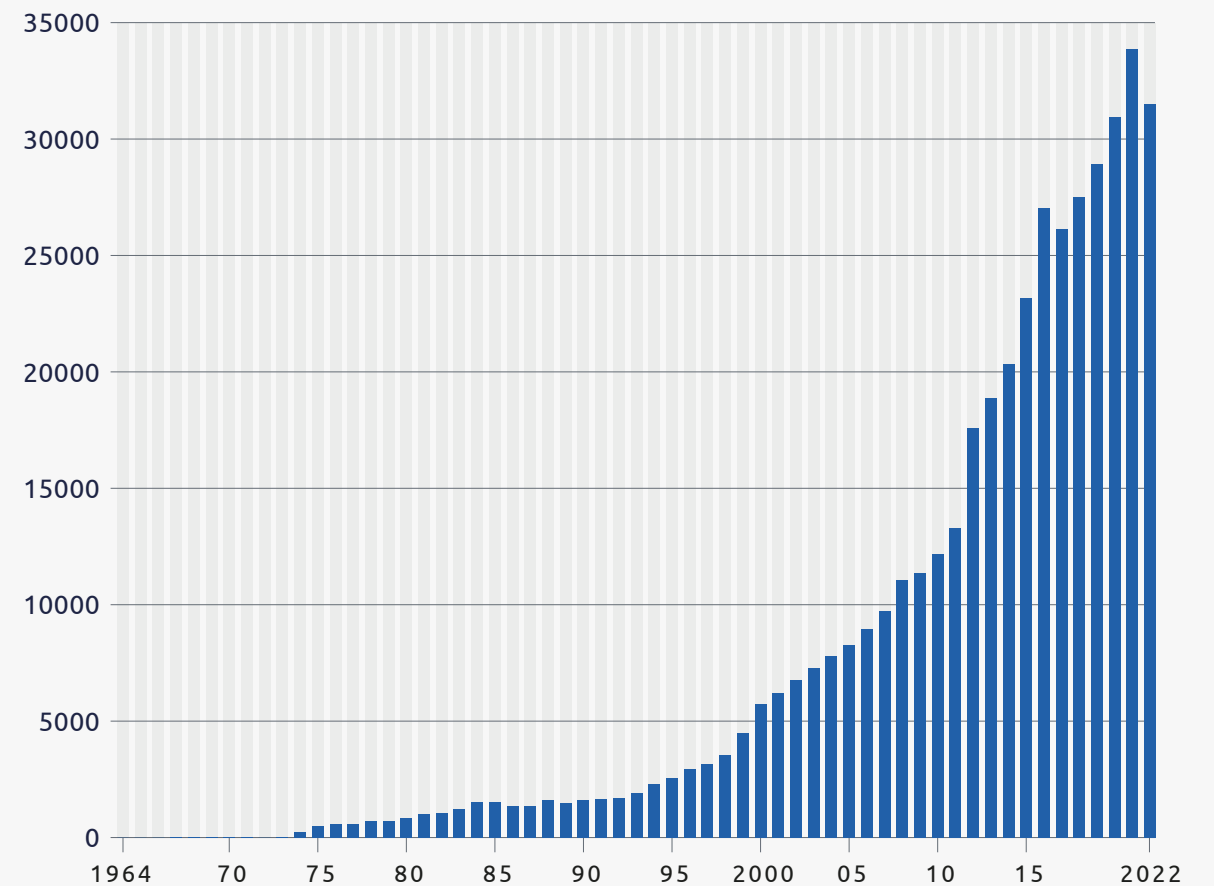
**NUMBER OF COUNTRIES REPRESENTED BY ICTP RESEARCHERS**

**41**

**NUMBER OF PAPERS PRODUCED WITHIN ICTP**



**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.

HECAP scientists study, for instance, 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.

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 modeling 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 flavor 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.

Although physicists have built a detailed picture of the world, unsolved mysteries remain. HECAP mostly follows a theoretical approach, with researchers concentrating on solving fundamental and sometimes purely mathematical problems using analytical methods. HECAP research is driven by slowly changing themes, since experiments require significant effort and long timescales.

There is a great deal of feedback between theory and experiment in the field, with certain ideas sometimes gaining or losing popularity as a consequence of experimental results. Even the lack of experimental data can prompt new directions and new experimental ideas, and improvements in experiments, which are then followed by new theoretical developments. For example, the discovery of gravitational waves, which are emitted by coalescing black holes, prompted a significant shift in recent research and triggered an avalanche of theoretical work. This work consequently had a profound effect on the research conducted at HECAP. Scientists at HECAP continue to push the boundaries of their fields, and one researcher recently obtained a European Research Council Starting Grant for his work on physics beyond the Standard Model.

Future research directions at HECAP depend on the results of ongoing experiments, such as gravitational wave measurement, dark matter detection and results from surveys of the distribution of matter in the universe. HECAP researchers use key results from such experimental studies to open new lines of investigation, and adapt to changing conditions within this evolving field.

PUBLICATION HIGHLIGHTS 2022

Gruzinov, A. & Mirbabayi, M. (2023). Shapes of non-Gaussianity in warm inflation. *Journal of Cosmology and Astroparticle Physics*, 2023(02), 012. <https://doi.org/10.1088/1475-7516/2023/02/012>.

Creminelli, P., Janssen, O., & Senatore, L. (2022). Positivity bounds on effective field theories with spontaneously broken Lorentz invariance. *Journal of High Energy Physics*, 2022(09) 201. <https://doi.org/10.1007/JHEP09%282022%29201>.

Putrov, P. (2022). Q/Z symmetry. *arXiv:2208.12071*. <https://doi.org/10.48550/arXiv.2208.12071>.

Miró, J. E., Guerrieri, A., & Gumus, M. (2022). Bridging positivity and S-matrix Bootstrap Bounds. *arXiv:2210.01502*. <https://doi.org/10.48550/arXiv.2210.01502>.

Notari, A., Rompineve, F. & Villadoro G. (2022). Improved hot dark matter bound on the QCD axion. *arXiv:2211.03799*. <https://doi.org/10.48550/arXiv.2211.03799>.

HECAP ACTIVITIES IN NUMBERS

02

HECAP SCIENTIFIC ACTIVITIES ORGANISED AT ICTP IN 2022

01

HECAP SCIENTIFIC ACTIVITIES ORGANISED ABROAD IN 2022

54

HECAP SEMINARS ORGANISED IN 2022

## RESEARCH AREA:

# Condensed Matter and Statistical Physics (CMSP)

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:

### THE 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.

### 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 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.

### 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, localization in disordered systems, many-body physics and light, dynamics and relaxation in complex systems, quantum simulators, and quantum computing.

### MATERIALS FOR RENEWABLE ENERGY APPLICATIONS

Advanced functional materials are required for the efficient collection and storage of sustainable forms of energy. At CMSP, quantum mechanical modeling 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 plays a pivotal role in both the Sustainable Energy Initiative and the Trieste Institute for Theoretical Quantum Technologies (TQT). The Sustainable Energy Initiative is focused on computational investigations into materials relevant for sustainable energy applications. Quantum atomistic simulations are employed to understand the behaviour of various materials and processes.

Since its foundation in 2019, the TQT Institute has focused on creating a Quantum-Hub in Trieste to coordinate and promote research activities related to emerging quantum technologies.

The CMSP section is also home to scientists who perform theoretical research and training in condensed matter and applied physics topics that are experimentally investigated using synchrotron radiation (SR). There are close collaborations with experimentalists at the nearby SR source Elettra and other similar facilities.

