## ICTP 2014

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1964 – ICTP co-founders Paolo Budinich and Abdus Salam in front of a model of the future ICTP Main Building, which is later renamed as the Leonardo Building

1965 – ICTP holds one of its first activities, the International Seminar on High Energy Physics and Elementary Particles, at its temporary headquarters in the centre of Trieste
The year 2014 marked an important milestone for ICTP: the Centre celebrated its 50th anniversary.

From an idea conceived by ICTP founder and physics Nobel laureate Abdus Salam, together with a group of scientists from Trieste and elsewhere, ICTP emerged as the first institute of its kind devoted both to nurturing an international centre of scientific excellence and to providing a lifeline to those scientists, like Abdus Salam himself in his native Pakistan, who languish in intellectual isolation due to a lack of local research infrastructure.

Salam believed that all scientists should be given the opportunity to explore the mysteries of the universe in the best possible environment, regardless of their country of origin. In its early years, ICTP was the only meeting place for physicists from the USA and USSR during the cold war; now, ICTP opens its doors every year to more than 5,000 scientists from 140 countries, in the spirit of Salam’s belief that “scientific thought is the common heritage of mankind”.

These visiting scientists attend the Centre’s offering of nearly 60 conferences a year. Some stay longer, perhaps as participants of the Centre’s Associates Scheme, which supports visits of several months at a time over a six-year period; or, as students in ICTP’s Postgraduate Diploma Programme, a year-long, intense course of study to prepare young scientists from the developing world for graduate study.

Over the decades, ICTP has stood witness to extraordinary physics discoveries, from cosmic microwave background radiation to electroweak theory (for which ICTP founder Salam shared the 1979 Nobel Prize in Physics) to string theory and the Higgs Boson. Many of the scientists involved with these discoveries have lectured at ICTP (indeed, the Centre has hosted more than 100 Nobel laureates and Fields medallists).

Today, ICTP continues its role as an international crossroad for those who are fascinated with physics or who marvel at the beauty of mathematics. Curiosity and the will to explore the mysteries of the universe are still at the very heart of what motivates the Centre. Its inclusive approach spreads knowledge and peace to every corner of the world, to every country despite adverse learning or research conditions. ICTP remains a lifeline for scientists that after 50 years is stronger than ever.
Dignitaries at ICTP’s 50th anniversary event included (from left) CERN Director-General Rolf-Dieter Heuer, Elisa Quevedo, ICTP Director Fernando Quevedo, Rwanda President Paul Kagame, UNESCO Director-General Irina Bokova, Prince El Hassan bin Talal of Jordan and his wife, Princess Sarvath, IAEA Director-General Yukiya Amano, TWAS Executive Director Romain Murenzi, and UNESCO ADG for Natural Sciences Flavia Schlegel

Opening ceremony, ICTP 50th Anniversary Event
In 2014, ICTP celebrated 50 years of a unique institution that over the years has become more and more relevant to the needs of our planet and its inhabitants, since science is a key component of our culture and of development, and is one of the most effective means of our survival.

ICTP's founding fathers, the Pakistani Nobel Laureate Abdus Salam and his visionary partner, the Italian physicist Paolo Budinich, had a dream more than 50 years ago to create an institution that could bring scientific excellence to all corners of the world by using the universal language of science to unite its people in a perfect example of what nowadays is called “science diplomacy”, and to raise the awareness of the importance of science worldwide. They managed to turn this dream into a reality, and it has been an honour for me during the past five years to contribute to keeping this dream alive.

Our path in the last 50 years has not been an easy one. The Centre would not be here to celebrate its 50th anniversary without the generous and continuous support of the Government of Italy as well as that of the IAEA and UNESCO. It is in this way that ICTP has succeeded to remain faithful to its mandate and to adapt itself to the changing world of science and technology.

By now, many people and world leaders are aware of the importance of science for our future. At ICTP, we strongly believe that the most important component of the scientific endeavour is the scientists themselves. They need to be continuously educated and supported throughout their whole research career for the benefit of their countries and society in general.

ICTP’s 50th Anniversary also marks the transition from my first to second mandates as Director of ICTP, and it is the perfect opportunity to summarize the developments of the past five years with a critical view on achievements and challenges. We are proud of the progress we have made in the past few years in response to the current scientific developments and demands from developing countries. We have initiated new ambitious programmes such as the opening of regional partner institutions worldwide; new research areas in quantitative life sciences and renewable energies; substantial developments in high performance computing; new degree programmes such as the joint ICTP/SISSA PhD and master programmes and the joint ICTP/IAEA/University of Trieste master in medical physics. This concrete progress and expansion has been achieved without an increase in the Centre’s budget and without sacrificing the commitment for excellence in ICTP’s existing programmes.

The main priority now is to consolidate the programmes that have started in the past few years. In addition, if conditions are favourable, ICTP would be interested in pursuing further activities important to the institution’s ongoing mission, such as: improving the gender balance; enhancing the presence of ICTP in developing countries by engaging postdocs, professors on leave of absence and retired professors from institutions throughout the world to participate in ICTP’s activities in the developing world; and to increase our activities in undergraduate and high school teacher training.

The next few years will mark a time of consolidation of all the initiatives mentioned above for which an increase in both the number of scientists working at ICTP and the corresponding infrastructures may be needed in order to reach the level required for the proper running of these activities. Extra sources of funding will be needed. This will be a major challenge for ICTP, one for which we hope to count on the continuing support of long-time sponsors as well as new partnerships.

Focussing on 2014, our achievements included the formal launching of a new research section in Quantitative Life Sciences as well as new master’s programmes in Medical Physics and High Performance Computing. ICTP’s 50th anniversary conference, which attracted highest-level scientists working at ICTP and the corresponding infrastructures may be needed in order to reach the level required for the proper running of these activities. Extra sources of funding will be needed. This will be a major challenge for ICTP, one for which we hope to count on the continuing support of long-time sponsors as well as new partnerships.

ICTP receiving the Premio Barcola prize and Honorary Citizenship of Trieste were timely events that sealed a year of celebration. But probably the most emotional moment during the 50th anniversary celebration was the short ceremony for the new “Spirit of Salam Award” given by Abdus Salam’s family, of whom more than 20 members were present to honour the well deserved awardees—Pierre Agbedjro, Anne Gatti and Andre-Marie Hamende—who are longtime members of ICTP. This was a very symbolic gesture that captured the essence of the meaning of ICTP over its 50-year history.

Fernando Quevedo, Director, ICTP
January

Condensed matter physicist Subir Sachdev delivers Salam Distinguished Lectures 2014.

February

ICTP officially inaugurates its new Master’s in Medical Physics degree programme.

ICTP and the International Commission for Optics (ICO) announce the recipients of the 2014 ICO/ICTP Gallieno Denardo Award: Maria Florencia Pascual Winter (CONICET and Instituto Balseiro, Bariloche, Argentina) and John Fredy Barrera Ramírez (Universidad de Antioquia, Medellín, Colombia).

May

More than 7,000 people descend on ICTP for the Centre’s first Trieste Mini Maker Faire, a show-and-tell event where innovators (“makers”) can show their creations, present their ideas and share what they are learning with the general public.

ICTP is awarded the 2014 Premio Barcola, a prestigious local prize given to people or institutes that have enhanced the image of Trieste and Italy throughout the world.

June

ICTP awards its 2014 Ramanujan Prize to Miguel Walsh, University of Oxford, in recognition of his outstanding contributions to Ergodic Theory and Number Theory. The Prize is awarded jointly with the Department of Science and Technology (DST, Government of India) and the International Mathematical Union (IMU).

August

ICTP opens its Scientific Fabrication Laboratory, or SciFabLab, the first of its kind in the Friuli-Venezia-Giulia region, a workshop space encouraging “makers” to bring their creative ideas to life.

ICTP awards its 2014 Dirac Medal to Ashoke Sen (Harish-Chandra Research Institute, India), Andrew Strominger (Harvard University, USA) and Gabriele Veneziano (CERN, Switzerland and Collège de France, France), three physicists who have made crucial contributions to the origin, development and further understanding of string theory.
Thirty-nine young scholars from developing countries around the world receive their Postgraduate Diplomas from ICTP after completing a year of rigorous coursework and projects.

**September**

ICTP and the International School for Advanced Studies (SISSA) open a new high performance computing facility, one of the largest of its kind in Italy.

**October**

Nobel Laureates, ministers, princes and presidents attend ICTP anniversary celebrations, held over four days and attracting more than 250 distinguished scientists, ministers and others.

During the 50th Anniversary Ceremony, ICTP dedicates its Main Lecture Hall to ICTP co-founder Paolo Budinich.

**November**

ICTP awards its 2014 ICTP Prize to Pablo S. Cornaglia, a condensed matter physicist from Argentina based at the Bariloche Atomic Center, Argentina, for his work on topics in solid state theory.

The family of Abdus Salam presents its first “Spirit of Abdus Salam Award” to longtime ICTP staff members Anne Gatti, Pierre Agbedjro, and Andre-Marie Hamende during ICTP’s anniversary celebrations.

ICTP is conferred honorary citizenship of Trieste in recognition of the Centre’s continuing efforts to advance scientific expertise, especially in the developing world.
favourite equation!
ICTP’s unique strength lies in its ability to bring together large numbers of gifted scientists from developing and developed countries to participate in joint research. From its early focus on theoretical high energy physics, the Centre’s research areas have evolved in response to the needs of physicists and mathematicians from the developing world, and now include:

- High Energy, Cosmology and Astroparticle Physics
- Condensed Matter and Statistical Physics
  (with a new research area in renewable energy)
- Mathematics
- Earth System Physics
- Applied Physics
- Quantitative Life Sciences

ICTP’s visiting researchers are immediately caught up in the culture of the Centre. Strategically placed blackboards welcome them to linger over physics and math problems, while bulletin boards announce a feast of upcoming seminars and colloquia. ICTP research is further strengthened by the Centre’s infrastructure, including its recent investment in high performance computing equipment and its highly regarded Marie Curie Library.

