NCTS Midterm Report, 2018
National Center for Theoretical Sciences,
Mathematics Division

Contents

I Overview

I.1 Report of Director

I.1.1 Goals and missions of the Center

In 1997, National Center for Theoretical Sciences (NCTS) was established by National Science Council. During the past two decades, the NCTS has been well-recognized as one of the leading research center in Asia. The mathematical community of Taiwan benefits a lot from the various program organized and offered by NCTS. The main purpose of NCTS on one hand is to promote cutting-edge research in theoretical sciences, and on the other hand, to serve as an platform for students, young researchers and researchers in the relative fields for idea exchange and collaboration opportunities seeking. The aim of NCTS consists of the following specific aspects:

a. Fostering world class outstanding researchers, and attracting top young researchers to do cutting-edge research in NCTS;

b. Attracting worldwide outstanding theoretical scientists to do research in Taiwan;

c. Developing international and inter-disciplinary scientific research program;

d. Promoting international cooperation and collaborations, aiming to become a leading research institution in Asia and worldwide.

National Center for Theoretical Sciences has provided the most important platform for the collaboration and interaction among Taiwanese mathematicians since its establishment. Since January 2015, NCTS was restructured and the Mathematics Division was moved to the campus of National Taiwan University. With the generous support of NTU and active researchers in mathematics and related areas, NCTS's academic activities were impressive domestically and internationally.

Youth training and youth empowerment have been the major goal of NCTS since its foundation. Taking into consideration of the fact of decreasing number of Taiwanese students in total, we feel that some more systematical and strategic planning are indeed necessary. One on hand, we will need a more solid and effective training program for our own students, and on the other hand, we will need to speed up and strengthen the international cooperation. With these goals in mind, we work on: RA (research assistant) program and USRP (undergraduate summer research program) in order to encourage undergraduate to pursuit advanced studies; Taiwan Mathematics School in order for graduate students to have wider spectrum of basic training; with our internationalized Postdoc program in order for our students to be exposed in the frontier environment. More details of these various programs can be found below.

During the year of 2018, we had various big events reflecting various aspects of our efforts. In May, we ran the first ever "NCTS Health Hackathon", to promote mathematical studies in medical science. In July, we held the 12th AIMS meeting in Taipei which attracts about 1600 mathematicians from all over the world for communication and collaboration. On the other hand, the ICM (International Congress of Mathematician) is a carnival happening every 4 years. NCTS was not absent in it! in the stage of ICM 2018, NCTS appeared as the place where the Field Medalist Prof. Caucher Birkar initiated his award-winning work. Also, the Director of NCTS was one of the invited speakers and also invited to be the Chair to host the Field Medal Lecture. We believe that these facts indicates that NCTS has received notable international recognition.

For the year 2019 to come, we aim at consolidating our Topical Programs and International Cooperation Programs. One of the exciting event to come in 2019 is the joint summer school with MSRI (Mathematical Sciences Research Institute, Berkeley) to be held in August in NCTS. Other than collaborating with well-established research center, we think it is about time for us to contribute more to developing countries. We had some preliminary discussion with representatives from south-east Asia and we are looking forward to the realization of certain program.

I.1.2 Brief summary and highlights of the year

a. Former NCTS Scholar won the Fields Medal

   The International Congress of Mathematics 2018 was held in Rio, Brazil. It is the most influential and possibly the biggest event of mathematicians which come to stage every 4 years. It was a exciting news that the former NCTS Scholar Caucher Birkar (2014-2017) was announced to be the Fields Medalist in Rio, ICM 2018. The main piece of his contribution, boundedness of Fano varieties, or so-called BAB conjecture, was initiated during his stay in NCTS. This was even quoted in this publication. It is really honor and pleasure that NCTS is the place that his prize-winning work was initiated. We hope that more fundamental and influential work will happen in NCTS in the future.

   Moreover, the Director was invited to give an talk at ICM and host the Field Medal Lecture of Caucher Birkar. We consider this as an strong recognition of NCTS internationally.

b. Undergraduate Summer Research Program

   In order to motivate more students for advanced studies in theoretical sciences, we initiated Undergraduate Summer Research Program in 2017. This summer, we got 47 applications and 23 of them were selected into 7 groups. Both the number of applications and selected students were double. We hope to make it (or part of it) an international program next year so that students can broaden their horizon more.

c. Cultivation the Youth

NCTS aims at improving the academic environment all over Taiwan. Ph.D students are getting fewer and fewer in Taiwan in recent years. This situation has happened overwhelmingly to all the academic fields, and mathematics is included . It turns out that each department has only very few Ph.D students. Hence, NCTS will not only put lots of efforts on student-training in each program by organizing student seminars and summer schools, but also promote and inspire more inter-university cooperations. With this mission in mind, we e serves as a platform for outstanding scholars from different institutes to participate in joint student-training programs. This leads to idea of Taiwan Mathematics School. Some of the formation and basic structure is modeled after Berlin Mathematical School. However, we are working on a soft-school instead of rigid ones. Up to now, we offer 14 courses with total 21 credits.

NCTS also designed cooperative programs for undergraduate and graduate students to work in the Center or to visit our partner foreign institutes, and the Program of Research Assistants (RA) is designed for this purpose. The criteria of our RA is the potential to be a Ph.D. candidate at prestigious institutions. However, even though we allocated 10 positions of RAs, we have only recruited 3 qualified RAs this year. Perhaps The rapid shrinking of student numbers of recent years is one of the reasons.

d. NCTS Health Hackathon 2018

National Center for Theoretical Sciences held the ”NCTS Health Hackathon 2018” hackathon from May 4th to May 6th this year. The organizers include Professor Weichung Wang from National Taiwan University, Dr. Cheyu Hsu from National Taiwan University Hospital, Professor Anthony Costa and Professor Eric Oermann from Mount Sinai Health System. Participants joined the 48-hour competition to develop brilliant ideas and made significant innovations in healthcare.

The core concept of this hackathon was ”Intelligent Hospital.” This competition aimed to integrate medicine, artificial intelligence, mathematics, high-performance computing, social economics, and other professional knowledge and techniques to generate innovative medical designs. Contestants chose topics from different aspects of the intelligent hospital, such as ”Elderly care,” ”Psychiatric care,” ”Hospice care,” ”Community healthcare,” and ”Health insurance system.” The joint effort came from a strong team of judges including Shan Zhao, Founder and CEO of Stealth Health, Andy Choi, CEO of IntuitiveX, Dr. Rajib Chakravorty, Research Scientist, IBM Research Australia, and Neha Dangayach, Professor of Neurology and Neurosurgery, Mount Sinai Health System, USA. Experts and scholars in mathematics, statistics, and medicine also assisted contestant with their expertise. In this competition, we provided the first prize of NT$120,000, the second NT$50,000, the

third NT$30,000. The top three teams were offered opportunities to enter training courses offered by YongLin Health Foundation and H. Spectrum. They will also be able to compete with other exhibitors at the TRANS Conference organized by H. Spectrum in September this year.

Eighteen teams, 79 contestants in total participated in the competition. Participants are from different departments of National Taiwan University, including Mathematics, Medicine, Life Sciences, Clinical Medicine, Electronic Engineering, Medical Engineering, Computer Science & Information Engineering, Engineering Science and Ocean Engineering. A few contestants also come from other universities and institutes such as National Cheng Kung University, National Yang-Ming University, National Chengchi University, National Chengchi University Hospital, Academia Sinica, Taiwan Artificial Intelligence School. Contestants came with diverse backgrounds including data analysis, deep learning, medical care, artificial intelligence, etc.

The hackathon competition held by NCTS took place for three days. During the hackathon, we arranged ten sessions for participants to consult with 24 experts from the fields of mathematics and medicine. We also organized a few other meetings where contestants listened to the speeches delivered by the judges and had a face-to-face consultation with them after the talks. Some contestants believed that they were more aware of the strengths and weaknesses of their projects after talking with judges and advisers. The advice from the experts helped them realize how to adjust the focus of their projects. On the last day of the competition, in the form of a project exhibition, each team used self-designed posters and PowerPoint file at their booths to show the judges the work they had accomplished during the past three days. Each team developed a new medical design based on the theme of this contest, the "Intelligent Hospital."

The project of the third prize winner, Blockfit, introduces a wearable device and virtual currency reward mechanism to encourage the public to exchange their fitness experience and increase the patient's motivation for recovery.