In the future, CMSP will examine new methods and approaches to data science, with big data potentially opening new avenues of exploration in the field. Information theory tools and unsupervised machine learning will be key to studying physical and biological systems, and quantum information processing, and many-body systems. Long-term goals also include functional material design, investigations of mesoscopic quantum systems and nanostructures, and approaches to forward the development of quantum technologies.

## PUBLICATION HIGHLIGHTS 2022

Balducci, Federico, et al. "Localization and Melting of Interfaces in the Two-Dimensional Quantum Ising Model." *Physical Review Letters*, no. 12, American Physical Society (APS), Sept. 2022. <https://doi.org/10.1103/PhysRevLett.129.120601>.

Hajdušek, Michal, et al. "Seeding Crystallization in Time." *Physical Review Letters*, no. 8, American Physical Society (APS), Feb. 2022. <https://doi.org/10.1103/PhysRevLett.128.080603>.

Rostami, S., et al. "Hematite Surfaces: Band Bending and Local Electronic States." *Physical Review Materials*, no. 10, American Physical Society (APS), Oct. 2022. <https://doi.org/10.1103/PhysRevMaterials.6.104604>.

Sengupta, Sanghamitra, et al. "Observation of Strong Synergy in the Interfacial Water Response of Binary Ionic and Nonionic Surfactant Mixtures." *The Journal of Physical Chemistry Letters*, no. 49, American Chemical Society

(ACS), Dec. 2022, pp. 11391–97. <https://doi.org/10.1021/acs.jpcllett.2c02750>.

Tarabunga, P. S., et al. "Gauge-Theoretic Origin of Rydberg Quantum Spin Liquids." *Physical Review Letters*, no. 19, American Physical Society (APS), Nov. 2022. <https://doi.org/10.1103/PhysRevLett.129.195301>.

## CMSP ACTIVITIES IN NUMBERS

# 18

CMSP SCIENTIFIC ACTIVITIES ORGANISED AT ICTP IN 2022

# 03

CMSP SCIENTIFIC ACTIVITIES ORGANISED ABROAD IN 2022

# 72

CMSP SEMINARS ORGANISED IN 2022



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 often 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, which combines 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 parametrize 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.

Work on the topology and geometry of microcanonical surfaces arising from the non-linear Schrödinger equations is ongoing at MATH. In purely geometric research, researchers tackle the famous isometric embedding problem for Kähler-Einstein spaces. Researchers at MATH also explore topological quantum field theories, which play a key role in condensed matter and particle physics.

MATH researchers use optimisation techniques to substantially improve the current upper and lower bounds for the pair correlation conjecture related to the Riemann hypothesis. Research also advances in algebraic geometry, with an emphasis on moduli spaces related to gauge theory in physics and differential topology; a focal point for interactions within mathematics and with physics. MATH also benefits from the contributions of the ICTP Ramanujan International Chair, Professor Don Zagier, via both his research and close interactions with researchers in the section.

MATH continues to strengthen its ties with the International Mathematical Union (IMU), who sponsor joint programmes with ICTP. The recent Group Theory and Representation Theory summer school was the first large school organised by MATH in conjunction with the Vietnamese Institute for Advanced Studies. Collaborations continue with EAUMP, and the Arithmetic, Groups and Analysis summer schools in South America. Upcoming invited seminars at MATH are aimed at highlighting future lines of research across machine learning, artificial intelligence, and mathematics. MATH researchers continue to consolidate their work on algebra, geometry, and differential geometry, and number theory, with a view to increasing collaborations within ICTP and beyond.

## PUBLICATION HIGHLIGHTS 2022

Abdelgadir, T., Mellit, A., & Villegas, F. R. (2021). The Tutte polynomial and toric Nakajima quiver varieties. Proceedings of the Royal Society of Edinburgh: Section A Mathematics, 5, 1323–1339. <https://doi.org/10.1017/prm.2021.61>.

Arezzo, Claudio; Balducci, Federico; Piargallini, Riccardo; Scardicchio, Antonello; Vanoni, Carlo Localization in the discrete non-linear Schrödinger equation and geometric properties of the microcanonical surface. J. Stat. Phys. 186 (2022), no. 2, Paper No. 24, 23 pp.

Carneiro, E., Chirre, A., & Milinovich, M. B. (2022). Hilbert spaces and low-lying zeros of L-functions. Advances in Mathematics, 108748. <https://doi.org/10.1016/j.aim.2022.108748>.

## MATH ACTIVITIES IN NUMBERS

# 03

MATH SCIENTIFIC  
ACTIVITIES ORGANISED  
AT ICTP IN 2022

# 03

MATH SCIENTIFIC  
ACTIVITIES ORGANISED  
ABROAD IN 2022

# 61

MATH SEMINARS  
ORGANISED IN 2022

Climenhaga, V., Luzzatto, S., & Pesin, Y. (2021). SRB Measures and Young Towers for Surface Diffeomorphisms. Annales Henri Poincaré, 3, 973–1059. <https://doi.org/10.1007/s00023-021-01113-5>.

Göttsche, L., & Kool, M. (2022). Virtual Segre and Verlinde numbers of projective surfaces. Journal of the London Mathematical Society, 3, 2562–2608. <https://doi.org/10.1112/jlms.12641>.

RESEARCH AREA:

# Earth System Physics (ESP)

The ESP section encompasses a range of research topics related to the interior and fluid (atmosphere and oceans) components of the Earth System. One major focus of ESP is anthropogenic climate change, together with the impact of climate phenomena on humans and ecosystems. Global models are used to study global patterns of variability, such as the North Atlantic Oscillation, whereas high-resolution regional models provide local climate information. The role of oceans in the climate system as a whole is also studied at ESP. Cloud behaviour is investigated from a physics perspective, along with the impact of climate change on various human sectors.

## RESEARCH AREAS INCLUDE:

### SOLID EARTH GEOPHYSICS

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

### CLIMATE APPLICATIONS

Dynamical and statistical modelling techniques are employed at ESP to assess the socio-economic impacts 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 hydrology model with regional climate models to describe water systems.

### 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, aerosols and atmospheric chemistry, biogeochemical cycles, the cryosphere, and land surface processes. ESP researchers use tools such as recent evolutions of the regional climate model RegCM and the intermediate complexity global model SPEEDY to understand our climate, its natural variability, and its response to anthropogenic forcing.

Very high-resolution regional climate modelling is performed at ESP using a non hydrostatic version of RegCM, in particular for the study of extreme events, such as floods. Precipitation and evaporation are input into a hydrology model that calculates river routing, and this information is used to determine river overflow and flooding, providing crucial data for high-flood-risk areas.

ESP scientists also use an atmospheric model coupled to a regional climate model to perform air quality studies, shedding light on the effect of aerosols on local climates, for example how aerosol-induced snow darkening effects over the Himalayas-Tibetan Plateau can affect pre-monsoon climate over northern India. ESP researchers recently published compelling results on the seasonal forecasting of malaria outbreaks. ESP is also one of two research groups involved in the worldwide CORDEX-CORE programme, in which regional climate models are used to obtain high-resolution projections for nine continental land areas. The resulting data were used for a special issue of the Journal Climate Dynamics and in a recent Intergovernmental Panel on Climate Change (IPCC) report.

