The Institute of Theoretical Physics, Chinese Academy of Sciences

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ITP's main building (left, since 1987) and the new building (right, since 2005).

INTRODUCTION

The Institute of Theoretical Physics (ITP) of the Chinese Academy of Sciences (CAS) was established in Beijing in June 1978. In fact, in the 1960s, many influential physicists in China already had made a proposal to found a research institute for theoretical physics which, however, could not be realized until the Cultural Revolution ended. It was Mr. Deng Xiao-Ping, then a vice-premier of China, who finally approved the proposal in 1978. 2018 marks the 40th anniversary of the founding of the ITP.

The ITP's mission is to play roles as (i) a center of excellence for fundamental research in theoretical physics and interdisciplinary sciences; (ii) a base for educating and fostering young talents; and (iii) a platform for domestic and international scientific exchange and collaboration. These roles are well in accord with CAS's strategy, which emphasizes "the combination of research and education". Therefore, from its founding, the ITP has been operating in a way that is different from other institutions in mainland China; it is comprised of a limited number of full-time research scientists, acting as a skeleton crew, who cover almost all fields of theoretical physics and supervise students. Furthermore, the ITP is also internationally "open" , in the sense of hosting research scientists from around the world for a certain period of time to carry out joint programs and develop collaborations.

The ITP has played an important role in the development of physics not only by conducting scientific research, but also by initiating many new innovative activities in mainland China. Listed below are some of the groundbreaking achievements of the ITP.

- In 1981, the ITP became one of the first institutions in mainland China to award PhD degrees.

- In 1984, the ITP firstly initiated a postdoctoral program in mainland China.
- In 1985, the ITP became one of the first two institutes in CAS to host guest scientists from institutions throughout China.
- In 1993, the ITP was selected as a Center of Excellence in the South by the Third World Academy of Sciences (TWAS-UNESCO) Associateship Scheme.
- In 1998, the ITP became one of the first twelve institutes selected from more than one hundred institutes in CAS to implement the Pilot Project of the Knowledge Innovation Program (PPKIP).
- In 2002, the Interdisciplinary Center of Theoretical Studies (ICTS) was established at the ITP.
- In 2004, the ITP was selected by CAS as one of the first four research institutes to be internationally evaluated. The panel of evaluation experts concluded that "the ITP is a strikingly active and productive theoretical physics research institute. The research conducted deals with the forefront of contemporary problems and, in its areas of specialization, is competitive with the research conducted in the best institutes and universities worldwide. The quality and the direction of research are excellent."
- In 2005, the International Advisory Committee (IAC) of the ITP was established and chaired by the Nobel Laureate David Gross.
- In 2006 the Kavli Institute for Theoretical Physics China (KITPC) was established in the ITP. This was the first Kavli Institute in Asia.
- In 2008, the CAS Key Laboratory of Theoretical Physics (CAS-KLTP) was established.
- In 2011, the CAS-KLTP was promoted as a State Key Laboratory for Theoretical Physics (SKLTP), authorized by the Ministry of Science and Technology.
- In 2013, the ITP was evaluated by an International Expert Diagnostic Assessment Team which concluded that "The ITP's mission is unique among China's physics-based institutes in that it does not have a narrow field focus and its researchers are free to choose their problem areas. It is China's principal platform for developing the cross-field and cross-disciplinary connections that are likely to characterize many of the most important advances in 21st-century science."
- In 2016, the Natural Science Foundation of China (NSFC) established the Peng Huan-Wu Innovation Research Center for Theoretical Physics (PCTP) at ITP, named after the founding director of the ITP.

FACULTY & RESEARCH

There are now 41 research scientists (who are either professors or associate professors). Among these research scientists, there are 7 academicians of CAS, 10 winners of the National Science Fund for Distinguished Young Scholars, 3 included in the "10000 Talents Plan" of China, 7 enrolled in the "1000 Young Talents Program" of China and 20 enrolled in the "100 Young Talents Program" of CAS.

The ITP is comprised of two research divisions and conducts research on the following fields: (1) Quantum Field Theory and Microscopic Structure of Matter (Particle Physics, Particle Astrophysics & Nuclear Physics); (2) String Theory, Gravity and Cosmology; (3) Statistical Physics and Theoretical Biophysics; (4) Condensed Matter Physics and Quantum Physics.

(1) Quantum Field Theory and Microscopic Structure of Matter

In the framework of quantum field theory, the Standard Model of the strong, electromagnetic and weak interactions has enjoyed many splendid successes in the last decades, especially with the detection of its last predicted particle, the Higgs boson, recently at LHC. However, the Standard Model still suffers from some unsolved problems, such as: why do particle masses and coupling constants have the values that we measure? Why are there three generations of particles? Why is there much more matter than antimatter in the universe? Where does dark matter fit into the model? Is it even a new particle? How can we modify the classic Standard Model to include the mass of neutrinos? These problems suggest new physics beyond the Standard Model. On the other hand, within the Standard Model, it is still a challenge to understand and describe the formation and the forms of strongly interacting matter such as hadrons and atomic nuclei due to the non-perturbative character of the underlying gauge theory, Quantum Chromodynamics (QCD), in the low energy regime. Aiming to solve these problems, the main research topics of this group currently include: models beyond the Standard Model including supersymmetry and grand unifications, Higgs phenomenology, dark matter models and detection, flavor mixing and CP violation, heavy flavor physics, neutrino physics, hadron structure and hadron spectroscopy, the structure of exotic nuclei and hypernuclei, the structure and synthesis mechanism of superheavy nuclei, compact stars, Lattice QCD, and AdS/QCD and effective theories.