The AI Doctor 3.0, a colonoscopy automatic driving detection instrument designed by the second prize-winning team, uses the mechanism of automatic driving to create artificial intelligence lenses to replace the traditional human operation, allowing the lens to detect intestinal tumors automatically. The Patient Relay Optimizer (PRO), the first prize winner's project, assists physicians by automatically generating each patient's profile, status, and task, and responding to the patient's critical situation. The prioritization of work uses visual sorting and reminders, as well as an overview of the entire medical team so that the next physician can get started immediately. The advantages of this system are to improve the workload of traditional paperwork, such as relying on verbal narratives and completing forms. In addition,

through the integration of the physician's edited data, the system can summarize similar symptoms of illnesses and provide appropriate advice to physicians, allowing the entire system to work with the medical team and enables doctors to quickly master ward work, which reduces the loss of information in communication, risks, and extra costs.

e. Academic Activities

We regard seminars as the core of our daily operation of topical programs. Our large variety of seminars provide group members good research environment to get together for discussion and exchange of idea. In order to to make it more accessible for researchers in remote places, some of the seminars were organized as online meetings, and broadcastings, by which lots of time and energy for research have saved for many participants. However, in fact, we feel that the traditional face to face discussion is still the best way for discussion, unless the technology can be improved better.

We have 27 conferences and workshops, accompanied by 23 courses and lectures. Extra efforts were made for the summer courses. We had 10 summer courses designed for students and young researchers this year. The topics had covered from pure mathematics, such as elliptic curves, geometric analysis, probability, dynamical system, to interdisciplinary mathematical sciences, such as mathematical biology, optimization, epidemiology. Some of the summer courses are in the umbrella of "Taiwan Mathemtical School". So that students are eligible to get official credits.

f. Efforts in reach-out and donations

We spend some effort to have communication with private sectors. By doing so, we successfully gain some donations. For example, our Health Hackathon got support from NTUH of $0.3M$ and from a private foundation of $0.2M$. Other than that, we also received a promised donation of $2M$ for modeling and decoration.