In the future, ESP researchers will move to viewing the Earth system as an interconnected whole, rather than as compartments of ice, ocean, land, and atmosphere. A possible avenue of investigation for the section could be to add a human component to climate models. This is a complex problem as human behaviours such as migration depend on various factors, and it is difficult to disentangle responses to environmental stresses from factors such as war and poverty. Another future direction for ESP could be to create a regional digital twin for the Earth, i.e., a complex software that is able to mimic the behaviour of the Earth system at the regional scale. Also in this case, the effective incorporation of the human factor will be essential.

## ESP ACTIVITIES IN NUMBERS

05

ESP SCIENTIFIC  
ACTIVITIES ORGANISED  
AT ICTP IN 2022

02

ESP SCIENTIFIC  
ACTIVITIES ORGANISED  
ABROAD IN 2022

11

ESP SEMINARS  
ORGANISED IN 2022

## PUBLICATION HIGHLIGHTS 2022

Farneti, R., Stiz, A., & Ssebendeke, J. B. (2022). Improvements and persistent biases in the southeast tropical Atlantic in CMIP models. *Npj Climate and Atmospheric Science*, 1. <https://doi.org/10.1038/s41612-022-00264-4>.

Giorgi, F., & Raffaele, F. (2022). Transitions to new climates (TNCs) in the 21st century. *Environmental Research Letters*, 7, 074020. <https://doi.org/10.1088/1748-9326/ac71b7>.

Ruane, A. C., Vautard, R., Ranasinghe, R., Sillmann, J., Coppola, E., Arnell, N., Cruz, F. A., Dessai, S., Iles, C. E., Islam, A. K. M. S., Jones, R. G., Rahimi, M., Carrascal, D. R., Seneviratne, S. I., Servonnat, J., Sörensson, A. A., Sylla, M. B., Tebaldi, C., Wang, W., & Zaaboul, R. (2022). The Climatic Impact-Driver Framework for Assessment of Risk-Relevant Climate Information. *Earth's Future*, 11. <https://doi.org/10.1029/2022ef002803>.

Sun, C., Liu, Y., Wei, T., Kucharski, F., Li, J., & Wang, C. (2022). Cross-hemispheric SST propagation enhances the predictability of tropical western Pacific climate. *Npj Climate and Atmospheric Science*, 1. <https://doi.org/10.1038/s41612-022-00262-6>.

Vičić, B., Momeni, S., Borghi, A., Lomax, A., & Aoudia, A. (2021). The 2019–2020 Southwest Puerto Rico Earthquake Sequence: Seismicity and Faulting. *Seismological Research Letters*, 2A, 533–543. <https://doi.org/10.1785/0220210113>.

RESEARCH AREA:

# Quantitative Life Sciences (QLS)

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

RESEARCH AREAS INCLUDE:

**QUANTITATIVE ECOLOGY AND EVOLUTION**

QLS researchers study species coexistence and evolution using a broad approach that lies between data-inspired modeling and model-driven data analysis. Community ecology and population genetics theories are developed at QLS using stochastic processes, random matrix theory, statistical mechanics, and non-linear dynamics.

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

QLS researchers study inference and learning efficiency, the influence of data structure on performance, and the amount of data required for accurate prediction using a quantitative, statistical physics-based approach.

**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 matter, and active systems.

**EMERGENT COLLECTIVE BEHAVIOUR IN INTERACTING AGENT SYSTEMS**

QLS researchers employ statistical mechanics-based methods to explore economical phenomena such as loss of transparency in financial transformations, the relationship between inequality and growth, and the unintended consequences of technological innovation.

**FEATURELESS STATISTICAL INFERENCE AND LEARNING:**

At QLS, a relevance and information theory-based approach to featureless inference is employed to determine generic relationships between maximally relevant datasets, or representations, and statistical criticality. This approach is also used to predict the way in which learning machines should ideally morph their energy landscapes to learn structured datasets.

**EFFICIENCY OF NEURAL COMPUTATION**

QLS researchers use statistical physics and theoretical machine learning to study how computation emerges from the complex dynamics of neural systems. Data-driven models are built to describe neural population dynamics using large-scale recordings of behaving animals performing tasks.

**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.

Another research theme is quantitative physiology: a recent work involving QLS scientists showed how protein degradation plays an important role in determining resource allocations in slow-growing cells. QLS scientists also model realistic data structure algorithms designed for the cleaning and dimensionality reduction of large data sets.

Statistical physics is applied to social sciences to quantitatively address sustainability and human societal problems at the community level. Ongoing work at QLS integrates ideas from economics, demography, social sciences, biology, and neuroscience to shed light on the underlying mechanisms of inequality. Research into irreversibility and time is also ongoing at QLS, with a recent collaboration with neuroscientists exploring time perception. A recent QLS study showed how neural networks learn in relation to a given input, while a QLS/SISSA collaboration led to the discovery that artificial neural networks can be used to determine symmetries in data. Another recent QLS study described the use of kites to help ship propulsion using a virtual environment.

Future avenues of exploration for QLS include increased links with computational neuroscience; investigations into human ecology, with possible applications in infectious disease modelling; and sustainability research.

**PUBLICATION HIGHLIGHTS 2022**

Barbier, J., & Macris, N. (2022). Statistical limits of dictionary learning: Random matrix theory and the spectral replica method. *Physical Review E*, 2. <https://doi.org/10.1103/physreve.106.024136> (Editor's suggestion).

Harunari, P. E., Dutta, A., Poletti, M., & Roldán, É. (2022). What to Learn from a Few Visible Transitions? *Statistics? Phys. Rev. X*. <https://doi.org/10.1103/PhysRevX.12.041026>.

Ingrosso, A., & Goldt, S. (2022). Data-driven emergence of convolutional structure in neural networks. *Proceedings of the National Academy of Sciences*, 40. <https://doi.org/10.1073/pnas.2201854119>.

Marsili, M., & Roudi, Y. (2022). Quantifying relevance in learning and inference. *Physics Reports*, 1–43. <https://doi.org/10.1016/j.physrep.2022.03.001>.

**QLS ACTIVITIES IN NUMBERS**

12

QLS SCIENTIFIC ACTIVITIES ORGANISED AT ICTP IN 2022

02

QLS SCIENTIFIC ACTIVITIES ORGANISED ABROAD IN 2022

30

QLS SEMINARS ORGANISED IN 2022

Zaoli, S., & Grilli, J. (2022). The stochastic logistic model with correlated carrying capacities reproduces beta-diversity metrics of microbial communities. *PLOS Computational Biology*, 4, e1010043. <https://doi.org/10.1371/journal.pcbi.1010043>.



RESEARCH AREA:

# Science, Technology and Innovation (STI)

The STI unit finds technological solutions to scientific and societal problems that impact humanity, through both in-house laboratory work and collaborations with UN agencies.

The unit has a broad scope, encompassing the development of wireless communication and Internet of Things applications; advanced instrumentation for sensors, optics and lasers, particle physics applications, and

supercomputing; and ionospheric physics, modelling and space weather. The last year marked a shift from two years of remote working to in-person activities, a crucial change for scientists at STI's laboratories.

## RESEARCH AREAS INCLUDE:

### WIRELESS ICT AND INTERNET OF THINGS

STI researchers employ unlicensed frequencies to provide broadband connections between academic institutions, while connecting Internet of Things-based scientific devices using narrowband alternatives. The Marconi Laboratory focuses on providing assessments and technical solutions in the rapidly evolving fields of wireless communication, Internet of Things applications, and ionospheric data sources.