The following pages provide a glimpse of ICTP’s research activities during 2014. For a more detailed description of ICTP research in 2014, please see the Full Technical Report at http://bit.ly/1PkOYsB.

### Research Successes at ICTP

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<td>1968</td>
<td>Salam Nobel prize</td>
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<td>Beyond the standard model</td>
<td>1974</td>
<td>Pati-Salam</td>
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<td>Superspace/superfields</td>
<td>1974</td>
<td>Salam-Strathdee</td>
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<td>Ab-initio molecular dynamics</td>
<td>1985</td>
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<td>1986</td>
<td>Bergshoeff, Sezgin, Townsend</td>
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<td>Large extra dimension</td>
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<td>Arkani-Hamad, Dimopoulos, Dvali</td>
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<td>Neutrino masses, see-saw mechanism</td>
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<td>Solar neutrino problem, MSW effect</td>
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<td>Local climate modelling/IPCC Nobel Prize</td>
<td>2007</td>
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<td>Higgs discovery</td>
<td>2012</td>
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Four broad areas are explored by the High Energy, Cosmology and Astroparticle Physics (HECAP) section at ICTP: cosmology; physics at the Large Hadron Collider (LHC); phenomenology of particle physics; and gravity, strings and higher dimensional theories. In 2014 the section has delved into the theory of gravitational signals from the Big Bang, helped confirm the properties of the Higgs particle, assessed a worsening problem for the Standard Model, and studied black holes and supersymmetry breaking.

**Primordial Tensor Modes**

Cosmology meets particle physics most notably in the theory of inflation. According to this hypothesis, in the earliest moments of the Big Bang, the universe underwent a stage of exponential growth, with all of the universe that is visible today ballooning out from a small region in a fraction of a second. During this extraordinary expansion, quantum effects would have generated gravitational waves—ripples in spacetime itself—which in turn would have left their imprint on the early universe. Experiments today are looking for signs of those waves in the polarization of the cosmic microwave background (CMB), which dates from 380,000 years after the Big Bang and still pervades all of space. 2014 saw impressive experimental progress reported, most notably from the BICEP2 telescope near the South Pole and the Planck spacecraft, renewing interest in the primordial gravitational waves produced during inflation.

The waves come in two broad types, tensor and scalar. The tensor modes are of much greater interest than the scalar modes. The characteristics of the scalar modes may vary considerably depending on the detailed properties of the fields responsible for inflation (there are numerous different theoretical models). Scalar modes could also be generated in many non-inflationary scenarios. Thus, signs of scalar modes can tell us little about whether inflation is correct or not. Tensor modes, in contrast, are much less dependent on the details of the inflationary model, and thus would provide a much more robust test of inflation.

Work by ICTP’s Paolo Creminelli has strengthened this robustness. He and his co-workers studied the simplest model of inflation in detail, a quadratic potential, to understand at what level experiments could constrain all possible deviations from this simplest scenario. In other work they showed that, unlike scalar modes, tensor modes cannot be modified by varying the speed at which gravitational waves propagate in the inflationary model. Creminelli, along with ITP researchers Sergei Dubovsky, Giovanni Villadoro and Diana López Nacir, also investigated the possible relation between scalar and tensor modes, and showed that under certain assumptions the amplitude of the primordial tensor modes is constrained to have a narrow set of possible values. These results will be of great value as the data from experiments improve.

**Yukawa Coupling to Tau Leptons**

ICTP researchers contribute to work at the Large Hadron Collider (LHC) as a part of the experiment’s ATLAS collaboration. Although the collider was dormant in 2014 as preparations advanced toward the start of Run II in 2015, analysis of data from Run I continued apace. CERN experiments (including ATLAS) published results further confirming that the particle discovered in 2012 was indeed the Higgs boson.

The Higgs was first hypothesized in the early 1960s to be responsible for giving mass to elementary particles such as electrons, quarks and W-bosons. It plays a crucial role in the Standard Model of particle physics developed by Abdus Salam and Steven Weinberg. If this “Higgs mechanism” works as theorized, the interactions of the Higgs with fermions (such as electrons and quarks) ought to have a specific strength, in proportion to the mass of each particle. These interactions are known as Yukawa couplings, after Hideki Yukawa. Concrete evidence that the Higgs-fermion interactions agree with the theory emerged in 2014, as analyses of Run I data showed that the strength of the interaction between the Higgs and the tau lepton (a heavy relative of the electron) is in the right ballpark.

**The Last Vestiges of Naturalness?**

One of the goals of the LHC is to uncover new physics that goes beyond the Standard Model. Physicists have many reasons for thinking that the Standard Model is fundamentally incomplete, but so far it has withstood every test. A very heavily studied idea is supersymmetry, which posits that every known particle species has a closely related “superpartner”. One of the perceived benefits of early supersymmetry theories was a property called naturalness, which is the idea that particle properties, especially the masses of as-yet-undiscovered particles, should not involve fine-tuning of the theory in order to be consistent with existing data. Naturalness tends to fail, for instance, if certain superpartners have masses too far above the...
LHC’s energy range. Quantum field theory calculations predict that these heavy particles should tend to drag other particles’ masses up in value, in contradiction with the known observed values. The mass of the Higgs particle as revealed by the LHC also happens to be in a range that makes this problem more acute.

ICTP physicist Giovanni Villadoro and his coworkers have been studying this issue. They note that many proposed resolutions of the problem fail because LHC results already place strong bounds on the mass of gluinos, the hypothetical superpartners of the gluons that mediate the strong force. They suggest that even if superpartners are discovered during LHC’s Run II, instead of rescuing the principle of naturalness, the result may amount to a confirmation of its failure.

**Related publication:**
A. Arvanitaki, M. Baryakhtar, X. Huang, K. Van Tilburg, G. Villadoro, The last vestiges of naturalness, JHEP 1403, 022 (2014)

### Black Hole Entropy and Holography

For many theorists, the most exciting embodiment of supersymmetry has long been string theory. This theory began with the idea that particles could be tiny threadlike entities, but it has since developed into a much more diverse menagerie, including membranelike “branes.” The theory provides a way to unite quantum mechanics and gravity, and it is hoped that it can provide a framework for understanding the Standard Model and beyond.

Befitting its role as a quantum theory of gravity, one of string theory’s great successes has been to provide a microscopic understanding of the entropy of black holes. In the 1970s, Jacob Bekenstein and Stephen Hawking concluded that black holes have an entropy proportional to the surface area of their event horizons. In most physical systems, entropy can be understood by counting microscopic quantum states of the system. Not so for black holes, until it was discovered that counting states of strings and branes related to special supersymmetric versions of black holes could account for the Bekenstein-Hawking (BH) formula as well as extending it with small correction terms, as often occurs with quantum results.

ICTP theorist Rajesh Gupta and coworkers have taken these calculations further in the context of certain supergravity theories that appear in string theory. Using a quantum entropy function introduced by Ashoke Sen, Gupta and colleagues calculated logarithmic corrections to the BH formula, and showed that these reproduced the results from microscopic counting in the cases where it is known.

Another area closely related to string theory is holography. In this context, holography is not the production of a three-dimensional image from a two-dimensional piece of film, but rather the equivalence (“duality”) of two superficially very different physical theories that live in realms of different dimensionality. ICTP theorists Daniele Musso, Matteo Bertolini and coworkers have studied an example of this in which a 4-dimensional supersymmetric quantum field theory is holographically equivalent to a 5-dimensional supergravity theory.

They are interested in the situation when the supersymmetry is said to be broken. Broken symmetry plays a fundamental role in the Standard Model, and the breaking is accompanied by particles called Goldstone bosons, which are related to the Higgs mechanism. The case of spontaneously broken supersymmetry involves a Goldstino particle. Among other results, Musso and colleagues deduce the presence of a Goldstino in their 4-D theory based on calculations in the corresponding 5-D theory.

**Related publications:**

Strange and unexpected behaviours may emerge when large numbers of particles collect together. Researchers in the Condensed Matter and Statistical Physics group at ICTP are tackling this challenging realm with a variety of analytical and numerical techniques, with a particular focus on the development of new methods of numerical simulation. Their work in 2014 has included study of topics ranging from the very familiar (water and renewable energy) to the exceedingly exotic (superfluid atomic gases and quantum mechanical engines).

**Molecular Dynamics: Unveiling the Janus-like Properties of Hydroxide**

Water is perhaps the most familiar example of condensed matter that we encounter in everyday life. Yet even common water contains mysteries still to be plumbed by theory and experiment. A small fraction of the $\text{H}_2\text{O}$ molecules in a sample of water self-dissociate, releasing hydroxide ($\text{OH}^-$) anions that are dispersed throughout the liquid. These hydroxide ions play a fundamental role related to the pH (acidity) of water and they are active participants in many biochemical processes.

Each hydroxide becomes surrounded by a solvation structure, a collection of water molecules arranged around it in some fashion, with their hydrogen atoms tending to be drawn closer to the anion, and the oxygen atoms repelled from it. Identifying and disentangling the nature of these solvation structures experimentally is a daunting task.

Yanier Crespo and Ali Hassanali of ICTP have tackled this problem by carrying out simulations of the molecular dynamics of a hydroxide in a cluster of 20 water molecules. They incorporated a computational technique known as metadynamics and found that the hydroxide has a "Janus-like" character. In some structures it shows its hydrophilic or water-loving face, being fully surrounded by the cluster and having as many as six water molecules closely coordinated with it. In others, the hydroxide appears hydrophobic, exposed at the surface of the cluster with a coordination number as low as three. These varied structures contribute in a nontrivial manner to the infrared spectrum, unequivocally illustrating the challenge and complexity of associating the experimental data with specific solvation patterns.