I.2 Summary of demographic data

I.2.1 Summary of activities

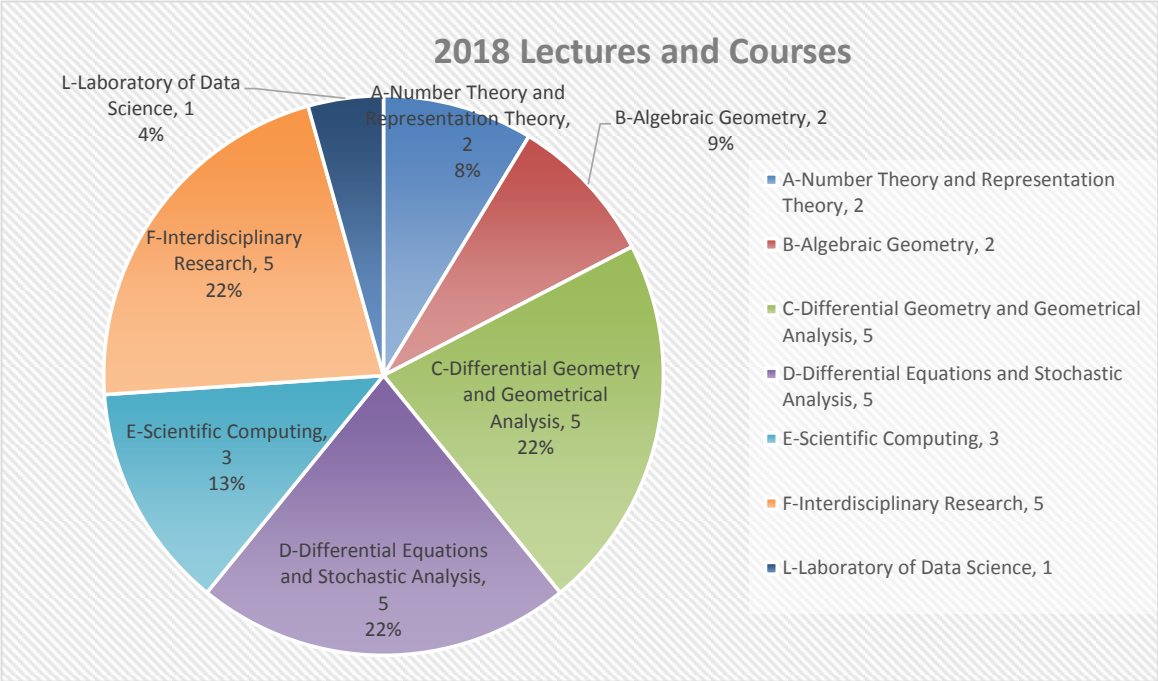


Figure 1. 2018 NCTS Lectures and Courses

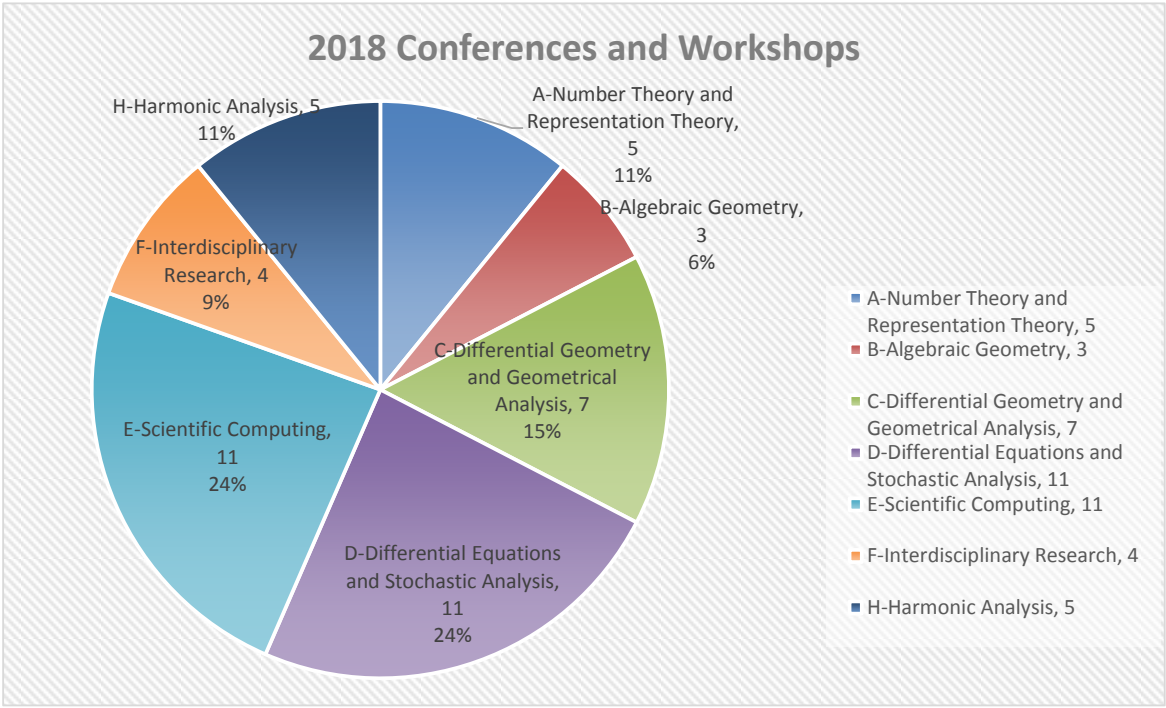


Figure 2. 2018 NCTS Conference and Workshop

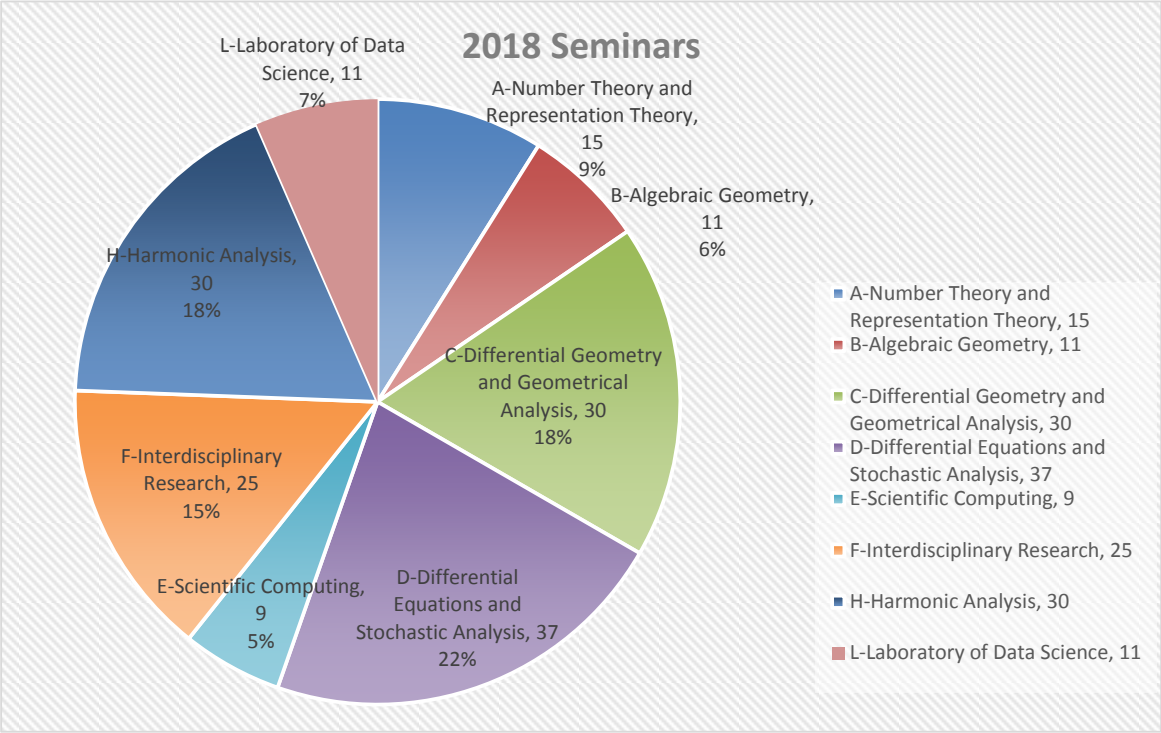


Figure 3. 2018 NCTS Seminars

I.2.2 Summary of visitors

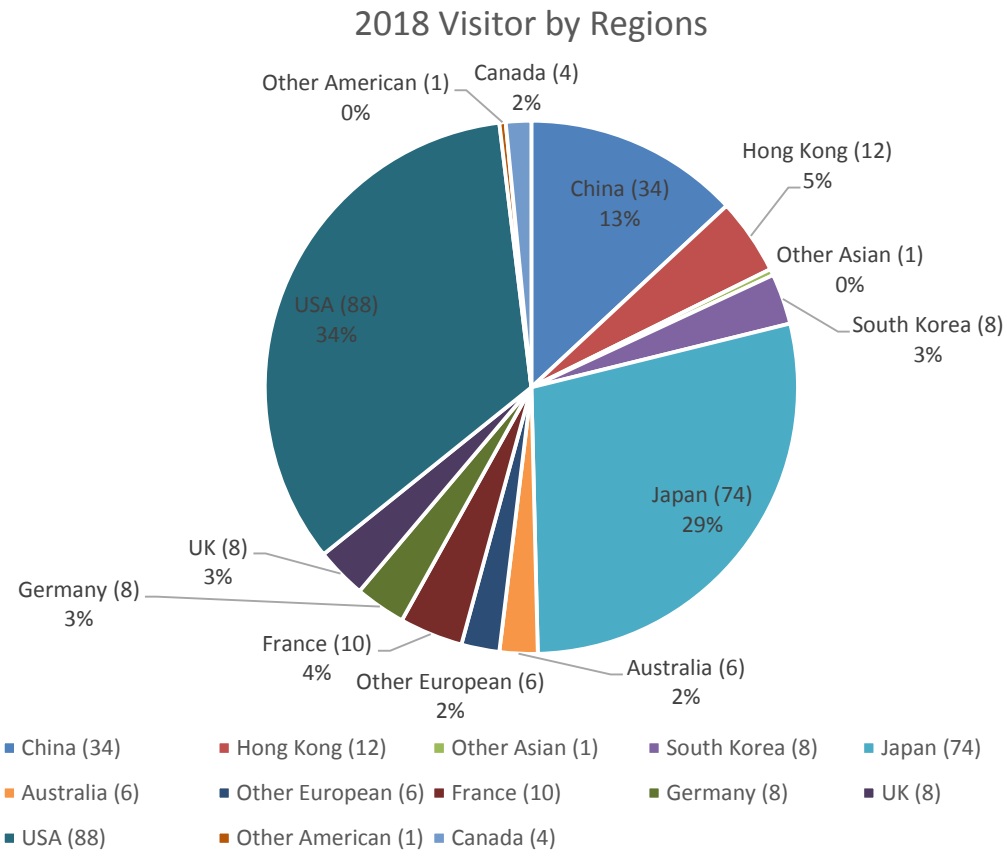


Figure 4. 2016 NCTS Visitors by Region

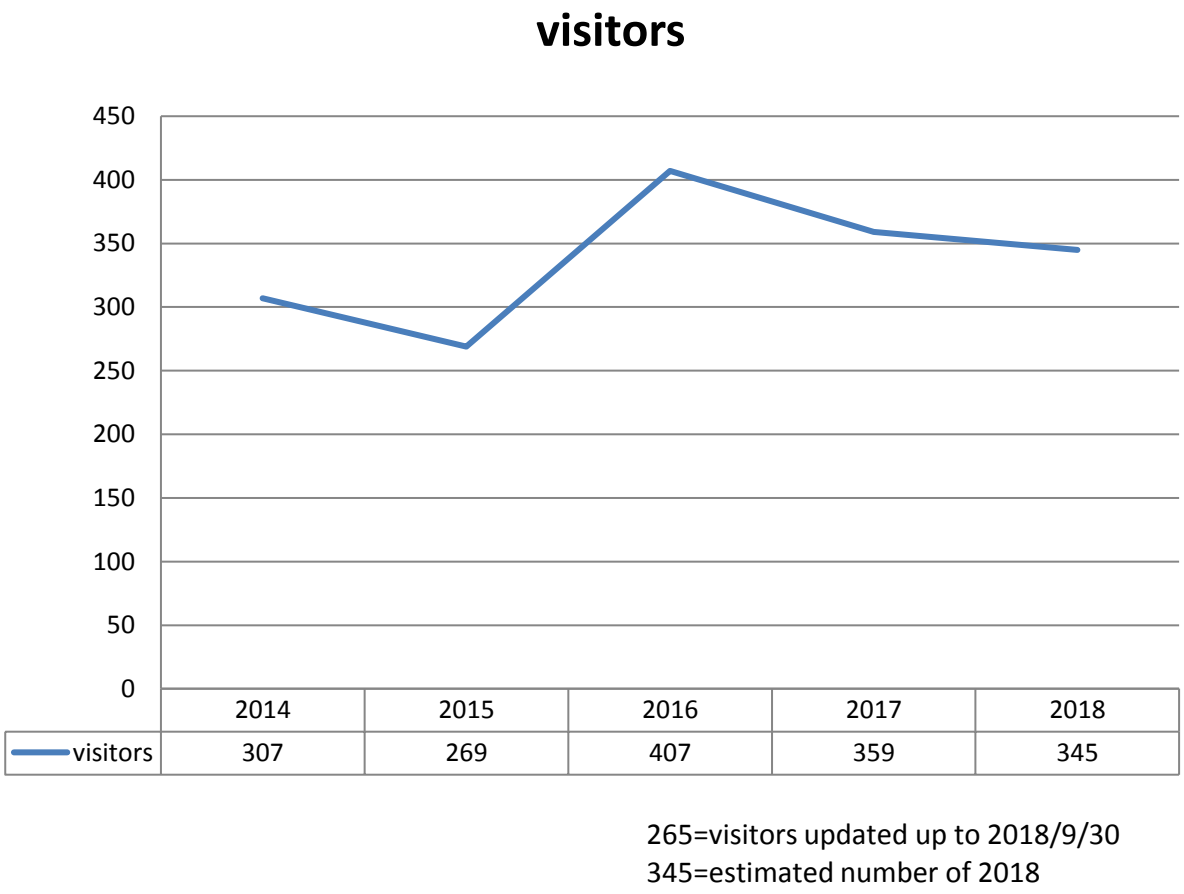


Figure 5. Visitors of Past 5 years

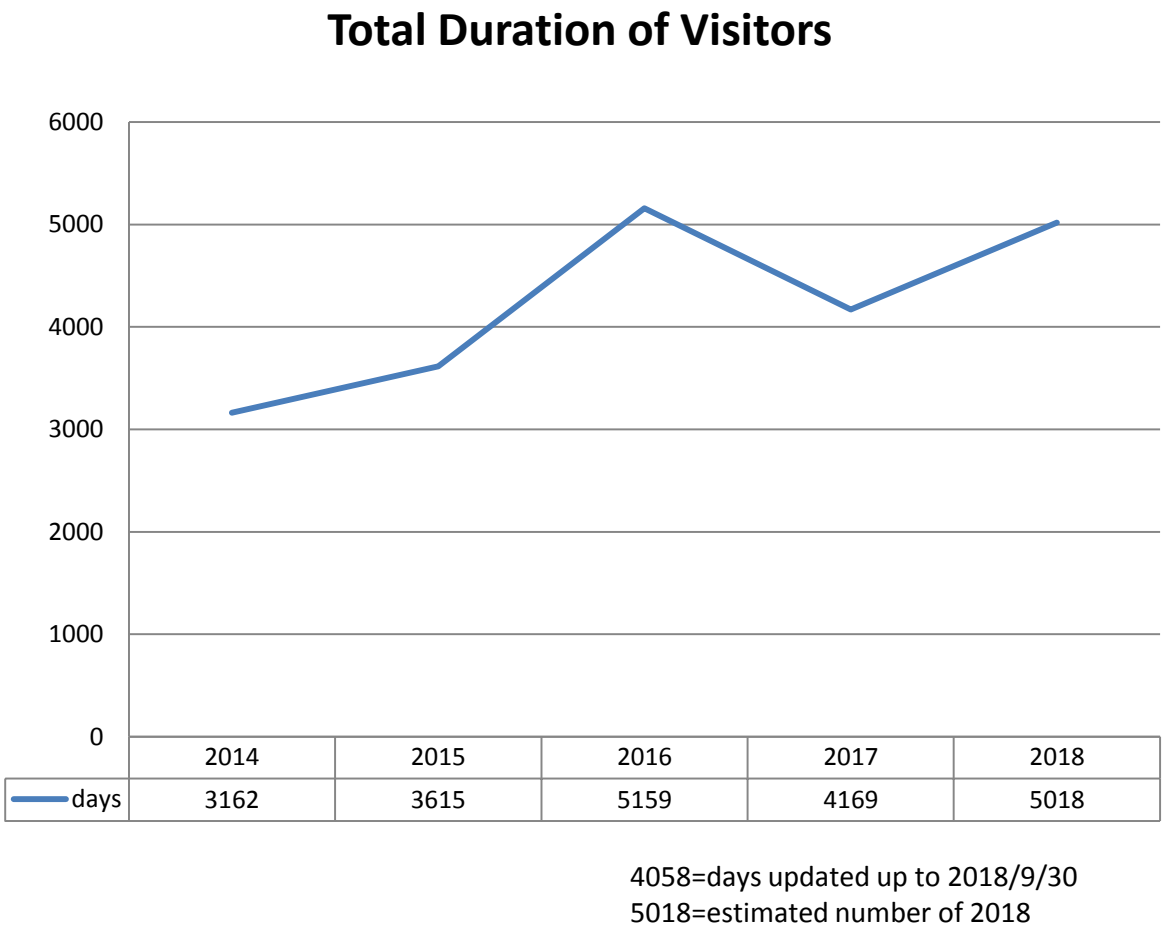
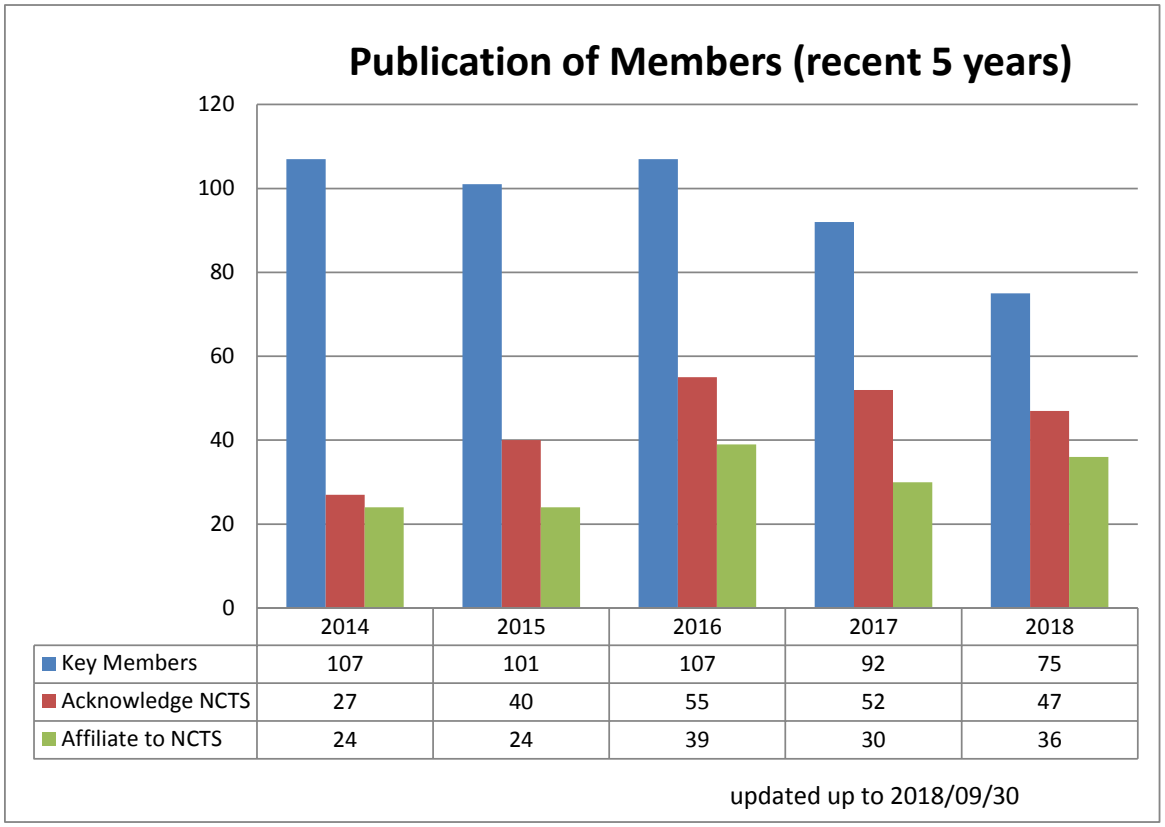


Figure 6. Total Duration of Visitors of Past 5 Years

I.2.3 Summary of publication data



	2014	2015	2016	2017	2018
Key Members	107	101	107	92	75
Acknowledge NCTS	27	40	55	52	47
Affiliate to NCTS	24	24	39	30	36

Figure 7. Visitors of Past 5 years

II Operation and Achievement of the Center

II.1 Visitor program

II.2 Postdoctoral program and cultivation program

II.2.1 Graduate and undergraduate program

1. Research Assistsnts
   We allocated 10 positions of Student Research Assistants. These positions are designed for students who are in the transition toward their advanced studies. We open call for applications twice a year. Qualified applicants are interviewed by some of our members. The selection criteria is basically the potential of students to be admitted by prestigious Ph.D. program or not. Each RA is associate to a topical program and a mentor. Moreover, they are required to take courses and participate seminars in their fields.

   Currently, we have 9 RAs, two of them starts from Feb 1, 2018 and 7 of them starts from Aug. 1, 2018. Statistics shows that about 2/3 of our pervious RA were admitted into Ph.D. program for advanced studies abroad.

2. Undergraduate Summer Research Program
   The purpose of this program is to provide project oriented studies for undergraduate students during summer. We started to run the USRP program in 2017. This year, we got a lot more applications. Among 48 applications, we selected 23 students in 7 groups. Their final presentation were quite impression. We are thinking to make the program an international program next year.

II.2.2 Postdoctoral program