### IONOSPHERIC PHYSICS, MODELLING AND SPACE WEATHER

STI researchers examine ionospheric physics, ionospheric models, and the effect of space weather on Global Navigation Satellite System (GNSS) performance.

### ADVANCED SCIENTIFIC INSTRUMENTATION

STI researchers develop advanced scientific instrumentation for particle physics experiments, nuclear applications, supercomputing, and multidisciplinary experimental research, including projects on cultural heritage and optics. The unit's Multidisciplinary Laboratory (MLab) focuses on developing scientific instruments and methods to address a range of scientific problems through internal and external collaborations.

### DIGITAL FABRICATION AND SCIENCE DISSEMINATION

Cost-effective, open-source digital technologies are used in science dissemination and support at STI. As part of the larger FabLab network, the SciFabLab laboratory boasts flexible manufacturing equipment for digital fabrication. The laboratory is open to ICTP researchers for prototyping. STI is also actively involved in science dissemination through laboratory visits and the yearly Hackathon and Maker Faire events.

Low-cost equipment development is a key theme at STI. Chips and sensors are increasingly affordable, and many regions that previously had no internet access are now connected. With this in mind, STI researchers design and fabricate low-cost instrumentation for use in developing countries. Researchers at the MLab recently produced a lower-cost version of the data processing system they developed for CERN for use in the SESAME synchrotron project.

MLab scientists also collaborated with SciFabLab to reproduce an ancient Slovenian flute in a cultural heritage project. STI recently began a project with the UN Environment Programme (UNEP) on the development of low-cost weather stations. STI works closely with the International Telecommunication Union (ITU), who nominated STI as a technology observatory to test new technologies and advise users in developing countries.

Future research directions for STI may involve the increased use of Machine Learning. Edge computing also presents a key advancement in the local processing of data, with lower latency, and the potential to increase security and privacy control. This is a lower-energy option than sending data over long distances. Internet governance is also a central focus for STI. The unit recently organised the international European Dialogue on Internet Governance (EURODIG) conference at ICTP. Technology ethics is a fundamental concern at STI, where device affordability is considered together with electronic waste, the ownership of technological projects in the developing world, and the effect of potential projects on local communities.

## PUBLICATION HIGHLIGHTS 2022

Canessa, E. (2022). Wave-like behaviour in (0,1) binary sequences. *Scientific Reports*, 1. <https://doi.org/10.1038/s41598-022-18360-z>.

Galkin, I., Froń, A., Reinisch, B., Hernández-Pajares, M., Krankowski, A., Nava, B., Bilitza, D., Kotulak, K., Flisek, P., Li, Z., Wang, N., Dollase, D. R., García-Rigo, A., & Batista, I. (2022). Global Monitoring of Ionospheric Weather

by GIRO and GNSS Data Fusion. *Atmosphere*, 3, 371. <https://doi.org/10.3390/atmos13030371>.

Molina, R. S., Gil-Costa, V., Crespo, M. L., & Ramponi, G. (2022). High-Level Synthesis Hardware Design for FPGA-Based Accelerators: Models, Methodologies, and Frameworks. *IEEE Access*, 90429–90455. <https://doi.org/10.1109/access.2022.3201107>.

Nakamura, K., Manzoni, P., Redondi, A., Longo, E., Zennaro, M., Cano, J.-C., & Calafate, C. T. (2022). A LoRa-based protocol for connecting IoT edge computing nodes to provide small-data-based services. *Digital Communications and Networks*, 3, 257–266. <https://doi.org/10.1016/j.dcan.2021.08.007>.

## STI ACTIVITIES IN NUMBERS

# 13

STI SCIENTIFIC ACTIVITIES ORGANISED AT ICTP IN 2022

# 05

STI SCIENTIFIC ACTIVITIES ORGANISED ABROAD IN 2022

# 07

STI SEMINARS ORGANISED IN 2022

# ICTP Impact

Science is a powerful driving force in the success of any nation, contributing to its economic well-being and the individual fulfilment of its people. Many countries, however, do not have the infrastructure or educational provision to support the growth of science and technology and to keep pace with the developed world. Technology unsupported by science simply does not take hold or flourish. It is not enough to have the know-how; countries also need the know-why. ICTP is committed to addressing and eliminating those inequalities.

ICTP's reach and impact is global. The Centre's four regional centres of excellence in Brazil, China, Mexico and Rwanda bring ICTP's unique blend of high-quality physics and mathematics education and high-level science meetings closer to scientists everywhere. Our Physics Without Frontiers programme spreads the joy and wonder of physics to students in science- and technology-lagging countries, helping to build the next generation of scientists.

ICTP also builds scientific capacity through programmes coordinated by its External Activities Unit. These include support for scientific meetings, research networks, visiting scholars, and collaborative agreements with universities in developing countries. The latter, which ICTP considers 'affiliated centres', receive ICTP support for their postgraduate programmes in physics or mathematics, and are encouraged to enrol staff and students in ICTP programmes.



## ICTP regional centres of excellence

### MEXICO:

The Meso-American Institute for Sciences (MAIS) was established in collaboration with the Universidad Autónoma de Chiapas (UNACH) as a regional headquarters of ICTP in Mexico, Central America and the Caribbean.

### BRAZIL:

The ICTP South American Institute for Fundamental Research (ICTP-SAIFR) is a regional centre for theoretical physics created in collaboration with the State University of Sao Paulo (UNESP) and the Sao Paulo Research Funding Agency (FAPESP).

### RWANDA:

Inaugurated in 2018, the East African Institute of Fundamental Research (EAIFR), based at the University of Rwanda's Kigali campus, offers an important educational and research hub for the region and for Africa.

### CHINA:

In Beijing, the International Center for Theoretical Physics-Asia Pacific (ICTP-AP) is hosted at the University of the Chinese Academy of Sciences (UCAS) and provides opportunities for advanced training, research and education in theoretical physics and related interdisciplinary areas.

04 ICTP Partner Institutes



19 ICTP Schools and Workshops



06 ICTP-EAU Affiliated Centres



06 ICTP-EAU Networks



39 ICTP-EAU Scientific Meetings



24 Physics Without Frontiers Activities



# ICTP: A Hub for Global Scientific Activities

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 Marie Curie 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 where ideas are discussed over meals or coffee.

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.

ICTP also reaches directly into the developing world. Our four partner institutes in Brazil, China, Rwanda, and Mexico give scientists in those countries access to our networks, expertise, and convening power and have flourishing research and training programmes of their own and in collaboration with ICTP.

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 collaboration within a short distance of our campus.

# Education & Training

ICTP believes that talent is found everywhere; we all gain from the diversity of perspectives created by ensuring that scientists are empowered and can contribute to scientific discourse independently of possibly constraining factors such as geography, gender, class, or ethnicity.

The Centre works to transcend such barriers both to individual achievement and to building the science base in developing countries, through our training and education programmes.

Developing scientific talent contributes to the economic well-being and the individual fulfilment of nations. Many countries, however, do not have the infrastructure or educational provision to support the growth of science and technology and to keep pace with the developed world. This is where ICTP can help.

ICTP offers a unique environment for scientists at all stages of their careers to advance their knowledge in physics and mathematics. From our intense, one-year Postgraduate Diploma Programme that prepares young scientists for doctoral studies, to the Associates Scheme, which supports sabbatical visits of established scientists, ICTP is committed to providing the training and educational opportunities needed to overcome scientific inequalities.