Reference:


**Strongly Correlated Systems: Cold Quantum Gases in Optical Lattices**

In recent years, ultracold gases of atoms have served as an immensely fruitful test-bed for experimentalists to study a variety of quantum processes. These clouds of atoms, held by laser beams and magnetic fields, exhibit phenomena related to systems as diverse as superconductors and neutron stars. Physicists can investigate different regimes of behaviour that would otherwise be difficult or impossible to explore. Yet on the theoretical side, even some seemingly simple properties of these gases have been very challenging to compute. In particular, ultracold atomic gas experiments that can probe the interesting regime where strong correlations exist between particles and so-called multiband processes are also important—a combination that confounds many of the standard computational methods.

ICTP researcher Sebastiano Pilati has therefore turned to a technique known as continuous-space quantum Monte Carlo simulation to calculate properties of ultracold gases in the presence of a three-dimensional periodic potential. (Such a potential can be generated by standing waves of laser beams, called an optical lattice.) Working with Thuong Thi Nguyen (a former ICTP Diploma student and now a PhD student at SISSA) and other colleagues, Pilati studied how bosons in such a potential behaved. Bosons are a class of particle (which includes some species of atoms) that can turn into a superfluid when they are sufficiently chilled. Pilati, Nguyen and company found that when a repulsive interaction between the bosons was gradually ramped up, the superfluid transition temperature at first sharply increased. Only with a much stronger interaction did the superfluidity become suppressed, with the system turning into a Mott insulator. Previous studies, which ignored multiband processes, had revealed only the suppression effect.

Reference:

Renewable Energy: Water Splitting on Defective Hematite

The global quest for cheap, clean, renewable energy resources is becoming increasingly urgent. A promising way to exploit solar energy would be the use of photoelectrochemical cells to split water into hydrogen and oxygen. This approach has the advantage of simultaneously harvesting the energy and converting it to a readily storable form, but it requires the development of suitable anode materials that can split water efficiently.

Hematite (Fe₂O₃) has emerged as an interesting possibility for photoanodes. In addition to being abundant, stable and nontoxic, hematite possesses an energy gap that is near the sweet spot for maximizing how much of the solar spectrum it can harvest. Numerous experiments have investigated hematite’s photocatalytic properties, but so far it has seen only limited use because of drawbacks such as its slow reaction kinetics.

Researchers in the renewable energy group at ICTP have carried out a number of calculations to investigate the physics of water splitting on hematite. The surface of a compound such as hematite can have a variety of structures, known as surface terminations. The theorists determined the relative stability of various surface terminations and then investigated the energetics of water adsorption on the most stable surfaces, as well as details of the water-splitting process.

Surfaces of real hematite photoanodes will typically have many kinds of defects, including vacancies (atoms missing from the regular crystal structure) and adsorbed foreign atoms (adatoms). But rather than being problems, such defects may function as helpful reaction centres. Manh-Thuong Nguyen, Nicola Seriani and Ralph Gebauer of ICTP, working with Simone Piccinin of SISSA, found that oxygen vacancies and nitrogen adatoms have an effect that should considerably improve hematite’s water splitting efficiency.

Reference:

Quantum Thermodynamics: Ultra-efficient Quantum Engines

What would happen if your car were the size of a small molecule? Although the car would only be useful for really short journeys, its engine might be much more efficient. That’s a possibility suggested by ICTP postdoctoral researcher John Goold and his collaborators, who analyzed how quantum mechanical “shortcuts” could circumvent the usual effects of friction in an engine.

Even in the idealized world of thought experiments, engines exhibit a trade-off between efficiency (how well they convert heat into work) and power (how quickly they perform this conversion). The faster the engine operates, the greater the losses to friction. But these conclusions from thermodynamics depend in part on the engine’s working elements behaving in the usual classical (non-quantum) manner of the everyday world around us.

Goold and his coworkers analyzed how quantum mechanics could alter an engine cycle known as the Otto cycle, the same process that drives a typical car engine. The Otto cycle has four basic elements: two steps which heat or cool, and two which compress or expand. But where a car engine has burning fuel to provide the heat, and the resultant hot gases push a piston, in the theoretical quantum version the myriad gas molecules were replaced by a single entity called a quantum harmonic oscillator—in essence, a single quantum particle. The compression and expansion stages of the cycle incorporated a special kind of evolution of the quantum particle called a shortcut to adiabaticity: the engine arrives at the usual endpoint at each stage but without the energy losses to friction that ordinary expansion or compression would entail.

Ultimately, Goold hopes that this result could help engineers build hyper-efficient nanoscopic machines. In the shorter term, experimental teams may test the theory by using lasers to trap a single atom and carry out the temperature and pressure changes of the Otto cycle, with and without the tricky shortcuts.

Reference:
ICTP's Mathematics section emphasizes two core functions: the creation of new mathematical knowledge and its global dissemination, in particular to developing countries. Members of the section build connections to groups and institutes in developing countries through a variety of activities. Research by the Mathematics section reflects the important synergy between mathematics and physics, as well as the role of mathematics in driving the rapid development of technological advances. Its members focus on algebraic geometry, commutative algebra, differential geometry, dynamical systems, and analysis and number theory.

**Modular Forms: A Social Network for Mathematics**

Can we organize mathematics like a social network? A network where mathematical objects have a "home page" and “friends”? What would the home page of the Riemann zeta function look like? What does the Riemann zeta function like to do? Who are its friends? This is the guiding principle behind the L-functions and Modular Forms Database (LMFDB) project, which was the subject of a workshop organized by the Mathematics section and co-sponsored by EPSRC (UK) and the NSF (US).

L-functions and modular forms are special types of functions on the complex plane, and the Riemann zeta function is the archetypal L-function. As well as having great importance in analytic number theory, L-functions and modular forms have applications in cryptography and in mathematical physics ranging from string theory to Bose-Einstein condensates.

At the LMFDB workshop, researchers shared their knowledge and contributed to the database. The database itself (www.lmfdb.org) is hosted at the University of Warwick in the UK. It allows different views of the data, including the links (some conjectural) between different mathematical objects. The project is implemented entirely as open source software, so that both the data and the computer code are fully available to the science community at large. As an example of the data, it includes over 100 billion zeros of the Riemann zeta function, each to 100-bit precision. By collecting and maintaining all this data, the project aims to push (and perhaps break) the boundaries of classical L-functions and modular forms, and to explore their applications to 21st century mathematics, physics and computer science.

The workshop also embodied another type of "social network for mathematics" that the ICTP takes very seriously. Traditional mathematics conferences often consist of talk after talk after talk. Increasingly, however, mathematics meetings include sessions for brainstorming and problem-solving in small groups, together with coding sessions and informal plenary discussions. These sessions are essentially unplanned beyond a general organization of themes and tasks at the start of each week. This approach recognizes that mathematics progresses as the result of interactions in a network of people, and not just by the contributions of individuals working in isolation. Participants of the ICTP workshop greatly appreciated having time to work together on problems and material discussed in the lectures. For those from very distant parts of the world, it was a rare opportunity to share their common interest face to face.

**Tropical Geometry: Refined Curve Counting**

Algebraic geometry involves the study of curves and surfaces related to algebraic equations. In tropical geometry, these complicated shapes are replaced by piecewise linear objects such as polyhedra—objects with flat sides. (The word “tropical” honours the late Imre Simon, a Brazilian mathematician who was a pioneer of the field.) The tropical theory often serves to translate difficult problems in algebraic geometry into much simpler problems in combinatorics.

The most important applications of tropical geometry in mathematics so far have been in the enumerative geometry of curves. This subject has been studied since the 19th century and in recent years it was revolutionized by input from theoretical physics, in particular from string theory. One would like to know, for example, how many algebraic curves of degree d in the plane have a given number of singularities (self intersections) and pass through a certain number of general points. It has been proven that the number of such algebraic curves is equal to the corresponding number of tropical curves. The tropical “curves”, being just piecewise linear graphs in the plane, are much easier to understand and count.

Recently, ICTP staff member Lothar Götsche introduced refined enumerative invariants of curves, first in algebraic geometry and then in tropical geometry. (An enumerative invariant is essentially a quantity or formula that counts the number of curves of a certain type.) The refined invariants developed by Götsche and his coworkers interpolate between two other types of counting: Severi degrees, which count singular complex curves, and Welschinger invariants, which count singular real curves. Götsche is studying the generating functions of these refined invariants and is trying to relate them to other curve-counting invariants, in particular refined Donaldson-Thomas invariants.

**Reference:**

Dynamical Systems: The Geometrical Structure of Chaos

A dynamical system, in one of its simplest and most studied incarnations, is a self-map of a manifold to itself. The points of the manifold represent the possible states of the system, and the map takes each point to its corresponding state at a later time. Iterates of such a map applied to some initial condition give rise to a trajectory and thus to an evolution of the system in time. In another incarnation, a system of ordinary differential equations defines a continuous flow.

The ultimate goals of dynamical systems theory are to classify, understand and describe possible structures defined by these dynamics, including measurable, topological, geometrical or probabilistic structures. Each of these approaches to dynamical systems has its own language and tools and defines its own sets of problems and conjectures. The extreme simplicity of the basic setting of the field and the multiplicity of viewpoints give rise to strong connections with other disciplines in both mathematics and many applied fields such as physics, engineering and economics.

ICTP staff member Stefano Luzzatto works in an area known as differentiable ergodic theory, often referred to as chaos theory. Ergodic systems are particularly complicated from a topological point of view and very unpredictable from a numerical point of view, but turn out to be quite well behaved from a probabilistic or statistical point of view. Luzzatto’s main interest revolves around the relationship between certain geometrical structures and the associated probabilistic descriptions that can be derived from them.