One of the main goal of NCTS is the to train our Taiwanese younger generation. Therefore, it is fundamental important to have a solid postdoc program. In fact, we aim to be the training camp for postdocs so that they are able to advance their pursuit of higher advanced research.

We allocated 20 positions of postdoc fellows out of our budget. We had 18 postdocs in 2017, and 11 of them have now received positions from other institutions and 2 of them terminated , such as Hiroshima Univ. of Japan, NYU at Shanghai, Wu Han Univ. and NCKU. We got the 12 other postdocs in 2015 renewed as 2016 NCTS postdoc.

Besides, we recruited 8 new postdocs, and their employment started from August this year. The current list of 20 postdocs consists of 6 Taiwanese and 14 international postdocs, and each of them is assigned to an adviser and a Topical Program. By doing so, each postdoc is involved in various activities of NCTS. Other than those seminars and events of each Topical Program, we have launched the cooperative project Taipei

Postdoc Seminar with Academia Sinica. This seminar is jointly organized by postdoc representatives from NCTS and AS, and the representative of NCTS this semester is Yu-Yen Chien. There are talks, which are supposed to be accessible to general postdocs, every week. It not only provides an opportunities for postdoc fellows to present their works, but also build a platform for them to seek for possible collaborations.

II.3 International cooperation

II.3.1 Cooperation with international institutions

a. active existing cooperation programs
There are several existing cooperation program with international institutions. For the exchange programs, we open call for proposals each year in Dec. The Executive Committee will make selection base on potential of individual proposal. Priority will be given to young members.

(1). RIMS, Japan
For example, base on the MoU with RIMS, we recommend two young researchers: Ching-Jui Lai (NCKU, Assist. Prof.) and Jia-Wei Guo (NTU, postdoc). These two researchers visited RIMS for one and two months respectively.

(2). KIAS, Korea
Also, base on the MoU with KIAS, we recommended a postdoc fellow to visit KIAS for one month. However, there is no one propose to visit KIAS this year.