(2) String Theory, Gravity and Cosmology

Gravitation is one of four kinds of fundamental interactions in nature. As a theory of gravitation, general relativity greatly succeeds in cosmology and astrophysics. It has been tested with great precision from scales as small as a millimeter, to extremely large scales, e.g., the solar system. However, determining whether general relativity holds in other scales is a fundamental problem. Difficulty still exists as to the unification of general relativity and quantum mechanics; to develop a theory of quantum gravity is one of most important challenges in modern theoretical physics. String theory is one of the most promising candidates of quantum gravity theory. On the other hand, with the development of modern high technology, cosmology enters into a precision era and "golden" time. All current observations indicate a concordance model: inflation & hot big bang & dark matter & dark energy. The research of this group currently focuses on topics in the theory of quantum gravity and cosmology, including: the holographic principle of gravitation, black hole physics, thermodynamics of apparent horizons, entropic force formalism, Harava-Lifshitz gravity, applications of AdS/CFT correspondence in condensed matter physics, the nature of inflation, dark matter and dark energy, and CMB physics.

(3) Statistical Physics and Theoretical Biophysics

The research of this group covers a wide range in theoretical statistical mechanics, biophysics, chemical physics, bioinformatics, and their interdisciplinary applications. In recent years, scientific studies in this group have concentrated on the following topics: 1) bioinformatics, i.e., the application of statistical and linguistic methods in genomics and proteomics; 2) statistical mechanics of molecular and cellular biological systems, such as single molecule biophysics of DNA, RNA, and proteins, elastic theory of bio-membranes, and self-assembly of nano and biomolecular systems; 3) theoretical and experimental investigation of biological networks (gene regulation, cell-cycle control, etc.); 4) statistical mechanics and physical properties of liquids and glassy systems; 5) phase transitions and critical phenomena of complex and social networks; and 6) spin-glass theories for finite-connectivity systems and their application to information systems and hard combinatorial optimization problems. These studies help us to understand how basic physics laws are transcribed into the rich diversity of nature. The distinct feature of this group is the focus on theoretical studies of biological, chemical, and complex systems from the perspective of statistical physics.

(4) Condensed Matter Physics and Quantum Physics

The research interests of this group cover a wide range of topics in condensed matter physics and quantum physics, such as strongly correlated systems, the topological states of matter, quantum information, quantum optics, atomic physics, and ultracold atomic gases. Specifically, the group members focus on: 1) the physical mechanisms of strongly correlated systems such as the quantum Hall effect, high temperature superconductivity and giant magnetoresistance systems, quantum liquids and quantum critical phenomena; 2) the development of the numerical simulation methods for the quantum many-body systems, including the density matrix renormalization group, quantum Monte Carlo simulations, and first principles and ab initio computational studies; 3) topological states of matter, e.g., the topological insulator and topological superconductor, non-abelian anyons and their application to topological quantum computation; 4) physical properties of mesoscopic systems, such as the coherence, correlation, fluctuation, dissipation, transports of the charge and spin of the current carriers, photons and neutral atoms; 5) the fundamental issues of quantum physics, such as quantum measurement and quantum decoherence/dissipation in quantum open systems; 6) quantum state engineering based on superconducting qubits and circuit quantum electrodynamics, and quantum phenomena in opto-mechanical systems; 7) exotic quantum phases in ultra-cold atomic and molecular gases, e.g., the dipolar Bose-Einstein condensates, degenerate Fermi gases with strong dipole-dipole interaction, and ultracold collisions of atoms and molecules; 8) coherent state transfer in quantum networks, in particular, single photon transfer in coupled cavity arrays and the quantum transfer of collective excitations in a bio-network, such as photosynthesis and avian compasses. The research topics also include the development of theoretical approaches for natural atoms and artificial systems in strong external fields, which is related to semi-classical physics and quantum chaos, and probing mathematical structures behind the dynamics of physical systems, such as quantum groups and the Berry phase.

POSTDOCTORAL FELLOWS & STUDENTS

In 1984, the ITP initiated the postdoctoral program in mainland China. Presently there are 33 postdoctoral fellows at the ITP. At the ITP, postdoctoral fellows have played important roles which, in other institutions, are played mainly by junior or mid-level researchers. Among the 206 individuals who have finished their postdoctoral

studies at the ITP, three have won awards for excellent postdoctoral fellows in mainland China, four have been elected as academicians of CAS and one has been elected as an academician of the Chinese Academy of Engineering.

