2017 NCTS Physics ANNUAL REPORT

NCTS

National Center for Theoretical Sciences

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科技部 Ministry of Science and Technology

NCTS National Center for Theoretical Sciences

National Tsing Hua University

ABOUT

The National Center for Theoretical Sciences was established on August 1997 by the National Science Council, NSC (NSC became Ministry of Science and Technology, MoST, since March 2014), with endorsement from some of the eminent scholars, including Professors Chen Ning Yang and Shing-Tung Yau. It was hosted on the campus of the National Tsing Hua University, Hsinchu, with National Tsing Hua University and the adjacent National Chiao Tung University acted as co-host in the last 18 years. The Center consists of two divisions: Mathematics and Theoretical Physics. In 2015, the Mathematics division moved to National Taiwan University and continue to serve the community.

The Physics Division, are committed to contribute to the advancement of frontier research in physics.

Missions

To act as an effective platform to stimulate and to enhance the interaction and collaboration among researchers.

To empower talented students and postdoctoral researchers to make significant contributions in the frontier of research subjects.

To serve as an efficacious channel to network the home researchers with other scholars and preeminent institutions abroad.

To explore new frontiers in physics research and innovation

To enhance the extent and breadth of interdisciplinary researches as well as the collaboration with scientists in the experimental fields.

Forward

I am pleased to present you with the 2017 Annual report of the Physics Division of NCTS. This year has been a productive and fruitful year.

NCTS scientists have made significant contribution in areas from such as pentaquark, 750 GeV diboson anomaly, core-cusp problem of the dark matter, holography of de Sitter space, quantum information and entanglement entropic properties of quantum gravity, unconventional soft limits for spacetime symmetry breaking in high energy physics, to quantum quenches in Luttinger model, emergence of Dirac semi-metallic phase at finite temperature, lattice instabilities and conductive interface, metallic quantum solid in system of cold atoms in condensed matter physics, as well as quantum steering and measurement characterization in quantum information theory and abnormal polymer transport in crowded media in soft matters and complex system.

NCTS published 115 papers in 2017. The publications are of high research quality with many high impacts results appearing in prestigious journals. About a third of them are published in high impact journals with the top 15 % of impact factor.

The DCS research program has performed well. Individual DCSs have successfully built up their research team with postdocs or assistant research scholars. On average, each DCS has about two postdoctoral researchers or assistant research scholars in his team. Together, the team as a whole interact with other scientists domestic or international collaborators, and students in the community, to engage in active research on frontier research topics. In terms of publication, the five DCS has written a total of 39 papers 2017. Out of which many important results has appeared in high impact journals such as Nano Letters, Nature communications, Physical Review Letters, 2d Materials, Journal of High Energy Physics etc. Collaboration is growing strong as can be seen from the many collaborative publications of the DCS research team.

NCTS has played active role in promoting interaction and collaboration within the Taiwan physics community and with researchers worldwide. We have hosted 226 visiting scientists from abroad in 2017. We organized around 30 international conferences and workshops in 2017. Among which 5 were joint meetings with other countries. Also over 300 seminars on various subjects took place. I would like to compliment my colleagues for their commitment and all the hard works they have put in organizing and keeping a vibrant program of research at NCTS.

The cultivation and nurturing of promising students and young researchers has been a very important part of NCTS efforts. The body of research fellows of NCTS has grown significantly. It has now a body of 26 research staffs consisting of 6 assistant research scholars and 20 postdocs. The society of postdoctoral researchers has been very active and has published 49 papers this year.

The quality of our hires has been good. Bo Xiong has obtained a faculty position at the Wuhung University of Technology, China in 2015 Dec. This spring, Chung-Chi Lee has been awarded a prestigious Newton International Fellow by the Royal Society of UK to join the cosmology group at DAMTP, Cambridge. This summer Carlos Cardona has joined Niels Bohr as a postdoc in Copenhagen; Jung Chang has continued as a postdoc at the Chonnam National University Gwangju, South Korea; Ya-Fen Hsu has continued as a postdoc at the National Taiwan University.

NCTS has been actively facilitating the transfer of frontier research to the young generations, through organization of advanced schools and workshops specifically with them as target audiences. About 5-7 advanced schools are organized each year. Some of the schools are of interdisciplinary nature, combining theory and experiments, or traditionally different subjects such as chemistry and computation.

NCTS has continued in developing new bilateral agreements with other international institutions in order to foster scientific collaboration. In 2016, NCTS has joined the research network, Fundamental Interaction Space Time (FIST), this year. FIST is a High Physics network formed by Research Institutions (primarily) in Asia in order to help building up and strengthening transnational research partnership and cooperation among researchers across Asia. NCTS has also joined the EU network Cooperation in Science and Technology (COST) on "Quantum structure of spacetime (QSPACE)".

NCTS has turned 20 years old this August. Like any journey, rough time is sometime unavoidable, nevertheless NCTS has successfully sailed through and has made remarkable achievements together with its international friends and partner institutions worldwide in the last 20 years. Clearly the success of NCTS would not be possible were it not for the firm foundation established through the selfless dedication and leadership of the previous directors of NCTS, and the tremendous

support and enthusiastic contributions that NCTS has received from colleagues in the Taiwanese community throughout the years. I am grateful to my friend and colleague Professor Daw-Wei Wang for his commitment as the vice director of the center. His assistance on administrative as well as academic matters has been a major source of support. Finally I would also like to compliment the team of administrative staff for their hard work in making the operation of NCTS smooth and successful, for their very positive altitude towards learning about new things, and for putting up with endless new demands and expectations from me.

Chu Chong Sun

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2018

Structure and Governance

Operation and Management

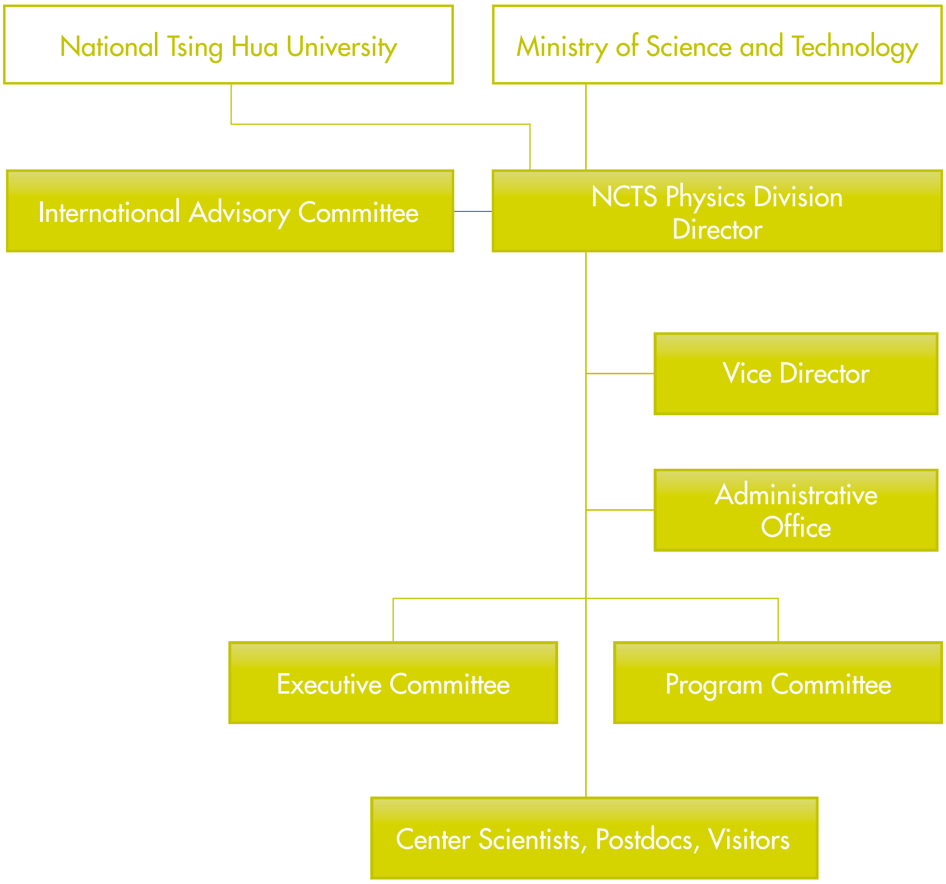
The director is responsible for all the decisions of the Center. He/She leads the Academic Executive Committee, and is responsible for the decision making for the operation inside the division. The Executive Director is appointed by the Director to assist him/her in implementing policies and operations of the Center. As an academic, he/she also held a vital role in helping to push the center's academic programs and initatives. The center routine and daily operation is carried out by the center adminstrative team which consists of six adminstrative staff, an accountant and an IT staff. The center submits an annual report, with financial statements to the Minstry of Science and Technology (MoST), usually in October of the year. A grant midterm review is conducted in MoST in December to discuss the annual budget for the following year.

The Center Academic Executive Committee is set up by the Director to help the Director to make decision on the scientific personnel and academic matters. For exmaple, to give advices on the general policies and guidelines for the NCTS scientific activities and financial affairs, and to give recommendations to the director on the appointment of the NCTS scientific personnel. The committee meets four times a year. The Program Committee is comprised of the coordinators of the academic research groups (Thematic research groups, Experimental collaboratio group,interdisciplinary research groups) advanced by the center.

International Advisory Committee

Carlo Beenakker	Instituut-Lorentz for Theoretical Physics, Leiden University, Netherlands
Tohru Eguchi	Department of Physics and Institute of Theoretical Physics, Rikkyo University, Tokyo; Former director of the Yukawa Institute for Theoretical Physics, Japan
Antoine Georges	Director of the Simons Center for Computational Quantum Physics, USA
Tao Han	Director of the Pittsburgh Particle Physics, Astrophysics, and Cosmology Center, University of Pittsburgh, USA
Steven G. Louie	University of California at Berkeley, USA
Allan H. Macdonald	Sid W. Richardson Foundation Regents Chair; Professor of Physics, University of Texas, Austin, USA
Henry Tye	Former diector of the Institute for Advanced Study, Hong Kong University of Science and Technology, Hong Kong

Organization



NCTS Review Committee Meeting hosted by MoST on October 20-21, 2017.

Left: Chon-Saar Chu, Chin-Chun Tsai, Ching-Ming Wei, Minn-Tsong Lin, Mei-Yin Chou, Ping Sheng, Kaoru Hagiwara, Shih-Chang Lee, Director General of MoST Chun-Chieh Wu, Director Chong-Sun Chu

Major Academic Program

Thematic Groups Research Program

In order to encourage and enhance the collaboration and innovation of the larger community, The primary aim of Thematic Group (TG) is to foster an efficient collaborative environment in the community.

act as an effective platform to bring together researchers with complementary scientific approaches and backgrounds so that a closer cooperation and collaboration of researchers could be fostered.

Experimental Collaboration and InterDisciplinary Research Program

In order to enhance the collaboration between theorists and experimentalists, and to promote the exchange and cooperation between researchers in tradition different disciplines, the Center operates the Experimental Collaboration Program (ECP) and the InterDisciplinary Research Program (IDP). In these programs, the role of NCTS is to

Seed Project

Seed Project (SP) is to support new research direction or research area where there is a relatively smaller representation in the local community.

The subject theme of the Thematic Research Program, Experimental Collaboration and InterDisciplinary Research Program and Seed Project as well as their coordinators are listed in the tables below.

Prof. Bruce H J Mckellar gave a talk in NCTS Special Colloquium, Nov 2, 2017

Thematic Groups

TG	PROGRAM TITLE	COORDINATORS
TG1	Particle Physics	Chuan-Ren Chen (NTNU)
TG2	Dark Physics of the Universe	Chao-Qiang Geng (NTHU)
TG3	Strings	Yu-Tin Huang (NTU)
TG4	Topology & Entanglement in Quan. Many-Body Systems	Po-Chung Chen (NTHU)
TG5	Complex Systems	Yeng-Long Chen (AS), Kuo-An Wu (NTHU)
TG6	Quantum Information Science and Quantum Control	Hsi-Sheng Goan (NTU), Yueh-Nan Chen (NCKU)
TG7	Quantum Gases	Ray-Kuang Lee (NTHU)
TG8	Topology & Strong Correlations in Quan. Many-Body Systems	Chung-Hou Chung (NCTU)
TG9	Quantum and Topological Materials	Feng-Chuan Chuang (NSYSU), Horng-Tay Jeng (NTHU)

Experimental Collaboration Program

ECP	PROGRAM TITLE	COORDINATORS
E1	Quantum Optics and Quantum Manipulation of Ultracold Atoms	Ying-Cheng Chen (AS)
E2	Light Dark Matter	Cheng-Pang Liu (NDHU), Henry Wong (AS)
E3	LHC Experimental/Theoretical Exploration	Kingman Cheung (NTHU), Jennifer Hsu (NTHU)

Interdisciplinary Research Program

IDP	PROGRAM TITLE	COORDINATORS
I1	Multiscale studies for complex materials, catalysts, and biological systems – theoretical and computational approaches, and experimental stimulus	Jer-Lai Kuo (AS)
I2	Geometry, Topology and String Theory	Nan-Kuo Ho (NTHU), Siye Wu (NTHU)
I3	Complex Systems and Mathematical Biology	Lee-Wei Yang (NTHU)

Seed Project

SP	PROGRAM TITLE	COORDINATORS
S1	Quantum Transport	Chao-Cheng Kaun (AS)
S2	Gravitional Wave and Numerical Gravity	Feng-Li Lin (NTNU)
S3	Parton Distribution Functions from Lattice QCD	David Lin (NCTU)
S4	Non-equilibrium Quantum Phenomena	Chung-Hsien Chou (NCKU)

PERSONNEL

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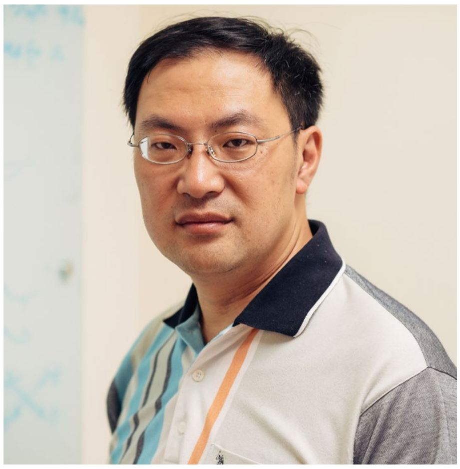

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Distinguished Center Scientists

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Professor
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Honorary Center Scientist
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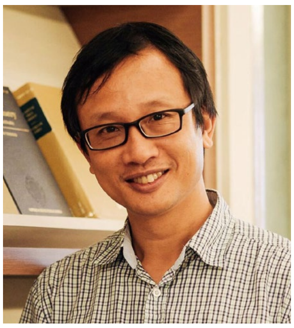

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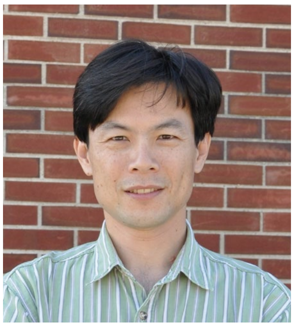

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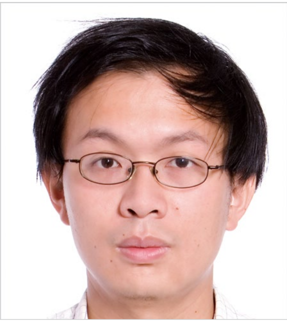

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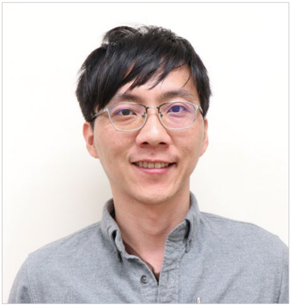

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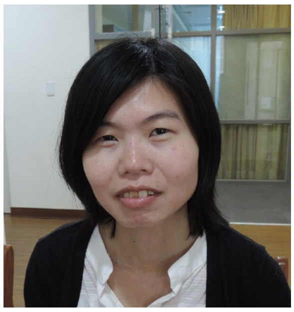

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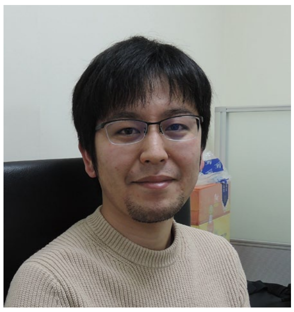

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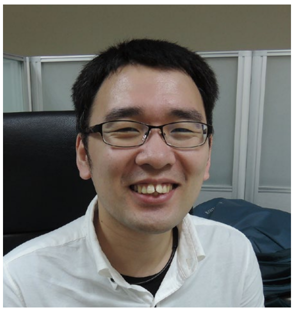

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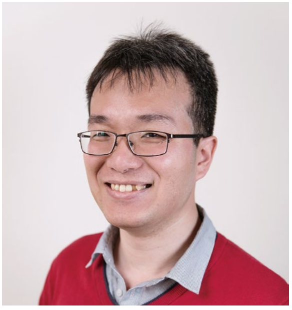

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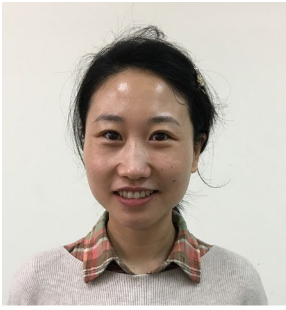

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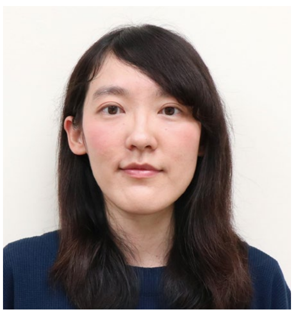

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RESEARCH

Research in NCTS is mainly conducted through the operation of the Center Scientists Program, Postdoctoral Research Program, Thematic Groups Research Program, Experimental Collaboration Program and the Interdisciplinary Research Program.

The principal function of thematic groups is to promote the growth and to strengthen the base of the larger community, through collaboration in research. Collaboration between theorists and experimentalists is essential and can be a very powerful way for advancing scientific discoveries and technological innovations. A successful and productive collaboration between theorists and experimentalists will also help to strengthen the overall research environment in the whole physics community. Besides, many major breakthroughs in science take place at the intersections of disciplines. This is particular so in the modern time due to the increasing complexity of problems. The Experimental Collaboration Program (ECP) is led by leading experimentalists. The interdisciplinary program (IDP) is led by PI in different research fields. These groups work closely with the Thematic research groups in their operation.

Apart from their own research, the center scientists (Distinguished center scientists DCS and center scientists CS) often work together with the Thematic groups (TG) to form collaborative research team. They also help to promote the research programs and activities of the center.

Below we give a description of some of the more representative research conducted by these respective entities.

Reports from Center Scientists

Ultralight Axion Dark Matter

Professor
Kingman Cheung
Distinguished Center Scientist
National Tsing Hua University
Particle Physics

There have been many compelling pieces of evidence for the existence of cold dark matter (CDM), which successfully explains the rotation curves of spiral galaxies, the cosmic microwave background power spectrum, the Bullet Cluster, and the large-scale structure formation of the universe. The best-motivated model for CDM is weakly interacting massive particles (WIMPs), whose mass range is from the sub-GeV to 100 TeV. Unfortunately, up to now, no compelling evidence of WIMPs has been found by different types of searches, such as collider searches, underground detections, and astronomical observations. The null signals reported in all these experiments have shrunk the parameter space of many WIMP models to some finely tuned regions. Also, the next generation of CDM searches are shifting their focus to different mass regions.

The CDM model, through detailed N-body simulations, although successfully explaining the observations on large scales, fails to account for the observations on relatively smaller scales; this is known as the "small-scale crisis," which includes (i) the missing satellites problem, (ii) the cusp–core problem, and (iii) the too-big-to-fail problem. Some believe that a new mechanism for velocity boost is needed for the DM momentum exchange beyond the collisionless picture of the CDM, such as the ultralight axionic dark matter.

The Ultra-Light Axion is a dark matter candidate with mass O(10^{-22}) eV and de Broglie wavelength of order kpc, also known as the Fuzzy Dark Matter (FDM), thermalizes via gravitational force and forms a Bose-Einstein condensate. The quantum pressure from the FDM can significantly affect the structure formation in small scales, thus alleviating the so-called "small-scale crisis". We develop a new technique to discretize the quantum pressure for FDM particles in the N-body simulation [1]. In a self-gravitationally-bound virialized halo, we find a constant density, solitonic core, thus, having the potential of solving the small-scale crisis.

In Fig. 1, we show the halo density profile after the system is fully virialized after 10 Gyr. We can easily see that the FDM produces a larger solitonic core than the CDM. Inside 1 kpc the density profile of FDM is lower than the CDM.

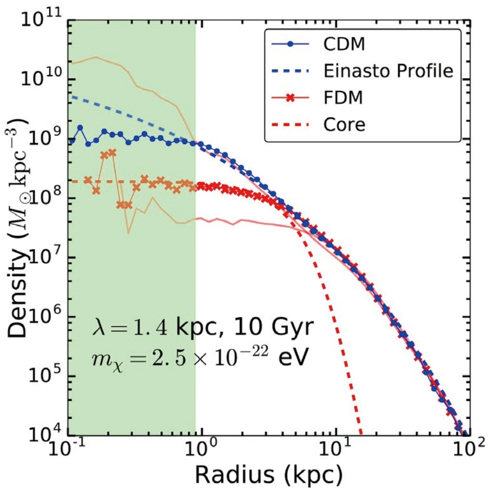

Fig. 1 *Density profiles for CDM and FDM after 10 Gyr.*

In Fig.2, we show the simulation results that at large scale we do not see the difference between CDM and FDM (upper panels), but as we close in to a halo size we can see that the FDM gives a more fuzzy structure (lower panels). Though these are simply toy simulations, it points to the right direction that the FDM can indeed solve the cusp-core problem, thus may solve the other small-scale problems too.