(3). PMI, Korea
The joint NCTS-PMI workshop has been held annually for years.

(4). Fields Insttitute, Canada
We have a MoU with Fields for exchange scholars. This year, we recommend Ser-Wei Fu (NCTS postdoc) and T. L Hong (Feng-Chia Univ.) to Fields for 2 months and one month respectively.

(5). AIMS, USA
The American Institute for Mathematical Sciences run a large scale conference on differential equations and dynamical systems every two years. The conference was arranged in Orlando in 2016 and NCTS host the next meeting in 2018 by cooperating with AIMS.

b. establishment of new cooperation programs
A lot of extra efforts were made in order to enhance the cooperation with international institutions this year.

(1). MSRI, USA
The Mathematical Sciences Research Institute (MSRI) is a successful center with

long history. After the discussion lasting for several months, we decided to start a joint summer school held at NCTS, which is confirmed to be on Toric Varieties in Jul 29 (Mon)-Aug 9 (Fri), 2019. MSRI will provided lecturers and partial support of American participants.

(2). Berlin Mathematical School, Germany
The Berlin Mathematical School (BMS) is an consortium consists of three major universities in Berlin: TU Berlin, HU Berlin, and FU Berlin. We had a small group visited BMS and learn a lot more about their functioning. Modeling after BMS, we initiated our Taiwan Mathematics School.

II.3.2 Cooperation with foreign research team

There are several cooperative programs with international teams, some of which are listed below.

a. East Asian Core Doctoral Forum in Mathematics

This is a forum organized by a team, whose members are 7 main universities: Tokyo, Kyoto, Tohoku, Seoul, Tsinghua, Fudan and National Taiwan University. It was initiated by Kotani, Tsutsumi, Kawahigashi, Ha, Jiou, Wu and Jungkai Chen. Every participating country recommends 8-10 Ph.D. (or postdoc) speakers. The purpose is to provide a platform for young students to present their works in an international meeting and to build up their international connections. It has been held in Kyoto, Taipei, and Fudan, Seoul, Tsing-Hua University and it's going to be in Tohoku in 2019

b. Reaction-Diffusion Network in Mathematics and Biomedicine: The GDRI ReaDiNet

This is an international cooperative program led by James D. MURRAY, and scientific coordinators are from KAIST, Tokyo, Meiji Univ., Paris-Sud, Nice, Univ.. Joseph Fourier, and NCTS. Chiun-Chuan Chen (NTU) and Jong-Shenq Guo (Tamkang Univ.) are representatives of NCTS.

c. Bilateral joint workshop

There are several bilateral (or trilateral) joint workshops supported by NCTS in order to promote further collaboration between Taiwanese team and international teams. For example, bilateral workshops with Japanese teams cover the areas of number theory, algebraic geometry, PDE, and applied mathematics.

II.4 Taiwan Mathematics School

II.4.1 Taiwan Mathematics School

We started the platform of Taiwan Mathematics School in 2017. It was started with a joint effort of Weichung Wang (NTU), Yu-Chen Su (NCKU), Min-Hsing Lin (NCKU), Tsung-Ming Huang (NTNU), and Wen-Wei Lin (NCTU). The course of "Scientific Computing and Machine Learning on Multi- and Manycore Architectures" was organized and held in different places (NTU and NCKU). Then it was broadcasted to many more different places (NTHU and NCTU). With the assistance of online system and modern internet technology, the inter-university courses was started and served to students from all over Taiwan. After that, a lot of efforts was made to tune up the infrastructure and logistic work. Up to now, we have (or plan to have) the following courses:

- Scientific Computing and Machine Learning on Multi- and Manycore Architectures, Winter 2017, 1 credit.
- High-Performance Numerical Solvers, Winter 2017, 1 credit.
- Kinetic Theory and Introduction to Shock Wave Theory, Spring 2018, 2 credits.
- Lectures on Lagrangian Floer theory, Spring 2018, 1 credit.
- Topics in Random Matrix Theory, Spring 2018, 1 credit.
- An introduction to Geometric Measure Theory, Spring 2018, 2 credits.
- Reaction-Diffusion and Mathematical Sciences, Spring 2018, 2 credits.
- Introduction to 3-manifold topology with some applications to Knot theory, Summer 2018, 1 credit.
- Introduction to Parallel Computing (II), Summer 2018, 1 credit.
- Fluid, water wave and phase transition problems, Summer 2018, 1 credit.
- Mathematical Modeling and Analysis of Infectious Diseases 1, Summer 2018, 1 credit.
- Mathematical Modeling and Analysis of Infectious Diseases 2, Summer 2018, 1 credit.
- Introduction to Automorphic Representations on GL(2), Fall 2018, 3 credits.
- Kinetic Equations and Related Topics, Fall 2018, 3 credits.

Among above courses, they are either offered by our long-term visitors, possibly with the assistance of local members, or offered by a group of local faculties in related fields jointly.

During the Fall semester of 2018, we are going to organize some seminar of "soft-skills" introducing the skill of TeX, preparing presentation, etc.

III Academic Programs

III.1 Number Theory and Representation Theory

1. Core members

a. Faculties: Chieh-Yu Chang (NTHU), Ming-Lun Hsieh (AS), Ching Hung Lam (AS), Chia-Fu Yu (AS), Yifan Yang (NCTU), Fu-Tsun Wei (NTHU), Ming-Hsuan Kang (NCTU), Yung-Ning Peng (NCU), Hsian-Yang Chen (NUT), Shih-Chang Huang (NCKU),

b. Postdocs: Nadim Rustom, Tse-Chung Yang, Jia-Wei Guo, Nobuo Sato.

c. Ph.D. students: Yao Cheng, Shi-Yu Chen (NTU).

d. Master students and Research Assistants: Nai-Heng Hsu (NTU), Wei-Cheng Huang (NCTS).

2. Program Overviews

The purpose of the number theory and representation theory program at NCTS is to assist domestic number theorists and algebraists to continue developing some active and promising research topics, and create some opportunities for international cooperation as well as cultivating young researchers and students. Our research topics cover a wide spectrum of algebra and number theory from various perspectives. In the past year, our members focus on the following four areas:

a. Iwasawa theory and p-adic methods in algebraic number theory and automorphic forms.

b. Special values over function fields and related topics.

c. Arithmetic and geometry of moduli spaces and explicit methods.

d. Classification of holomorphic VOAs.

We run this program by having regular seminars on number theory and arithmetic geometry, summer/winter schools and hosting some international workshops and conferences. NCTS Number theory seminars are organized by C.-Y. Chang, and they were held in Taipei on Friday and in Hsinchu on Wednesday. Seminars on arithmetic geometry and representation theory are organized by C.-F. Yu and they were held in Taipei. Half of the speakers are from foreign visiting scholars, and the other half are from domestically active researchers. These regular seminars provide a platform for research exchanges and discussions, and an opportunity for young scholars to broaden their horizons.

3. Research highlight

a. Iwasawa theory and p-adic methods in algebraic number theory and automorphic forms, *by M.-L. Hsieh*.

In [1], we construct the triple product p-adic L-functions attached to Hida families (f,g,h) and prove the explicit interpolation formulae. With this construction, we plan to show that this p-adic L-function can be obtained by a p-adic deformation of p-adic Abel-Jacobi images of regularized diagonal cycles in a product of three modular curves, and thus obtain the Perrin-Riou's explicit reciprocity law for the diagonal cycle Euler system. Applying this expected outcome to the case where f is the Hida family passing through the weight two modular form associated with an elliptic curve over the rational number field, g and h are primitive Hida families of CM forms, we can give an Euler system construction of anticyclotomic p-adic L-functions attached to elliptic curves. In a forthcoming work with Francesc Castella, we will use this result to prove the non-triviality of generalized Kato classes constructed by Darmon and Rotger for elliptic curves of rank two. This would be the first result regarding the explicit construction of non-trivial elements in the Selmer group of ellitpic curves of rank two.

On the other hand, in [2] we aim to construct anticyclotomic p-adic L-functions for spinor central L-values of cuspidal automorphic representation of GSp(4). This idea is to work out the p-adic interpolation of Bessel periods for Siegel modular forms by adapting the previous construction of Chida-Hsieh for GL(2) case and then use Gan-Gross-Prasad conjecture for Bessel models (Yifeng Liu's conjecture) to reduce the interpolation formula to calculations of local Bessel integrals. We have successfully found an elegant way to compute the p-adic Bessel integrals, currently we are working on the local integrals at ramified places, at least for the Stienberg case.