145

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

61

COUNTRIES REPRESENTED (INCLUDING 8 LEAST DEVELOPED COUNTRIES)

195

SCIENTISTS FROM 43 COUNTRIES ENGAGED IN CAREER DEVELOPMENT PROGRAMMES (ASSOCIATES, TRIL, AND ELETTRA)

## ICTP ACTIVITIES IN NUMBERS, 2022

7127

SCIENTIFIC VISITORS, INCLUDING THOSE WHO PARTICIPATED REMOTELY

60

CONFERENCES, SCHOOLS AND WORKSHOPS

157

NATIONS REPRESENTED

29%

OF VISITORS WERE WOMEN

## DEVELOPING STATUS OF VISITORS' COUNTRIES, 2022

10%

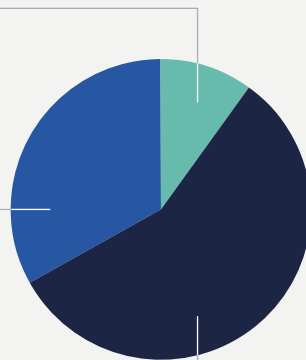
Least Developed Countries

33%

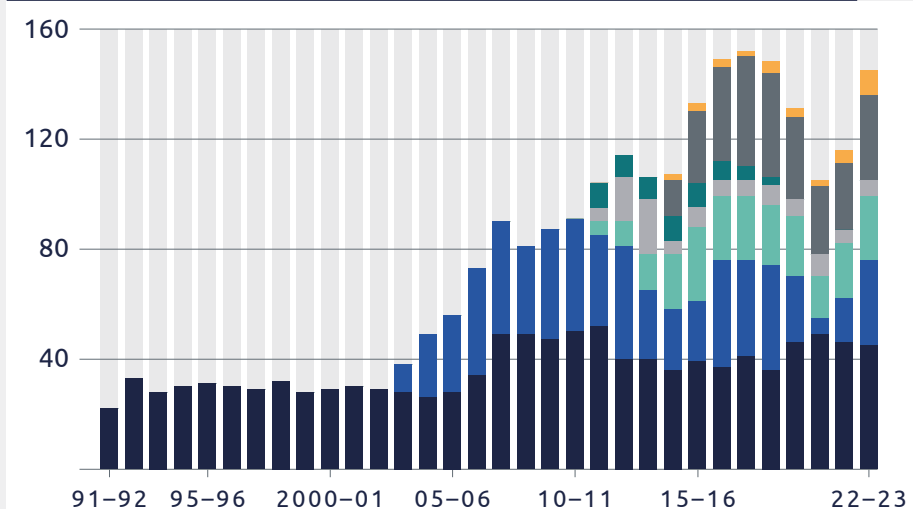
Developed Countries

57%

Developing Countries



## TREND IN ICTP PROGRAMMES AND ENROLLMENT, 1991-2022



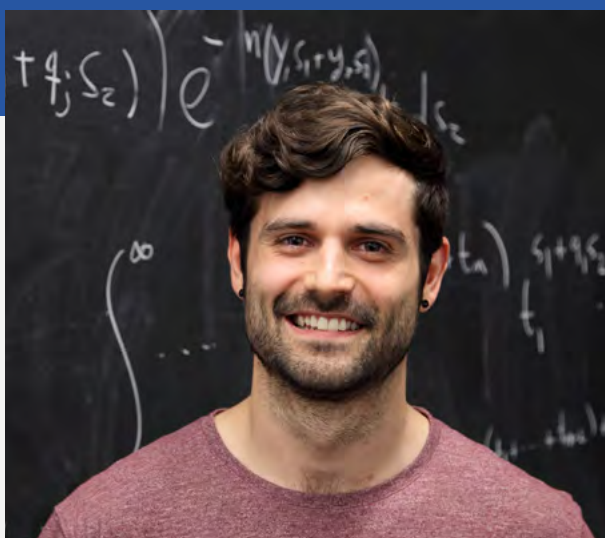
- Master in High Performance Computing
- Master of Advanced Studies in Medical Physics
- Joint PhD Programme, Earth Science and Fluid Mechanics
- ICTP-Units Joint Masters in Physics (ended in 2019)
- Joint ICTP-SISSA PhD Programme in Physics and Mathematics
- ICTP-STEP Fellow visits
- Postgraduate Diploma Students



# 2022

## Timeline

### January



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ICTP Photo Archives

#### ICTP RESEARCHER AWARDED MAJOR ERC STARTING GRANT

ICTP researcher Jean Barbier was awarded a prestigious European Research Council Starting Grant to support his research in statistics for machine learning. A statistical physicist with a strong interest in mathematics and data science, Barbier works in ICTP's Quantitative Life Sciences section. The ERC grant will fund a five-year multidisciplinary project that will tackle questions concerning machine learning and neural networks using high-dimensional statistics.

#### SPIRIT OF SALAM AWARD 2022

Three members of the extended ICTP community shared the 2022 Spirit of Abdus Salam Award: Malik Maaza (South Africa), for his major role in helping to shape Africa's science and technology landscape; Concetta Mosca (Italy), for her profound commitment to supporting the Diploma Programme during its first years; and Adnan Shihab-Eldin (Kuwait), for his unwavering, long-time support of ICTP's mission and his exceptional advocacy of ICTP to major donors.



Malik Maaza



Concetta Mosca



Adnan Shihab-Eldin



#### SALAM DISTINGUISHED LECTURES SERIES 2022

Physicist Alessandra Buonanno of the Max Planck Institute for Gravitational Physics, Germany, and one of ICTP's 2021 Dirac Medallists, delivered the 2022 Salam Distinguished Lectures Series. Professor Buonanno gave three lectures on gravitational waves and the fundamental observations carried out with the LIGO and Virgo detectors.

### February



#### CELEBRATING WOMEN IN SCIENCE

ICTP celebrated the 2022 International Day of Women and Girls in Science with a number of events that reflected its commitment to reducing the gender gap in science and research. Activities included an exhibit of statistics and a book display, a social media campaign, and a virtual event for high schools featuring a talk by ICTP scientists Erika Coppola and Anna Pirani of the Earth System Physics section.

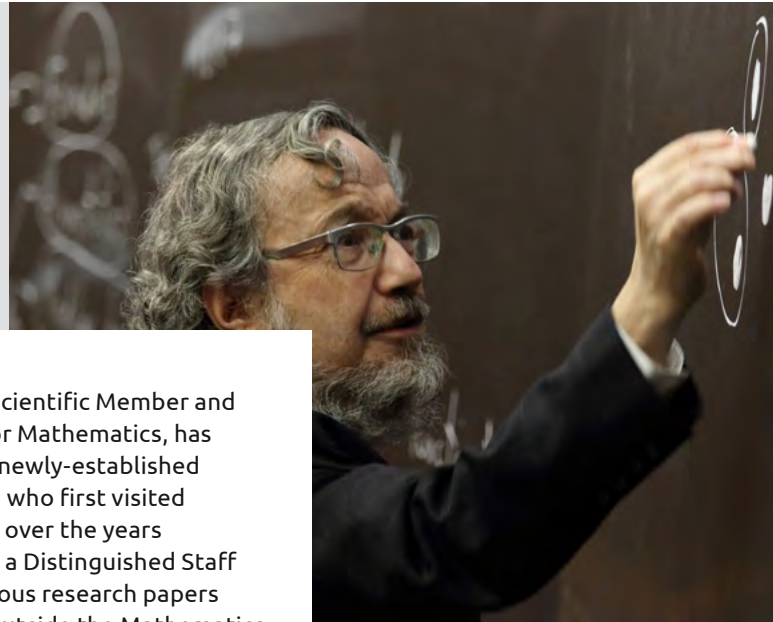
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ICTP Photo Archives



## 2022 TIMELINE

### ICTP'S NEW RAMANUJAN INTERNATIONAL CHAIR

Mathematician Don Zagier, Emeritus Scientific Member and Director at the Max Planck Institute for Mathematics, has been named the first holder of ICTP's newly-established Ramanujan International Chair. Zagier, who first visited ICTP more than 10 years ago, has built over the years strong connections with the Centre as a Distinguished Staff Associate, and collaborated on numerous research papers with ICTP scientists, both within and outside the Mathematics section. In addition to his ICTP affiliation, Zagier is a distinguished affiliated member of the Trieste-based Institute for Geometry and Physics, run jointly by ICTP and SISSA.