In 2014, Luzzatto helped to build and strengthen the Mathematics section’s connections with several groups and institutes in developing countries. He visited and lectured at the Abdus Salam School of Mathematical Sciences in Lahore, Pakistan, and at the Institute for Mathematics in Tashkent, Uzbekistan. He was an invited speaker at the Annual Meeting of the Nigerian Mathematical Society and a lecturer at the CIMPA School on Aspects of Dynamical Systems at Tribhuvan University in Kathmandu, Nepal. He also co-organized the ICTP-NLAGA School in Dynamical Systems and Ergodic Theory in Senegal. At this school, students from Europe and the US participated alongside students from sub-Saharan Africa and Asia. This innovative mixture proved to be extremely effective, giving African students both an opportunity to meet international students and pride in seeing these students coming to Africa to learn. In return, the visitors to Africa received a great cultural experience.

Differential Geometry: Constant Curvature Kähler Metrics

The mathematical language of Einstein’s description of gravity as curved spacetime is differential geometry. The curvature is expressed in a quantity called the Riemannian metric for the manifold that is spacetime. For mathematicians, one of the most classic problems in differential geometry is the existence of Riemannian metrics of constant curvature. When the manifold is complex, it is natural to require the Kähler condition, which requires that the metric and the complex structure be compatible. Determining which manifolds admit Kähler metrics of constant curvature is arguably the central problem in complex geometry.

There are two main variants of “constant curvature” of interest—constant scalar curvature and constant Ricci curvature (a case which is also known as an Einstein manifold). ICTP mathematician Claudio Arezzo has studied the curvature behaviour of Kähler-Einstein manifolds with conical singularities, and has produced many new families of examples of constant scalar curvature Kähler metrics.

In 2014 Arezzo co-organized an advanced school on Geometric Analysis in Hefei, China, attended by about 40 young researchers from developing countries. The school was co-sponsored by the School of Mathematical Sciences, University of Science and Technology of China, Hefei. There were six mini-courses and a number of research seminars on various geometric partial differential equations arising from geometry and physics.
Our Earth may appear as no more than a pale blue dot when seen from space. But this blue dot and the life on it are part of a complex system of intricate processes in physics, chemistry and biology that are continually interacting with each other. Understanding the various components of this system, their interactions and processes forms the basis of research by ICTP’s Earth System Physics section (ESP). From building and using models of climate change and its impacts to deciphering the mechanics of earthquakes and volcanoes, ESP research covers a wide spectrum.

**Summing up Climate Analyses**

Using climate models to study the dynamics of weather and climate systems and making projections of future climate have been the core facets of research by ESP. The section maintains the RegCM4, a flexible, portable, easy-to-use regional climate model that can be applied to any region of the world for a wide range of studies, from climate processes to paleoclimate and future climate simulations. The model has made important contributions to the science reports published by the Nobel Prize-winning Intergovernmental Panel on Climate Change (IPCC).

The RegCM4 is now playing a crucial role in another international effort, the Coordinated Regional Downscaling Experiment (CORDEX), a modeling framework coordinated by the World Climate Research Programme that aims to improve regional model downscaling. No climate model is perfect, and it is important to test how a model deals with the uncertainties inherent to climate prediction and simulations. ESP has been rigorously testing its RegCM4 model against CORDEX standards, and in 2014 published the results (phase 1) of these simulations in a special issue of the journal *Climate Change*. The experiment involved teams of students and postdoctoral fellows from around the world and required the use of high performance computing resources to handle the nearly 160 Terabytes of data produced.

The research team performed simulations of 34 scenarios over five world regions defined by CORDEX for the time period of 1970 to 2100, evaluating the model’s performance in identifying climate change signals, climate extremes, tropical storms, effects of land-atmosphere interactions, and monsoons and El Niño Southern Oscillation (ENSO) related processes.

The results strongly suggest that using ‘off-the-shelf’ configurations of climate models will not give optimal results, and careful model validation and customization are crucial. More importantly, the results show that regional climate models such as the RegCM4 provide added value to projections when higher-order statistics and regional circulation features and feedbacks are considered.

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**Beneath and Around the Himalaya**

For geologists and seismologists, few features on Earth are more fascinating than the Himalaya. Home to the tallest peaks on our planet, the Himalayan range is one of the ‘youngest’ mountain ranges on Earth and started forming some 40 to 50 million years ago when two large landmasses (India and Eurasia), driven by plate-tectonic forces, collided. This collision continues even today, making the region along the Himalaya one of the most seismologically active, and thus more prone to earthquakes and landslides.

Considering the region’s propensity to earthquakes, it is crucial to gain a deeper understanding of the different layers of the Earth there—the crust, the intracrustal regions and the mantle. ICTP Junior Associate and Marie Curie Fellow Naresh Kumar (who worked at ICTP under the supervision of ICTP scientist Abdelkrim Aoudia) and his colleagues carried out a study to characterize the intracrustal zone that lies beneath the India-Asia collision zone.

Kumar, a scientist at the Wadia Institute of Himalayan Geology, India, looked at teleseismic data obtained from seismological stations across the northwestern parts of the Tethyan (Tibet) Himalaya and eastern Ladakh (a region in India). His analysis uncovered compelling evidence that the intracrustal low velocity zone existing at a depth range of between 15 to 40 km beneath the Himalaya extends beyond the suture zone—the zone which marks the collision and subsequent subduction of both the Tethyan oceanic plate and Indian continental plate beneath Eurasia—and into the Tethyan Himalaya. This has implications on mountain building processes and on the geodynamics of Himalaya and Tibet.

The study, titled “Characterizing the intracrustal low velocity zone beneath northwest India–Asia collision zone” was published in the December 2014 issue of the *Geophysical Journal International*. 
An Inconvenient Buzz about Malaria

The World Health Organization lists malaria among the top ten leading causes of death in low-income countries. With 198 million malaria cases occurring in 2013 (resulting in an estimated 584,000 deaths), malaria threatens almost half the world’s population and lays a heavy burden on health systems.

Is there a link between the spread of this mosquito-borne infectious disease and the changing climate? This has been one of the focus areas for ICTP scientist Adrian Tompkins. Tompkins (who is the author of VECTRI, a mathematic dynamical model for malaria transmission) and his team, which includes ICTP postdoctoral fellow Felipe Colon Gonzalez, have looked at how the changing balance of factors such as temperature, rainfall and humidity, and population density affect the spread of malaria.

In 2014, Tompkins, Gonzalez and colleagues published the results of the first ever multimalaria model intercomparison exercise. The study estimates the impact of future climate change and population scenarios on malaria transmission at a global scale. The team compared the projections of five climate models for three future time periods in the 2030s, 2050s and 2080s.

Research has already established that malaria is climate sensitive. The Anopheles mosquito that harbors the malarial parasite thrives in tropical climates and not in dry and cold areas. Results from Tompkins’s study, however, show that the changing climate has made conditions in tropical highland regions suitable for malaria transmission. The authors also point out that other important socioeconomic factors such as land use change, population growth and urbanization, migration changes, and economic development will have to be accounted for in further details for future risk assessments.

The study, titled “Impact of climate change on global malaria distribution”, was published in the March 2014 issue of the Proceedings of the National Academy of Sciences. The paper has been widely reported in the press and has achieved 12 citations of the Web of Science in 2014.

The Interplay of Oscillations

A delicate balance between various processes controls the Earth’s climate, and pinpointing the causes of climate shift has been particularly challenging for researchers, in no small part due to effects of human activities. Along with anthropogenic factors, there are natural mechanisms that nudge the climate towards change. One such mechanism is the phenomena of climate oscillations, cyclic processes that recur and cause fluctuations in atmospheric and ocean temperatures and precipitation levels.

A significant contributor to oscillation-related changes is the El Niño Southern Oscillation (ENSO). The ENSO impacts sea surface temperatures (SST) along a stretch of the equatorial Central and East Pacific Ocean and the western coast of tropical South America, and this in turn affects the climate worldwide.

The effects of ENSO do not occur in isolation; ICTP scientist Fred Kucharski and research associate In-Sik Kang have shown that the ENSO is modulated by the Atlantic Multidecadal Oscillation (AMO), which is an on-going series of temperature changes involving most of the Atlantic between the equator and Greenland and parts of the Northern Pacific.

In a study published in 2014 Kucharski, Kang, and co-author Hyun-Ho No investigated the AMO impact on ENSO by looking into long-term historical observational data. Their study results, based on data for the period from 1900 to 2013, indicate that the SST cooling in the central Pacific that occurred in the recent decades is associated with warming of the northern Atlantic SST, which is in fact an AMO-induced effect. The frequent occurrences of the central Pacific El Niño, therefore, can be attributed to a complex interplay between ENSO and AMO. This is the first step toward understanding the relationship between the central Pacific El Niño and the AMO.

The paper, titled “ENSO Amplitude Modulation Associated with the Mean SST Changes in the Tropical Central Pacific Induced by Atlantic Multidecadal Oscillation”, appeared in the July 2014 issue of the Journal of Climate.
Research
Applied Physics

From archaeology to X-ray imaging, and from optics and lasers to satellite navigation and turbulent fluid mechanics, ICTP’s Applied Physics section encompasses diverse areas of research that respond to the most critical needs of the ICTP scientific community. The areas are, in fact, among the activities for which the demand in developing countries is enormous and growing.

The bulk of the work carried out in the Applied Physics section takes place in its three laboratories:

- Multidisciplinary Laboratory (MLab)
- Applied Physics Laboratory (at Trieste’s Elettra Sincrotrone)
- Telecommunications/ICT for Development Laboratory

plus three other shared laboratories:

- Laser Laboratory (at Elettra)
- ICTP-SPIE-INFN Quantum Cascade Laser Laboratory (Area Science Park, Trieste)
- Optical Tweezer Laboratory (at the Istituto Officina dei Materiali (IOM), Trieste)

ICTP’s MLab promotes interdisciplinary experimental activities based on advanced instruments and methods developed in basic physics research. MLab activities include scientific instrumentation development, novel detector and electronic circuit design and prototyping, X-ray imaging, and accelerator-based analytical techniques.