More recently, we successfully construct the four variable p-adic triple product L-functions associated with three Hida families of ellitpic newforms in the balaned case with explicit interpolation formulae at all critical values. Hsieh's previous work has obtained three variable p-adic L-functions (the weight variables), but in this work, we are able to include the most important cyclotomic variable. Our method combines the ideas the work of Orloff on the rationality of critical values for balanced triple L-functions, Ikeda's determination of archimedean Gamma factors for triple product, Hida's p-adic Rankin-Selberg method explicit calculation of local Piateski-Shapiro and Rallis integerals. Our result leads to several new problems in Iwasawa theory. For example, our next project is to prove the p-adic Gross-Zagier fomrula relating the cyclotomic derivative of our p-adic L-function and the p-adic height of diagonal cycles in a product of three modular curves.

b. Special values over function fields and related topics, *by C.-Y. Chang* and *F.-T.*

Wei.

We are mainly interested in special values both in zero characteristic and positive characteristic over function fields in positive characteristic from the points of view of arithmetic geometry.

(1) For special values in positive characteristic, we are interested in multiple zeta values (abbreviated as MZV's). In [4], we define v-adic multiple zeta values of arbitrary depth that generalize the work of D. Goss in the depth one case. The first major result of [4] is to give a logarithmic interpretation both for ∞-adic and v-adic MZV's, which completely generalizes the work of Anderson and Thakur in 1990 to arbitrary depth. One important application of this work is to prove a function field analogue of Furusho's conjecture asserting that the p-adic MZV's satisfy the same linear relations that the real-valued MZV's satisfy. That is, we show that the v-adic MZV's satisfy the same linear relations that the ∞-adic MZV's satisfy. Constructions via special points and t-modules from certain Frobenius modules are based on our previous works in [3]. We mention that Furusho's conjecture for classical MZV's is still wild open.

(2) For special values in characteristic zero, we are concerned special values arising from automorphic forms. For instance, we study the central critical value of Rankin-type L-functions coming from "Drinfeld-type"automorphic cusp forms convolved with "imaginary"quadratic characters. Rankin-Selberg method provides us with a very explicit functional equation for these Rankin-type L-functions. When the "root number"in question is positive, we derive a Gross-type formula over arbitrary global function field. Via the theta series constructed from definite pure quaternions, we then establish a Shimura correspondence between Drinfeld-type forms and metaplectic forms on $\widetilde{SL_2}$. Having this correspondence at hand leads us to an explicit Waldspurger-type formula in [7].

To investigate Taguchi's heights for Drinfeld modules, we develop the theory of Eisenstein series over functions fields and prove a Kronecker-type limit formula for their derivatives in terms of units in the corresponding Drinfeld period domain in [8]. The previous work on lower rank case was published in [5]. One important application is that we prove a complete analogue of Colmez's conjecture for Faltings' heights of abelian varieties with complex multiplication, where we replace Falting's heights by Taguchi's heights and replace abelian varieties by Drinfeld modules. Note that known cases of Colmez's conjecture are restricted to low dimension and abelian CM fields, and the general case is still open.

We also study an analogue of a Green's function on Mumford curves in [6]. The meromorphic continuation of this Green's function comes from a " dif-

ferential equation", and we interpret the special value at s = 0 as a " volume" of the corresponding curve. Using harmonic analysis on Bruhat-Tits trees, we derive a Kronecker limit formula for the Green's functions in question, which connects the derivative at s = 0 with the Manin-Drinfeld theta functions. Following Gross' description of Néron's local height pairing on Mumford curves, the special derivative here then equals twice of the Néron's local height with sign changed.

c. Arithmetic and geometry of moduli spaces and explicit methods, by *C.-F. Yu* and *Y. Yang*.

In [10], we show that any basic abelian variety with additional structures over an arbitrary algebraically closed field of characteristic p is isogenous to a same object which is defined over a finite field. We also work out on certain direction of the converse, in the sense that we construct an embedding of the category of abelian varieties over finite fields up to isogeny into the category of basic abelian varieties with suitable endomorphism structures. Using this connection, we derive a new mass formula for certain polarized abelian surfaces over a finite field.

In [11], we develop a method for describing the Galois action on the superspecial locus of the Siegel moduli space in characteristic p. Using this description, we give a modern treatment for the main results of Ibukiyama and Katsura [Compos. Math., 1994] concerning the $\mathbb{F}_p$-rational points and the trace of a Hecke operator of Atkin-Lehner type. This leads to analogues with level-N structure. We also calculate the trace of the Hecke operator by the trace formula when N is large. In [12], we extend the main result of Waterhouse [Ann. Ecole. Normal, 1968] on the classification of simple abelian varieties over a prime field $\mathbb{F}_p$ in terms of lattices. We work out in details Eichler's trace formula and derive explicit formulas for the number of abelian varieties in the isogeny class corresponding to the Weil number $\sqrt{p}$. In the course of our proof, we also give a self-contained treatment for Eichler's trace formula for an arbitrary Z-order in any definite quaternion algebra.

In [9], we study quaternionic loci in Siegel's modular threefold. We determine the number of irreducible components in a quaternionic locus of discriminant D and then for each irreducible component of genus 0, we determine its modular parameterization in terms of a Hauptomodul of the associated Shimura curve.

d. Classification of holomorphic VOAs, *by C.-H. Lam*.

We continue our program on classification of holomorphic vertex operator algebras of central charge 24. By studying certain subgroups of the automorphism group that act trivailly on the weight one Lie algebras, we show that the isomorphism class of a strongly regular holomorphic vertex oper-

ator algebra of central charge 24 is determined by its weight one Lie algebra structure if the weight one subspace is nonzero. The classification of holomorphic VOA of central charge 24 with non-zero weight one space is completed in [13]. In [14], we prove the conjectual isomorphism between the level k $\hat{sl}_2$-parafermion vertex operator algebra and the $(k+1, k+2)$ minimal series W_k-algebra for all $k \geq 2$.

On the other hand, we consider a $\mathbb{Z}_p$-orbifold construction of the Moonshine vertex operator algebra $V^\natural$ for $p = 3, 5, 7, 13$. We show in [15] that the vertex operator algebra obtained by the $\mathbb{Z}_p$-orbifold construction on the Leech lattice vertex operator algebra V_Λ and a lift of a fixed-point-free isometry of order p is isomorphic to the Moonshine vertex operator algebra $V^\natural$. We also describe the relationship between those $\mathbb{Z}_p$-orbifold constructions and the $\mathbb{Z}_2$-orbifold construction in a uniform manner. A characterization of the Moonshine vertex operator algebra $V^\natural$ by the existence of an orthogonal pair of Ising vectors is also obtained.

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4. Highlights of Events

During the past year, we have hosted several significant academic activities at NCTS. Continuing the past cooperation plan, we held the NCTS-POSTECH joint workshop on number theory between Taiwan and Korea, and the next will turn to be held in Korea in 2019. Starting from this year, we have a new joint program with Japan on multiple zeta values, which has become a hot research topic in number theory in recent years. This is a bilateral joint program supported by NCTS and JSPS for two years, and on this August we hosted the Taiwan-Japan Joint Workshop on Multiple Zeta Values. Most speakers of this workshop are very young and active in this research area, and so starting from this occasion we look forward to having more research cooperations between Taiwan and Japan in the future. Below is the list of workshops and conferences we hosted during the past year.

Workshops and conferences

(a) Workshop on p-Adic L-functions and Algebraic Cycles, September 11 - 15, 2017. Organizer: M.-L. Hsieh.

(b) NCTS One Day Workshop on Multiple Zeta Values in Positive Characteristic, September 18, 2017. Organizer: C.-Y. Chang.

(c) 2017 NCTS (Taiwan)-POSTECH (Korea) Joint Workshop on Number Theory, December 27 - 29, 2017. Organizers: J. Park and C.-F. Yu.

(d) International Workshop on Algebra, June 8-9, 2018. Organizers: J. Chen and C.-F. Yu.

(e) Taiwan-Japan Joint Workshop on Multiple Zeta Values, August 2-5, 2018. Organizers: C.-Y. Chang, J. Yu and M. Kaneko.

As one of the major tasks of NCTS is to cultivate outstanding students, it is important to organize suitable lectures and courses for students to build up relative

background. One highlight along this direction is to have a course of Taiwan Mathematical School on the theory of automorphic representations in the upcoming academic year. In order to prepare adequately, M.-L. Hsieh organized a winter school in January of 2018 starting from Tate's thesis and then gradually going to the core theory of automorphic representations. Also, C.-F. Yu continued his courses on abelian varieties and Shimura varieties for establishing the background of arithmetic geometry in the frame of Taiwan Mathematical School. The following is the list of past lectures and courses.

Courses and lectures

(a) Mini-course on Representation Theory, July 10 - 13, 2017. Lecturer: K. Coulembier. Organizers: C.-W. Chen and Y.-N. Peng.

(b) 2017 NCTS Fall Course: Topics on Abelian Varieties and Shimura Varieties. Lecturer and organizer: C.-F. Yu.