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## 2022 TIMELINE

### ICTP COLLOQUIUM

"To Thermalize or Not to Thermalize, That is the Question"

Maciej Lewenstein,  
ICREA Research Professor, ICFO

### ICTP COLLOQUIA 2022

To Thermalize or Not to Thermalize,  
That is the Question



Professor **Maciej Lewenstein**  
ICREA Research Professor,  
Institute of Photonic Sciences (ICFO) Castelldefels,  
Spain

Wednesday 23 February 2022 at 16.00

Advanced registration at:  
[WEBINAR Link](#)



The Abdus Salam  
International Centre  
for Theoretical Physics



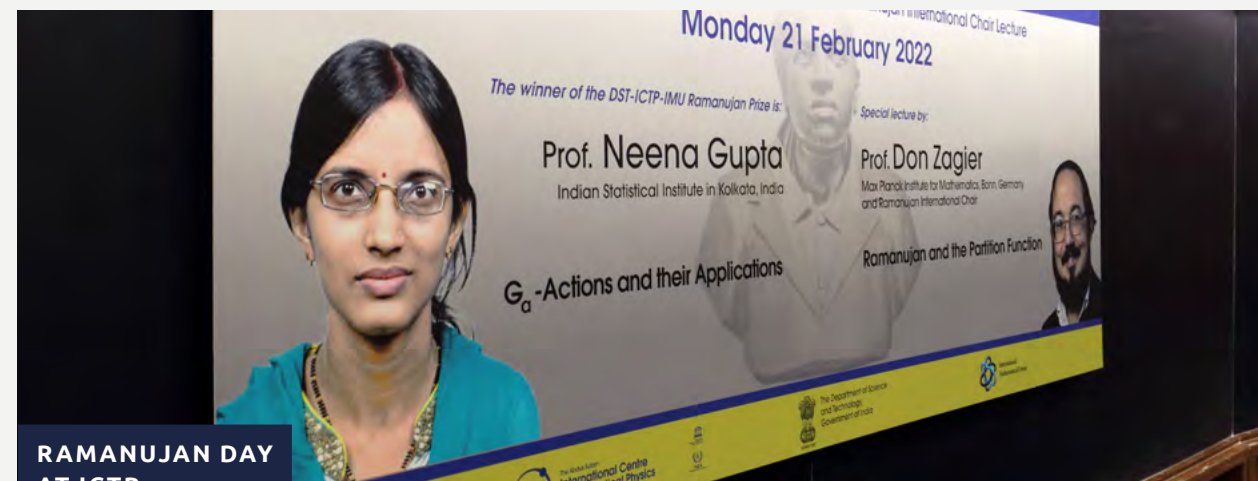
### ICTP IN THE MIDDLE EAST

ICTP was represented at two key events in the United Arab Emirates related to the promotion of science. On 24 February, Director Atish Dabholkar signed an agreement with the University of Sharjah to promote joint research opportunities and academic exchanges. On 25 February, Dabholkar and Rosario Fazio, head of the Condensed Matter and Statistical Physics (CMSP) section, were among the speakers in a delegation of scientific leaders from Italy's Friuli-Venezia-Giulia region to present highlights of their respective institutes. The event took place in the Italy pavilion at the World Expo in Dubai.

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### RAMANUJAN DAY AT ICTP

ICTP dedicated a day to mathematics to celebrate the awarding of the 2021 DST-ICTP-IMU Ramanujan Prize to Indian mathematician Neena Gupta, and to present the first lecture by its new Ramanujan International Chair, Don Zagier. Gupta, a mathematician at the Indian Statistical Institute in Kolkata, received the Ramanujan Prize for her outstanding work in affine algebraic geometry and commutative algebra. Zagier's talk was titled "Ramanujan and the Partition Function".



ICTP Director Atish Dabholkar presenting ICTP at an event held at the World Expo in Dubai.

## 2022 TIMELINE

### ICTP COLLOQUIUM

“EGO and VIRGO: The Past, Present, and Future of the Physics of Gravity Waves”

Giancarlo Cella, National Institute of Nuclear Physics (INFN), and Stavros Katsanevas of the European Gravitational Observatory (EGO)

## 2022 TIMELINE



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ICTP Photo Archives

### EUROPEAN RESEARCH COUNCIL ADVANCED GRANT AWARDED TO ICTP SCIENTIST

ICTP condensed matter physicist Rosario Fazio has been awarded a prestigious European Research Council (ERC) Advanced Grant, supporting his research in quantum information and quantum dynamics. Fazio’s five-year grant, titled “UnRAVELling the dynamics of many-body open systems: Collective dynamics of quantum trajectories,” or RAVE, will investigate the intricacies and collective phenomena emerging in open quantum systems, research vital for the success of developing quantum technologies.

## May

### ICTP CELEBRATES INTERNATIONAL YEAR OF BASIC SCIENCES

ICTP Director Atish Dabholkar was among top global science dignitaries addressing the official launch of the United Nations International Year of Basic Sciences for Sustainable Development (IYBSSD2022) at a ceremony on 8 July at UNESCO headquarters in Paris. In honour of the year, ICTP organised a colloquia series on the following topics:

- “The Importance of Basic Sciences in Addressing the Global Energy Crisis”
- “Artificial Intelligence for Detection and Attribution of Climate Extremes”
- “Quantitative Human Ecology: Untangling the Determinants of Sustainability”
- “Embedding Ethics in Machine Learning”



### 100 YEARS OF IUPAP: ICTP HOSTS CENTENNIAL CELEBRATIONS

ICTP was pleased to host the Centenary Symposium of the International Union for Pure and Applied Physics (IUPAP), from 11 to 13 July. IUPAP represents the global community of physicists and promotes the global development of physics to address problems of concern to humanity. Among the keynote speakers were Nobel Prize laureates Takaaki Kajita and William Phillips.

## March



Ali Hassanali

### ICTP SCIENTISTS WIN PRESTIGIOUS EUROPEAN RESEARCH COUNCIL GRANTS

Two ICTP scientists have won prestigious European Research Council (ERC) grants that will provide substantial financial support for their frontier research. Ali Hassanali, of ICTP’s Condensed Matter and Statistical Physics section, has been awarded an ERC Consolidator Grant for mid-career scientists, while Joan Elias Miró, a physicist in the High Energy, Cosmology and Astroparticle Physics section, has received an ERC Starting Grant for early career scientists. Both types of grants are given to outstanding researchers whose scientific track records show great promise.