In 2014, MLab scientists uncovered an important clue in a relatively empty corner of the jigsaw puzzle of human evolution that reveals the diversity of humans living in Africa about one million years ago. Using non-invasive X-ray microtomography technology, MLab scientist Clement Zanolli analyzed a human molar from that era found during an archaeological expedition in the Eritrean desert. His analysis—along with other scanning procedures done to the tooth—led to the creation of a 3D image of the tooth that hinted at evolutionary linkages between the species Homo erectus/ergaster and a more direct ancestor, Homo heidelbergensis. The wealth of information hidden in the tooth revealed by high-tech medical imaging equipment was presented in a paper in the *Journal of Human Evolution* by lead author Zanolli and his collaborators.

The MLab’s X-ray microtomography equipment helped unravel other archeological mysteries in 2014. In one case, researchers were able to determine that a piece of humanoid skull found in Italy’s Po River basin belonged to a Neanderthal, making it the first evidence of Neanderthal existence in the Po valley. In another case, the MLab analyzed 8- to 12-million-year-old fossil remains of apes to establish if they relate to the present day orangutan as suggested by some aspects of skull anatomy. Understanding this relation will help researchers identify patterns of evolution among apes and also understand instances of parallel or convergent evolution in unrelated animals.

MLab scientists are also involved in the COMPASS high energy physics experiment at the Super Proton Synchrotron at CERN, as well as the ReDSoX (Research Drift for Soft X-ray) project with INFN, and ran an important school and conference in Costa Rica in December, namely the ICTP Latin American FPGA School and the Regional Conference on Advanced Instrumentation.
The Telecommunications/ICT for Development Laboratory researches ionospheric radiopropagation, with a particular focus on ionospheric effects on satellite navigation and positioning systems (the Lab’s proprietary NeQuick model is used by scientists around the world for this purpose). The Lab also does research and training on wireless communications. Its Guglielmo Marconi ICT Wireless Laboratory houses training programmes on wireless communications technologies, providing much-needed support in wireless technology education to students and researchers from developing countries.

A longtime goal of the wireless research at ICTP has been to provide reliable and sustainable wireless solutions to help foster science and research in developing countries. For the past few years, researchers have been investigating the use of TV White Spaces (TVWS) for affordable, wireless connectivity. TVWS refers to unused broadcasting frequencies, most often spaces that exist between channels to avoid interference. Those frequencies could be harnessed for Internet connectivity, offering a promising solution for developing countries that lack advanced telecommunications infrastructures. In 2014, ICTP wireless experts Marco Zennaro and Ermanno Pietrosemoli published a book on the topic, titled “TV White Spaces: A pragmatic approach”, along with five papers.

ICTP’s Applied Physics Laboratory, located at Elettra, conducts basic research activities and supports advanced courses for PhD students in turbulent fluid mechanics, as well as providing support for joint synchrotron-related lab experiments. One of the most important results appeared in *Physical Review Letters* on ground-breaking research into geostrophic turbulence under rotation, in collaboration with R. Ecke, Director of the Center for Nonlinear Studies at Los Alamos National Laboratory and using the large ICTP cryogenic convection apparatus.

The ICTP Laser Laboratory is a collaborative experimental facility serving the needs of both ICTP and Trieste’s Elettra Sincrotrone. Students and researchers in the lab investigate the physics and applications of short pulse lasers, specifically femtosecond lasers used in the seeding of the FERMI Free Electron Laser at Elettra. Many ICTP Associates take advantage of this laboratory during their visits to ICTP.

Under the ICTP-SPIE Anchor Research Programme, researchers at the ICTP-INFN-SPIE Quantum Cascade Laser Laboratory are developing quantum cascade lasers (QCL) for numerous applications, from fundamental measurements of the proton charge radius to applications in environmental sensing. Under this Programme, the IOM optical tweezer laboratory of Dan Cojoc has ICTP’s optical tweezer apparatus installed and an ICTP STEP student from Senegal is working there on biological applications related to the characterization of elasticity of cancer cells.

Other research in the Applied Physics section focuses on Synchrotron Radiation Related Theory, where researchers are investigating electronic, magnetic and structural properties of systems with strong electron correlations, including transition-metal oxides and related materials and the physics of low-dimensional systems and nanostructures.
Microscopic cells flit towards their food source, a male moth sniffs out its female partner, fish schools lose their collective memories, economies rise and fall as the world of finance faces seemingly unpredictable fluctuations—although these disparate phenomena don’t seem to belong to the same list, they are in fact connected by the common thread of physics. Scientists of the ICTP’s newest research section, Quantitative Life Sciences (a spin-off from ICTP’s Condensed Matter and Statistical Physics section), are uncovering the underlying physics in the broad domain of life sciences that encompasses disciplines ranging from molecular and cell biology to terrestrial and oceanic ecology, and economics and quantitative finance.

**It’s All in the Whiff**

During their one week of adult life, female moths release molecules known as pheromones to attract male suitors. These pheromone molecules waft through the air, reach the feathery, neuron-filled, antennae of the male moths, who then follow the scent and make their way to the females. Following the scent, however, is no trivial task. Our atmosphere is an extremely noisy medium, and the pheromone molecules, which essentially travel through atmospheric turbulence, get diluted and mixed with other molecules by the time they reach their target. But studies have shown that male moths are very efficient at decoding the scrambled signals they receive from females. They respond to as few as 10 pheromone molecules, and 80% of male moths find the female source in as little as 15 minutes from a distance of several hundred metres.

How the pheromone molecules drive the mating process in moths despite the turbulence and dilution has been a puzzle in fluid dynamics, neurobiology, and entomology. ICTP researcher Antonio Celani and his colleagues have worked out a theory that for the first time provides pieces to this puzzle.

Celani and his team used what is known as the Lagrangian approach to develop a theory on how the pheromone molecules propagate through atmospheric turbulence. They applied the theory to predict the intensity, duration, and frequency of pheromone signals. Their findings, which have been validated by numerical simulations and laboratory and field data, suggest that moths are sensitive to the temporal structure of the pheromone ‘plume’ and that signals are most commonly detected as intermittent ‘whiffs’ that last only a few milliseconds rather than as a constant stream.

The patterns of pheromone propagation allow males to distinguish between different species of females with similar pheromones. Moreover, male moths can set thresholds that allow them to determine that the mixture they are smelling is coming from one female of their species rather than from two separate sources, enabling them to navigate to the right place.

Celani’s study has broader applications, as it makes it possible to describe how all sorts of chemicals, from pheromones to pollutants, travel through the air. This could be useful for designing artificial noses, attuned to gather information from the patterns of molecules floating through the air. Another practical application could be for pest management devices, which currently use a constant stream of pheromones to attract insects, made more efficient by matching the pattern of pheromone whiffs to that actually present in the wild.

The findings of Celani’s study have been published in the October 2014 issue of *Physical Review X.*

**A Case of Missing Memories**

ICTP researcher Matteo Marsili and Giancarlo De Luca, a former PhD student from the International School for Advanced Studies (SISSA), might have found answers to what ails the Mediterranean Bluefin tuna. This troubled fish that often finds itself on the red list of endangered species seems to have forgotten where to find its favourite food—herrings from the Norwegian Sea.

Marsili and his collaborators have built a simple model of animal behaviour which shows that the collapse of animal populations or sudden shifts in their collective behaviour may be traced back to their loss of ability to coordinate and take collective decisions.

The sudden disappearance of the Bluefin tuna from its old feeding grounds in Norway and its failure to return there as it used to after spawning in the Mediterranean Sea is one such example of shift in collective animal behaviour.

The model indicates that the Bluefin tuna have lost their collective memory of where to find the tastiest herring because the older fish with previous knowledge of migratory routes and feeding grounds have been fished out of the schools. And so, despite the reappearance of the once overfished food source (the herrings), the tuna are yet to return to their old feeding grounds.
De Luca and Marsili’s model describes a frequently changing network between fishes and their neighbours. The rules are simple: if two fish swim in the same direction, they can form a link, but if they swim in different directions, they won’t be part of the same group. These general rules are enough to spread the knowledge (or memory) of the route to feeding sites from a few knowledgeable individuals to the whole population. Removing knowledgeable fish, as might happen through fishing, can result in a sudden change in the direction of travel—and this is exactly what happened to the tuna.

Unlike previous models of collective animal behaviour that incorporate more detailed information, the simplicity of the model designed by De Luca and Marsili provides an exact solution and a complete picture of what is going on. In principle, the model could be applied to studying the behaviour of other animals such as birds and flies.

The study, which was carried out in collaboration with marine ecologists in Denmark, appeared in the March 2014 issue of *The Royal Society Interface*.

**The Importance of Being Critical**

Framing the correct questions has been the key to doing good physics. When one wants to calculate the time required for an object to fall from a given height, questions about the color of the object, for example, are irrelevant. The sharp separation between what is relevant and what is not (in controlled systems) has allowed physicists to make remarkably accurate quantitative predictions. But, increasing availability of Big Data, especially in quantitative life sciences, has made it difficult to parse out the relevant variables from the irrelevant ones.

Systems typically studied in quantitative life sciences (the cell, the genome, financial data, etc.) are considered high-dimensional inference problems in statistics involving large data sets with numerous variables, many of which are unknown, and their behaviour unconstrained by well established laws. While dealing with such high-dimensional inference problems, researchers use what is known as dimensionality reduction schemes: data is projected into a low-dimensional space where statistics can provide accurate conclusions. This process, however, leads to information loss. Therefore, understanding which are the relevant variables is crucial in order to limit information losses.