(c) NCTS Winter School on Automorphic Representations, January 16 - 19, 2018. Organizer: M.-L. Hsieh.

(d) 2018 NCTS Spring Course: Topics on abelian varieties and Shimura varieties and related topics. Lecturer and organizer: C.-F. Yu.

5. The Future Plan

For the future plan of research, we continue to broaden and deepen our investigation on our ongoing projects. Joint with M. Chida, M.-L. Hsieh will study the double derivatives of the triple product p-adic L-functions when (f,g,h) have split multiplicative reduction at the weight two specialization. The goal is to derive a formula relative the derivatives to the p-adic Abel-Jacobi image of the diagonal cycle in a product of Shimua curves with semi-stable reduction at p. They plan to use unitary Shimura curves to construct general anticyclotomic p-adic L-functions of Hilbert modular forms over CM fields and prove its non-vanishing by extending Hida's theorem on the equal-distribution of CM points in Hilbert modular varieties. The aim is to obtain a p-adic Gross-Zaiger formula relating the value of this anticyclotomic p-adic L-function outside the range of the interpolation to the p-adic Abel-Jacobi image of generalized Heegner cycles over the generalized Kuga-Sato varieties over unitary Shimura curves. In particular, this will have application to construct Chow-Heegner points for CM abelian varieties when elliptic units are not available for general CM fields. Together with K. Namikawa, they plan to construct Hida families of Yoshida lifts. Combined with Hsieh's previous work on the non-vanishing of Yoshida lifts modulo a prime and the the inner product formula of Yoshida lifts, they plan to study Yoshida congruences (i.e. the congruence between Yoshida lifts and non-endoscopic holomorphic Siegel modular forms of genus two by extending a methd of Agarwal

and Klosin.

Continuing their previous work, C.-Y. Chang and Y. Mishiba will cooperate to study the precise connection between ∞-adic MZV's and v-adic MZV's. In their previous paper, they have created a nontrivial linear map from the space of ∞-adic MZV's to the space of v-adic MZV's. Their current project is to compute the exact kernel of this homomorphism, and hope to establish a precise connection between these two different worlds, whose classical counterpart is till far from known. In the upcoming year, F.-T. Wei will first finish the on-going project (with C. Ariana) about Storm-Type bounds over function fields, and explore (with M. Papikian) the rational torsions of the Drinfeld modular Jacobians in higher rank. In the mean time, he will also continue his own project about the connection between Eisenstein series and Green's functions over function fields.

Langlands program is one of the most important topics in number theory and representation theory. Joint with U. Hartl, C.-F. Yu will start a new direction in Langlands program over function fields. Based on Pink's construction of Satake compactifications of Drinfeld moduli schemes of higher rank, they will develop a fundamental theory for Drinfeld modular forms modulo a prime v. They hope to prove that the Hecke-eigenvalues arising from Drinfeld modular forms modulo v are the same as the systems of Hecke-eigenvalues on automorphic forms modulo v for certain division algebras. The aim is to establish a modulo v version of the celebrated Jacquet-Langlands correspondence. Y. Yang will continue to the study of quaternion loci. In particular, he will study the intersection number of Shimura curves and Humbert surfaces and the class number relations arising from such intersections, and also study non-principally polarized abelian surfaces with quaternionic multiplication. A related topic is Siegel paramodular threefolds, which are moduli spaces of abelian surfaces with given type of polarizations. His method of constructing Borcherds forms is very suitable for constructing Siegel modular forms on paramodular groups.

In the upcoming year, there will be two important courses and lecture series. As pointed out above, one is the Taiwan Mathematical School on Automorphic Representations. This is organized by M.-L. Hsieh, and F.-T. Wei will give the first semester course on the basic theory for $GL(2)$. The other is the lecture series given by the prestigious mathematician J.-M. Fontaine. We highly believe that his lectures will bring state of the art mathematics and will benefit audiences. Below is the list of courses of lecture series in the upcoming year.

Courses and lectures:

(a) Taiwan Mathematical School (2018 Fall): Introduction to Automorphic Representations on GL(2). Lecture: F.-T. Wei. Organizer: M.-L. Hsieh.

(b) AS-NCTS Special Lecture Series, October 7-November 6, 2018. Lecturer: J.-M. Fontaine. Organizer: C.-F. Yu.

(c) NCTS Course on Topics on Arithmetic Geometry I (2018 Fall): Lecturer and organizer: C.-F. Yu.

(d) NCTS Course on Topics on Arithmetic Geometry II (2019 Spring): Lecturer and organizer: C.-F. Yu.

(e) Taiwan Mathematical School (2019 Spring): Introduction to Automorphic Forms and Automorphic Representations. Organizer: M.-L. Hsieh.

In the upcoming year, we will organize three important conferences. The first one is 4th joint conference on number theory between Taiwan and Japan. Such a cooperation activity has been going on for several years, and the conference will take place in Goto Retto of Japan on September 2018. The second one is the conference on Arithmetic of Function Fields and Diophantine Geometry to be held in NCTS in May of 2019. We have invited several prestigious mathematicians and very active researchers to this conference, and hope to bring more inspirations and stimulations to our research groups in this occasion. The third one is the joint workshop between Taiwan and Korea on number theory, and it will be held in Postech in May 2019. Through such a occasion, we hope to have real research cooperations in the near future. Below is the list of activities mentioned above.

Workshops and conferences:

(a) Japan-Taiwan Number theory conference, (Goto Retto), September 3-7, 2018. Organizes: M. Chida, M.-L. Hsieh and S. Kobayashi.

(b) Arithmetic of Function Fields and Diophantine Geometry, May 20-24, 2019. Organizers: D. Brownawell, C.-Y. Chang and M. Papanikolas.

(c) NCTS-POSTECH Joint Workshop on Number Theory, (Postech) May 2019. Organizers: J. Park and C.-F. Yu.

III.2 Algebraic Geometry

1. Core Members

a. Faculties: Jiun-Cheng Chen (NTHU), Jheng-Jie Chen (NCU), Jungkai Chen (NTU), Wan Keng Cheong (NCKU), Wu-Yen Chuang (NTU), Jen-Chieh Hsiao (NCKU), Shin-Yao Jow (NTHU), Ching-Jui Lai (NCKU), Jia-Ming Liou (NCKU), Eugene Xia (NCKU)

b. Postdocs: Mario Chan(NCTS), Hiep Dang(NCTS), Zheng-Yu Hu (NCTS), Tomohiro Uchiyama(NCTS), Sheng-Fu Chiu(AS), Hong-Yu Yeh (AS)

c. Long-term visitors: Caucher Birkar (Cambridge), Paolo Cascini (Imperial College London), Yujiro Kawamata (Tokyo)

2. Program Overview

Algebraic geometry is considered to be one of the most important fields in modern mathematics. It has much interaction with many other fields, such as, number theory, representation theory, differential geometry, mathematical physics, as well as analysis. In the past 20 years, thanks to the consistent and generous support from NCTS the research group of algebraic geometry in Taiwan has grown up substantially and obtained certain international recognition and reputation. Through our strategic planning of seminar, courses, and workshops, designed for undergraduate and graduate students, postdocs, and researchers, the size of the group grows notably and much progress in the research has also been made in recent years. The main goal of the Topical Program of Algebraic Geometry is to achieve important advances and to cultivate the young generation to come.

Taiwan has a very strong research group in higher dimensional birational geometry. Almost all the experts in the field of birational geometry visited Taiwan and NCTS for some period of time. Not only this, we also attracted world leading experts, including our long term visitors, Caucher Birkar, Paolo Cascini, and Yujiro Kawamata, to visit NCTS for a longer period of time for research collaboration.

We would like to emphasize that the former NCTS Scholar Caucher Birkar (2014-2017) was announced to be the Fields Medalist in Rio, ICM 2018. The main piece of his contribution, boundedness of Fano varieties, or so-called BAB conjecture, was initiated during his stay in NCTS. This was even quoted in this publication. It is really honor and pleasure that NCTS is the place that his prize-winning work was initiated. We hope that more fundamental and influential work will happen in NCTS in the future.

It is worthwhile to mention that in recent years many international postdocs in algebraic geometry choose NCTS to do their postdoctoral research, for example, Zheng-yu Hu from Cambridge, Mario Chan from KIAS and Dang Hiep from Kaiserslautern in the year 2015. Our recent activities also attracts many foreign Ph.D. students and postdocs. They come to participate our activities with their own financial resource. For example, Iacopo Brivio from UCSD (Ph.D. student of McKernan), Stefano Filipazi from Utah (Ph.D. student of Hacon), Haidong Liu from Kyoto (Ph.D. student of Fujino), and Roberto Svaldi from Cambridge (postdoc of Birkar) are the the participants of the Workshop of Singularities, Linear System, and Fano Varieties.