[1] J. Zhang, K. Cheung, J.-L Kuo,Y.-L. Tsai, M.-C. Chu, Astrophys.J. 853 (2018) no.1, 51.

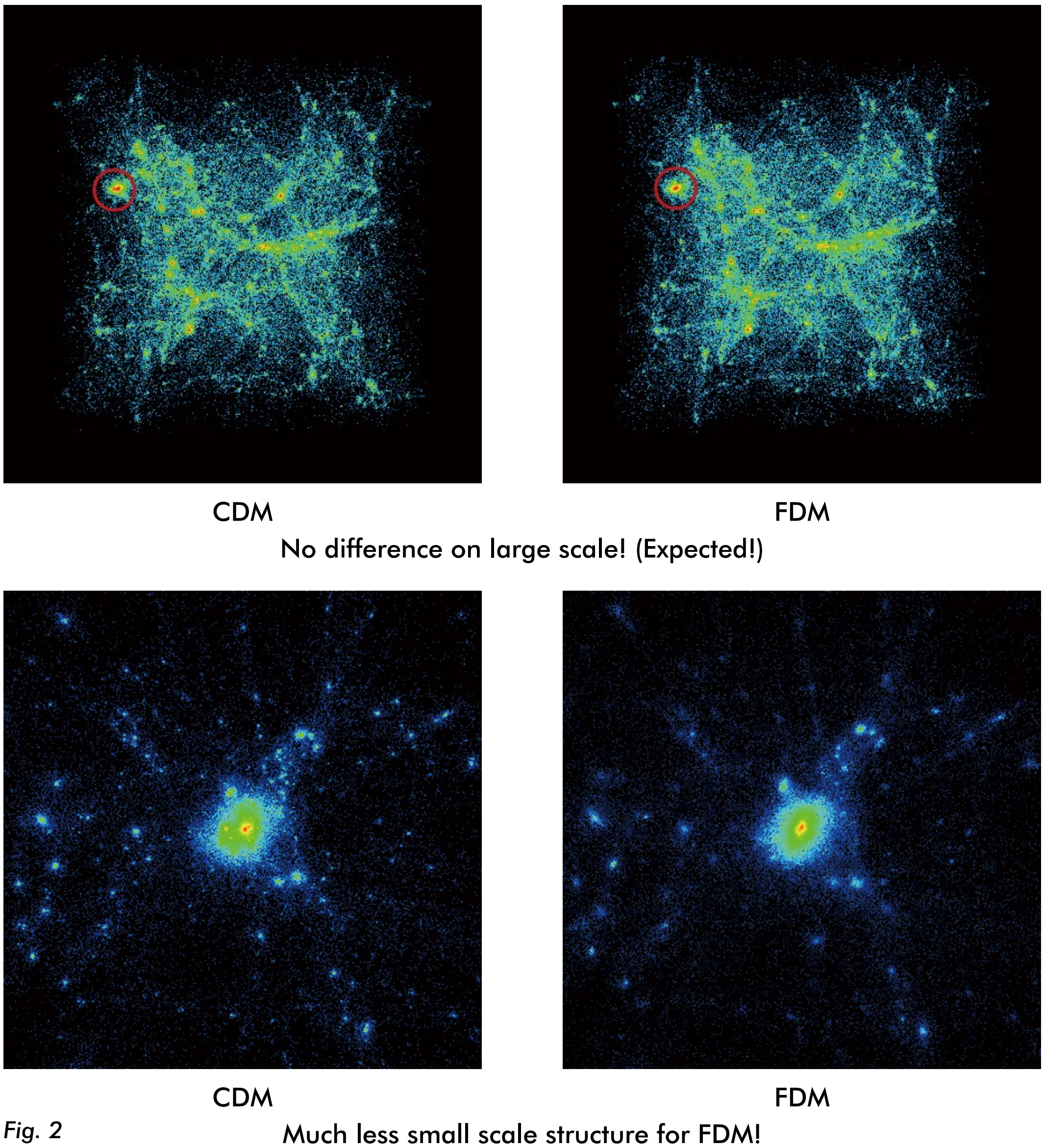

Fig. 2

Boundary Conformal Field Theory

Professor
Chong-Sun Chu
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National Tsing Hua University
Particle Physics

This year I have worked on holographic models of boundary conformal field theory (BCFT). In particular our group have made advances in the subject and proposed consistent models of holographic BCFT that worked for general shape of boundary. In addition, we have also constructed the adiabatic regularization scheme for gauge fields, completing the program 40 years after Parker and Fulling invented the scheme for scalar field theory in curved background.

Holographic BCFT (Boundary Conformal Field Theory)

BQFTs/BCFTs describe physical systems with boundaries. In recent years, the field of BCFTs has developed rapidly. In addition to traditional field theory techniques, holographic models of BCFTs have been developed which allow for non-perturbative analysis of the boundary systems. Holographic dual of BCFT was originally introduced by Takayanagi [1] by considering a Neumann boundary condition in the bulk dual manifold. The proposal has been applied to geometrical shape of boundaries with high symmetry such as the case of a disk or half plane, and produces many elegant results for BCFT. However the tensor type embedding equations of the proposal contain too many constraints in general and cannot be solved consistently for general shape of boundary. The difficulty was analyzed in [2,3]] and a consistent model of holographic BCFT was found by replacing the tensor type embedding equation by a scalar type embedding equation. More recently we found that [4] the original set of tensor embedding equations can also be consistent if one is to allow for a non-FG expansion of the metric in the bulk.

Our proposal [2-4] can apply to general boundaries and agrees with the previous proposal of Takayanagai for the special case of a disk and half plane. Using the new proposal of AdS/BCFT, we have successfully obtained the expected boundary Weyl anomaly. The obtained boundary central charges satisfy a c-like theorem holographically. We have also investigated the holographic entanglement entropy of BCFT and find that the minimal surface must be normal to the bulk spacetime boundaries when they intersect. Interestingly, the entanglement entropy depends on the boundary conditions of BCFT and the distance to the boundary. The entanglement wedge has an interesting phase transition which is important for the self-consistency of AdS/BCFT.

Casimir Effects and Exact Relations in BCFT

The Casimir effect originates from the effect of boundary on the zero point energy-momentum of quantized fields in a system. As a fundamental property of the quantum vacuum, it has important consequences on the system of concern and has been applied to a wide range of physical problems, such as classic applications in the study of the Casimir force between conducting plates (and nano devices), dynamical compactification of extra dimensions in string theory, candidate of cosmological constant and dark energy, as well as dynamical Casimir effect and its applications. In [4], we reveal elegant relations between the shape dependence of the Casimir effects and Weyl anomaly in BCFT. We show that for any BCFT which has a description in terms of an effective action, the near boundary divergent behavior of the renormalized stress tensor is completely determined by the central charges of the theory. These relations are verified by free BCFTs. We test them with holographic models of BCFT and find exact agreement. We propose that these relations between Casimir coefficients and central charges hold for any BCFT. With the holographic models, we reproduce not only the precise form of the near boundary divergent behavior of the stress tensor, but also the surface counter term that is needed to make the total energy finite. As they are proportional to the central charges, the near boundary divergence of the stress tensor must be physical and cannot be dropped by further artificial renormalization. Our results thus provide affirmative support on the physical nature of the divergent energy density near the boundary, whose reality has been a long- standing controversy in the literature.

It is worth emphasising that as long as we can checked, so far the scalar-type holographic model [2,3] and the tensor type holographic model [1,4] have yield exactly the same results for the Weyl anomaly as well as for the universal relations between the generalized Casimir coeffcients and the central charges. All evidences indicate that the two proposals of holographic models are both consistent and correspond to two different kinds of BCFT.

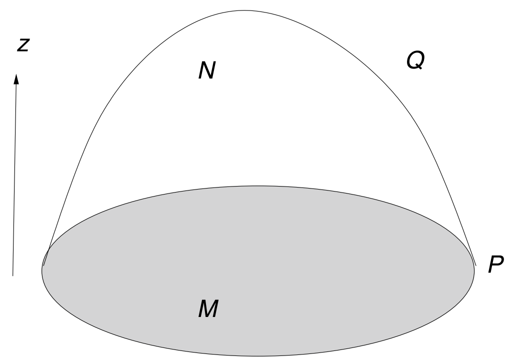

Fig. 1 *BCFT on M and its dual N*

Adiabatic regularization scheme for gauge field

In general, the study of dynamics of quantum field theory in curved spacetime is not only relevant for the understanding of a number of important physical problems such as inflation or Hawking radiation, to name a few, it is also rather challenging. Various methods have been developed to regularize the UV divergence for QFT in curved spacetime. These includes, for example, the Dewitt-Schwinger geodesic point splitting method, zeta-function regularization and the adiabatic regularization method. Among these, adiabatic regularization is systematic and particularly useful for doing perturbative computation of QFT in curved spacetime. To our surprise, even after almost 40 years since Parker and Fulling invented the adiabatic regularization scheme for scalar fields, progress in this field has been slow and adiabatic scheme for spin half field were only constructed in 2014, and adiabatic scheme for gauge field is absent. In our paper [5], we filled the gap by constructing the adiabatic regulariation scheme for gauge field in a conformally flat spacetime. The availability of the adiabatic expansion scheme for gauge field allows one to study the renormalization of the de-Sitter space N=4 maximal superconformal Yang-Mills theory using the adiabatic regularization method. Further investigation is under progress

References

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RESEARCH

Exotic Phases of Matter in Oxides and their Interfaces

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Transition metal oxides span a wide range of crystalline structures and host a rich variety of fascinating phenomena and extraordinary phases. The best known examples are high temperature superconductivity in cuprates and colossal magnetoresistance in manganites. We recently studied a new phase of hybrid improper ferroelectrics (HIF), which is distinguished from conventional ferroelectrics by the coexistence of head-to-head and tail-to-tail domains, of which the domain walls shall be charged due to respective screening electrons and holes. However, a given material is eligible for only one type of charges, rendering the microscopic screening mechanism at the nominally charged domain walls mysterious. Using macroscopic group-theoretical analysis and *ab* initio density functional calculations of electronic and phononic band structures as well as atomic-resolution structural, electronic characterizations by electron microscopy and spectroscopy, we demonstrated the existence of a hidden antipolar order parameter in model HIF $(Ca_{2.5}Sr_{0.5})Ti_2O_7$ due to the condensation of a weak, previously unnoticed antipolar lattice instability, turning the order-parameter spaces to be multicomponent, with the distinct polar-antipolar interwining and accompanied formation of Neel-type antipolar domain walls between the head-to-head and tail-to-tail domains [1]. This polar-antipolar domain topology also sheds light on the ferroelectric switching by providing a distinct twin-assisted pathway.

Magnetite (Fe_3O_4), the first known magnetic mineral, has fascinated mankind for centuries because of its fascinating properties. In particular, it undergoes a metal-insulator (M-I) phase transition at around 120 K with an abrupt change in structure and electrical conductivity. This M-I (Verwey) transition, however, still leaves us with intriguing puzzles, although its principal driving force was attributed to a nontrivial charge-orbital ordering of Fe t_{2g}-orbitals on the Fe^{2+} octahedral sites which was discovered through ab initio density functional calculations[2]. Here we used resonant inelastic X-ray scattering over a wide temperature range across the Verwey transition as well as theoretical modelling and *ab initio* calculations to identify and separate out the magnetic excitations derived from nominal Fe^{2+} and Fe^{3+} states [3]. Comparison of the experimental results with crystal-field multiplet calculations shows that the spin–orbital d-d excitons of the Fe^{2+} sites arise from a tetragonal Jahn-Teller active polaronic distortion of the Fe^{2+} O_6 octahedra. These low-energy excitations, which get weakened for temperatures above 350 K but persist at least up to 550 K, are distinct from optical excitations and are best explained as magnetic polarons [3].

Hetero-structures of transition metal oxides offer the prospect of greatly enhancing the aforementioned bulk properties or of combining them to realize totally new properties and thus give rise to novel device functionalities. An excellent example is the conductive interface between two insulating nonferroelectric oxides $SrTiO_3$ and $LaAlO_3$ discovered in 2004 (see [4] and references therein). This fuels the modern quest of electronics based on correlated electrons in oxides and collective characteristics of superconductivity and ferromagnetism. Despite a decade of extensive research efforts on the problem, however, the mechanism for the formation of the conductive interface remained unresolved. Using electron spectroscopy with unparalleled charge-counting capability and structural analyses as well as *ab initio* calculations of the electron and phonon band structures, we recently uncovered surprising ferroelectric-like lattice instabilities near the interface by lattice mismatch strain and thus established the metallic interface as due to the two-dimensional (2D) electron-gas formation for screening these head-to-head electric polarizations near the interface [4].

The quantum anomalous Hall (QAH) phase is a bulk 2D ferromagnetic insulator with a nonzero Chern number in the presence of spin-orbit coupling (SOC) but in the absence of applied magnetic fields. Associated metallic chiral edge states host dissipationless current transport in electronic devices and thus promise great applications in low-power-consumption electronic and spintronic devices. This intriguing QAH phase has recently been observed in the Cr-doped topological insulator $(Bi,Sb)_2Te_3$ (see [5-6] and references therein). Nevertheless, the QAH phase appears at extremely low temperatures due to the small band gap, weak magnetic coupling and low carrier mobility. This hinders further exploration of the exotic properties of the QAH phase and its applications. The problems of the weak magnetic coupling and small band gap could be overcome by adopting 4d and 5d transition metal atoms which simultaneously have more extended d-orbitals and stronger SOC. Therefore, through ab initio density functional calculations, we recently made a systematic search for high-temperature QAH phases in bulk *4d* and *5d* transition metal oxides and their bilayer superlattices. Indeed we discovered that layered rhodium oxide $K_{0.5}RhO_2$ in the noncoplanar antiferromagnetic state is an QAH insulator with a large band gap and a Néel temperature of a few tens of Kelvins [5]. Furthermore, this QAH phase is revealed to be unconventional and also an exotic quantum topological Hall effect caused by nonzero scalar spin chirality due to the topological spin structure in the system and without the need of net magnetization and SOC. We also found that due to quantum confinement, the (111) $(ABO_3)_2/(AB'O_3)_{10}$ (B = Ru, Rh, Ag, Re, Os, Ir, Au; $AB'O_3$ = $LaAlO_3$, $SrTiO_3$) superlattices are ferromagnetic with ordering temperatures up to room temperature [6]. In particular, bilayer $(LaOsO_3)_2$ is a rare spin-polarized QAH insulator, while the other ferromagnetic bilayers are metallic with a large Hall conductance comparable to the conductance quantum. Furthermore, bilayers $(LaRuO_3)_2$ and $(SrRhO_3)_2$ are half-metallic, while bilayer $(SrIrO_3)_2$ exhibits peculiar colossal magnetic anisotropy. All these findings thus show that layered *4d* and *5d* metal oxides and their heterostructures are a class of quasi-2D materials for exploring exotic phases and also for advanced applications such as low-power nanoelectronics and oxide spintronics.

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RESEARCH

Flavor, Collider and Cosmology Studies Beyond Standard Model

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The aim of this NCTS research team on Flavor, *Collider and Cosmology Studies Beyond Standard Model* is to carry out forefront research in particle physics, particularly in the areas: 1) Beyond SM and Flavor Physics; 2) Beyond SM and Collider Physics; and 3) Beyond SM and Dark Matter and Dark Energy. Since the execution of this project in June 2015, we have vigorously carried out research in related fields and also organized activities accordingly.

The current team members directly hired by NCTS in different capacities include Professor Xiao-Gang He as a NCTS Distinguished Center Scientist, Dr. Jusak Tandean as a research fellow, and Dr. Xingbo Yuan as a postdoc. Several postdocs and students from NTU actively participate in related activities. We invited about 20 international visitors to come to Taiwan for visit and collaborations in 2017. With NCTS and NTU supports, we have obtained substantial progresses in research projects in 2017.

We have organized a weekly Journal Club on Particle Physics (Seminar type) every Monday during semesters at NTU. We have also organized a new journal club aiming introduce new papers of interesting to our group members.

To gather momentum in research fields related to our team, we started a Frontier in Particle Physics conference series from 2016. In 2017, the topics was on Energy Frontier in Particle Physics: LHC and Future Colliders, held from 29 to 30 of September 2017. The aim of this workshop is to bring together experts on physics at the energy frontier from around the world to discuss the latest theoretical developments and experimental findings and their implications. The meeting also addressed how future colliders can help us understand better physics at the TeV regime. We invited 9 international and more than 17 domestic researchers to give talks on related areas. About 60 participants attended the meeting.

In 2017, we carried out research with emphasis on flavor physics and CP violation in B, Higgs physics and Dark Matter physics. We published 11 papers in SCI journals and another paper written in Nov. 2017 on indirect dark matter search from DAMPE e+e- cosmic ray detection has recently been published (Phys. Lett. B778, 292, 2018). In 2017, team members have been invited 10 times to present talks at various international conferences. We have made considerable progresses in related areas. In the following we describe a few results obtained for illustration.

Studies of Anomalies in B Meson Decays

In April 2017, the LHCb showed that there is an anomaly in B to K* mu mu decay, a deficit compared with SM prediction. Together with previous anomalies observed by Belle, Babar and LHCb, in B to $D^{(*)}$ tau nu, and in several b to s mu mu induced processes, such as B to K mu mu, phi mu mu and etc., these provide hints for new physics beyond SM at about 4sigma level. There are far reaching implications. We have engaged in active research in related areas as early as 2013. In 2017, we wrote 5 research papers, Eur. Phys. J. C77, 134(2017), Phys. Rev. D96, 035032(2017), Phys. Rev. D96, 115022(2017), arXiv: 1706.07570 (accepted for publication in Phys. Lett. B), arXiv 1711.09525 on related subject providing solutions to the anomalies fro various beyond SM physics models.

We have been invited to give talks at several international conferences, such as XIth International Conference of Interconnections between Particle Physics and Cosmology (PPC2017), and 26th International Workshop on Weak Interactions and Neutrinos (WIN 2017). One of our papers published in 2017 on B anomalies was selected as a highly cited paper by Essential Science Indicators.

Dark Matter Studies

In 2017, our team put a lot of research time in dark matter (DM) studies. We have written 5 papers on dark matter physics with 4 of them published. In a series of papers published in 2017, *JHEP* 04 (2017) 107; JHEP12 (2016) 074 and Phys. Rev. D96, 075026(2017). The most recent direct search for DM by the LUX and PandaX-II Collaborations, along with the latest LHC data on the 125-GeV Higgs boson, have led to very stringent constraints on the simplest Higgs-portal weakly interacting massive particle (WIMP) DM models. Specifically, that only a narrow mass range around the Higgs pole is still viable if the DM has spin 1/2 or 3/2 and a purely scalar effective coupling to the Higgs. Moreover, if the DM is a real singlet vector (scalar) particle, we determine in these papers that its mass has to be also close to the Higgs pole or exceed roughly 1.4 (0.5) TeV or a small region around the Higgs resonant region with DM mass about half of the Higgs mass. However, we show that in the two-Higgs-doublet extension of each of the preceding models, with a Yukawa sector arranged to be that of the two-Higgs-doublet model of type II, substantial portions of the DM mass regions ruled out in the simplest scenario by direct search bounds can be reclaimed due to suppression of the effective DM interactions with nucleons at some ratios of the *CP*-even Higgs bosons' couplings to the up and down quarks.

In Nov. 2017, the DAMPE collaborations announced their new results on possible indirect dark matter from cosmic electron-positron spectrum indicating the possibility of an electrophilic dark matter with a mass about 1.4 TeV. We quickly reacted with new data and proposed our new beyond SM explanations and predictions in two papers: Electrophilic dark matter with dark photon: from DAMPE to direct detection (Phys. Lett. B778, 292(2018)) and Leptophilic dark matter in gauged $U(1)_{Le-Lm}$ model in light of DAMPE cosmic ray e+e- excess (arXive:1711.11563). These papers were well received by peers and have been cited 28 and 20 times each.

RESEARCH

Higgs Boson and Beyond

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National Taiwan University
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Three of the works that I published in 2017 were related to Higgs boson, particularly its physics beyond the Standard Model (SM) and beyond tree level.

I. Phys. Lett. B774 (2017) 119-122

This work was done in collaboration with An-Li Kuo and Kei Yagyu. This was part of our program to perform a full 1-loop renormalization for the Georgi-Machacek (GM) model. In this work, we calculated 1-loop radiative corrections to the hZZ and hWW couplings in models with next-to-simplest Higgs sectors satisfying the electroweak $\rho = 1$ at tree level: the real Higgs singlet model ($rHSM$), the two-Higgs doublet models ($2HDM$), and the GM model. Under theoretical and current experimental constraints, the three models had different correlations between the deviations in the hZZ and hWW couplings from the SM predictions. In particular, we found for each model predictions with no significant overlap with the other two models, as shown in the following plot.