Joan Elias Miró  
© Roberto Barnaba/  
ICTP Photo Archives



## 2022 TIMELINE

### ICTP COLLOQUIUM

“Interplay between Natural Variability and Anthropogenic Climate Change at Regional Scales”

Carolina Vera,  
University of Buenos Aires - CONICET, Argentina

### ICTP COLLOQUIA 2022

Interplay between Natural Variability and Anthropogenic Climate Change at Regional Scales



Professor **Carolina Vera**  
University of Buenos Aires - CONICET, Argentina

Monday 30 May 2022 at 16.00

Online via a Webinar and in person in the Budinich Lecture Hall

Advanced registration at:  
[WEBINAR Link](#)



## 2022 TIMELINE

### July



2021 DIRAC MEDAL CEREMONY

ICTP celebrated its 2021 Dirac Medal winners on 14 July, honouring Alessandra Buonanno of the Max Planck Institute for Gravitational Physics, Germany; Thibault Damour of the Institut des Hautes Études Scientifiques (IHÉS), France; Frans Pretorius of Princeton University, USA; and Saul Teukolsky of Caltech and Cornell University, USA. Physics Nobel Laureate Kip Thorne joined the ceremony virtually to give an overview of the Medallists' work. The four were awarded the Medal for establishing the predicted properties of gravitational waves in the curvature of spacetime produced when stars or black holes spiral together and merge.

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ICTP Photo Archives

(from left) ICTP Director Atish Dabholkar at the award ceremony for 2021 Dirac medallists Frans Pretorius, Alessandra Buonanno and Thibault Damour (Medallist Saul Teukolsky had attended the ceremony remotely).

### June

## QUANTUM ENTANGLEMENT AT ALL DISTANCES



JOINT ICTP-SISSA COLLOQUIUM  
“Quantum Entanglement at all Distances”

Subir Sachdev, Harvard University

A JOINT ICTP-SISSA COLLOQUIUM  
PROFESSOR SUBIR SACHDEV  
HERCHEL SMITH PROFESSOR OF PHYSICS  
HARVARD UNIVERSITY, USA  
TUESDAY 14 JUNE 2022 AT 16:00  
BUDINICH LECTURE HALL  
ICTP LEONARDO BUILDING  
OR FOLLOW ONLINE VIA ZOOM WEBINAR:  
[WEBINAR LINK](#)



### ICTP PRIZE CEREMONY HONOURS TWO CLIMATE SCIENTISTS



ICTP Prize recipients Rondrotiana Barimalala (left) and Narendra Ojha (right) with ICTP scientist Fred Kucharski

A ceremony for the recipients of the 2021 ICTP Prize honoured Rondrotiana Barimalala of the University of Cape Town, South Africa, and the Bjerkeness Center for Climate Research, Norway, and Narendra Ojha of the Physical Research Laboratory, Ahmedabad, India, for their important work on diverse aspects of climate change in Africa and Asia.

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## 2022 TIMELINE

### ICTP POSTGRADUATE DIPLOMA GRADUATION CEREMONY 2022



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Some 43 young scientists from 26 countries now count themselves as graduates of ICTP's intense Postgraduate Diploma Programme after a ceremony on Friday 26 August celebrating their successful completion of the programme.

The ceremony included a keynote lecture by ICTP Dirac Medallist Dam Thanh Son on "Particles and Quasiparticles: Between Particle and Condensed Matter Physics".

The Diploma students, who have spent the past year at ICTP attending graduate-level courses in physics and mathematics, are now equipped with the knowledge and learning skills needed to advance their careers. As a result of their ICTP studies, many have been accepted to doctoral or master's programmes at top universities around the world, while others will return to their home countries to share their knowledge with colleagues and students.

ICTP's Postgraduate Diploma Programme is designed to assist students from developing countries who are interested in further study in physics or mathematics. The programme especially helps students reach international standards of knowledge and competences, striving to fill in any past gaps in their education. This is done in order to prepare them to compete successfully for graduate studies at any institution in the world.

#### MEET THE GRADUATES:

##### JOHANN SEBASTIAN QUENTA RAYGADA

Peru

Diploma in High Energy Physics; admitted to master's programme at the University of Burgundy in France

“The Diploma Programme has been a great experience, both for my career and personally. The strength of the Programme is its basic idea, that you take people from developing countries who are having a hard time finding the research opportunities, and you put them in this programme and train them, and then they can freely go to, say, PhD programmes overseas. For many of my classmates, I've seen how they've succeeded in doing this.”

© Roberto Barnaba/ICTP Photo Archives



## 2022 TIMELINE

##### KADJA FLORE GALI

Chad

Diploma in Earth System Physics; admitted to PhD, Michigan Technological University, USA

“ICTP is the perfect place for a young scientist from a developing country to find an opportunity to pursue a career in science. My dream is to be a professor one day, and open my own department of atmospheric physics in my country. I will do my best, but of course I need a bit of help. My favourite thing about the Diploma Programme is how they managed to give us everything that we needed, so we could just concentrate on studying and not worry about anything else.”

© Roberto Barnaba/ICTP Photo Archives



##### MOHAMED ALIOUANE

Algeria

Diploma in Mathematics; admitted to PhD, SISSA, Italy

“I think the best thing, in the programme and in ICTP in general, is the environment; it is perfect for studying and concentrating on your work. For example, when I was at university studying three hours was too much. But here the environment really allows you to study for five hours very easily. Moreover, even when you have lunch, you can discuss about maths with other students or even the professors. I think this is the most important part of the programme.”

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##### HUMA NAWAZ

Pakistan

Diploma in Condensed Matter Physics; admitted to PhD, University of Houston, Texas, USA

“I loved ICTP; the Galileo guesthouse is like a home to me. I made so many friends and I share a special bond with them, we have so many memories together. The ICTP community is really hospitable and always willing to help us for any kind of need. I believe I could go to any place but not get so much care, love and affection that ICTP has shown us. It was an incredible experience for me, and I'm going to miss everything so much.”

© Roberto Barnaba/ICTP Photo Archives



##### KRISTIAN PAJANONOT

Philippines

Diploma in Quantitative Life Sciences; admitted to five-year master's and PhD programme, Max Planck School (Matter to Life), Germany

“The Diploma Programme motivated me to try my best to really study hard--I never thought I could study as hard as I did here at ICTP. I think that was really good, because I developed a good habit of studying. I started applying to graduate schools; ICTP was the key for me to get into a graduate programme.”

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## 2022 TIMELINE

### August

#### ICTP DIRAC MEDAL 2022



#### 2022 ICTP DIRAC MEDAL WINNERS ANNOUNCED

ICTP awarded its 2022 Dirac Medal to three distinguished physicists “for groundbreaking and mathematically rigorous contributions to the understanding of the statistical mechanics of classical and quantum physical systems”. The 2022 Dirac Medallists are: Joel L. Lebowitz, Center for Mathematical Sciences Research, Rutgers, The State University of New Jersey, USA; Elliott H. Lieb, Princeton University, USA; and David P. Ruelle, Institut des Hautes Études Scientifiques, France. The three physicists received the medal for their important work in the field of statistical mechanics that has very significantly deepened and expanded our mathematical understanding of physical systems in many new directions, sometimes different from the traditional ones.