But, is there a guiding principle for the choice of dimensional reduction schemes, or for measuring the relevance of a given set of variables? ICTP scientist Matteo Marsili and his colleagues have recently shown that a criterion exists: relevant variables are those for which the system exhibits critical fluctuations.

To establish the criterion, Marsili focussed on two examples: the selection of relevant amino acids in proteins, starting from multiple sequence alignments of homologous proteins and a measure to score different data clustering or community detection algorithms. In both cases, the method is able to uncover non-trivial structures and known information.

Two papers on the subject—“Identifying relevant positions in proteins by critical variable selection”, and “Criticality of relevant descriptions in the under-sampling domain”— have been accepted and will be published in 2015.
As an international crossroad of scientific excellence, ICTP offers a unique environment for scientists at all stages of their careers to advance their knowledge in physics and mathematics. Each year more than 5,000 scientists from about 160 countries pass through ICTP, taking advantage of the Centre’s worldwide reputation for truly outstanding workshops, conferences and advanced educational programmes that explore topics at the cutting edge of physics and mathematics.

From the Centre’s Postgraduate Diploma Programme, an intense, year-long course of study that gives young scientists from developing countries the boost they need for acceptance into doctoral programmes anywhere in the world, to the Centre’s Associates Scheme, which supports visits of several months at a time over a three-year period, ICTP provides a lifeline for a lifetime of learning.

Today, more than 140,000 ICTP alumni can now be found in 188 countries around the world, serving as science ambassadors in their home countries and sharing their knowledge with new generations of scientists.

The full spectrum of ICTP’s training and education programmes are described here; for a glimpse of their global impact in 2014, please see the inside back cover of this report.

New Programmes for 2014

ICTP is investing in scientific capacity building by supporting the studies of students from developing countries who qualify to enroll in the Centre’s masters and doctorate programmes. In 2014, the number of degree options available through ICTP increased to 7 with the addition of two new masters programmes offered in cooperation with Trieste institutes of higher education. The Master in Medical Physics degree programme, coordinated jointly with the University of Trieste, began in February and is designed to provide graduates of physics or related fields (mainly from developing countries) with postgraduate theoretical and clinical training so that they may be recognized as clinical medical physicists in their home countries. The inaugural class includes 13 students from 11 developing countries.

In October ICTP, working in partnership with the International School for Advanced Studies (SISSA), launched the Master in High Performance Computing (MHPC) programme, an innovative course of study that prepares students for exciting careers in the fast-growing field of high performance computing. 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. The initial class of 15 students—selected from more than 160 applicants—included three students from developing countries whose studies were fully supported by ICTP.

ICTP Degree Programmes

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<tr>
<th>Programme</th>
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<tr>
<td>Joint Master in Physics</td>
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<tr>
<td>Master of Arts in Economics</td>
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<tr>
<td>Master of Complex Systems</td>
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<tr>
<td>Master in Medical Physics</td>
<td>(with University of Trieste)</td>
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<td>Master in High Performance Computing</td>
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<tr>
<td>PhD in Earth Science and Fluid Mechanics</td>
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The Path to a Doctorate Degree Begins Here

ICTP recognizes that many students from developing countries lack the rigorous educational training needed to succeed in doctoral studies. Since 1991, the Centre’s Postgraduate Diploma Programme has addressed this need by offering an intense, 12-month course of study for talented young science students who have limited possibilities to pursue advanced studies in their home countries. More than 700 students from 75 countries have graduated from the programme; of these, 75% have gone on to attain doctoral degrees. For the academic year 2013-2014, 39 students from 28 different countries completed the programme.

Doctoral students in the developing world often face a local shortage of expertise in their field or laboratories necessary to complete their desired research. ICTP, along with its UN partner the IAEA, has developed a Sandwich Training Education Programme (STEP) for these young researchers. STEP is a visiting programme that provides support for three- to six-month stays each year for three successive years at either ICTP or a collaborating institute, providing students with the opportunity to work with world-class researchers who they may not have had access to in their home countries. Launched in 2003, STEP has assisted 145 students from 45 countries to accomplish their educational objectives.
Life-long Learning

Scientists from the developing world often need opportunities to break the intellectual isolation many of them experience in less-advantaged countries. That is why ICTP developed its Associateship Scheme: a sabbatical programme for scientists at different stages of their careers to maintain long-term, formal contact with the Centre and its well established network of world renowned scientists as well as its modern facilities. Over the years ICTP has supported 2,670 Associates from 108 countries.

Following up on the success of its Trieste Mini Maker Faire in May 2014, ICTP opened a workshop space encouraging “makers”—people who like to design and build technology-based products—to bring their creative ideas to life. The space, called the Scientific Fabrication Laboratory, or SciFabLab, opened in August, and is the first “fabrication laboratory” in Italy’s Friuli-Venezia-Giulia region. It offers modern and versatile computer-controlled rapid prototyping tools such as 3D printers, 3D scanners, laser engraving and cutting machines.

Specialized Training

ICTP complements its broad selection of conferences, programmes and laboratory opportunities with specialized training activities in fluid mechanics, information and communication technology (ICT), optics and lasers, and telecommunications and wireless technologies. A sample of those activities that took place in 2014 includes:

- African School on Space Science, Rwanda
- Wireless Sensor Networks Workshop, Thailand
- Workshop on Internet of Things, Benin
- Technical support to Federal University of Technology (for deployment of new HPC facility), Nigeria
- Technical support for the MSc in Computational Science (HPC stream), Addis Ababa University, Ethiopia

ICTP specialized training extends to the Middle East. Since 2009, the Centre and the Jordan-based Synchrotron Light for Experimental Science and Applications in the Middle East (SESAME), a third-generation light source operating under the auspices of UNESCO, have coordinated a programme of joint training activities taking place at both the Middle East facility and in Trieste. SESAME is the Middle East’s first major international research centre; when the facility starts operations (probably in early 2016), scientists from the Middle East and neighbouring countries, in collaboration with the international synchrotron light community, will have the possibility of performing world-class scientific studies. In 2014, ICTP held a workshop on Structural Biology: Using Synchrotron Radiation to Visualise Biological Molecules, attended by 34 participants from 13 countries.

A similar scheme between ICTP and developing-country institutes, called the Federation Scheme, allows the institutes to send young scientists (up to age 40) to ICTP for shorter stays.

A Gateway to Italian Laboratories, and New Skills

ICTP’s Training and Research in Italian Laboratories (TRIL) programme offers scientists from developing countries the opportunity to undertake training and research in an Italian laboratory in different branches of the physical sciences. The aim of the programme is to promote, through direct contacts with high-level research, collaborations between the Italian scientific community and individuals, groups and institutions in developing countries. Since its inception in 1983, the TRIL programme has supported the visits of 1,300 scientists from 88 countries.

Another laboratory-based programme, the ICTP-Elettra Users Programme, offers access to Trieste’s Elettra synchrotron radiation facility for scientists from developing countries who work in those countries.

The Associateship scheme affords scientists the opportunity to do meaningful research, interact with other scientists across the globe, and have possible collaborations through the exchange of ideas and data for publications. I sincerely thank the ICTP for this great opportunity to carry out my research as an Associate.

Elijah Oyedola Oyeyemi, 
Nigeria, ICTP Associate

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Elijah Oyedola Oyeyemi, 
Nigeria, ICTP Associate
The Texas Connection
Diploma Alumni Excelling in Lone Star State

They left ICTP with hard-earned knowledge gained through their experience in the centre’s intense, one-year Postgraduate Diploma Programme, and with an appetite to learn more.

Now, seven ICTP Postgraduate Diploma alumni are pursuing PhDs at the University of Houston (UH) in Texas, thanks to an agreement signed 5 years ago between UH and ICTP.

The students, whose disciplines include high energy, condensed matter and Earth system physics, presented their research to the UH community in an event organized by Carlos Ordonez, UH associate professor of physics and director of the ICTP/UH student programme.

“It’s such a neat programme, and it’s working so well that I believe more people need to learn about it, and in fact, learn more about ICTP this way, and how we’re greatly benefiting by having such a group of talented and diverse students on our campus, and in our city,” says Ordonez, adding, “Beyond the publicity, though, I think it’s also important to acknowledge the effort these students make, at all levels, to take advantage of the opportunities to do state-of-the-art science that they are given here.”

The students represent a wide geographic distribution, coming from Nepal, Cameroon, Ethiopia, Mozambique, Ghana, and Pakistan. Yet they share a common characteristic, according to Ordonez: a strong belief in their abilities. “To me at least, it’s clear that the ICTP was the institution that instilled these values in them, and therefore it deserves a lot of credit for having created a system that not only gives young students solid knowledge and training in science, but also a tremendous boost in self confidence.”
Office of External Activities

Established in 1985, the Office of External Activities (OEA) has been helping to support science and technology in the developing world for more than 25 years. Its objective has been to help the 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 OEA actions are aimed at individuals, groups or institutes in developing countries to accelerate their promotion to an international level (North-South collaboration) and to stimulate networking of scientists in the developing regions to reach a critical mass of researchers (South-South collaboration).

The OEA programmes can also provide funds for graduate schools to support student grants, fellowships for young researchers, visits of research collaborators and other activities.

Assistance is provided through Affiliated Centres (currently eight centres in eight different countries), Projects (seven in 2014), Network Programmes (nine in 2014), support for scientific meetings (61 in 2014), and support for visiting scholars and consultants (seven in 2014). The full extent of the OEA’s global reach can be seen on the map inside the back cover of this publication.