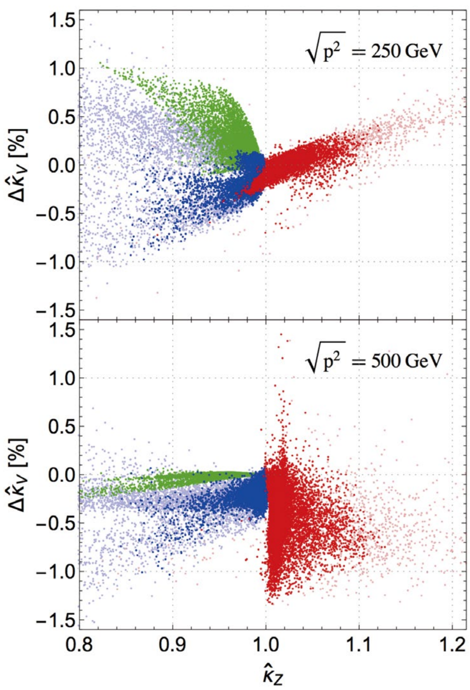

Fig. 1 *Correlation between κ_Z and $\Delta\kappa_V$ for p^2 = 250 GeV (upper plot) and 500 GeV (lower plot) in the rHSM (green), Type-I 2HDM (blue) and GM model (red).*

II. Phys. Lett. B774 (2017) 489-493

This work was done in collaboration with Eibun Senaha. We studied gauge dependence of gravitational waves produced from a first-order phase transition in classical scale-invariant U(1)′ models. Accidental gauge independence of the one-loop effective potential in this class of models was spoiled by including thermal resummation. The gauge artifact in the resummed effective potential propagated to the gravitational wave (GW) spectrum and resulted in one order of magnitude uncertainties in the prediction under a specific gauge choice, as shown in the following plot.

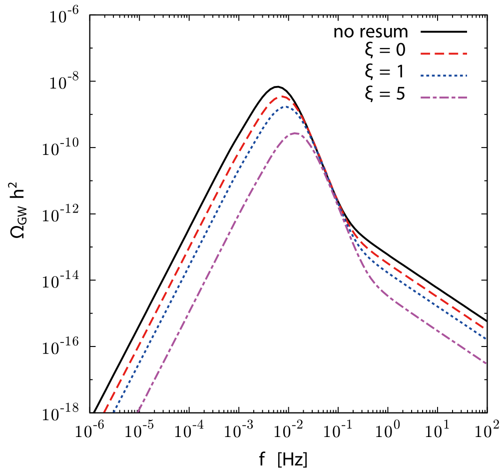

Fig. 2 *GW power spectrum as a function of frequency. The black-solid curve represents the unresummed (ξ-indep.) case. The resummed case with $\xi = 0$, 1 and 5 are marked as red-dashed, blue-dotted and magenta-dot-dashed lines, respectively.*

III. Phys. Rev. D97 (2018) no.1, 015005

This work was done in collaboration with Michael Ramsey-Musolf and Eibun Senaha over many years. We analyzed the theoretical and phenomenological considerations for the electroweak phase transition and dark matter in an extension of the Standard Model with a complex scalar singlet (cxSM). In contrast with earlier studies, we used a renormalization group (RG) improved scalar potential and treated its thermal history in a gauge-invariant (GI) manner. The RG improvement effect can be seen in the following plot.

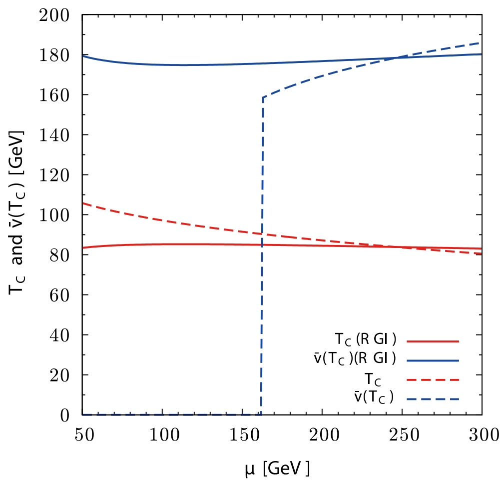

Fig. 3 *Renormalization scale dependence of TC and vC in one scheme. The dashed curves are calculated based on the GI scheme to $O(\hbar)$ while the solid ones are the RG-improved version.*

We found that the parameter space consistent with a strong first order electroweak phase transition (SFOEWPT) and present dark matter phenomenological constraints was significantly restricted compared to results of a conventional, gauge non-invariant analysis. In the simplest variant of the cxSM, recent LUX data and a SFOEWPT required a dark matter mass close to half the mass of the SM-like Higgs boson. We also commented on various caveats regarding the perturbative treatment of the phase transition dynamics.

Novel Electronic Structures of Topological Materials and Heterostructures

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National Tsing Hua Unviersity
Atomic, Molecular & Optical Physics

Newtype large Rashba splitting in quantum well states induced by spin chirality in metal/topological insulator heterostructures

To fulfill the large Rashba-type splitting in the QWSs of metallic thin films on the nonmetallic substrate, we propose a new physical source: the spin chirality at the boundary of a topological insulator (TI). The TI is a newly discovered phase of matter in which the chiral conducting channels, namely, the SOC caused spin-momentum-locked SSs, form at the boundaries of the bulk insulators, and are protected by the time-reversal symmetry. For the heterostructure: normalmetal (NM)/TI, or equivalently NM/semiconductor with a chiral spin texture surface state, the SOC in TI plays the role as the orbital-dependent magnetic field in an insulator and allows NM QWS with the same spin and chirality as the TI SS to penetrate deeper than those with opposite spin and chirality. As a consequence of the spin-momentum-dependent penetration depth and trapping width, the Rashba type splittings arise in the NM QWSs. In this work we propose a newtype large Rashba splitting in the NM-QWSs induced by the TI-SSs spin-chirality at the NM/TI interface by the combined analytical method

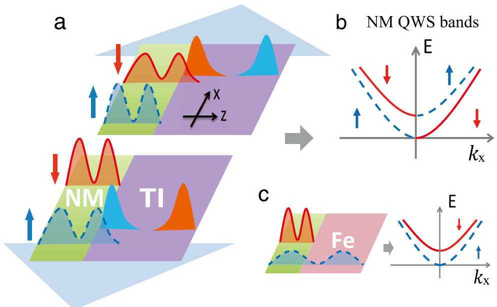


Fig. 1 *The spin-chirality-induced Rashba-type splitting in the NM-TI junction. a, At the interface, the spin up (blue filled curve) and down (red filled curve) chiral TI edge states move in negative and positive x directions, respectively. The spin up (blue dashed curve) and down (red solid curve) NM QWS moving respectively along −x and +x directions penetrate deeply into the TI and lower down the band energies (see panel b). c, A reference case of the effective Zeeman type splitting induced by a ferromagnetic layer.*

and first principle calculations. We demonstrate the momentum separation of the Rashba-like splitting in Ag/Bi_2Se_3 junction is the largest one among the previously reported values for non-metallic-substrate systems. Moreover, the spin polarization of the splitting QWS could be nearly 100% which is much higher than the typical value of 40 ~ 50% in the Dirac bands of TI such as Bi_2Se_3. Both properties are ideal for realizing the spintronic devices in the nano-scale. We note that to achieve the main goal of this work, the interaction between the NM QWSs and the TI SSs, we use the model system: Ag/Bi_2Se_3 to demonstrate the spin splitting in Ag-QWSs induced by the Bi_2Se_3-SS. From the theoretical viewpoint, the 4d transition metal Ag film with weaker spin-orbit coupling (SOC) helps to clarify whether the SOC in the NM film or the interaction with the TI-SS is the main driving force of the large Rashba splitting in the QWS. Practically all kinds of NMs and TIs are possible to fulfill the NM/TI heterostructure and the Rashba splitting in future experiments. Heavy elements such as Au with strong SOC could be intuitively an even better candidate. (Nature Asia Materials 8, e332; doi:10.1038/am.2016.173 (2016))

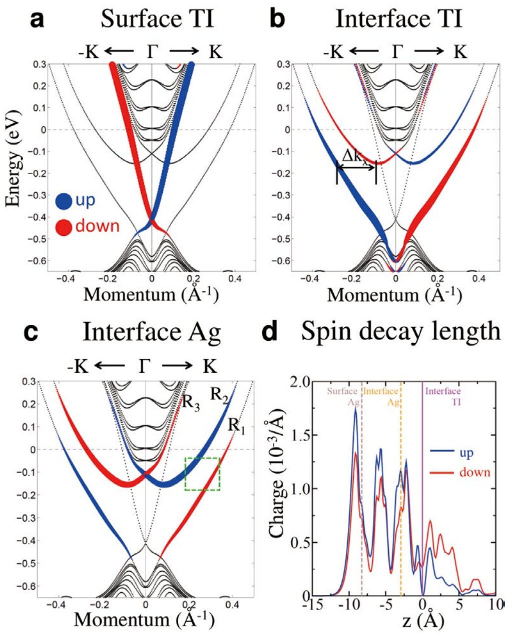


Fig. 2 *Site-spin-decomposed band structure of Ag(5ML)/Bi_2Se_3(6QL). a,b, In-plane spin polarization <Sx,y> of Bi2Se3 surface state at the surface (a) and at the interface (b). (c) In-plane spin polarization <Sx,y> of Ag-QWS at the interface Ag. Blue and red dots indicate spin-up and spin-down components, respectively. R1, R2 indicates outer and inner Rashba band, respectively.(d) Spin penetration depth of Rashba-splitting band (green dash box in the panel c).*

Wide-range ideal 2D Rashba electron gas with large spin splitting in Bi_2Se_3/$MoTe_2$ heterostructure

A pure two-dimensional (2D) Rashba electron gas (REG), i.e., nearly all the conduction electrons occupy the Rashba bands (RBs), is crucial for semiconductor spintronic applications. Wedemonstrate that a pure 2D REG with a large Rashba splitting can be realized in a topologicalinsulator (TI) Bi_2Se_3 ultra film grown on a transition metal dichalcogenides (TMD) $MoTe_2$ substrate through first-principle calculations. Our results show the RBs exclusively over a very large energy interval of about 0:6 eV around the Fermi level within the $MoTe_2$ semiconductinggap. Such a wide-range pure 2D REG with a large spin splitting, which is ideal for real devicesutilizing the Rashba effect, has never been found before. Due to the strong spin-orbit coupling, thestrength of the Rashba splitting is comparable with that of the heavy-metal surfaces such as Au andBi surfaces, giving rise to a spin precession length as small as ~10 nm. The maximum in-plane spinpolarization of the inner (outer) RB near the G point is about 70% (60%). The room-temperaturecoherence length is at least several times longer than the spin precession length, providing good coherency through the spin processing devices. The wide energy window for pure RBs, small spinprecession length, as well as long spin coherence length in this 2D TI/TMD heterostructure pavethe way for realizing an ultrathin nano-scale spintronic device such as the Datta-Das spin transistor at room-temperature. (Nature Computational Materials 3:5 ; doi:10.1038/ s41524-017-0011-5 (2017))

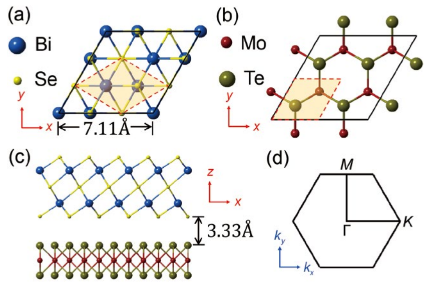


Fig. 1 *The optimized lattice of the 1QL-Bi_2Se_3/1TL-$MoTe_2$ heterostructure. (a) Top view of the Bi_2Se_3 part. (b) Top view of the MoTe2 part. (c) Side view of the whole system. The supercell used in the calculations is denoted in (a) and (b) by the black solid line, in which the Bi_2Se_3-(root 3xroot 3) R30/MoTe2-(2x2) system is incorporated. The shaded regions in (a) and (b) denote, respectively, the Bi_2Se_3 and the MoTe2 1x1 unit cell. The corresponding Brillouin zone is shown in (d).*

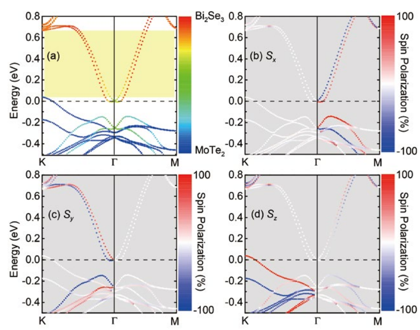
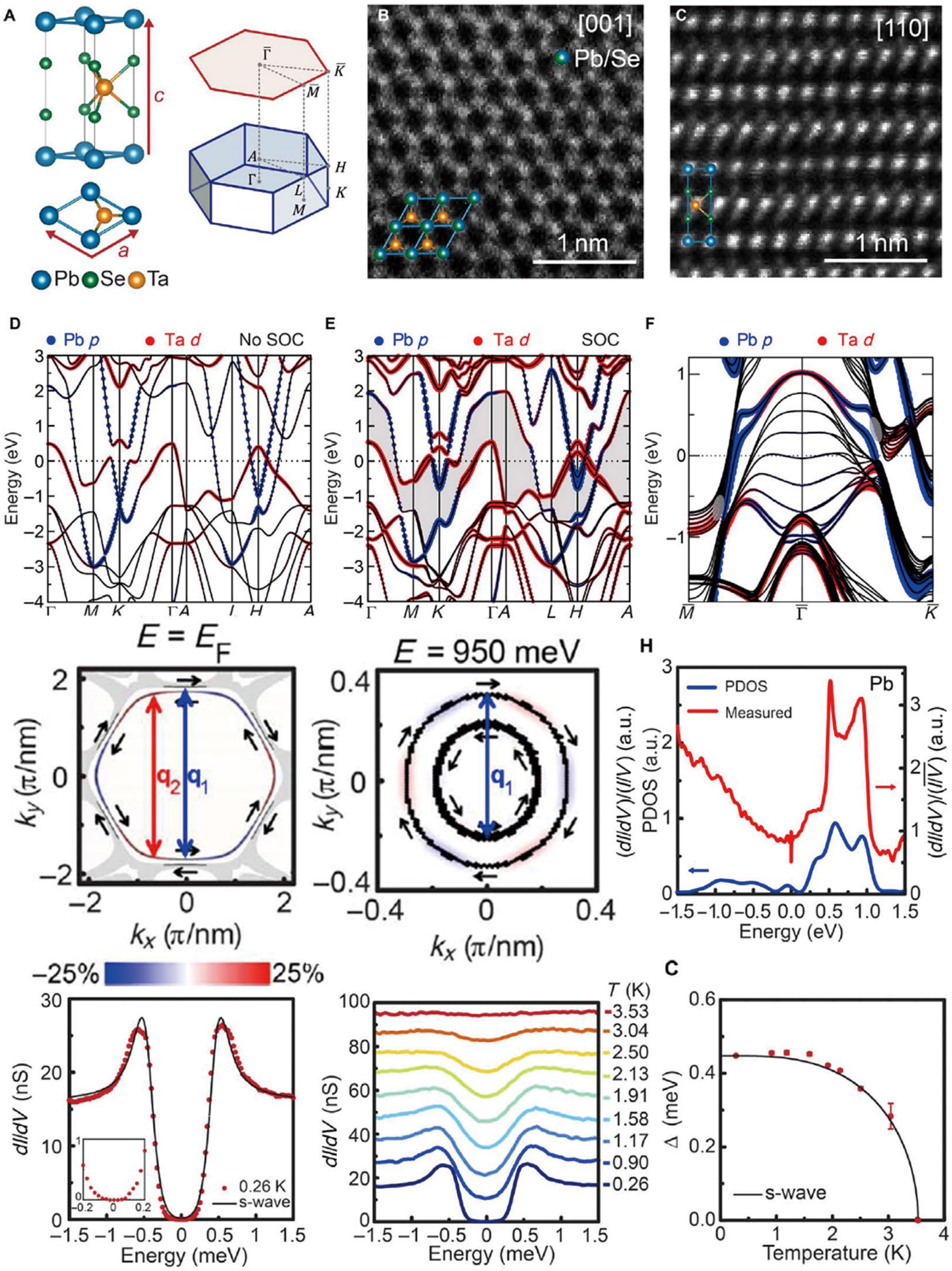


Fig. 2 *Electronic structures of the 1QL-Bi_2Se_3/1TL-$MoTe_2$ junction, where (a) the Bi_2Se_3 and the $MoTe_2$ components, (b-d) spin polarization along the x, y and z directions are represented by the color of the dots. The yellow-shaded region in (a) indicates the energy window (over 0.6 eV) for pure Rashbabands without any other electronic states.*

Superconducting topological surface states in the noncentrosymmetric bulk superconductor PbTaSe2

In collaboration with Dr. Tien-Ming Chuang of the Institute of Physics, Academia Sinica, we discovered the superconducting topological surface states in a layered material, PbTaSe2. Our findings provide a great platform for the study of topological superconductivity toward the future application for the fault-tolerant quantum computing. These breakthrough results were published in the high-impact journal Science Advances in 2016.

When a topological insulators (TI) combined with superconductivity, it can lead to another important class of materials: topological superconductors (TSCs). TSCs are characterized by a full superconducting gap in the bulk and topologically protected gapless surface states. In a TSC, Majorana fermion, a hypothetical particle is its own anti-particle, is bound to a topological defect such as a superconducting vortex. Such combined objects are predicted to exhibit non-Abelian statistics and to form the basis of the faulttolerant quantum computation. The simplest way to introduce superconductivity in a TI is by making it superconducting by doping or by coating a layer of s-wave superconductor. However, both approaches are technically challenging because it is difficult to make a homogenous doped material or a heterostructure with a clean interface. A better way is to find a stoichiometric material that exhibits topological surface states at Fermi level combined with fully gapped bulk superconductivity below TC. So far, no such a bulk material is reported. Prof. Horng-Tay Jeng's group from NTHU found such requirements for a TSC are satisfied in a layered material PbTaSe2 using density functional theory. By visualizing the electron wavefunction at atomic scale using scanning tunneling microscopes, PhD student Syu-You Guan from NTU, Dr. Chia-Seng Chang and Dr. Tien-Ming Chuang from AS confirm the spectroscopic signature of the calculated topological band structures and superconducting properties in PbTaSe2. The fully gapped superconducting topological surface state is reported for the first time in a stoichiometric bulk material. Our work shows PbTaSe2 is a promising TSC candidate.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Holographic QCD

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We constructed a bottom-up holographic QCD model to study the various properties in QCD using gauge/gravity correspondence. We solved the gravity system coupled to a U(1) gauge field and a neutral scalar in five-dimensional space-time, i.e., a five-dimensional Einstein-Maxwell-scalar system, and obtained a general class of analytic black hole solutions. The meson spectrum in our model satisfies the linear Regge behavior. We obtained the phase structure of the black hole background by studying its thermodynamic quantities.

To realize the confinement-deconfinement phase transition in QCD, we added probe open strings in the black hole background and studied the shape of their stable configurations. Different U-shaped and I-shaped configurations were identified for confinement and deconfinement phases, respectively. We found that there exists a dynamical wall, which the strings cannot pass, for a small enough black hole. The appearance/disappearance of the dynamic wall implies the confinement-deconfinement phase transition. By combining the phase structure of the black hole background and the U-shaped to I-shaped transformation of the open strings, we obtained the phase diagram of the confinement-deconfinement phase transition in our holographic QCD model [1], as shown in Fig.1. In our model, the critical point—where the first-order phase transition becomes a crossover—is predicted to be at (0.1043 GeV, 0.1538 GeV), which is consistent with the recent lattice QCD result. We also obtained the Cornell form of the quark potential by calculating the Wilson loop.

Furthermore, we studied the speed of sound in -dimensional QCD. We show that there are several universal bounds for the speed of sound in QCD from holographic correspondence. In addition to the well-known upper bound in the conformal limit, we reveal two more universal quantities: in the low temperature limit and in the large chemical potential limit [2], as shown in Fig.2.

The magnetic field can be introduced into the background geometry by embedding the magnetized background geometry into the holographic QCD model. The magnetic field dependent behavior of chiral condensate is worked out numerically. It is found that, in the chiral limit, the chiral phase transition remains as a second order at finite magnetic field B , while the symmetry restoration temperature and chiral condensate decrease with the increasing of magnetic field in small B region. When including finite quark mass effect, the phase transition turns to be a crossover one, and the transition temperature still decreases with increasing magnetic field B when B is not very large. In this sense, inverse magnetic catalysis effect is observed in our holographic QCD model [3].

[1] Meng-Wei Li, Yi Yang and Pei-Hung Yuan, "Approaching Confinement Structure for Light Quarks in a Holographic Soft Wall QCD Model", Phys. Rev. D96, (2017) 066013.

[2] Yi Yang and Pei-Hung Yuan, "Universal Behaviors of Speed of Sound from Holography", arXiv:1705.07587 (2017).

[3] Danning Li, Mei Huang, Yi Yang and Pei-Hung Yuan, "Inverse Magnetic Catalysis in the Soft-Wall Model of AdS/QCD", JHEP 02 (2017) 030.