In 1981, the ITP became one of the first institutions in mainland China to award PhD degrees. The ITP was ranked No. 1 in theoretical physics in the national evaluation of physical education for graduate students in 1984. 134 graduate students (mostly PhD) are now studying at the ITP. Since its establishment, the ITP has awarded Master's degrees to 120 candidates and PhDs to 358 candidates among whom, two were elected as academicians of CAS, five were awarded the National Excellent PhD Thesis, 12 were awarded the CAS Excellent PhD Thesis and nine were winners of the CAS President's Special Award.

THE CAS-KLTP & THE PCTP

Since its foundation, one of the main features of the ITP has been the promotion of openness to scientists from outside the institute. In 1985, the ITP became officially one of two "open" institutes in CAS and the ITP started a Guest Scientist Program. The Guest Scientist Program runs research programs on selected topics in theoretical physics and attracts and hosts theoretical physicists from throughout mainland China. In 1998, the ITP was included in the Pilot Project of the Knowledge Innovation Program (PPKIP) of CAS. Since then, the ITP has extended the Guest Scientist Program to include scientists from both inside and outside of mainland China.

The ITP's role to be a platform for scientific exchange and collaboration was reinforced when the Interdisciplinary Center of Theoretical Studies (ICTS, 2002) and the Kavli Institute for Theoretical Physics China (KITPC, 2006) were established. The ICTS, aiming to encourage multidisciplinary dialogue and to promote the interdisciplinary collaboration, was superseded by the CAS Key Laboratory of Theoretical Physics (CAS-KLTP) which was set up in 2008. The KITPC closed in 2017 and part of its role has now been adopted by the Peng Huan-Wu Innovation Research Center for Theoretical Physics (PCTP).

The CAS-KLTP, following its policy "To be open, to encourage mobility (of talents), to compete and to unite" is

oriented to both the frontiers of science and the national strategic demands. It unites Chinese theoreticians in order to solve cutting-edge problems in theoretical physics. It also aims at developing interdisciplinary science and providing theoretical support and guidance for big science facilities in China.

The PCTP was established by the National Science Foundation of China (NSFC) in the end of 2016 with the aim to carry out original research and to promote more collaboration in theoretical physics. The center is run in a "problem driven" mode. Since 2017, the PCTP has annually organized the "Young Scientists' Forum on Theoretical Physics and Interdisciplinary Studies". Since 2018, the PCTP has begun to offer an advanced visiting program for scholars from all over the world (Peng Huan-Wu Visiting Professors) .

SCIENTIFIC EXCHANGE & COLLABORATION

One of the ITP's main roles is to be a platform for scientific exchange and collaboration. In every year more than 500 international or domestic scientists visit the ITP for scientific exchanges and/or collaborations. The ITP has signed collaborative agreements or memorandum of understanding (MOU) with more than twenty institutions around the world. With the fast development of scientific research in mainland China, the ITP is becoming a more internationalized institution.

VACANCIES

The ITP opens multiple research faculty positions at the tenure-track level, including positions for those who are eligible for the "1000 Young Talents Program" of China and the "100 Young Talents Program" of CAS, and the non-tenure fixed-term level. The PCTP offers an advanced visiting program (Peng Huan-Wu Visiting Professors) for researchers from all disciplines of theoretical physics and interdisciplinary studies.

The ITP also continually accepts applications for postdoctoral research positions supported by either the ITP or CAS's President's International Fellowship Initiative (PIFI).

For more information, please visit: http://www.itp.cas.cn/.

Cai Ronggen is the current director of the ITP (Institute of Theoretical Physics, Chinese Academy of Sciences). He obtained his BSc at the Hangzhou Normal University in 1985, and his PhD at Fudan University in 1995. He subsequently worked at the ITP, Seoul National University, and Osaka University as a postdoctoral researcher. He has been working at the ITP since 2001 after he was enrolled in the "100 Young Talents Program" of CAS (Chinese Academy of Sciences). He was awarded the National Science Fund for Distinguished Young Scholars in 2003 and the National Natural Science Award (2nd class) in 2011 and was included in the "10,000 Talents Plan" of China in 2016. In 2017 he was elected as an academician of CAS. He was one of Thomson Reuters' Highly Cited Researchers in 2014, and one of Elsevier China's Most Cited Researchers in 2014, 2015, 2016 and 2017. He is a member of the National Council of the Chinese Physical Society (CPS), the Chair of the Committee on Gravitation and Relativistic Astrophysics of the CPS, an IUPAP Representative in the International Society on General Relativity and Gravitation (ISGRG), a vice-chair of the Division of Astrophysics, Cosmology and Gravitation of the Association of Asia Pacific Physical Societies (AAPPS), and the president of the BRICKS Society on Gravitation, Astrophysics and Cosmology. He serves as a co-editor-in-chief of *SCIENCE CHINA (Physics, Mechanics & Astronomy)* and a co-editor-in-chief of *Communications in Theoretical Physics*. He is a member of the advisory panel of *Classical and Quantum Gravity*, and is a member of the editorial boards of *Modern Physics Letters A, International Journal of Modern Physics D, Advances in High Energy Physics* and the *Chinese Science Bulletin*.