Regional Centres of Excellence

ICTP has opened regional branches to bring its unique blend of high-quality physics and mathematics education and high-level science meetings closer to scientists in the developing world:

Sao Paulo, Brazil: The ICTP South American Institute for Fundamental Research (ICTP-SAIFR), created in collaboration with the Sao Paulo State University (UNESP) and the Sao Paulo Research Funding Agency (FAPESP), is located on the campus of the Instituto de Fisica Teorica (IFT-UNESP). Activities, which are modelled on those of ICTP, include international schools and workshops. In 2014, more than 150 seminars and colloquia were held in diverse areas of theoretical physics and quantitative biology.

Chiapas, Mexico: The Mesoamerican Centre for Theoretical Physics (MCTP) offers conferences, schools and seminars on physics, mathematics, energy and the environment. It is also works with ICTP to create a programme for students at universities in Central America and the Caribbean to earn physics or mathematics PhD degrees, which currently are not offered in the region. In 2014, MCTP attracted 500 visitors and ran nearly 20 scientific meetings.

Izmir, Turkey: Turkey’s Izmir Institute of Technology hosts the ICTP–Eurasian Centre for Advanced Research, which is designed as an international centre to serve as a “meeting point” for the scientists, researchers and students of the broad Eurasia region. A conference to inaugurate the centre was held in May 2014, attracting 350 participants; other activities in 2014 included a summer school, an advanced workshop, several seminars and a colloquium.

Physics without Frontiers

Physics without Frontiers is a science roadshow funded by ICTP and CERN that brings physics to the far reaches of the developing world to inspire and engage undergraduate physics students. Co-founded by ICTP high energy physics postdoc Kate Shaw, the programme offers one-day, intensive master classes where students analyze real data from the ATLAS experiment at CERN, which Shaw has been involved with as a member of the ICTP/University of Udine ATLAS team. In 2014, Shaw brought the wonder of particle physics to 120 students in Vietnam and Nepal.
Throughout the year, ICTP engages with the public through numerous outreach activities aimed at spreading the joy of science to the young and old.

**Alternating Currents**

In March, ICTP hosted a local school performance that highlighted the brilliant mind of Nikola Tesla. Students from local Trieste middle school Guido Corsi, along with several ICTP staff and scientists, recreated the life of the eccentric scientist, from his early days in Croatia to his later life in New York. The performance included live music, several magic tricks, and a demonstration of a real Tesla coil.

**Public Reading: “An International Centre, in Trieste”**

April 23rd is UNESCO’s “World Book and Copyright Day”. The Marie Curie Library joined the celebrations and organized a public reading to discover the motivations and efforts that led to the creation of ICTP 50 years ago, in the written words of the project’s fathers and their biographers. All excerpts were taken from books in the Library collection and read by students, scientists, and staff of ICTP.

**Trieste Mini Maker Faire**

Over 7000 visitors flocked to the ICTP campus for the first Trieste Mini Maker Faire held on 17 May 2014. The event, which was organized by ICTP’s Science Dissemination Unit in collaboration with Immaginario Scientifico and Maker Media Inc., showcased the exhibits and innovations of over 300 “makers” (tech enthusiasts, crafters, homesteaders, scientists and even garage tinkerers). Exhibit stands included a wide range of innovations from drones that used open-source hardware such as Arduino microcontrollers to personal 3D printers and kits for children to create their own switch-operated toys. The makers came in from the Triveneto region of Italy, Slovenia, Croatia, Austria, and beyond.

**Nobel Laureate, Fields Medallist Wow Trieste**

ICTP’s 50th anniversary celebrations were not limited to the ICTP campus. Two key speakers at the event, Nobel laureate Carlo Rubbia and Fields medallist Cédric Villani presented talks geared to the general public. Rubbia’s talk, titled “Quale futuro per l’energia?” (“What is the Future of Energy?”), was held at Politeama Rossetti in Trieste on 7 October. Villani spoke to high school students about the beauty of mathematics on 9 October.

**ICTP Goes Solar at Trieste Science Festival**

Solar energy expert Daniel Egbe, head of the ICTP-supported African Network for Solar Energy, demonstrated the power of the sun at ICTP’s exhibit on renewable energy at the 2014 TriesteNext, the city’s public science festival. Armed with the Centre’s solar cooker and an abundant supply of sun, Egbe and ICTP scientists enlightened the public on solar energy facts, sweetening their delivery with solar-cooked cakes!

**A View to the World of Crystallography**

ICTP joined up with the University of Trieste and Italy’s Consiglio Nazionale delle Ricerche to create a public exhibit on crystals in honour of the UN International Year of Crystallography 2014. Hundreds of people viewed the week-long event, which was held in the centre of Trieste.

**A Tribute to Italian Innovation**

In October 2014, ICTP collaborated with the local newspaper Il Piccolo to host an event celebrating the past, present and future of Italian innovation. The programme featured an exhibit of the “Olivetti Programma 101,” the world’s first desktop computer, at the Centre’s new SciFabLab. Giovanni de Sandre and Gastone Garziera, the two surviving members of the team of three Olivetti engineers who designed and built this revolutionary machine first produced in 1965, were present.
ICTP places fundamental support services at the disposal of its scientists. The Centre’s Marie Curie Library—containing some 70,000 books, as well as 137 subscriptions to print journals and electronic access to 3,162 journals—offers visitors one of the largest collections of literature in physical and mathematical sciences in Europe.

ICTP’s Information and Communication Technology Section (ICTS) maintains the Centre’s advanced computing capacity. In 2014 ICTS, together with the International School for Advanced Studies (SISSA), launched one of the largest high performance computing centres in Italy. From simulating molecular interactions to calculating climate forecasts, supercomputers are becoming an increasingly important tool for scientists seeking to solve complex scientific computational problems. The results of these supercomputing exercises are being used in important, practical ways, from the development of improved solar energy cells to input into international agreements such as the Intergovernmental Panel on Climate Change (IPCC) climate assessment reports.

For ICTP, the new facility expands opportunities not only for its staff researchers but also for the thousands of scientists from developing countries doing collaborative research with the Centre. In addition, ICTP and SISSA inaugurated their new joint master’s programme in high-performance computing (MHPC).

Another service that ICTP provides to scientists from around the world is the possibility to follow all ICTP conferences and courses online. In 2014, ICTP invested in more equipment for high definition video recording, resulting in the recording and publishing of 25 events (conferences, schools, seminars, interviews). In addition, since 2007 the Centre’s Science Dissemination Unit (SDU) has recorded all Postgraduate Diploma Programme courses, as well as many conferences and workshops, using their automated EyA system for the webcasting of physics and mathematics. As of 2014, ICTP’s nearly 12,304 hours of online Diploma Programme lectures had received more than one million unique visitors, around 50% of whom come from India, China and Africa. These numbers suggest that the lectures, taught in English by ICTP scientists, are a useful learning resource for students in developing countries. Some parts of the world, however, are restricted both by language barriers and bandwidth constraints. To tackle these issues, SDU has implemented the project “Didactica para el Desarrollo” with educational scientific lectures in different languages.

Other SDU services include the development, implementation and management of open source applications, especially in support of science and education in developing countries via mobile science and learning platforms, and the provision of grants and training for the low-cost production of scientific contents by institutions and scholars.

African Review of Physics

ICTP has published the African Review of Physics (www.aphysrev.org) since 2007. The free, open access, on-line, peer reviewed, international publication is the official journal of the African Physical Society. It publishes high-quality reviews, research articles, and brief communications in all branches of experimental and theoretical physics. As of 2014, the journal website has received 45,000 visits from 155 countries.
ICTP Steering Committee

The ICTP Steering Committee, comprising representatives from UNESCO, IAEA and the Italian government, 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. The ICTP director is the ex-officio chairperson of the Steering Committee. The chairperson of the Scientific Council attends the Steering Committee meeting in an advisory capacity.

UNESCO:
Flavia Schlegel
Assistant Director General for Natural Sciences

IAEA:
Aldo Malavasi
Deputy Director General
Department of Nuclear Sciences and Applications

Italian Government:
Fabio Zwirner
Department of Physics and Astronomy, University of Padua

ICTP Scientific Council

ICTP’s Scientific Council is composed of distinguished specialists in disciplines relevant to the Centre’s activities and representing 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.

F.K.A. Allotey
Institute of Mathematical Sciences
Legon-Accra, Ghana

Carlos Alberto Araújo de Carvalho
Institute of Physics, The Federal University of Rio de Janeiro
Rio de Janeiro, Brazil

William Bialek
Department of Physics
Princeton University
Princeton, NJ, USA

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Laboratoire de Physique Théorique de l’ENS
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José Antonio de la Peña
Instituto de Matemáticas
Universidad Nacional Autonoma de México
México City D.F., Mexico

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Stanford, CA, USA

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Università di Roma La Sapienza
Rome, Italy

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Michele Parrinello
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Martin Rees
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Valery A. Rubakov
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Princeton University
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Cumrun Vafa
Department of Physics
Harvard University
Cambridge, MA, USA

Jean-Christophe Yoccoz
Collège de France
Departement de Mathematiques
Paris, France
ICTP is funded largely through generous contributions made by the Italian government, which has served as ICTP’s chief benefactor since the Centre’s inception. ICTP operates under a joint administrative framework established by the United Nations Educational, Scientific and Cultural Organization (UNESCO) and the International Atomic Energy Agency (IAEA). UNESCO also serves as the Centre’s leading administrative agency.