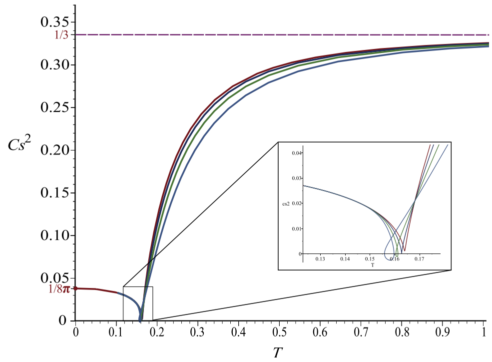


Fig. 1

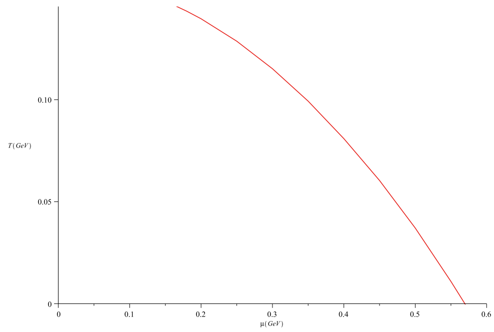


Fig. 2

Research Highlights of Postdocs

Md. Manirul Ali investigated the transient dynamics of photon statistics through two-time correlation functions for optical field coupled to a non-Markovian environment. They find that the transient correlation at different times yield a smooth transition from antibunching to bunching photon statistics in the weak system-environment coupling regime. For the strong system-environment coupling, they find an interesting nonequilibrium oscillatory behavior in the photon statistics that persists for an arbitrary initial temperature of the environment. The oscillatory behavior of photon statistics is a manifestation of strong non-Markovian memory dynamics where the system remains in nonequilibrium from its environment. [Phys. Rev. A95, 033830 (2017)]

Carlos Cardona works on scattering amplitude in QFT and strings. One of his most important results as a member of NCTS are the generalization of some tree level to one-loop level by developing a graphical algorithm that encode the information coming from all possible Feynman diagrams in the theories considered.His results have appeared in JHEP 1708 (2017) 133 and arXiv:1708.06339

Chih-Piao Chuu cooperates extensively with experimentalists to study the novel 2D materials, as in his recent cooperated work "Janus monolayers of transition metal dichalcogenides" [NATURE 12, 744–749 (2017)], the existence of optically active vertical dipole in new 2D asymmetric transition metal dichalcogenide monolayers was confirmed with both experimental evidence and his theoretical calculations. This discovery provides a two-dimensional platform to study light–matter interactions where dipole orientation is critical, and an extra degree of freedom for nanoelectromechanical devices.

Wu-Zhong Guo mainly works on entanglement properties in the field theory. In the paper arXiv:1708.07268 he study the entanglement properties of boundary state and thermalization of this state, point out the possible relation. In paper arXiv:1708.09544 he and his collaborator construct a set of POVM operators in CFT and study the information task in field theory.

Dimitrios Giataganas, together with Chong-Sun Chu, has put forward a proposal for the holography of deSitter Space in terms of a string theory in Anti-deSitter space [Phys.Rev. D94 (2016) no.10, 106013]. They have also found novel properties and phase transition of field theories in deSitter space [Phys.Rev. D96 (2017) no.2, 026023]. More recently, Dimitrios has initiated with coauthors a non-perturbative study of non-conformal and confining gauge theories under strong external fields [arXiv:1708.05691], where among other findings his work sheds light on new properties of the inverse magnetic catalysis phenomenon.

Yoshinori Honma examined moduli stabilization of the F-theory compactified on an elliptically fibered Calabi-Yau fourfold. The setup was based on the mirror symmetry framework including brane deformations. The complex structure moduli dependence of the resulting 4D N=1 effective theory is determined by the associated fourfold period integrals. By turning on appropriate G-fluxes, he explicitly demonstrated that all the complex structure moduli fields can be stabilized around the large complex structure point of the F-theory fourfold. His result about F-theory compactifications is also useful to study the non-perturbative aspects of string compactification and its application to phenomenology and cosmology [arXiv:1706.09417].

Ya-Fen Hsu research interests mainly focused on Josephson effect in the context of exciton condensates and conductance anomalies in quantum point contacts. In the paper Fractional Solitons in Excitonic [Scientific Reports 5, Article number: 15796 (2015)], she found robust evidence for exciton condensation. She also showed that the quantum Hall bilayer can be mappedinto a pseudospin ferromagnet by treating layer degrees of freedom as pseudospins and therefore can be described by the Landau-Lifshitz-Gilbert (LLG) equation. In view of pseudospin conservation. She also showed that the variation of magnetic field due to Josephson currents in a ring-shaped excitonic Josephson junction and this can be regarded as an indirect detection of excitonic Josephson effect.

Bor-Luen Huang's work on the current response of a 3D topological insulator to a static Zeeman field [J. Phys.: Condens. Matter 28 (2016) 026002] shows that there is no change in the surface current by changing the occupancy of the surfaces states or applying a time-reversal symmetry-breaking terms near the boundary. From the relation between the current and the orbital magnetization, he found that magnetization is a bulk property, independent of the details at the boundaries of the sample. He also studies effects of crystal symmetry on the spin-texture of topological surface states.

Ching-Yu Huang studied the topological properties of spin polarized fermionic polar molecules loaded in a multi-layer structure with the electric dipole moment polarized to the normal direction by an external electric field. She and her cooperators find that when fermions are paired by attractive inter-layer interaction, unpaired Majorana Zero Modes (MZMs) can be macroscopically generated in the 2D surface layers, depending on the interlayer tunnelling amplitude and in-plane kinetic energy [arXiv:1707.06419v1 [cond-mat.quant-gas]].

Group picture of NCTS Postdocs

Guan-Rong Huang worked on the chemical master equation of gene regulation network insingle cell to find an accurate energy landscape function in explaining the state switching between different phenotypes, and collaborated with NSYSU on the analysis of heat transfer trying to find an optimized design of light emitting diode aluminum heat sink through coupled-equations of heat dissipation. His works in biophysics is recently reviewed by Phys. Rev. E(R) for publication and in computational materials science were published in Materials 10, 454 (2017). Currently, he is a visiting research assistant professor in Shull-Wollan center of National Oak Ridge Laboratory in United States, and has been working on the development of new data analysis for small-angle scattering spectra [Phys. Rev. E 96, 022612 (2017)].

Hiroyuki Ishida found a new source of the baryon asymmetry and the possibility of the late-time lepton asymmetry for the dark matter production which was thought as the lack of the model [Physics Letters B Volume 763, 10 December 2016, Pages 393-396]. He also found plausible origin of the inverse seesaw model built by the symmetry point of view [arXiv:1708.02355 [hep-ph]] and the interesting collider signatures to investigate a new particles with distinguishing from other similar models at the current and future hadron collider experiments were discussed.

Ioannis Kleftogiannis studied topologically ordered phases of matter using the Hubbard models with various strengths of interaction 1707.07840 [cond-mat.str-el], which has allowed him to study different many-body phases in the same model, like the superfluid and the Mott insulating phase. Kleftogiannis has also worked with Victor Gopar from the University of Zaragozain Spain on the quantum transport properties of disordered mesoscopic systems, including 2D-materials like graphene, topological insulators and quantum wires.

Yoji Koyama has developed and extended the adiabatic regularization method for computing quantum corrections to correlation functions of gauge fields in a conformally flat spacetime which has never been done in the literature [Phys. Rev. D 95, 065025 (2017)]. The results has arosed interests from expert such as Bei-Lok Hu and will be included in a forthcoming textbook on the subject.

Rong-Xin Miao expertise is in quantum information and holography. Together with Chong-Sun Chu, they resolved an important issue in the formulation of holographic principle for conformal field theory with boundary [Phys. Rev. D96 (2017) no.4, 046005; JHEP 1704 (2017) 089]. Their proposal has pass many tests and has resulted in new results for boundary Weyl anomaly and entanglemnt entropy. More recently, they have found universal relations between the Casimir coefficients and central charges of the boundary conformal field theory [arXiv:1706.09652 [hep-th]].

Martin Spinrath has worked on a new supersymmetric low scale seesaw model which avoids certain common ad-hoc assumptions in the literature [arXiv:1707.04374 [hep-ph]]. He has also studied the detection prospects for cosmic relics using mechanical force experiments. While the main focus of this publication lies on the Cosmic Neutrino Background such an experimental setup is also very interesting and promising for light dark matter searches [JCAP 06 (2017) 055].

Jusak Tandean has explored various scenarios beyond the standard model of particle physics, including models of dark matter and nonstandard flavor physics in both the quark and lepton sectors. His recent work [JHEP 1612 (2016) 074] deal with the implications of recent dark-matter direct detection experiments for a couple of the simplest dark-matter models which are currently among the most popular scenarios.

Yue-Lin Sming Tsai and collaborators examined crticially the properties of fuzzy dark matter (FDM) and find that the quantum pressure of FDM leads to further suppression of the matter power spectrum at small scales. They also found that the lyman-alpha forest constraints do not exclude the ultralight Fuzzy Dark Matter. Thus FDM is still a viable model that explain the small scale crisis of cold dark matter [arXiv:1708.04389 [astro-ph.CO].

Introduction of Research in Different Fields

Phenomenological Particle Physics

Particle physicists in Taiwan work on the frontier of intensity, favor and cosmology. Frequent collaboration occurs among the theorists as well as among the theorists and experimentalists. Some of the results obtained this year are described below.

Muon jet (J. Chang, K. Cheung, S.C. Hsu, C.T. Lu, Phys.Rev. D95 (2017)035012). A muon jet is a very special feature that consists of a cluster of collimated muons from the decay of a fast-moving light particle of mass about O(1 GeV). We use this feature to search for very light particles from rare decays of the Higgs boson. We use two simple models of the Higgs portal type to explore the possibilities of event topologies with two 2μ-jets, one 2μ-jet and one 4μ-jet, and two 4μ-jets in the final state at LHC-14. With the present capability of ATLAS detector, one may be able to detect such light particles down to about 0.3 GeV.

Ultralight axion dark matter and structure formation (J. Zhang, K. Cheung, Y.-L. Tsai, M.-C. Chu, arXiv: 1611.00892). The Ultra-Light Axion is a dark matter with mass $O(10^{-22}$ eV and de Broglie wavelength of order kpc, also known as the Fuzzy Dark Matter (FDM), thermalizes via gravitational force and forms a Bose-Einstein condensate. The quantum pressure from the FDM can significantly affect the structure formation in small scales, thus alleviating the so-called small-scale crisis. We develop a new technique to discretize the quantum pressure for FDM particles in the N-body sim- ulation. In a self-gravitationally-bound virialized halo, we find a constant density, solitonic core, thus, having the potential of solving the small-scale

Constraints on the Higgs portal dark models by the new LUX and PandaX-II results (JHEP 04 (2017) 107). Recent direct searches for DM by the LUX and PandaX-II Collaborations, along with the latest LHC data on the 125-GeV Higgs boson, have led to very stringent constraints on the simplest Higgs-portal weakly interacting massive particle (WIMP) DM models. Specifically, we find that only a narrow mass range around the Higgs pole is still viable if the DM has spin 1/2 or 3/2 and a purely scalar effective coupling to the Higgs. Moreover, if the DM is a real singlet vector particle, their paper shows that its mass has to be also close to the Higgs pole or exceed roughly 1.4 TeV. However, the paper also show that in the two-Higgs-doublet extension of each of the preceding models, with a Yukawa sector arranged to be that of the two-Higgs-doublet model of type II, substantial portions of the DM mass regions ruled out in the simplest scenario by direct search bounds can be reclaimed due to suppression of the effective DM interactions with nucleons at some ratios of the CP-even Higgs bosons couplings to the up and down quarks. The regained parameter space contains areas which can yield a DM-nucleon scattering cross-section that is far less than its current experimental limit or even goes below the neutrino-background floor. Alternatively, in the fermionic (spin 1/2 or 3/2) DM case, much of the excluded zone could also be recovered by adding to the minimal model an effective DM-Higgs pseudoscalar coupling.

Higgs boson pair productions in the Georgi-Machacek model at the LHC (JHEP 1703 (2017) 137). Higgs bosons pair production is well known for its sensitivity to probing the sign and size of Higgs boson self-coupling, providing a way to determine whether there is an extended Higgs sector. The Georgi-Machacek (GM) model extends the Standard Model (SM) with an $SU(2)_L$ triplet scalar field that has one real and one complex components. CS Cheng-Wei Chiang, TG1 coordinator Chuan-Ren Chen and NCTS postdoc Jung Chang have scanned in detail viable mass spectra of exotic Higgs bosons in the Georgi-Machacek model and the associated phenomenology at the LHC and a future hadron collider. They found that new heavy singlet Higgs boson can contribute to s-channel production of the *hh* pairs. Double Higgs production is a very important channel to probe the self-coupling of the Higgs boson, which has not been measured yet.

Signals of New Gauge Bosons in Gauged Two Higgs Doublet Model (arXiv:1708.02355). CS and TG1 coordinator T.C. Yuan, center research scholar Sming Tsai examined the phenomenology of a recently constructed gauged two Higgs doublets model and examined the collider signals of the heavy gauged bosons at the LHC and the future 100 TeV proton-proton collider. They also found that certain kinematical distributions for the two/four leptons plus missing energy signals have distinguishable features from the Standard Model background.

Constraints and Implications on Higgs FCNC Couplings from Precision Measurement of B decay (Phys.Rev. D96 (2017) no.3, 035032). CS Cheng-Wei Chiang, DCS X. G. He, F. Ye and center postdoc X. B. Yuan study constraints and implications of the recent LHCb measurement of the decay process $B_s \to \mu^+\mu^-$ for the tree-level Higgs-mediated flavor-changing neutral current (FCNC) interactions. They find that the Higgs FCNC couplings are severely constrained. This decay channel is one of the most important ones to identify the FCNC couplings and particles running in the loop level. And so it is very sensitive to new physics.

Observational constraints on successful model of quintessential Inflation (JCAP 1706 (2017) no.06, 011). TG2 coordinator and CS Chao-Qiang Geng, former NCTS Postdoc Chung-Chi Lee and their international collaborator Alexi Staroinsky investigated in details models of quintessential inflation in the light of the Planck 2015 results. Among other things, they found that the sum of neutrino masses is significantly enhanced as compared to that in the standard CDM model.

Group picture of Annual Theory Meeting 2017: Particles, Cosmology and Strings, Dec 5-8, 2017

Strings and Gravity

In NCTS, research in string and gravity theory is mainly conducted by DCS Chong-Sun Chu, CS Kazuo Hosomichi and Yi Yang, CS Chao-Qiang Geng and TG members Yutin Huang and Feng-Li Lin. Below we list some of the results obtained in this area of research.

Observational constraints on successful model of quintessential Inflation (JCAP 1706 (2017) no.06, 011). TG2 coordinator and CS Chao-Qiang Geng, former NCTS Postdoc Chung-Chi Lee and their international collaborator Alexi Staroinsky investigated in details models of quintessential inflation in the light of the Planck 2015 results. Among other things, they found that the sum of neutrino masses is significantly enhanced as compared to that in the standard CDM model.

Adiabatic regularization scheme for gauge field (Phys.Rev. D95 (2017) no.6, 065025). In general, the study of dynamics of quantum field theory in curved spacetime is not only relevant for the understanding of a number of important physical problems such as inflation or Hawking radiation, to name a few, it is also rather challenging. Various methods have been developed to regularize the UV divergence for QFT in curved spacetime. These includes, for example, the Dewitt-Schwinger geodesic point splitting method, zeta-function regularization and the adiabatic regularization method. Among these, adiabatic regularization is systematic and particularly useful for doing perturbative computation of QFT in curved spacetime. To our surprise, even after almost 40 years since Parker and Fulling invented the adiabatic regularization scheme for scalar fields, progress in this field has been slow and adiabatic scheme for spin half field were only constructed in 2014, and adiabatic scheme for gauge field is absent. In our paper [1], Chong-Sun Chu and Yoji Koyama

has constructed the adiabatic regulariation scheme for gauge field in a conformally flat spacetime. The availability of the adiabatic expansion scheme for gauge field allows one to study the renormalization of the de-Sitter space N=4 maximal superconformal Yang- Mills theory using the adiabatic regularization method. Further investigation ofis under progress.

Holographic BCFT (Boundary Conformal Field Theory)(Phys.Rev. D96 (2017) no.4, 046005, JHEP 1704 (2017) 089). BCFT has important applications in string theory and condensed matter physics. In the literature there is a proposal by Takayanagi on the holographic dual of BCFT. The proposal has been applied to geometrical shape of boundaries with high symmetry such as the case of a disk or half plane, and produces many elegant results for BCFT. However the proposal has an apparent shortage that it does not cover general shape of the BCFT boundary. In our papers [2,3] we propose an alternative holographic dual for BCFT. Our proposal can apply to general boundaries and agrees with the previous proposal of Takayanagai for the special case of a disk and half plane. Using the new proposal of AdS/BCFT, we successfully obtain the expected boundary Weyl anomaly and the obtained boundary central charges satisfy naturally a c-like theorem holographically. We also investigate the holographic entanglement entropy of BCFT and find that the minimal surface must be normal to the bulk spacetime boundaries when they intersect. Interestingly, the entanglement entropy depends on the boundary conditions of BCFT and the distance to the boundary. The entanglement wedge has an interesting phase transition which is important for the self-consistency of AdS/BCFT.

Casimir Effects and Exact Relations in BCFT (JHEP 1803 (2018) 046). The Casimir effect originates from the effect of boundary on the zero point energy-momentum of quantized fields in a system. As a fundamental property of the quantum vacuum, it has important consequences on the system of concern and has been applied to a wide range of physical problems, such as classic applications in the study of the Casimir force between conducting plates (and nano devices), dynamical compactification of extra dimensions in string theory, candidate of cosmological constant and dark energy, as well as dynamical Casimir effect and its applications. In [4], we reveal elegant relations between the shape dependence of the Casimir effects and Weyl anomaly in BCFT. We show that for any BCFT which has a description in terms of an effective action, the near boundary divergent behavior of the renormalized stress tensor is completely determined by the central charges of the theory. These relations are verified by free BCFTs. We test them with holographic models of BCFT and find exact agreement. We propose that these relations between Casimir coefficients and central charges hold for any BCFT. With the holographic models, we reproduce not only the precise form of the near boundary divergent behavior of the stress tensor, but also the surface counter term that is needed to make the total energy finite. As they are proportional to the central charges, the near boundary divergence of the stress tensor must be physical and cannot be dropped by further artificial renormalization. Our results thus provide affirmative support on the physical nature of the divergent energy density near the boundary, whose reality has been a long-standing controversy in the literature.

Scattering Amplitudes For All Masses and Spins (ArXiv:1709.04891 [hep-th]). TG3 cordinator Yutin Huang and collaborator Nima Arkani-Hamed etal introduced a new formalism for describing four-dimensional scattering amplitudes for particles of any mass and spin, extending naturally the familiar spinor-helicity formalism for massless particless. . Unitarity, in the form of consistent factorization, imposes algebraic conditions that can be used to construct all possible four-particle tree amplitudes. The Higgs and Super-Higgs mechanisms are naturally discovered as an infrared unification of many disparate helicity amplitudes into a smaller number of massive amplitudes, with a simple understanding for why this can't be extended to Higgsing for gravitons. "Off-shell" observables like correlation functions and form-factors can be thought of as scattering amplitudes with external "probe" particles of general mass and spin, so all these objects–amplitudes, form factors and correlators, can be studied from a common on-shell perspective.

AMO and QIS

Through the support of NCTS, both Atomic-Molecular-Optical (AMO) Physics and Quantum Information Sciences (QIS) have grown rapidly in recent years. Support is channelled through the operation of the Thematic Group on Quantum Gases (TG7) led by Center Scientist Ray-Kuang Lee (NTHU) and the Thematic Group on Quantum Information Science and Quantum Control (TG6) led by Center Scientist Yueh-nan Chen (NCKU). These groups work closely with the Experimental Collaborative Group on Quantum Optics and Quantum Manipulation of Ultracold Atoms (ECP1). Some of their researches are described below:

Work extraction and fully entangled fraction (Phys. Rev. A 96, 012107 (2017)). CS Ray-Kuang Lee and his collaborators prove that one can obtain work gain under Landauer's erasure process on one party in the identically and independently distributed limit when the corresponding fully entangled fraction is larger than 1. By processing a given state to the maximally mixed state, we give and approximation for the largest extractable work with an error in the energy scale, which becomes negligible in the large system limit. As a step to link quantum thermodynamics and quantum nonlocality, we also provide a simple picture to approximate the optimal work extraction and suggest a potential thermodynamic interpretation of the fully entangled fraction for isotropic states.

Setting a disordered password on a photonic memory (Phys. Rev. A 95, 061805R (2017). Core members of TG7 and ECP1, Shih-Chuan Gou, Ite A. Yu, and Wen-Te Liao have theoretically demonstrated a protocol using spatially disordered laser fields to encrypt data stored on an optical memory, namely, encrypted photonic memory. To address the broadband storage, they also investigate a scheme of disordered echo memory with a high fidelity approaching unity. The proposed method increases the difficulty for the eavesdropper to retrieve the stored photon without the preset password even when the randomized and stored photon state is nearly perfectly cloned. Their results pave ways to significantly reduce the exposure of memories, required for long-distance communication, to eavesdropping and therefore restrict the optimal attack on communication protocols. The present scheme also increases the sensitivity of detecting any eavesdropper and so raises the security level of photonic information technology.

Spatio-Temporal Steering for Testing Nonclassical Correlations in Quantum Networks (Sci. Rep. 7, 3728 (2017)). CS Yueh-nan Chen (CS and coordinator of TG6) and his international collaborators (Prof. Nori in Riken, Japan) introduced the concept of spatio-temporal steering (STS), which reduces, in special cases, to Einstein-Podolsky-Rosen steering and the recently-introduced temporal steering. They describe two measures of this effect referred to as the STS weight and robustness. They suggest that these STS measures enable a new way to assess nonclassical correlations in an open quantum network, such as excitation transfer in a complex biological system.