### September

#### QUANTUM COMPUTING FOR APPLICATIONS IN PHYSICS & CHEMISTRY

A JOINT ICTP-SISSA COLLOQUIUM  
PROFESSOR IVANO TAVERNELLI  
IBM QUANTUM, ZÜRICH, SWITZERLAND  
FRIDAY 23 SEPTEMBER 2022 AT 15:00  
BUDINICH LECTURE HALL  
ICTP LEONARDO BUILDING



#### JOINT ICTP-SISSA COLLOQUIUM “Quantum computing for applications in physics and chemistry”

Ivano Tavernelli, IBM

## 2022 TIMELINE

### October

#### PHYSICS WITHOUT FRONTIERS TURNS 10

Physics Without Frontiers (PWF), ICTP’s flagship outreach programme for university students, celebrated its tenth anniversary with a hybrid event. In its 10 years of existence, PWF has reached more than 10,000 students through more than 300 activities in at least 50 countries. Some 300 students have continued their science studies at the masters and PhD levels thanks to the programme.



Kate Shaw and Bobby Acharya coordinate ICTP’s Physics Without Frontiers programme, © Roberto Barnaba/ICTP Photo Archives

#### ICTP COLLOQUIUM

#### “Hydrodynamics of Quantum Liquids: From Electrons to Quarks”

Giovanni Vignale,  
University of Missouri-Columbia, USA

#### ICTP COLLOQUIA 2022

Hydrodynamics of Quantum Liquids:  
From Electrons to Quarks

Professor **Giovanni Vignale**  
Institute for Intelligent Functional Materials (IFIM),  
National University of Singapore



Monday 10 October 2022 at 16.00  
Budinich Lecture Hall  
Leonardo Building ICTP





## 2022 TIMELINE

### December



#### ICTP SIGNS AGREEMENT WITH SOUTH AFRICAN INSTITUTE

ICTP has signed an agreement with South Africa's National Institute for Theoretical and Computational Sciences (NITheCS) to strengthen their collaboration and support of basic and computational science in South Africa. The signing, which took place at the World Science Forum 2022 in Cape Town, paves the way for joint research, education and visiting opportunities as well as collaboration with ICTP's partner institute in Rwanda, the East African Institute for Fundamental Research.

ICTP Director Atish Dabholkar (seated right) signing the agreement together with Francesco Petruccione, Director of NITheCS (seated, left), in the presence of (standing, from left to right) Dr Phil Mjwara, Director General, Department of Science and Innovation, Republic of South Africa; Sandro Scandolo, Senior Coordinator of Research and Partnerships, ICTP; Dr Blade Nzimande, South Africa's Minister of Higher Education, Science and Innovation; and Dr Happy Sithole, Center Manager, National Intergrated Cyber-Infrastructure, CSIR-NICIS

## 2022 TIMELINE

#### ICTP AT WORLD SCIENCE FORUM 2022

ICTP joined up with the Synchrotron-light for Experimental Science and Applications in the Middle East (SESAME) to host a session at the 2022 World Science Forum on "Physics and Accelerators for Science and Social Justice". The session addressed how networks of researchers and multi-disciplinary scientific facilities can bring together global scientific communities, where the mission of advancing science intermixes finely with a firm societal commitment.



#### WALTER KOHN PRIZE 2022 ANNOUNCED

The 2022 Walter Kohn Prize for quantum-mechanical materials and molecular modeling was awarded to Debashree Ghosh, of the Indian Association for the Cultivation of Science in Kolkata, India. The prize recognises her "pathbreaking work in developing novel quantum chemical tools for materials design and the study of biological function."

© Roberto Barnaba/  
ICTP Photo Archives

### ICTP COLLOQUIA 2022

Programming Quantum Simulators with Atoms and Ions

**Professor Peter Zoller**  
University of Innsbruck, and  
IQOQI, Austrian Academy of Sciences, Innsbruck,  
Austria

Wednesday 14 December at 16:00  
Budinich Lecture Hall

### ICTP COLLOQUIUM

## "Programming Quantum Simulators with Atoms and Ions"

Peter Zoller,  
University of Innsbruck, and  
IQOQI Innsbruck



#### MEDICAL PHYSICS ACHIEVEMENT

On 14 December, ICTP's Masters in Medical Physics (MMP) programme celebrated the graduation of 22 students from its two-year advanced training programme run jointly with the University of Trieste. The students, representing 16 mainly developing countries, completed the MMP's postgraduate theoretical and clinical training so that they may be recognised as clinical medical physicists in their home countries.



## 2022 TIMELINE



Shant Baghram



Mohammad Hossein Namjoo

### ICTP PRIZE 2022 ANNOUNCED

The 2022 ICTP Prize was awarded to two outstanding Iranian cosmologists: Shant Baghram of the Sharif University of Technology and Mohammad Hossein Namjoo of the Institute for Research in Fundamental Sciences. The two share the prize for their pioneering contributions to developing robust theoretical, computational and statistical frameworks to compare theoretical predictions for various cosmological and astrophysical phenomena with high-precision observational data.

© Roberto Barnaba/  
ICTP Photo Archives



### RESEARCH EXCELLENCE

ICTP climate scientist and head of the Earth System Physics' section Filippo Giorgi was named to the 2022 Highly Cited Researchers list from Clarivate. The Highly Cited Researchers 2022 are scientists who have published multiple highly cited papers, ranking in the top 1% by citations for field and year over the last decade. Giorgi is an international expert in the field of climate modeling, and in the study of climate change and its impacts on society.

# 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.

### ICTP STEERING COMMITTEE

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In addition, ICTP employed 112 General Service staff in 2022.



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# In Memoriam

The ICTP community was saddened by the passing of the following members in 2022; they will be missed.



## FRANK SILVIO MARZANO

Frank Silvio Marzano, a former colleague of several scientists in ICTP's Earth System Physics (ESP) section, was director of the Center of Excellence on Remote Sensing and Hydro- Meteorological Modeling (CETEMPS), in L'Aquila, and vice director of LMAST (Laurea Magistrale in Atmospheric Science and Technology for Meteorology and Climate). Thanks to him, graduates of ICTP's Postgraduate Diploma Programme who were accepted for graduate studies at LMAST were able to count their ESP Diploma courses as credits in the programme.



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## PHILIPPE NOZIERES

Philippe Nozieres was an eminent French theoretical condensed matter physicist. He was awarded numerous prizes and recognitions, including the Wolf Prize, and membership in the United States Academy of Sciences and in the French Academy of Sciences. Nozieres lectured at ICTP's 1994 Spring College in Condensed Matter on Quantum Phases (smr 758; his hand-written transparencies are available at <https://indico.ictp.it/event/a02273/speakers>).



## PATRICIA DOHERTY

Patricia Doherty was Director and Senior Research Scientist at Boston College Institute for Scientific Research, USA, and a long-term collaborator with ICTP. Beginning in 2006, she co-directed with former ICTP scientist Sandro Radicella the Workshop on the Future of Ionospheric Research for Satellite Navigation and Positioning: its Relevance for Developing Countries. After that, she co-organised yearly training activities to advance studies on the ionosphere and space weather effects on Global Navigation Satellite System (GNSS) dramatically increasing the publication rate of scientists from developing countries in the area of space science.

## VALERY RUBAKOV

Valery Rubakov, one of the most prominent theoretical physicists of his generation, served on the ICTP Scientific Council from 2010 to 2020. He made fundamental contributions at the interface of particle physics and cosmology, in particular writing pioneering papers about baryogenesis (the mechanism that explains why the Universe contains matter and not antimatter), non-perturbative methods in Quantum Field Theory (including his insightful work on monopole catalyzed proton decay, now known as the 'Callan-Rubakov effect'), and the braneworld scenario (the possibility that additional large space dimensions exist on top of the usual three).



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