### Income for 2014 (in Euros)

<table>
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<tr>
<th>Source</th>
<th>Amount</th>
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<tr>
<td>IAEA</td>
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<td>UNESCO</td>
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<td><strong>Plus voluntary contributions:</strong></td>
<td><strong>611,235.03</strong></td>
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<tr>
<td><strong>Total income 2014:</strong></td>
<td><strong>23,908,434.33</strong></td>
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Donors

American Astronomical Society, USA
American Chemical Society, USA
American Institute of Physics, USA
American Physical Society, USA
American Society for Laser Medicines & Surgery, USA
Amptek Inc., USA
Asian Pacific Centre for Theoretical Physics (APCTP), Korea
Associazione per l’Insegnamento della Fisica, Italy
Aston University, UK
Austrian Physical Society, Austria
Banque CPH SCRL, Belgium
Berliner Glas KGaA, Herbert Kubatz GmbH & Co., Germany
BOSCA SpA, Italy
Boston College, USA
Bruker-Nano GmbH, Germany
Brussel Photonics Team, Vrije University, Belgium
Carnegie Mellon University, USA
Canon Foundation for Scientific Research, UK
CERN/ASP IOC, Switzerland
CERN/ATLAS, Switzerland
CETEMPS, Italy
China International Optoelectronic Exposition (CIOE), China
CINFAL, Italy
City of Light Jyväskylä, Finland
Civilian Research & Development Foundation, USA
CMC Microsystems, Canada
CNS International Srl, Italy
Commissionatà l’energie atomique, France
Commissione Internazionale de l’Eclairage, Austria
Consiglio Nazionale delle Ricerche (CNR), Italy
Consorzio per la Fisica di Trieste, Italy
COST grant through Univ. of Oulu, Finland
CUDOS, Univ. of Sydney, Australia
Deutsche Physikalische Gesellschaft, Germany
Dodd-Walls Centre, Univ. of Otago, New Zealand
E4 Computer Engineering SpA, Italy
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European Federation of Organisations in Medical Physics (EOMP), UK
European Optical Society, Finland
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European Physical Society (EPS), France
European Science Foundation (ESF)
European Space Agency, France
European X-Ray Spectrometry Association, Hungary
eXat Lab, Italy
Forschungsverbund Berlin eV, Germany
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Hamamatsu Photonics, Japan
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Hillarys Blinds, UK
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Illuminating Engineering Society, USA
Indian Institute of Science, India
Indian Institute of Tropical Meteorology (IITM), India
Institut Femto-ST, France
Institute for Complex Adaptive Matter (ICAM), USA
Institute of Photonics and Quantum Sciences, UK
Institute of Physics, UK
International Association of Physics Students, France
International Commission on Optics (ICO)
International Electrotechnical Commission, Switzerland
International Light Association, Belgium
International Organization for Medical Physics, USA
International Union of Crystallography, UK
International Union of Geodesy and Geophysics (IUGG)
International Union of Pure and Applied Physics (IUPAP), UK
Istituto Nazionale di Astrofisica, Osservatorio Astronomico di Trieste, Italy
Istituto Nazionale di Fisica Nucleare (INFN), Italy
Istituto Nazionale di Oceanoografa e Geofisica Sperimentale (OGS), Italy
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Japan Society of Applied Physics, Japan
King Abdulaziz University, Saudi Arabia
Kuwait Foundation for the Advancement of Sciences, Kuwait
LABEX Action, Institut Femto-ST, France
Laser Institute of America, USA
LENS, Italy
Chinese Academy of Sciences, China
Lighting Urban Community International, France
LUX-TSI Limited, UK
National Academy of Sciences, USA
National Electrical Manufacturers Association, USA
Nature Photonics, UK
Network Startup Research Center (NSRC), USA
NetworkTheWorld, USA
Norwegian Physical Society, Norway
Office of Naval Research Global, USA
Omega Light, Brazil
Open University, UK
Optical Society of America (OSA), USA
Optical Society of Korea, Korea
OPTIS, France
PennWell Corp., USA
Philips Lighting, The Netherlands
PhotonExport SCP, Spain
Photonics Centre, Osaka University, Japan
Photonics Communication Research Laboratory, Greece
Pilkton Conference & Expo, USA
Politecnico di Torino, Italy
PriTel, Inc., USA
Provincia di Trieste, Italy
RANA Diving SpA, Italy
RES Marino Srl, Italy
School of Physics, Sydney University, Australia
Scientomics, France
SCOSTEP - The Scientific Committee on Solar-Terrestrial Physics
Scuola Superiore Sant’Anna di Pisa, Italy
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Sincrotrone Trieste, Italy
SISSA Medialab, Italy
SISSA, Italy
SO.PRO.MAR SpA, Italy
Società Astronomica Italiana, Italy
Società Italiana di Fisica, Italy
Society for Applied Spectroscopy, USA
Society of Light and Lighting, UK
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Swedish National Resource Centre for Physics Education, Sweden
Swiss Physical Society, Switzerland
TAQL, USA
Tampere Univ. of Technology, Finland
TELLIT SpA, Italy
The International Society for Optical Engineering (SPIE), USA
The Photonics Institute, Nanyang Technological University, Singapore
The Zhaga Consortium, USA
Thinklight, Portugal
Thorlabs SAS, France
UL, LLC, USA
Università di Firenze, Dip. Ingegneria Industriale, Italy
University of Eastern Finland, Institute of Photonics, Finland
University of Southampton, UK
Università degli Studi di Trento, Italy
Università degli Studi di Trieste, Italy
Università degli Studi di Udine, Italy
Université Toulouse III - Paul Sabatier, France
University of Auckland, New Zealand
University of Hamburg, Germany
Uppsala University, Sweden
Velux A/S, Denmark
Wiley-VCH Verlag GmbH & Co., Germany
Summary of Activities ICTP 2014

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**Acting Deputy Director:** Seifallah Randjbar-Daemi

**High Energy, Cosmology and Astroparticle Physics**

Bobby Acharya
Paolo Creminelli
Atish Dabholkar
Kumar Narain (Section Head)
Goran Senjanovic (Emeritus)
Ravi Sheth
Alexei Smirnov (Emeritus)
George Thompson
Giovanni Villadoro

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Basudeb Dasgupta
Rajesh Kumar Gupta
Edward Hardy
Ehsan Hatefi
Vid Irsic
Diana Lopez Nacir
Daniele Musso
Gabrijela Zaharijas
Ahmad Zein Assi

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Alejandro Cabo Bizet
Marco Dos Santos
Imtak Jeon
Eric Juan Ravira
Ambroise Lafont
Jovana Petrovic
Kate Shaw
Driba Tolla

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Andrea Romanino

**String Phenomenology and Cosmology:**
Fernando Quevedo (Section Head)

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Gustavo Alfredo Arciniega Duran
Roberto Valandro
Leo Van Nierop

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Vladimir Kravtsov (Section Head)
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Markus Müller
Sandro Scandolo
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Taegeun Song
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Vipin Varma

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Giuseppe Mussardo
Giuseppe Santoro
Alessandro Silva
Erio Tosatti

* staff of new Quantitative Life Sciences research section

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Lolhar Gütsche
Stefano Luzzatto
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Distinguished Staff Associate:
Don B. Zagier

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Lassina Dembélé

Shiing-Shen Chern Senior Postdoctoral Fellow:
Qingtao Chen

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Vittoria Bussi
Erik Carlsson
Xin Li
Anton Mellit
Ayesha Asloob Qureshi
Maxim Smirnov

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M. Soufi Neyestoni

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Erika Coppola
Riccardo Farnetti
Filippo Giorgi (Section Head)
Fred Kucharski
Fabien Solmon
Adrian Tompkins

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In Sik Kang

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Laura Mariotti
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Ahmed Kamal Shalaby
Lina Sitz
Csaba Torma
Giovanni Tumolo

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Livio Bernardini

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Maria Liz Crespo
Carlo Fonda
Bruno Nava
Joseph Niemela (Section Head)
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Marco Zennaro

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Sandro Radicella

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Clément Zanolli

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Arca-Moret, A.
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Anton Kashcheyev
Rodrique Herbert Ngaya
Claudia Paparini
Juan Sebastian Rodriguez Zuluaga
Natasa Stojic

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Luigi Ciraoelo
Yenca Olivia Migoya Orue
Ermanno Pietrosemoli

Technical Assistant:
Andres Cicuttin

Director’s Office

Staff Associate:
Rohini Godbole, India

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Ricardo Gallego Torrome
Mohammad Reza Mohammadi Mozaffar
Brent Nelson
Kate Shaw

Scientific Consultants:
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Luciano Bertocchi Medical Physics
Giulio Boneilli DIR
Stefano Cozzini ICTS
Giuseppe Furlan TRIL
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Massimo Malabotta ICTS
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Tahir Shah DIR
Daniele Treleani TRIL
Claudio Tuniz DIR
Livio Tenza SDU

Administrative Staff:
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Elio Fiego, Technical Officer
Carlo Fonda, Technician, SDU
Anne Gatti, Programme Support Officer
Dag Johannessen, Senior Administrative Officer
Andrej Michelcich, Senior Budget and Finance Officer
Clement Onime, System and Network Analyst
Dora Phiotiou, Supervisor, Housing and Guesthouses
Yamiko Samu, Institute Advancement Officer
Ulrich Singe, Head, ICTS
Dorothy Smith-Grafts, Human Resources Officer
Lucio Visintin, Head, Library Services
Mary Ann Williams, Public Information Officer

In addition, ICTP employed 127 General Service staff in 2014.
ICTP IN NUMBERS 2014

5,670 visitors [25% female]

58 postdocs on campus [57% from developing countries]

142 nations represented

98 students enrolled in pre-PhD educational programmes from 39 developing countries, including:

56 training activities on campus

76 Postgraduate Diploma Students enrolled in academic years 2013-14, 2014-15;

24 training activities in developing countries

22 ICTP-STEP Fellows

327 scientists engaged in career development programmes:

13 days average length of visit for conference participants

165 Associate Members

66 days average length of visit for research visitors

59 Affiliates

327 scientists engaged in career development programmes:

42 ICTP-Elettra students

61 TRIL Fellows

REGION OF ORIGIN, FEMALE VISITORS AT ICTP, 2014

ICTP TRAINING ACTIVITIES, 2014

HECAP CMSP MATH ESP AP

790 1400 464 675 1400

234 357 159 189 622

PARTICIPANTS

PERSON MONTHS