Plasmonic bio-sensing for the Fenna-Matthews-Olson complex (Sci. Rep. 7, 39720 (2017)). CS Yueh-nan Chen and his collaborators (Guang-Yin Chen, NCHU) study theoretically the bio-sensing capabilities of metal nanowire surface plasmons. The results provide a feasible way, using single photons, to detect mutation-induced, or bleaching- induced, local defects or modifications of the FMO complex. In particular, they find that the change of the Fano lineshape in the scattering spectra further reveals that site 5 in the FMO complex plays a distinct role from other sites. This theoretical prediction has been experimentally confirmed very recently.

Development of the framework to calculate the quantum noises in quantum memory (arXiv: 1703.09890). CS Ray-Kuang Lee and NCTS postdoc You-Ling Chuang have developed the framework to calculate the quantum noises in quantum memory for optical probe pulses propagating in electromagnetically-induced-transparency (EIT) media by including Langevin noise operators and asking the field operator to satisfy bosonic commutation relation. They demonstrate that the quantum squeezing of output probe pulses could be preserved with a stronger classical control field, and proposed how to utilize the effect of coherent population trapping (CPT) to directly generate squeezed light without any optical cavity.

Group picture of Taiwan-France Workshop on Drop Dynamics and its Applications, Dec 11, 2017

Soft Matters and Complex System

The community of soft matters and complex systems is rather diverse. Support of NCTS is mainly channelled through the operation of the thematic group of Complex Systems (TG5) led by Yeng-Long Chen (AS), Kuo-An Wu (NTHU), and the Interdisciplinary group of Complex Systems and Mathematical Biology (I3) led by Lei-Wei Yang (NTHU). For example, core member of TG5, Pik-Yin Lai (NCU) has derives general analytic results relating the weighted connection matrix of the network to the correlation functions obtained from time-series measurements of the nodes for networks with one-dimensional intrinsic node dynamics (Phys. Rev. E 95, 022311 (2017). Information about the intrinsic node dynamics and the noise strengths acting on the nodes can also be obtained. Based on these results, we develop a scheme that can reconstruct the above information of the network using only the time-series measurements of node dynamics as input. Reconstruction formulas for higher-dimensional node dynamics are also derived and illustrated with a two-dimensional node dynamics network system. Furthermore, he extends his results and obtain a reconstruction scheme even for the cases when the noise-free dynamics is periodic. He demonstrates that the method can give accurate reconstruction results for weighted directed networks with linear or nonlinear node dynamics of various connection topologies, and with linear or nonlinear couplings.

The group I3 has started a regular monthly seminars. Besides, two symposiums and one workshop had been held in NCTS as of Aug 2017 (another regional (cross-strait) symposium will be held in Nov). The symposium "Challenges in Neuroscience" covers topics on both the molecular and animal levels as well as, to a modest extent, on the crosstalk between these two levels; the symposium Advances in Structural Biology and Beyond, co-hosted by NCTS and IBSB, CLS, NTHU, gathered experimental/theoretical structural biologists/biophysicists who showcased their problems and the solutions to them in efforts to observe functional structures and dynamics of protein complexes.

RESEARCH

Experimental Collaboration InterDisciplinary Research Program

In order to enhance the collaboration between theorists and experimentalists, and to promote the exchange and cooperation between researchers in tradition different disciplines, the Center has launched the Experimental Collaboration Program (ECP) and the Interdisciplinary research Program (IDP) two years ago. In these programs, NCTS act as a platform to bring together researchers with complementary scientific approaches and backgrounds so that a closer cooperation and collaboration of researchers could be fostered. Since its launching, it is evident that collaboration has been strengthened and new collaboration is forming. We highlight some of the developments in this regard.

Quantum Optics and Quantum Manipulation of Ultracold Atoms

Built on previous ground, the collaboration is strong in the group of quantum optics and quantum manipulation of ultracold atoms and the group of quantum gases (TG7), where stimulation has been mutually exerted and a number of collaborative results have been written up already. For example, experimentalist Ying-Cheng Chen and theorist Hsiang-Hua Jen has initiated a collaboration on the topic of spectral shaping of cascade emission form cold atomic ensembles considering the effect of superradiance (Phys. Rev. A). Experimentalist Ite A. Yu and CS Ray-Kuang Lee has initiated a collaboration on the topic of full quantum theory of light propagation and light storage process in electromagnetically-induced-transparency (EIT) media. Their works have been published in JOSAB 32, 1384(2015) and Phys. Rev. A91 (2015) 063818.

Low-D Emergent Quantum Matters and Beyond CMOS Devices

Through the operation of the group Low-D Quantum Matters and Beyond CMOS Devices, NTHU professor Shu-Jung Tang, an experimentalist working on organic materials is the organic-metal interface has the chance to meet with a visitor Theodoros A. Papadopoulos (Chester Univ, UK) of NCTS and started a fruitful collaboration. A paper Control of the dipole layer of polar organic molecules adsorbed on metal surfaces via different charge-transfer channels (Physical Review B, 95(8), 085425) has been published. The collaboration is still on-going.

Another example is that Horng-Tay Jeng (center scientist) et al found via first-principle calculation that a pure 2D Rashba electron gas (REG) with a large Rashba splitting can be realized in a topological insulator (TI) Bi_2Se_3 ultra-thin film grown on a transition metal dichalcogenides (TMD) $MoTe_2$ substrate, ideal for real devices utilizing the Rashba effect. Prof. Kwo (NTHU) et al then have employed the MoS_2 mono layer, a van der Waals type surface with hexagonal symmetry as a growth template to obtain high quality Bi_2Se_3 (TI) thin films. Larger triangular domains of sizes up to 1.5 μm with less spiral defects, about 2-3 times enhancement in mobility and much more intense SdH oscillations have been demonstrated. They expected more fruitful results will be discovered and published soon in this year. Similarly, Shu-Jung Tang (NTHU) and Wei-Wu Pai (NTU) have demonstrated that under the optimal growing condition, germanene would form as a freestanding configuration with 1x1 honeycomb structures on top of Ag(111). Photoemission measurement also reveals the corresponding energy band structures symmetry in collaboration with Horng-Tay Jeng (NTHU). The manuscript is under preparation and will be submitted to Nature Materials shortly.

LHC Experimental/Theoretical Exploration

This group works to involve LHC experimentalists and theorists. Their approach is to organize regular workshops to bring the community together for interaction. For example, Kingman and Pai-Hsieh Hsu (NTHU) held the Rapid Response Workshop to the 750 GeV Resonance (Jan 2016), gathering all the peoples in Taiwan who have performed works related to the new resonances. They had a successful workshop and especially some important information from the CMS and ATLAS experimentalists. This was the first of such a type. Besides of that, they also hosted a workshop, "Beyond the Standard Model Higgs Searches" (March 2017), inviting a numbers of ATLAS experimentalists from nearby countries, including Japan, China, and Hong Kong, and also local ATLAS and CMS members, together with theorists. This year they have a workshop "Dark matter at the LHC" (Aug 2017). Two publications have resulted as a true collaborations between theorists and experimentalists: (1)Detecting multimuon jets from the Higgs exotic decays in the Higgs portal framework, Jung Chang, Kingman Cheung, Chih-Ting Lu, and Shih-Chieh Hsu Phys. Rev. D95 (2017) 035012; (2)Vector Boson Fusion versus Gluon Fusion, Chen-Hsun Chan, Kingman Cheung,Yi-Lun Chung, Pai-Hsien Hsu, arXiv:1706.02864, submitted to PRD.

Light Dark Matter

Cheng-Pang Liu and the other members of the group have weekly meetings of group members by teleconferencing, with experimentalist members. They have physical collaboration meetings (one-day- long) held either at NTU, NDHU, or AS every two months. Besides, they also support students and postdocs domestic travels when special training is needed for project execution. The group on Light Dark Matter has obtained many publications out of the group collaboration, e.g. "Constraints on dark photon from neutrino-electron scattering experiments", Phys. Rev. D 92, 033009 (2015). [by H.T. Wong, L. Singh, et al.] and "Electronic and nuclear contributions in sub-GeV dark matter scattering: A case study with hydrogen", NCTS preprint: NCTS-ECP-1501; arXiv:1508.03508. [by J.-W. Chen, H.-C. Chi, C.-P. Liu, C.-L. Wu, and C.-P. Wu]; ii. "Atomic ionization by sterile-to-active neutrino conversion and constraints on dark matter sterile neutrinos with germanium detector", Phys. Rev. D 93, 093012 (2016).

Theoretical Chemistry

Multi-scale studies for complex materials, catalysts, and biological systems – theoretical and computational approaches and experimental stimulus, Chao-Ping Hsu (IoC, AS) and her coworkers hosted The Seventh Asian Pacific Conference of Theoretical and Computational Chemistry (APCTCC7) in January 25-28, 2016. This is a biannual conference for Asian-Pacific theoretical and computational chemistry, covering physics and biology as well. Through the discussion and social connection in this conference, core members in this group have a great interaction and connection with important visitors. Another important event, which is for the purpose of nurturing, is a student conference which took place last year September, where students compete for the best oral and poster presentation. The overall presentation quality has been increased significantly. By asking the PIs to serve as juries of the contests, this occasion also allows PIs to learn from each other through their students' presentations.

Following the spirit of interdisciplinary program (IDP), the group has co-organized three events in 2017. In Jan, we had an annual meeting of theoretical and computational chemistry in IAMS (see item (1)). This was a small-group meeting for the faculty members to exchange their ideas (mainly related to their MOST projects). The second one is a small workshop in March on the Physics and Chemistry in Atmosphere organized mainly by Dr. Kaito Takahashi (see item (2) for details). The third is a small workshop on "computational materials" (see item (5)) in July, four researchers from NIMS, Japan came to visit us, there are more than 8 CMR researchers in Taiwan (from AS, NTUST, NCTU, NCKU, NTU). After this event, some participants have agreed to file joint proposal to MOST to look for more research funding to continue collaboration along this direction.

Big Data Analysis and Mathematical biology

Ming-Chya Wu (NCU) and his group has developed data analysis approaches (algorithms) based on concepts in statistical physics and nonlinear dynamics to investigate biological problems (such as protein data bank and protein aggregation database), biomedical science (such as biomedical signals), financial and social systems (such as financial data and networks). They do modelling and simulations for the physical systems associated with the big data. One of their achievement is to initiate a very good collaboration with medical doctors on analyzing biomedical signals and obtained the research results published in a biomedical journal: L.-C. Tu, et al. Surface electromyography analysis of blepharoptosis correction by transconjunctival incisions, J. Electromyogr. Kinesiol. 28, 23-30 (2016), as well as results published in physical journal: M.-C. Wu et. Disorder profile of nebulin encodes a vernierlike position sensor for the sliding thin and thick filaments of the skeletal muscle sarcomere, Phys. Rev. E 93, 062406 (2016).

Complex System and Mathematical Biology

Chen-Hsien Yeang (ISS, AS) led a group in 2015-16 to investigate the interdisciplinary research between mathematics, biology, medical system, and physics. Their regular activity is to have regular seminar to collect people from different background together and to share their experience. Besides, they also hosted a conference of "Time in Biological Systems and Beyond" on March 2016, with several important researchers in Taiwan and other countries to discuss possible collaboration between them. Prof Lei-Wei Yang became the group coordinator since 2017 and the group became even more active. For example, the group has started a regular monthly seminars. Besides, two symposiums and one workshop had been held in NCTS as of Aug 2017 (another regional (cross-strait) symposium will be held in Nov). The symposium "Challenges in Neuroscience" covers topics on both the molecular and animal levels as well as, to a modest extent, on the crosstalk between these two levels; the symposium "Advances in Structural Biology and Beyond", co-hosted by NCTS and IBSB, CLS, NTHU, gathered experimental/ theoretical structural biologists/ biophysicists who showcased their problems and the solutions to them in efforts to observe functional structures and dynamics of protein complexes.

Geometry, Topology and String Theory

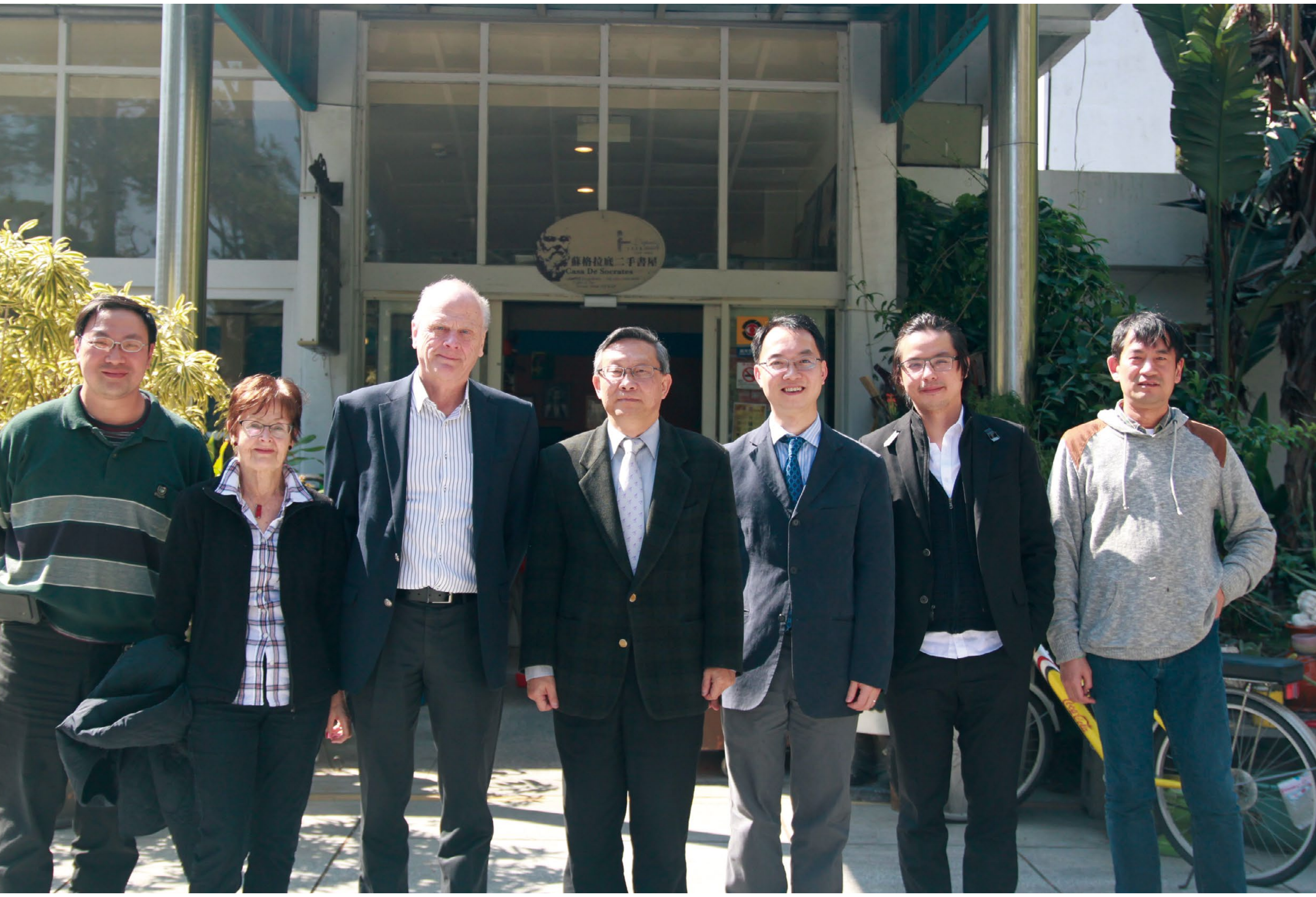
Nan-Kuo Ho (NTHU), Siye Wu (NTHU) started the program by an international workshop 'Geometry, Topology, and Physics'. They invited leading experts both in Taiwan and from Japan and Korea. The talks covered various topics in mathematical physics such as symplectic geometry, quantum field theory, gauge theory, mirror symmetry and string theory. In November 2016, we have invited Huijun Fan from Peking University, Varghese Mathai from University of Adelaide and Armen Sergeev from Moscow Steklov Institute to deliver a lecture series on Gromov-Witten invariant, K-theory and T-duality, and the geometry of loops spaces. These lecture series will benefit young researchers and postgraduate students working in these and related areas.

HIGHLIGHTS of RESEARCH ACTIVITIES

Interview with Lars Blink

Lars Brink on Superstring Theory

One of the pioneers of superstring theory, Lars Brink visited NCTS Taiwan in Feburary. Being a member of Royal Swedish Academy of Sciences he has been involved in the Nobel Committee for Physics and Chairman of it. We interviewed him during his visit to Taiwan.



Prof. Lars Brink visited NCTS on Feb 15, 2017.
(Left) Vice director Daw-Wei Wang, Mrs. Brink , Prof. Lars Brink, President Hong Hocheng, Director Chong-Sun Chu, Profs. Yu-Tin Huang, Siye Wu

Chu: We are planning to outreach a publication to stimulate the younger generation to come to do theoretical physics. Therefore, we would like to know about your journey of physics to superstring theory, your experience and your vision and suggestions about the subject.

Huang: I read in some of the articles that you wrote about the history of supersymmetric Yang-Mills theories something interesting in that in your discussion about the beta function vanishing and when you proved that, you mentioned that Gell-Mann had said that it probably means that it is trivial. So my question is that, is it true that during that time particle physicists were not really familiar with conformal field theory?

Brink:

It is a good question. At that time or even before that, there were some people who were interested in Conformal Field Theory. But, I think the rest of us did not pay much attention to that. Because, somehow we were convinced by the aftermath of the field theory revolutions, which took place in 1971 after 't Hooft' s work, that it should be a renormalizable Yang-Mill's theory. With renormalizability, we got a hand in the theory. With asymptotic freedom, it worked the way you wanted.

So when Schwarz and Scherk and I constructed the supersymmetric Yang-Mill's, people had been discussing extended supersymmetry with N=1, N=2. I don't know if people had tried higher N. But N=4 is very complicated to construct. We had been doing string theory and we had been living in 10 dimensions. For us, it was natural to think about Yang-Mill's theory in 10 dimensions and then perform dimensional reduction. In the paper we wrote, we tried to construct Yang-Mills theories, which are maximally supersymmetric in various dimensions especially for those seen in lower dimensions. Then at that time supergravity had been discovered, so we also wanted to do supergravity. We didn't do much with N=4 SYM at that time. But then in summer 1977, people in Aspen were discussing the N=4 theory. Someone knew that the beta function was zero to the first loop order. Then Gell-Mann said it is probably finite to all orders. I don't know why he said that. Then somehow he comissioned people to check the two loops and it took a few months. It turned out to be zero. Then there was a race to do it to 3 loops and it took some three years. In 1980, people did it.

In 1981 Green, Schwarz and I were checking if we could see anything from string theory for it. We used the one loop graph of closed and open string field theory and took the zero slope limit. We could get the complete one loop S-matrix for graviton and for Yang-Mills bosons. The result was remarkably simple. We could also then follow to see for which dimension the theory would be finite. It was a very strong result but it wasn't conclusive. But I was taken by the fact that it just looked like a phi cube theory and only involved just box diagrams.

In the spring of 1982, I got an idea when we were working on the light cone that we should consider the light cone of 10D Yang-Mill's and go down to 4-dimensional Yang-Mill's. Then we wrote a paper presenting the proof of the finiteness. Mandelstam had a similar proof. Then I went into Gell-Mann's office. And he said you cannot have a field theory without a scale (laughter). It was clear that it was an interesting result. But it took until Maldacena to realize you can use the CFT in a different way, by duality.

Chu: The Montonen-Olive duality conjecture was around at that time in 1976. How did the concept of duality change people from the belief that the N=4 theory is trivial?

Brink:

I went on telling people that N=4 must be a simple theory then but not trivial. It looks so simple, almost trivial and I remember very respected field theorist at that time said that there is nothing in it; it is too simple. But then it was found out that monopoles exist in that. For that, you wanted the spectrum, and all that is so beautiful.

I am thinking nowadays that perturbatively N=4 super Yang-Mills theory as well as N=8, supergravity is as simple as they can be, and yet have all the required physical properties. Non-perturbatively, N=4 is very complicated and contains the information about gravity and string theory. So I think we are just beginning to understand the concept of quantum field theory, which may be deeper than what we thought before.

When I was at CERN, 't Hooft and Veltman came to CERN. Veltman was the very domineering person and they were giving lectures on Yang-Mills theory. They wrote a rather famous yellow report at CERN called "Diagrammar". Veltman was then saying that quantum field theory is defined by the Feynman rules. How wrong he was! He had some arguments. But I think what we had not really realized is that the Quantum Field Theory, a many-body theory, has to contain so much information in it in order to treat any number of particles. Somehow there must be so much in it. Then in 1974 't Hooft and Polyakov found monopole solutions in non-perturbative Yang-Mills which could not be seen in Feynman diagrams.

I came to CERN before having written my thesis. It was the old Ph.D. system, so the last year was for thesis writing. My thesis was an old fashioned thesis that contained 14 papers. I had a long song and dance number about how a field theory could describe all the discontinuities. The theory should be able to describe every discontinuity in S-matrix. That looked impossible to understand, But, now things are much simplified by dualities. I think AdS/CFT duality is a wonderful discovery. It solved many of these conceptual things.

I was worried and thinking how would we ever be able to do a strong coupling results with the help of quantum field theory. Now with duality you solve it. You can get the strong coupling results by simple perturbative calculations in the dual theory. That was extremely important. That's also why we have understood so much about non-perturbative theories. There were lots of beautiful results by Nati Seiberg on non-perturbative aspects of supersymmetric theories before for sure. But now everything has fallen into place.

Chu: How was it like to work on string theory in the early 70's when people were convinced that QCD is described by Yang-Mills gauge theory?

Brink:

QCD was not there to start with you know. It came in 1973 and most people then left string theory. I went back to Sweden in 73 from CERN. So somehow I was allowed to continue doing string theory, which was nice. I mean, my dream was not a unifying string theory at the time but a theory for the strong interactions. Even a guy like Mike Green left string theory. Somehow John Schwarz who was at Caltech, was about to leave but then Gell-Mann was keeping him. But, he was also in bad position. He had not given up but was close to giving up.

Paolo di Vecchia who were in Copenhagen and I were for some time trying to find new string theories and we succeeded: when supergravity came in 76, we realized that we could use that technique to construct the action for superstring theory. We did that with Paul Howe. We were still thinking about string theory at that time but had practiced on Yang-Mills theories earlier.

When I was in the second year at CERN, I started a long collaboration with David Olive. He was a person who wanted to work on deep issues. It could take any amount of time and he was not rushed. He said, "Let's try to construct correct 1-loop graphs in Dual Models as string theory was called then". People had been doing it by sewing tree diagrams together. It was not correct because it did not invoke gauge invariance but you could and you could sort of see the structures. So we started to study Yang-Mills theory. There was also 'gauge invariance' in the dual models which worked very much like Yang-Mill's theory. After solving and practicing finally we could construct 1-loop graphs using the Feynman tree theorem for Yang-Mill's theory, a method he had alluded to in a talk, but not written up. We worked for several months learning Yang-Mills theory. But, even then it was not until later when we actually connected it to superstring theory, which was strange.

Just after we had found the action for Superstrings, I moved to Caltech and I started to look into Supergravity. Before that, we wanted to see what kind of Yang-Mills theories we get from Superstring Theory. We did it by letting the slope of the Regge trajectories alpha' go to zero and also by dimensional reduction. That was interesting because at that time nobody was thinking about working in higher dimensions. People were laughing at us when we said 26-dimensions. 10 was more acceptable but the damage was already done, because we had been talking about 26 dimensions which sounded just stupid and crazy. When John and I did this work and talked to the people at Caltech, we were careful to say that it was just a technique to construct the four-dimensional theory. We were not arguing that 10 dimensions is there in the real sense. Kaluza-Klein has been completely forgotten.

Huang: Any quantum field theory satisfies S matrix axioms. At which point in the early days of development did people starting from the S-matrix program miss QCD? Could you pinpoint the conceptual or physical point causing it?

Brink:

Yes. I think people were so discouraged by quantum field theory. Of course, QED was very successful. You could compute up to 8 digits correctly compared with data. It was clearly right in that sense. Even though Landau pointed out the, what is now known as, Landau poles, people wanted to do the Yukawa theory for the strong interactions. That was also renormalizable. However, compared with the data, the coupling constant looked as if it would be 14. You could not do perturbation expression or perturbation theory. Then people adopted to say that there is something wrong in the quantum field theory. The concept of quantum field theory does well as S-matrix theory. Then Geoff Chew wanted to just extract the good properties like crossing symmetry and all those things. He advocated that this must be the basis for many bodies theory. We knew then at the time that there were lots of resonances and they should be considered as elementary particles. Once you have got enough information about the particles that existed in the experiments then it should be self-regulating and solve itself once you set up an S-matrix. It probably would look like a quantum field theory, but of course with many many particles. When Veneziano wrote down his four-point amplitude, it satisfied the properties that an S-matrix should satisfy. It was realized by having infinitely many states.

My advisor in my early days as a graduate student in 1967, suggested me to do phenomenology because he had some connections to the experiments. He wanted me to write a model for pion-pion interaction amplitudes. During that time I learned about the finite energy sum rules which was saying that when you have an amplitude in strong interaction, you could either regard it as the sum of all resonances in the s-channel/direct channel or you could write it as Regge poles in the t-channel which was in asymptotic form. You cannot have both. There must be a way to write the amplitudes in terms of the sum of all intermediate states.

On the other hand in the Regge analysis, amplitudes behave in certain way asymptotically. Then it is said that you should not add these two properties. If you have one, that's enough in principle. It also, if summing it up properly, would give you the other property. Veneziano gave an example of this, which was a great thing. If you wanted to do the strong interactions with all the physical states, it will not be in an ordinary kind of field theory. A field theory in terms of quarks had indeed already been suggested by Han and Nambu in 1965, but people did not pay much attention to it at that time. Gell-Mann apparently did not know about it because in 1966, Victor Weisskopf, the former advisor of Gell-Mann, had a celebration of his 60'th birthday and Gell-Mann was supposed to write a contribution. He wanted to be certain what he wrote and he was procrastinated. In the end he didn't write it up. Then when he got the book eventually, Nambu had an article in it, but he didn't open it because he was so ashamed. He said later, "had I only written what was my contribution, then I had open it up, I had read what Nambu wrote and we would have solved QCD much earlier. And Nambu was not a person who was forcing. He was very modest. He did not like the quarks with fractional charges. So he had introduced integer charged quarks. Then he was forced to have 3 families of them. In a sense averaging it up. It is not a perfect theory but it was close to being a right kind of theory. For example, he would have 3 quarks something like down with 0 and others with 1 and -1.

We now know that this model would be renormalizable. But I don't know if people at that time believed Yang-Mill's theory would be renormalizable or not. I think people probably thought that pure Yang-Mill theory would be ok. But, spontaneous broken versions were more difficult because it had some scale conversion. But, I am not sure since it was before my time. I would think because it is little before my time, people were skeptical about that. Even you know, Salam and Weinberg's had the correct papers in 68 and 67 resp., but nobody referred to Weinberg between 67-71 not even himself. Evidently they didn't believe it. And this is interesting. There was a Solvay meeting in 1967 and Weinberg talked about this theory there.

You can see it in the text he said, "I don't believe this theory is renormalizable". Brout and Englert had written a paper a year before arguing that it should be renormalizable, because they could see that the propagator in the broken case had the same asymptotic behavior as in the unbroken. Not like putting mass by hand that gives a different behavior. And then Weinberg had said, "one of us is right." And he indicated that he was right.

On the other hand, if you read his paper he mentions mild phrases about renormalizability. He didn't believe in it. That's why it was such a big surprise for him when 't Hooft wrote that paper. Veltman was very much against the spontaneous symmetry breaking. But 't Hooft has been to the summer school and learned from Ben Lee about spontaneous symmetry breaking. He came back and told his advisor that he would like to try that but Veltman told him that it is not going to work. Veltman had developed a computer program with which you could compute one-loop amplitudes. When 't Hooft tried his one-loop calculation it was renormalizable. There were then lots of the things to check for the proof. But that was a turning point in the particle physics.

String theory had a glorious year in 1972 because there were still those problems that were solved, for example, the no-ghost theorem. Also the showing that the spectrum of relativistic strings is the same as dual resonance models and that it worked only in 26 dimensions. There were however lots of other activities. People who had been working on weak interactions were very excited because of the 't Hooft result. People were computing like mad at CERN, checking with experiments to see whether it really worked. But, I think it was when the asymptotic freedom came in the spring of 1973 that made people leave the dual models and start to work on QCD. Then the theory of strong interaction was there. The problem was moved to see whether one can prove confinement. In 1975, Mandelstam constructed a confined vacuum, but he could not prove that this was the lowest vacuum state. Feynman got interested in quark confinement but a bit later. He was doing it in 3 dimensions, which had been done by Polyakov, who had a gas of condensed instantons so he could argue that the theory is confined in 3 dimensions. And Feynman was trying it in 4 dimensions but did not really have any proofs for the confinements.

Chu: You are one of the creators of the field string theory from the beginning and the thing you are doing today. String theory is facing some criticism recently. What do you think about the future of string theory?

Brink:

In the 80s, when string theory was solving the problems of quantum gravity, you could argue that this is the perturbative quantum gravity theory. I think we were all mistaken in this case. We also saw that it was so unique in 10 dimensions with these five theories. Somehow we believed that one would find the criterion what would happen in 4 dimensions such that we would get a unique theory. We probably were overstating the case. What we have learned over the years is that string theory is more of a framework, a class of theories which is not only to solve the perturbation problems but also to connect with the standard model. People are still trying to do phenomenology. It has not been as successful as we hoped it would be at that time and it is a disappointment from that point of view. On the other hand, what we learned is that string theory is richer than we could expect. I think the lesson is that if you could go to smaller and smaller scales, the theory gets more and more complicated. At least if you try it with the means we have today. There is probably a different way of doing it. I think that this is what AdS/CFT is nicely doing, helping to solve the difficult problems of string theory. There are techniques to solve the difficult problems. It just takes a long time. I am bit disappointed that it is not going quicker. On the other hand, in the long run probably it would be good. It is the correct way of going. As a physicist, you have to be optimistic. You really have to hope that the problems have simple solutions. Simple but also beautiful solutions to the problems. But we want be able to solve it in a short time. Then we are too optimistic. I would say that the framework is the correct one. We have to keep on working on it.

Celebrating 20th Anniversary

From the Director

NCTS was established in 1997 with a goal to raise the standard of the basic science research in Taiwan, in accordance with the ROC White Paper on Science and Technology produced in 1997.

In this 20 years, the world has experienced with many dramatic challenges and difficulties. We have seen deadly tsunamis in Japan. Scientists are now convinced without doubt of the reality of climate change and global warming. Political tensions and terrorism are increasing worrisome. Not to mention the recent terrifying action of the North Korea. All these are quite disturbing. On the other hand, there has been increasing amount of scientific collaboration across countries because scientists have the same goal for a unified truth and therefore can work together without political or cultural barrier. This is particularly true in fundamental sciences where the language of mathematics and models are universal. The friendship and trust built through the process of scientific cooperation is precious and invaluable.

Throughout these years, being one of the first interdisciplinary science centers in Asia, NCTS has been working closely with its partner institutions in the promotion and advancement of scientific knowledge and nurturing of young scientists. The Physics Division of NCTS now has a body of 13 staff scientists and over 20 postdoctoral research staff, working in various areas of theoretical physics, all fully committed to contribute to the advancement of frontier research in physics and interdisciplinary sciences.

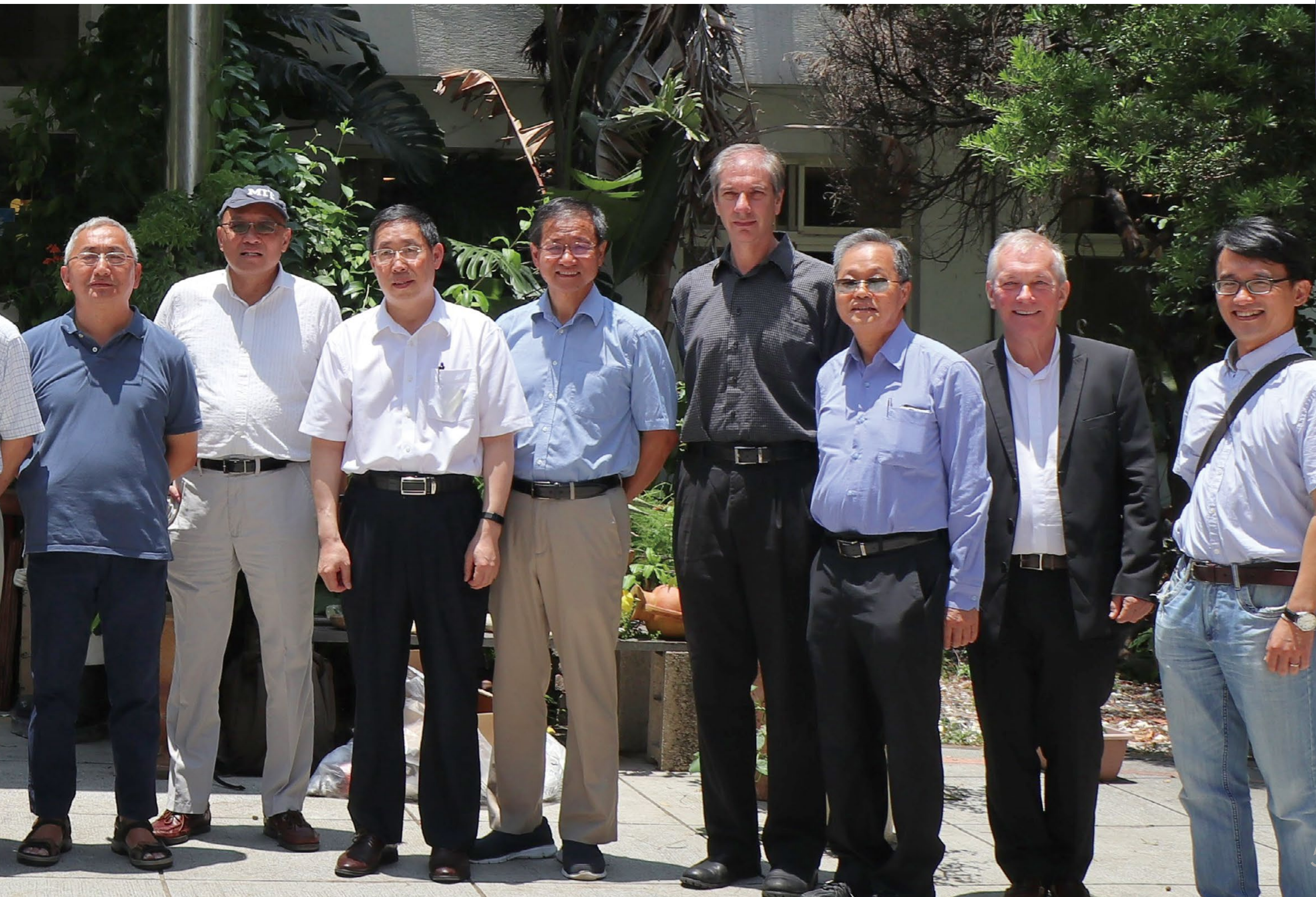
In order to achieve these goals, we organize many programs and activities through the year in order to encourage interaction and engage scientists in collaboration. In 2016, we have organized more than 25 international workshops and conferences, including 5 joint meetings with other international institutions. Not including

participants for meetings, we have had over 70 visitors from around the globe. NCTS has also been a very successful breeding ground for generation of physicists in Taiwan. About 65% of our previous postdocs have become faculty in universities and research institutions in Taiwan and abroad. Many of them are distinguished professors in their respective universities, holding national awards such as MoST and MOE academic awards, and international recognition such as Fellowships of international academic society.

As part of the celebration activities, we have had public talks and forum by Professor Takaaki Kajita and Professor Shing-Tung Yau on gravity on Aug 2nd. Gravity is everywhere, not just in everyday life, but also in the world of physics research as there are still many things we do not understand about it, such as dark energy, holographic property and quantum informatic property of gravity. The talks of Professor Yau and Professor Kajita have been very inspiring. We also received many questions during the Forum. Prof Yau also shared his own personal experience in research, particularly during his student's time. He encouraged students and researchers to work on original ideas and directions. He also emphasized the importance of reading original papers as they contain the germs of original ideas and are often most inspiring.

On Aug 3rd, we had a Symposium on the Frontiers in Physics research, covering topics from particle physics, quantum field theory, strings, gravitational wave and cosmology to strongly correlated or topological materials, superconductivity and cold atoms research.

On behalf of the Taiwan theory community, I would like to thank the previous directors of NCTS for their selfless dedication and hard work. I would also like to thank my fellow physics colleagues, not only those in NCTS or NTHU, but also others from collaborating institutions such as Academic Sinica, NTU, NCTU, NCKU, NCU, NTNU, NSYSU, NDHU, NCCU, NCHU, CYCU, NUK, THU, TKU, FJU, FCU etc., for their devotion and enthusiastic contribution to physics research and to NCTS. Without them, NCTS would be an empty shell without content. I look forward to seeing another 20 glorious years of NCTS and physics research in Taiwan.



August 2, 2017
NCTS 20th Anniversary Official Celebration

13:30 - 14:15	Tea Reception
14:30 - 14:35	**Ceremony Opening** Welcome & presentation of Speakers & Invited Guests
14:35 - 16:10	**Opening Address** President Hong Hocheng, NTHU Director General Chun-Chieh Wu, Department of Natural Sciences & Sustainable Development, MOST Director of IoP, AS, Former Division head Ting-Kuo Lee Division Director Chong-Sun Chu
15:10 - 16:10	Public talk by Dr. Shing-Tung Yau
16:10 - 17:15	Public talk by Dr. Takaaki Kajita
17:30 - 18:00	Q&A
18:30 - 20:00	Banquet

Video


國家理論科學研究中心
20 週 年 慶 祝 活 動


丘成桐
菲爾茲獎得主
Fields Medalist 1982
Harvard University
諾貝爾物理獎得主
Nobel Prize in Physics 2015
University of Tokyo
梶田隆章
Gravitational Wave
TAKAAKI KAJITA
2017 08 02
NCTS

SPEAKERS AND ABSTRACTS

Takaaki Kajita

Professor Kajita is a world-leading experimental physicist. He led the experiments at Kamiokande and Super-Kamiokande, and made many important contributions to particle physics. In particular, he discovered neutrino oscillations, showing that neutrinos have mass, hence solving the long-standing solar neutrino problem. In addition to the Nobel Prize, he also received many other awards such as the Fundamental Physics Prize and the Japan Academy Prize. His works have not only greatly enhanced our understanding of the mysterious fundamental nature of neutrinos, and but also deepen our understanding of the Standard Model of High Energy Physics.

Exploring the Universe with Gravitation Waves

Starting from the Newton theory of gravity, Prof. Kajita first explains the revolutionary idea of Einstein about gravity in his famous General theory of relativity in 1916. He then introduce the history of experimental efforts in search of gravitational waves, starting with the works by Taylor and Hulse of binary pulsar (Nobel Prize 1993), then he talks about the detection of gravitational wave by the LIGO project (USA) in 2016. The discovery reported the first direct evidence of gravitational waves as a result of the merging of binary blackholes. The released energy is estimated to be about 30 billion times the energy of our whole Milky Way Galaxy in 0.2 sec: the most violent phenomena we human beings ever observed.

Finally, Prof. Kajita introduces the Kagra Project in Japan (which scientific groups in Taiwan also participated) for the next generation of gravitational wave detector. The operation of the gravitational wave detector network implies that we could explore the universe through completely different new channels, and could lead to a much deeper understanding of the universe.

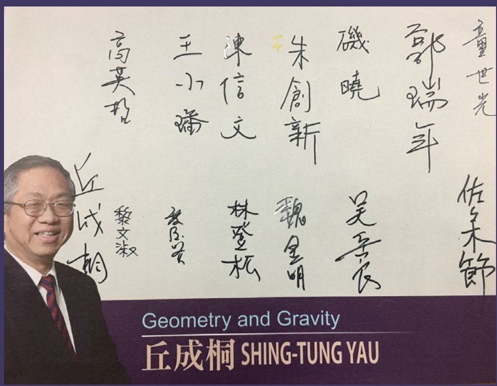
Shing-Tung Yau

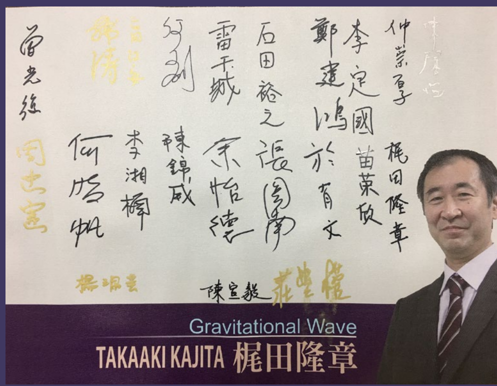
Professor Yau is one of the most important mathematicians in the world. He proved the Calabi conjecture in algebraic geometry and the positive energy theorem in general relativity, among his numerous breakthroughs that opened new directions in mathematics. He received the Fields Medal and many other awards such as the US National Medal of Science and the Wolf Prize in Mathematics. His contribution to geometry and theoretical physics has reshaped the faces of both. In particular, his works laid the foundation for modern studies on general relativity and string theory.

My Personal Journey on the Geometric Aspect of General Relativity

General relativity, a theory of gravity, has not only revolutionized our understanding of gravity, spacetime and matter, it has also lead to many interesting ideas and deep principles such as extra dimensions of spacetime and unification, and gauge symmetry of interaction. The latter has been generalized to non-abelian Yang-Mills gauge symmetry which govern the world of elementary particles physics.

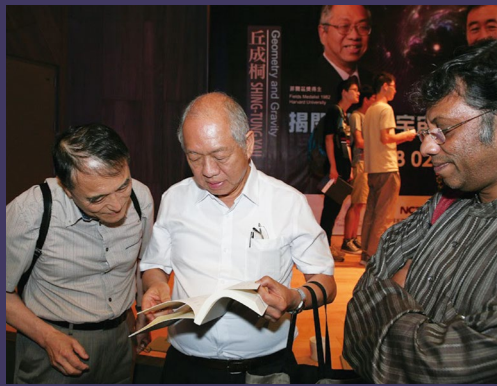
In this talk, after a brief exposition of how Einstein invented the theory of general relativity, Prof Yau introduces, from his own geometric perspective, to the audience some of its more modern developments and applications. Topics include Calabi-Yau manifold and its application in string theory, positive energy theorem and blackhole physics, memory effects of gravitational waves, and quasilocal energy of gravitational spacetime.


Geometry and Gravity
丘成桐 SHING-TUNG YAU


Gravitational Wave
TAKAAKI KAJITA 梶田隆章


國家理論科學研究中心
20週年慶祝活動


梶田隆章
Gravitational Wave


丘成桐
Geometry and Gravity


丘成桐
SHING-TUNG YAU


The Period of Southwest Associated University

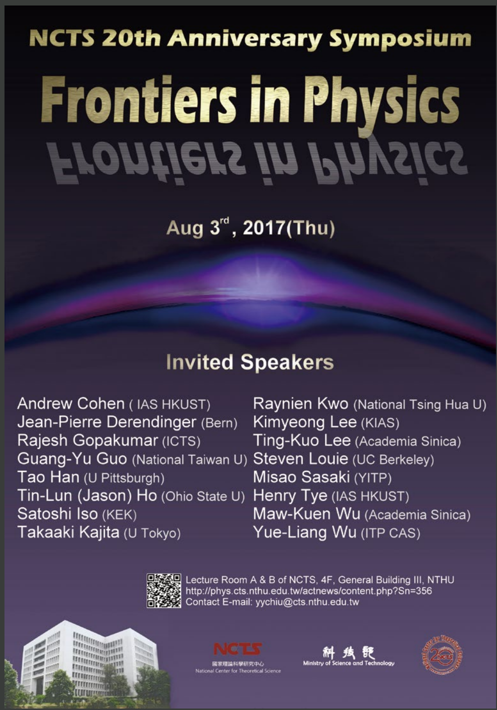
August 3, 2017
NCTS 20th Anniversary Symposium on Frontier in Physics

Lecture room A, NCTS

Time	Speakers	Titles
09:00-09:30	Takaaki Kajita	Status and Prospect of Neutrino Oscillation Experiments
09:40-10:10	Rajesh Gopakumar	Down-to-Earth String Theory
10:10-10:40		Tea Break
10:40-11:10	Yue-Liang Wu	Taiji Program in Space and Unified Field Theory in Hyper-Spacetime
11:20-11:50	Misao Sasaki	Inflation, Primordial Black Holes and Gravitational Waves
12:00-12:30	Henry Tye	Gravitational Wave Bursts from Cosmic Superstrings
12:30-14:00		Lunch
14:00-14:30	Kim-Yeong Lee	Instantons in 5 and 6 Dim Quantum Field Theories
14:40-15:10	Jean-Pierre Derendinger	Supersymmetry, Old and New
15:10-15:40		Tea Break
15:40-16:10	Satoshi Iso	A Possibility of QCD-Induced Electroweak Phase Transition in the Early Universe
16:20-16:50	Andrew Cohen	Lorentz Violation and the Higgs
17:00-17:30	Tao Han	Higgs Boson Radiative Decays

Lecture room B , NCTS

Time	Speakers	Titles
09:00-10:00	Steven Louie	The Fascinating Quantum World of Two-Dimensional Materials: Interaction and Topological Effects
10:00-10:30		Tea Break
10:30-11:30	Ray-Nien Kwo	Spin Structures Engineered at the Nano Scale: From Magnetic Superlattices to Topological Spintronics
11:30-12:30	Guang-Yu Guo	From Large Spin Hall Metal to Topological Chern Insulator: Materials Discovery through First Principles Calculations
12:30-14:00		Lunch
14:00-15:00	Maw-Kuen Wu	From Copper-Based to Iron-Based Superconductors— Recent Development in Superconductivity
15:00-15:30		Tea Break
15:30-16:30	Tin-Lun Ho	Some New Directions in Cold Atom Research
16:30-17:30	Ting-Kuo Lee	A New Phase in the Strongly Correlated Cuprate


NCTS 20th Anniversary Symposium
Frontiers in Physics
Aug 3rd, 2017(Thu)
Invited Speakers
Andrew Cohen (IAS HKUST)
Jean-Pierre Derendinger (Bern)
Rajesh Gopakumar (ICTS)
Guang-Yu Guo (National Taiwan U)
Tao Han (U Pittsburgh)
Tin-Lun (Jason) Ho (Ohio State U)
Satoshi Iso (KEK)
Takaaki Kajita (U Tokyo)
Raynien Kwo (National Tsing Hua U)
Kimyeong Lee (KIAS)
Ting-Kuo Lee (Academia Sinica)
Steven Louie (UC Berkeley)
Misao Sasaki (YITP)
Henry Tye (IAS HKUST)
Maw-Kuen Wu (Academia Sinica)
Yue-Liang Wu (ITP CAS)
Lecture Room A & B of NCTS, 4F, General Building III, NTHU
http://phys.cts.nthu.edu.tw/actnews/content.php?Sn=356
Contact E-mail: yychiu@cts.nthu.edu.tw
NCTS
Ministry of Science and Technology


國家理論科學研究中心20週年慶祝活動
NCTS 20th Anniversary Celebration 2017.08.02-03


國家理論科學研究中心20週年慶祝活動
NCTS 20th Anniversary Celebration 2017.08.02-03


National Center for Theoretical Sciences
20 Anniversary NCTS
國家理論科
20週年
Geometry and G
丘成桐 SHING-TUNG
菲爾茲獎得主
Fields Medalist 1982
Harvard University
揭開引力與宇宙


梶田隆章
Gravitational Wave
諾貝爾物理獎得主
Nobel Prize in Physics 2015
University of Tokyo
BOY

Cultivation Program

The cultivation and nurturing of students and young researchers is very important as a successful nurturing of young talents is our guarantee for a bright future for the science and economy of Taiwan.

Recruitment of Postdoc

The recruitment of outstanding young people to come to work in the Center is very important. In order to facilitate a good quality of training, we have been very careful in selecting our post-docs so as to maintain a high level of research. Out of the first bunch of researchers we hired since 2015, apart from Bo Xiong which we have mentioned above, particularly worth mentioning is Chung-Chi Lee who has been awarded a prestigious Newton International Fellow by the Royal Society of UK to join the cosmology group at DAMTP, Cambridge. Carlos Cardona has joined Niels Bohr as a postdoc in Copenhagen; Jung Chang has continued as a postdoc at the Chonnam National University Gwangju, South Korea; Ya-Fen Hsu has continued as a postdoc at the National Taiwan University; Yu-Kuo Hsiao has continued as a postdoc at the National Tsing Hua University. We wish them brilliant success in their new positions.

Director Chong-Sun Chu presented a certificate to Dr. Chung-Chi Lee, the winner of NCTS Best Postdoc Paper Award 2017.

Director Chong-Sun Chu presented a certificate to Prof. Yu-Tin Huang, the winner of NCTS Young Theoretical Scholar Award 2017.

Student and Postdoc Training

We pay much attention on efforts to facilitate the transfer of frontier research to the young generations, through organization of advanced schools and workshops specifically with them as target audiences. The center has regularly organized a number of schools this year. Some of the schools are of an interdisciplinary nature, combining theory and experiments, or traditionally different subjects such as chemistry and computation.

We also support promising students to attend international schools and conferences (about 50 per year), and exchange visit of our postdocs to institutes where we have an agreement on international exchanges.

NCTS SCHOOL	DATE
2017 Spring School on First Principles Computational Materials Research -Introductory Level	Apr 29-30 May 20-21
2017 Summer Mini-School of Gravitational Wave Research	July 13-15
2017 Summer School on First-principles Computational Materials Research -Advance Level	July 24-28
Topical Summer School on Theoretical and Computational Chemistry: kinetic Monte Carlo Modeling	July 31-Aug 02
2017 TEQMS Summer School: From Tensor Network to Deep Learning	Aug 07-09
2017 AMO Physics Summer School	Aug 22-25
Summer School on Gravity, Fields and Strings	Sep 04-08

Outreach

To develop the new generation of talented theorists, it is necessary to identify brightest students, including undergraduates or master students, and attract them into theoretical sciences. One of the key event is the annual Nobel lecture held in the summer on NTHU campus we co-organize together with the physics department of NTHU. The Nobel lecture in the previous 3 years were: 2015 Nobel lecture: Eric Cornell (2001 Nobel Laureate), 2016 Nobel lecture: Jerome Friedman (1990 Nobel Laureate), 2017 Nobel lecture: Takaaki Kajita (2015 Nobel Laureate). In addition this year we have organized a number of special colloquium on black holes, topological materials,gravity wave and LIGO, public talk "UNESCO talk on CERN", visits and presentation of Chief editors from PRL, Nature etc.

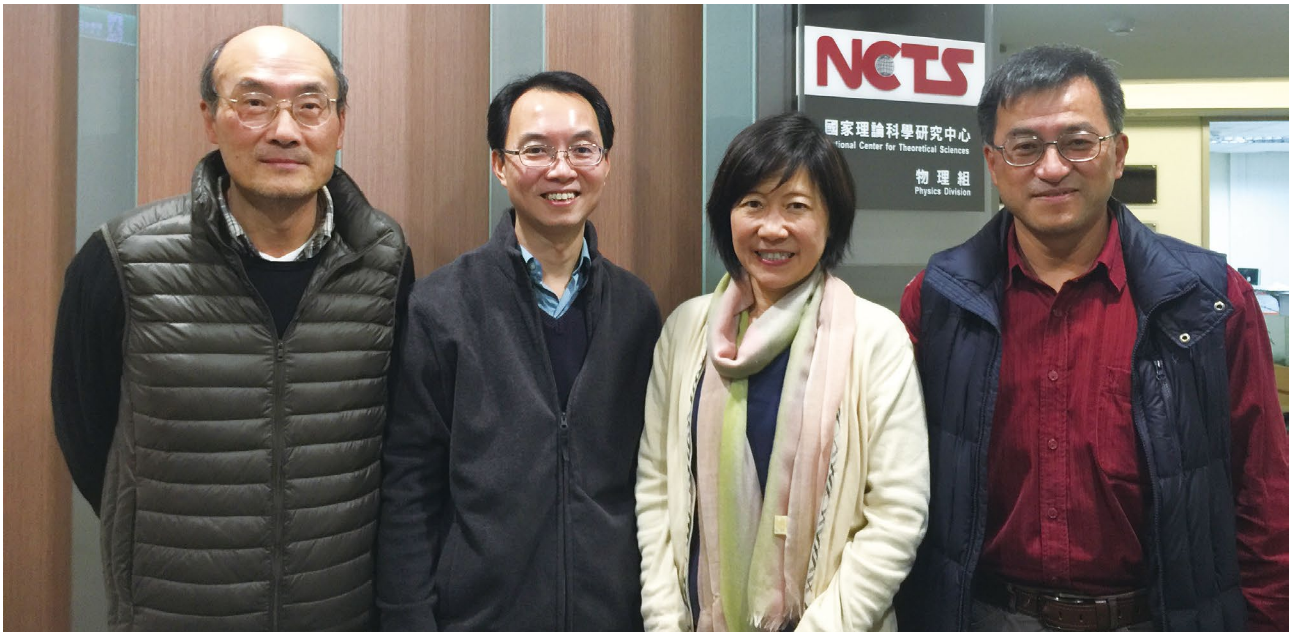
Workshops

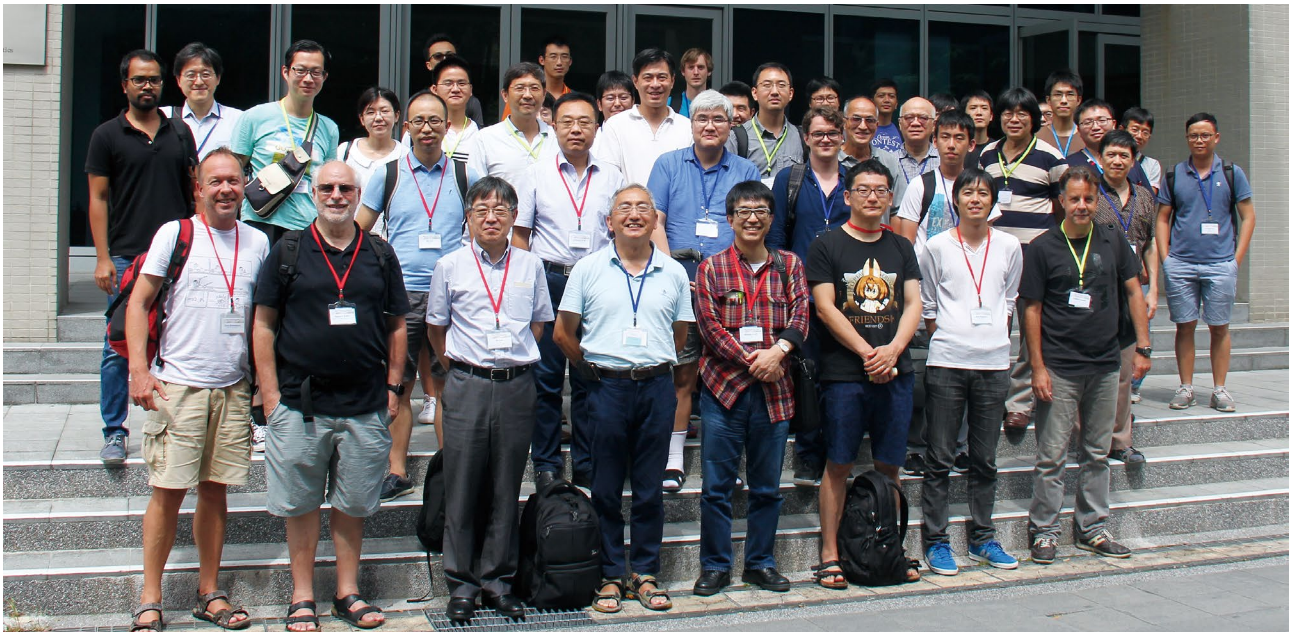
WORKSHOPS/SYMPOSIA/CONFERENCES	DATE
Quantum Entanglement 2017	Jan 03-09
Frontiers of Complex Systems Science: Soft Matters, Statistical Physics, and Big Data	Jan 14-15
Particle Phenomenology Mini Workshop	Jan 18
One-day Theoretical Physics Workshop: Journeys in Quantum Field Theory and Condensed Matter Physics	Mar 03
The NCTS mini-workshop on Correlation, Topology and Non-equilibrium Physics in Quantum Many-body Systems	Mar 27
2017 NCTS March Workshop on Critical Phenomena and Complex Systems	Mar 30-31
Challenges in Neuroscience	Apr 14
Third TEQMS hackathon	Apr 29-30
Complex Systems Symposium	May 05-06
Advances in Structural Biology and Beyond	May 11
Mini-workshop on Non-equilibrium Quantum Phenomena	May 31
Taiwan-Thailand 2017 Workshop on Theoretical and Computational Chemistry	Jun 16
The NCTS mini-workshop on Topological Quantum Matters	Jun 19
Complex Fluids Workshop	Jun 21-22
Young Researchers Forum on Quantum Information Science	Jun 23-24
15th Workshop on First-Principles Computational Materials Physics	Jun 26-28
Taiwan-Thailand 2017 Workshop on Theoretical and Computational Chemistry	Jun 16
Computational Biology Workshop	Jul 29
NCTS 20th Anniversary Symposium: Frontiers in Physics	Aug 03
Quantum Transport Workshop	Aug 17
Dark Matter at the LHC	Aug 29-31
Workshop on Quantum Science and Technology	Sep 04-06
Noncommutative Geometry, Duality and Quantum Gravity	Sept 4-6
Summer School on Gravity, Fields and Strings	Sep 04-08
Energy Frontier in Particle Physics: LHC and Future Colliders	Sep 29-30
Quantum Transport Workshop (junior section)	Oct 06
1 day Workshop on Ab Initio Calculations of Excited State Properties of New Materials	Oct 06
1st Taiwan-Philippines Workshop on Computational Chemistry and Physics	Oct 13
2017 NCTS Workshop on Dark Matter, Particles and Cosmos	Oct 13-15
The 4th East Asia Joint Seminars on Statistical Physics	Oct17-20
2D Materials and Interfaces for Spintronics	Oct 23-25
NCTS/FRIS/YITP Joint Workshop on Issues on Perturbations from Inflation	Oct 23-25
10th Taiwan String Workshop	Oct 26-29
Parton Distribution Functions and Lattice QCD	Nov 02-03
2nd East Asia Joint Workshop on Fields and Strings	Nov 13-17
Quantum Transport: Challenges and Opportunities	Nov 15
Mini-Workshop on Higgs Physics and Gravitational Waves	Nov 17-18
Autumn day on Algebraic and Geometric Structure in QFT	Nov 19
Mini-workshop on Dynamics and Inelastic Spectroscopy of Novel Materials: Theory Meets Experiment	Dec 01
NCTS Annual Theory Meeting 2017: Particles, Cosmology and Strings	Dec 05-08
Taiwan-France Workshop on Drop Dynamics and its Applications	Dec 11
Mini Workshop on Active Matter	Dec 12
2017 NCTS December Workshop on Critical Phenomena and Complex Systems	Dec 28

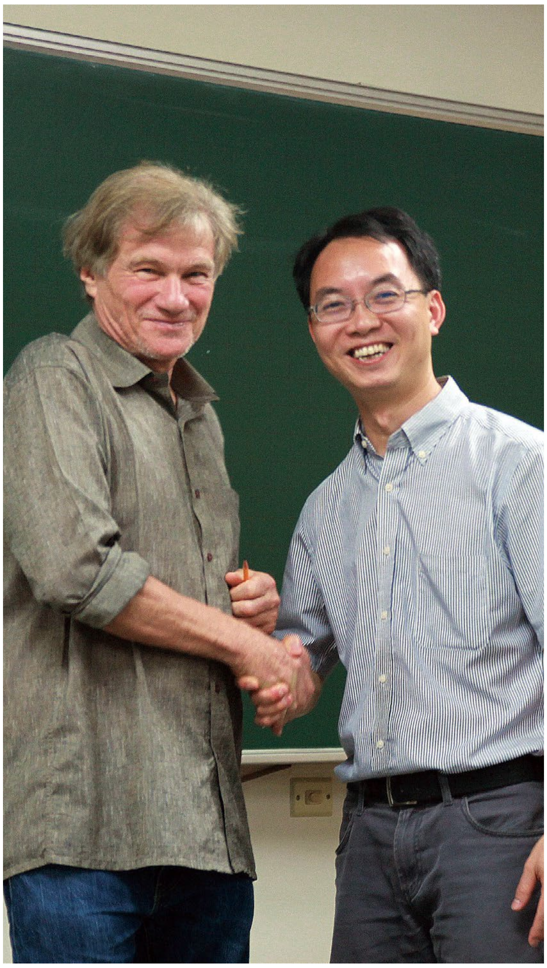
Joint Meetings

JOINT MEETINGS	INVOLVED PARTIES	DATE
Taiwan-Thailand 2017 Workshop on Theoretical and Computational Chemistry	Taiwan/Thailand	Jun 16
Noncommutative Geometry, Duality and Quantum Gravity	Kyoto/NCTS	Sept 4-6
1st Taiwan-Philippines Workshop on Computational Chemistry and Physics	Taiwan/Philippines	Oct 13
The 4th East Asia Joint Seminars on Statistical Physics	China/Japan/Korea/Taiwan	Oct 17-20
2nd East Asia Joint Workshop on Fields and Strings	China/Japan/Korea/Taiwan	Nov 13-17

Group picture of the 4th East Asia Joint Seminars on Statistical Physics, Oct 17-20, 2017


NCTS
國家理論科學研究中心
物理組
Physics Division



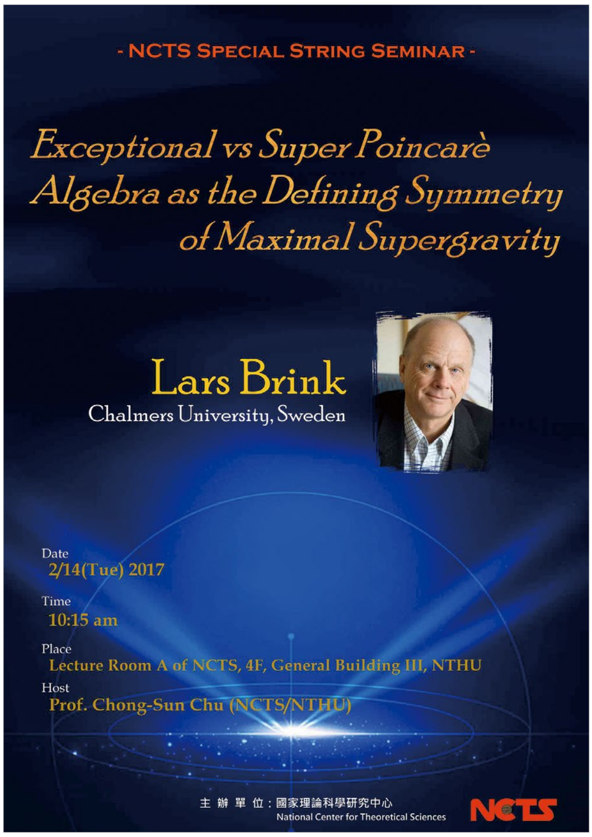


International Cooperation

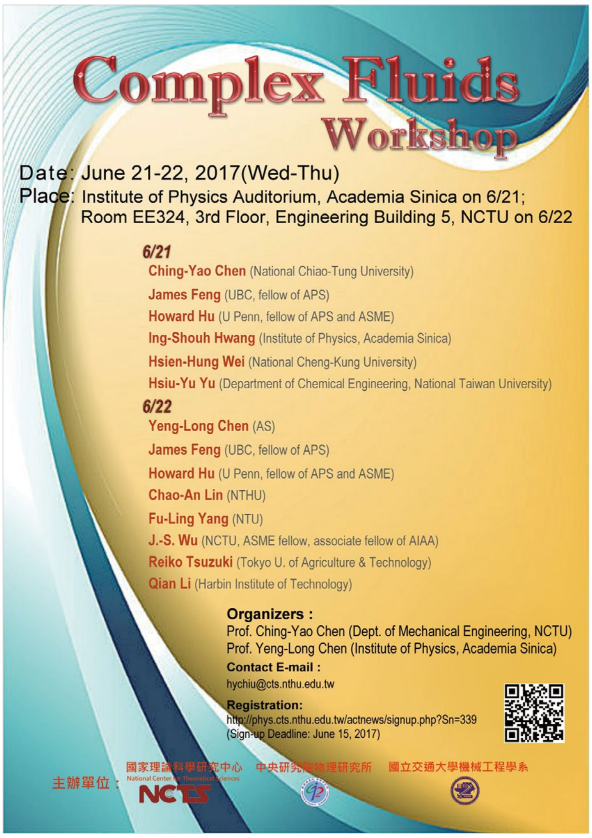
NCTS has continued in developing new bilateral agreements with other international institutions in order to foster scientific collaboration. We have built since 2015 new bilateral agreements with the Institute of Basic Science - Center for Theoretical Physics of the Universe, Korea; the institute of High Energy Physics, the Chinese Academy of Sciences, Beijing; the Donostia International Physics Center, San Sebastian, Spain; Vilnius University, Lithuania, with plans to organize joint conferences and to work together on collaborative research projects. In 2016, NCTS has joined the research network, Fundamental Interaction SpaceTime (FIST), this year. FIST is a High Physics network formed by Research Institutions (primarily) in Asia in order to help building up and strengthening transnational research partnership and cooperation among researchers across Asia. NCTS has also joined the EU network Cooperation in Science and Technology (COST) on “Quantum structure of spacetime (QSPACE)”. The network started in 2015 and is for 5 years. It involves over 50 institutions from more 28 countries in Europe, as well as four international partner from Japan, India, Australia and Taiwan. NCTS has also joined, together with IOP Academic Sinica, the Institute for Complex Adaptive Matter (ICAM) in summer 2017.

NCTS has an active visitor program where we welcome scientists from all over the world to visit the center to exchange scientific knowledge through seminars, lectures and conference meetings, and to conduct collaborative projects with local scientists and staff. In the year 2017, we have hosted 226 international visitors.

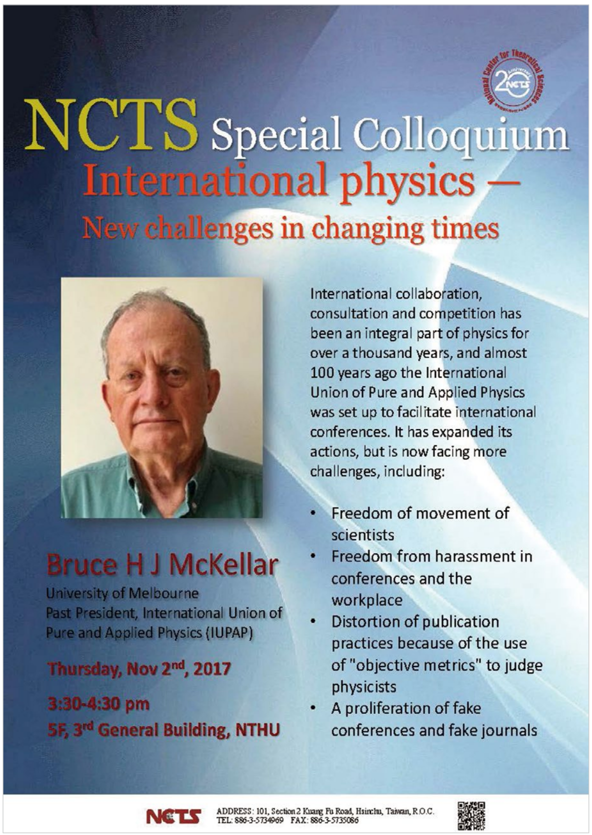
Some of the Representative Meetings




Searching for–and finding!
Gravitational Waves
Gabriela Gonzalez
Louisiana State University, for the
LIGO Scientific Collaboration & the Virgo Collaboration
15:30, May 24 (Wed), 2017
Lecture Room A of NCTS, 4F, General Building III, NTHU
On September 14 2015, the two LIGO gravitational wave detectors in Hanford, Washington and Livingston, Louisiana registered a nearly simultaneous signal with time-frequency properties consistent with gravitational-wave emission by the merger of two massive compact objects. Further analysis of the signals by the LIGO Scientific Collaboration and the Virgo Collaboration revealed that the gravitational waves detected by LIGO came from the merger of a binary black hole system. This observation, followed by another one in December 2015, marked the beginning of gravitational wave astronomy. I will describe some details of the observation, the status of LIGO and Virgo ground-based interferometric detectors, and prospects for future observations.
NCTS
國家理論科學研究中心
Institute of Astronomy
NTHU
國立清華大學 新竹市光復路二段101號 National Tsing Hua University, No. 101, Section 2, Kuang-Fu Road, Hsinchu, Taiwan +886-35715131


Complex Fluids
Workshop
Date: June 21-22, 2017(Wed-Thu)
Place: Institute of Physics Auditorium, Academia Sinica on 6/21;
Room EE324, 3rd Floor, Engineering Building 5, NCTU on 6/22
6/21
Ching-Yao Chen (National Chiao-Tung University)
James Feng (UBC, fellow of APS)
Howard Hu (U Penn, fellow of APS and ASME)
Ing-Shouh Hwang (Institute of Physics, Academia Sinica)
Hsien-Hung Wei (National Cheng-Kung University)
Hsiu-Yu Yu (Department of Chemical Engineering, National Taiwan University)
6/22
Yeng-Long Chen (AS)
James Feng (UBC, fellow of APS)
Howard Hu (U Penn, fellow of APS and ASME)
Chao-An Lin (NTHU)
Fu-Ling Yang (NTU)
J.-S. Wu (NCTU, ASME fellow, associate fellow of AIAA)
Reiko Tsuzuki (Tokyo U. of Agriculture & Technology)
Qian Li (Harbin Institute of Technology)
Organizers :
Prof. Ching-Yao Chen (Dept. of Mechanical Engineering, NCTU)
Prof. Yeng-Long Chen (Institute of Physics, Academia Sinica)
Contact E-mail :
hychiu@cts.nthu.edu.tw
Registration:
http://phys.cts.nthu.edu.tw/actnews/signup.php?Sn=339
(Sign-up Deadline: June 15, 2017)
主辦單位：
國家理論科學研究中心
National Center for Theoretical Sciences
NCTS
國立交通大學機械工程學系

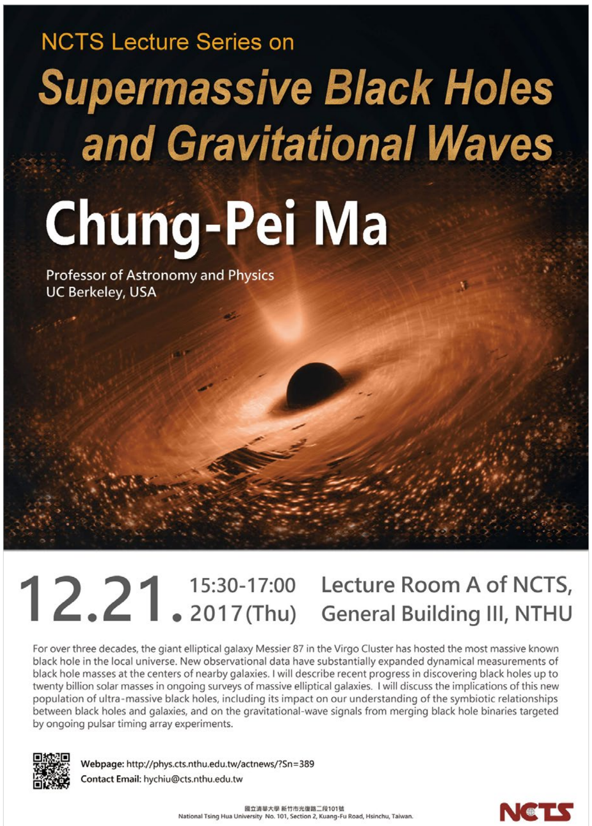

10th Taiwan String Workshop
Lecture Room A of NCTS, 4F, General Building III, NTHU
26 (Thu) - 29 (Sun)
Oct. 2017
Invited Speakers
Ning Bao (Caltech/Berkeley)
Aleksey Cherman (University of Washington)
Song He (IAS)
Yang-Hui He (University of London)
Ramalingam Loganayagam (ICTS)
Ruben Minasian (CEA Saclay)
Costis Papageorgakis (Queen Mary)
Vladimir Rosenhaus (KIT)
Yi Wang (HKIAS)
Organizers
Chuan-Tsung Chan (THU)
Heng-Yu Chen (NTU)
Chong-Sun Chu (NCTS)
Yu-Tin Huang (NTU)
Feng-Li Lin (NTNU)
Wen-Yu Wen (CYCU)
This is the 10th of our annual event which started in 2009.
The workshop will focus on the recent developments in string theory and quantum field theories. The main focus topics this year will include SUSY gauge theories, integrability, AdS/CFT correspondence and its applications, holography and quantum entanglement. We will invite several international speakers for plenary talks.
In addition, this event will provide an opportunity for us string theorists in Taiwan to meet, share our ideas and results, and discuss on the future directions. We will have more talks by local string theorists than previous years. There will also be additional short talk opportunities for younger participants.
Registration:
http://phys.cts.nthu.edu.tw/actnews/signup.php?Sn=366
(Sign-up Deadline: 2016/10/11)
Contact Email:
chaojungkuo@cts.nthu.edu.tw
主辦單位：國家理論科學研究中心 National Center for Theoretical Sciences NCTS
協辦單位：國立臺灣大學物理學系 Department of Physics, NTU


NCTS Special Colloquium
International physics —
New challenges in changing times
International collaboration, consultation and competition has been an integral part of physics for over a thousand years, and almost 100 years ago the International Union of Pure and Applied Physics was set up to facilitate international conferences. It has expanded its actions, but is now facing more challenges, including:
• Freedom of movement of scientists
• Freedom from harassment in conferences and the workplace
• Distortion of publication practices because of the use of "objective metrics" to judge physicists
• A proliferation of fake conferences and fake journals
Bruce H J McKellar
University of Melbourne
Past President, International Union of Pure and Applied Physics (IUPAP)
Thursday, Nov 2nd, 2017
3:30-4:30 pm
5F, 3rd General Building, NTHU
NCTS
ADDRESS: 101, Section 2 Kuang Fu Road, Hsinchu, Taiwan, R.O.C.
TEL: 886-3-5734969 FAX: 886-3-5735086


NCTS Annual Theory Meeting 2017
Particles, Cosmology and Strings
05th-08th Dec. 2017
12/5
Zyxel Auditorium, 1F of General Building I
12/6-8
International Conference Hall, 8F, General Building II, National Tsing Hua University. Hsinchu, Taiwan
NCTS Annual Theory Meeting is organized by the National Center for Theoretical Science. The main purpose of this series of annual meetings is to bring together leading physicists to report on their latest research results and to speak on prospects for the future as well as to interact with the physicists especially young researchers in Taiwan. There is one meeting on high energy physics (particles, cosmology and strings) and one on condensed matter physics held annually in December.
Invited Speakers
Sinya Aoki, YITP
Eric Braaten, Ohio State Univ
Amihay Hanany, Imperial College London
Koji Hashimoto, Osaka Univ
Zuowei Liu, Nanjing Univ
Ian Low, Northwestern Univ
Takeo Moroi, Univ Tokyo
Mihoko Nojiri, KEK
Diego Sáez Gómez, IEEC-CSIC
Jiro Soda, Kobe Univ
Liantao Wang, Univ Chicago
Kentaroh Yoshida, Kyoto Univ
Naoki Yoshida, Kavli IPMU
+ Others
Scientific organizing committee
Kingman Cheung, Cheng-Wei Chiang, Chong-Sun Chu (Chair)
Chao-Qiang Geng, Xiao-Gang He (Co-chair), Kin-Wang Ng, Tzu-Chiang Yuan
Registration:
http://phys.cts.nthu.edu.tw/actnews/signup.php?Sn=352
Please sign-up before 2017.11.20
Contact Email:
yychiu@cts.nthu.edu.tw
NCTS


Taiwan-France Workshop on Drop Dynamics and its Applications
- Poster Submission is Welcome -
Place: R400 of Institute of Applied Mechanics, National Taiwan University, Taipei, Taiwan
Invited Speakers
David Quéré (LadHyX laboratory/Ecole Polytechnique)
Stéphane Zaleski (Jean Le Rond d'Alembert Institute/Université Pierre et Marie Curie)
Christophe Josserand (LadHyX laboratory/Ecole Polytechnique)
Thomas Séon (Jean Le Rond d'Alembert Institute/Université Pierre et Marie Curie)
An-Bang Wang (IAM/National Taiwan University)
Kuo-Long Pan (ME/ National Taiwan University)
Chuin-Shan Chen (CE/ National Taiwan University)
Ying-Chih Liao (ChE/ National Taiwan University)
Yeng-Long Chen (Physics/Academia Sinica)
Ching-Yao Chen (ME/National Chiao Tung University)
Muh-Rong Wang (IAA/National Cheng Kung University)
Hsien-Hung Wei (ChE/ National Cheng Kung University)
12/11 (Mon), 2017
8:30-17:50
Chair An-Bang Wang, Stephane Zaleski, Yeng-Long Chen
Member of Organizing Committee Ching-Yao Chen, Ying-Chih Liao, Kuo-Long Pan
Registration: http://phys.cts.nthu.edu.tw/actnews/signup.php?Sn=382
Please sign-up before 2017.12.1
Contact Email: chingyao@mail.nctu.edu.tw
Sponsored by the MOST CNRS program
Jointly Sponsored by National Taiwan University National Center for Theoretical Sciences NCTS Academia Sinica


Mini Workshop
Active Matter
Date: Dec. 12th, 2017
Venue: 2nd floor Physics building, National Central University
Program
Swimmer-microrheology
Shigeyuki Komura (Department of Chemistry, Tokyo Metropolitan University)
Hydrodynamic interactions in active fluids
Heng-Kwong Tsao (Department of Chemical and Materials Engineering/Department of Physics, National Central University)
Electrically Enhanced Self-Thermophoresis of Laser-Heated Janus Particles under a Rotating Electric Field
Hong-Ren Jiang (Institute of Applied Mechanics, National Taiwan University)
A particle-scale statistical description of semi-dilute suspensions of active microswimmers
Andreas Menzel (Institut fur Theoretische Physik II - Soft Matter, Heinrich-Heine-Universitut Dusseldorf)
Dynamics of self-organized rotating spiral-coils in bacterial swarms
Chien-Jung Lo (Institute of Applied Mechanics, National Taiwan University)
Cancer cell invasion enhanced collective motion of endothelial/cancer cell mixtures
Hsiang-Ying Chen (Department of Physics, National Central University)
Tail retraction dynamics of MDCK cells
Jilin Jou (Department of Physics, National Central University)
主辦單位：國家理論科學研究中心 National Center for Theoretical Sciences NCTS 國立中央大學物理系 National Central University Department of Physics


NCTS Lecture Series on
Supermassive Black Holes and Gravitational Waves
Chung-Pei Ma
Professor of Astronomy and Physics
UC Berkeley, USA
12.21. 15:30-17:00
2017 (Thu)
Lecture Room A of NCTS, General Building III, NTHU
For over three decades, the giant elliptical galaxy Messier 87 in the Virgo Cluster has hosted the most massive known black hole in the local universe. New observational data have substantially expanded dynamical measurements of black hole masses at the centers of nearby galaxies. I will describe recent progress in discovering black holes up to twenty billion solar masses in ongoing surveys of massive elliptical galaxies. I will discuss the implications of this new population of ultra-massive black holes, including its impact on our understanding of the symbiotic relationships between black holes and galaxies, and on the gravitational-wave signals from merging black hole binaries targeted by ongoing pulsar timing array experiments.
Webpage: http://phys.cts.nthu.edu.tw/actnews/?Sn=389
Contact Email: hychiu@cts.nthu.edu.tw
國立清華大學 新竹市光復路二段101號
National Tsing Hua University No. 101, Section 2, Kuang-Fu Road, Hsinchu, Taiwan.
NCTS

Visitors

Akkerma, Eric
Technion, Israel
Aug 21-26, 2017

Albao, Marvin Argulla
University of the Philippines Los Baños
Oct 12-13, 2017

Aoki, Shinya
Yukawa Institute for Theoretical Physics
Dec 03-06, 2017

Aryasetiawan, Ferdi
Lund University
Nov 29-Dec 02, 2017

Assad, Syed M.
Australian National University
Jul 24-Aug 09, 2017

Baiotti, Luca
Osaka University
Jul 12-15, 2017

Bancal, Jean-Daniel
University of Basel
Mar 18-30, 2017

Baulieu, Laurent
Laboratoire de Physique Théorique et Hautes Energies
Apr 16-May 04, 2017

Belosludov, Rodion
Tohoku University
Oct 31-Nov 04, 2017

Bhattacharyya, Arpan
Indian Institute of Science
Mar 26-Apr 01, 2017
Sep 04-06, 2017

Braaten, Eric
Ohio State University
Dec 03-08, 2017

Braun, Daniel
Eberhard Karls Universität Tübingen
Sep 03-07, 2017

Brink, Lars
Chalmers University
Feb 14, 2017

Buchleitner, Andreas
Albert-Ludwigs University of Freiburg
Sep 08-10, 2017

Calibbi, Lorenzo
Chinese Academy of Sciences
Jul 10-14, 2017

Chang, Ching-Hao
Leibniz Institute for Solid State and Materials Research Dresden
Dec 16 ,2017-Jan 25, 2018

Chang, Der Chen
Georgetown University
Jun 01-Jul 30, 2017
Dec 15-31, 2017

Chang, Huai-Liang
Hong Kong University of Science and Technology
Dec 03-08, 2017

Chang, Jung
Chonnam National University
Jul 06-Aug 18, 2017
Dec 24-31, 2017

Chang, Po-Yao
Rutgers University
Dec 20-24, 2017

Chang, Tu-Nan
University of Southern California
Apr 05-May 06, 2017
Jul 13-Aug 05, 2017
Oct 20-Nov 21, 2017

Cheng, Hsin-Chia
University of California
Dec 16-31, 2017

Cherman, Aleksey
University of Washington
Oct 25-29, 2017

Ching, Emily S.C
Chinese University of Hong Kong
Oct 17-20, 2017

Chong, Yi-Dong
Nanyang Technological University
Sep 26-28, 2017

Chun, Eung-Jin
Korea Institute for Advanced Study
May 07-15, 2017

Claudio, Gil
University of Philippines
Oct 12-13, 2017

Cohen, Andrew
Jockey Club Institute for Advanced Study, HKUST
Aug 01-03, 2017

Conti, Claudio
University Sapienza of Rome
Dec 03-06, 2017

Crichigno, Patricio
University of Amsterdam
Jan 15-22, 2017

Cui, Xiao-Dong
University of Hong Kong
Jun 26-28, 2017

Dai, Li-Ming
Case Western Reserve University
Oct 31-Nov 04, 2017

David, Melanie Yadao
De La Salle University
Oct 12-13, 2017

Deniz, Muhammed
Dokuz Eylul University
Jun 20-Sep 20, 2017

Derendinger, Jean-Pierre
Bern University
Jul 28-Aug 17, 2017
Oct 24-Nov 09, 2017

Egwolf, Bernhard
University of Santo Tomas
Oct 12-13, 2017

Fang, Shiang
Harvard University
Jan 08-12, 2017

Feng, Xu
Peking university
Nov 01-05, 2017

Fowlie, Andrew
Monash University
Sep 28-Oct 15, 2017

Fujii, Keisuke
KEK
Sep 28-Oct 01, 2017

Fukuda, Haime
The University of Tokyo
Mar 08-14, 2017

Furey, Cohl
University of Cambridge
Jan 16, 2017

Gao, Jie
Chinese Academy of Sciences
Sep 28-30, 2017

Gneiting, Clemens
RIKEN
Apr 23-29, 2017

Goh, Kwang-Il
Korea University
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Jun 22-Jul 03, 2017

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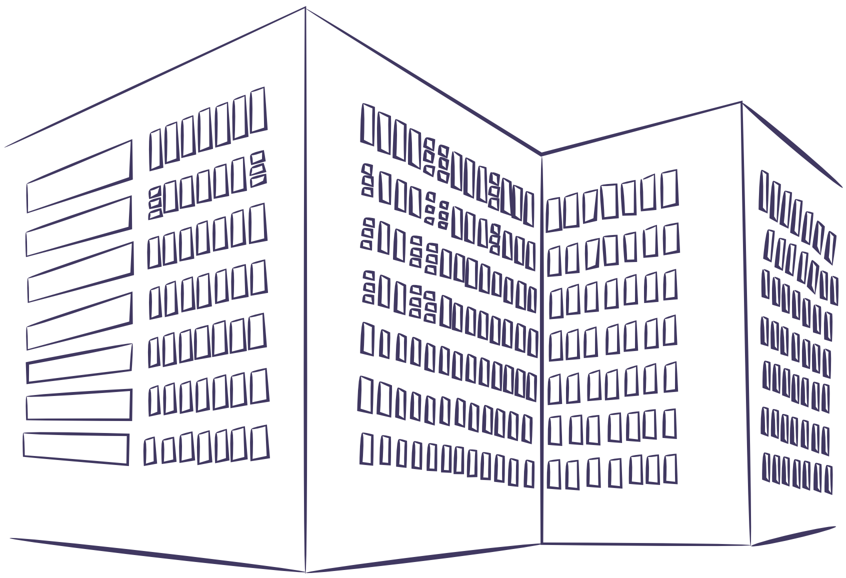

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