3. Research Highlights

The research highlights of the program consists of the following parts: explicit

birational geometry in dimension three; the studies on derived categories on special varieties; twisted spectral correspondence and torus knots; mean field equations on algebraic curves.

a. Geography of varieties of general type, *by Jungkai Chen*. Varieties of general type plays very interesting role in the birational geeomtry, especially in the birational classification theory. The study of geography of varieties of general type is to understand the relation between important birational invariants, and more over to understand the special geometric properties of varieties satisfy certain conditions. There are some previous work of Jungkai Chen, mainly jointly with Meng Chen, on the geography of threefolds, including the extremal lower bound of canonical volume and Noether inequality which asserts that Vol $\geq \frac{4}{3}p_g - \frac{10}{3}$. In a joint work with C.J. Lai, higher dimensional analogue was investigates. They produced examples of dimension n of general type satisfying

$$\text{Vol} = \frac{n+1}{n}p_g - \frac{n^2+1}{n}.$$

They conjectured that higher dimensional Noether inequality take the above form for varieties of general type (with Gorenstein minimal model), and hence their examples provide the extremal case, if the conjecture holds. We would like to remark that this is considered to be pioneering attempt toward explicit geoemtry of dimension 4 or higher.

b. Boundedness of Fano threefolds, *by Ching-Jui Lai*.
It is known by Kollar-Miyaoka-Mori-Takagi that Fano threefolds with at most canonical singularities form a bounded family. In particular, numerical invariants such as c_1^3 should have optimal bounds. It has been found by Jungkai Chen and Meng Chen a sharp lower bound $c_1^3 \geq 1/330$ with $c_1^3 = 1/330$ for $X_{66} \subseteq \mathbb{P}(1,5,6,22,33)$. For the upper bound, based on the work of Kawamata, Suzuki, and many others, Prokhorov has established that $c_1^3 \leq 72$ when a Fano threefold is Gorenstein or is $\mathbb{Q}$-factorial of Picard number one. In a recent project, Jungkai Chen, Jheng-Jie Chen, and Ching-Jui Lai aim to explore the optimal upper bound of c_1^3 in full generality. By using Mori's theory of extremal contractions, it has been proved that $c_1^3 \leq 72$ if Picard rank of a weak Fano threefold X is two, e.g., when X equips with a del Pezzo fibration. For the next step, we study weak Fano threefolds with a conic bundle structure. In corporate with recent result of Mori-Prokhorov on the local structure of extremal neighborhood of conic bundles, it is expected to find such a bound. A detail study of our method shall lead to concrete examples attaining the equalities. This gives us a better understanding of the geometry of Fano varieties acquiring singularities coming from the development of the minimal model program.

In the recent work of Lai, it is shown that weak $\mathbb{Q}$-Fano threefolds has $-K^3 \leq 72$ if $\rho = 2$. This partially answered the conjecture that $-K^3 \leq 72$. Please note that there are exactly two sets of examples such that $-K^3 = 72$.

c. homological algebraic geoemtry and its application, *by Jungkai Chen* and *by Jheng-Jie Chen*.

Derived categories was very useful tool in understanding certain positive properties. An important feature is to apply the derived categoty to the study positivity of varieties related to abelian varieties. This was mainly the joint work of Jungkai Chen and Jiang, following the previous joint work of Chen and Hacon.

A smooth projective variety X is said to be a variety of maximal Albanese dimension if there exists a generically finite morphism $f\colon X \to A$ to an abelian variety. It is known that the birational geometry of X is very much governed by the positivity of $f_*\omega_X$ and the sheaf $f_*\omega_X$ is known to be a GV-sheaf but is not necessary M-regular. The joint work of Chen and Jiang proved a general decomposition theorem for $f_*\omega_X$, which implies that $f_*\omega_X$ is not far from being M-regular.

In fact, Kollár proved another decomposition theorem for higher direct images in general in 1985. The new results shows that it is possible to characterize each components explicitly by cohomological properties for varieties with maximal Albanese dimension. It is ecpected that the decomposition theorem is related to Hodge theory. The recent work of Popa and Schnell shed some light along this direction. The connection with Hodge ideals and D-module was also further investigated in NCTS learning seminars.

Moreover, there are some more specific application to varieties over elliptic curve. In this setting, many of push-forward sheaves are turned out to be positive vector bundles on elliptic curve. Thanks to the famous work of Atiyah on structure of vector bundles over elliptic curves, one can in particular consider the push-forward of pluricanonical sheaves over elliptic curves and their tensor product structure. An nice application is that $|5K_X|$ is birational (which is optimal) for irregular threefolds of general type.

d. Twisted spectral correspondence and torus knots, *by Wu-yen Chuang*.

In the joint work with Diaconescu, Donagi, Nawata, and Pantev, Wu-yen Chuang considered the cohomological invariants of twisted wild character varieties constructed by Boalch and Yamakawa. The invariants are derived from enumerative Calabi-Yau geometry and refined Chern-Simons invariants of torus knots. Generalizing the untwisted case, the present approach is based on a spectral correspondence for meromorphic Higgs bundles with fixed conjugacy classes at the marked points. This construction is carried out for twisted

wild character varieties associated to $(l, kl-1)$ torus knots, providing a colored generalization of existing results of Hausel, Mereb and Wong as well as Shende, Treumann and Zaslow.

e. Mean field equations on algebraic curves, *by Jia-Ming Liou*.
Jia-Ming Liou considered the mean field equation

$$\Delta u + e^u = 4\pi \sum_P \delta_P \ ,$$

for any genus two complex smooth curve X for canonical metric, where the sum is over the set of all ramification points P of the degree two meromorphic map from X to $\mathbb{P}^1$. This kind of mean field equation was considered before by Chang-Shou Lin and Chin-Lung Wang and has deep connection with algebraic geometry.

Liou discovered an explicit solution to the mean field equation above and determined a family of mean field equations parametrized by divisors on X. He also discovered an interesting commutative $\mathbb{C}^*$ algebra defined by effective divisors on X whose Gelfand spectrum is $\mathbb{P}^1$. An algebraic construction of the mean field equation for hyperelliptic curves is also found.

4. Highlights of Events

a. Workshop on Singularities, Linear System and Fano Varieties.
There is a recent breakthrough in minimal model program done by NCTS Scholar Caucher Birkar. In a series of groundbreaking papers, he proved the BAB (Borisov-Alexeev-Borisov) Conjecture together with many boundedness problems around Fano varieties. This fundamental contribution to minimal model program also leads him to win the Fields Medal in 2018.

With the assistance and contribution of Kawamata and Birkar himself, NCTS organized a workshop focusing on his recent work in April 2017. With 19 talks contributed by 12 speakers from all over the world, we went through the details of Birkar's work.

We are now in the process to publish a proceeding on this topic based on the workshop. The volume will be published by American Math. Soc. The contributors including top-notched mathematicians such as Christopher Hacon, Caucher Birkar.

b. Taiwan Math School: Derived and Homological Algebraic Geometry.
From October 2017 we started a program consisting of joint courses on derived and homological algebraic geometry for advanced undergraduate students, graduate students, and researchers interested in this area. The topics include basic homological algebra, derived categories, Fourier-Mukai transforms, derived category in birational geometry and minimal model program,

and Bridgeland stability. Right after the school, we organized a winter school in January 2018, in which we focused on related but more advanced topics.

c. Lectures on Noncommutative Deformations in Algebraic Geometry.
It has been realized recently that it is necessary to consider noncommutative deformations in order to understand the derived autoequivalences of a 3-fold. Due to this importance of noncommutative deformations, we invite NCTS scholar Professor Yujiro Kawamata to deliver two lectures on this subject. In the lectures he explains general theory of multi-pointed non-commutative deformations of simple collections, and calculate some versal deformations in abelian categories of perverse coherent sheaves arising from tilting bundles for projective morphisms.

d. NCTS Seminars in Algebraic Geometry.
We used only to have our regular seminars in Taipei or Hsinchu. Due to the increasing number of algebraic geometers in NCKU, now regular seminars in algebraic geometry also hold in Tainan starting from 2016.

e. NCTS Algebraic Geometry Day.
Other than regular seminars, we initiated NCTS Algebraic Geometry Days every month from 2016. Each time there will be 4 talks. It serves as a platform for people to share their current projects and to seek for possible collaboration.

5. Plan for the Comming Year(s)

In the future, we will plan or continue ro work on the following:

a. Joint Summer School with MSRI on Toric Varieties.
In the summer of 2019, there is going to have joint summer school with MSRI. The topic is set as Toric Variety. The lecturer and 20 international students will be supported by MSRI. NCTS provide local supports.

b. Regular seminars, lecture series, and workshops.
We will continue to run regular seminars and to hold lecture series and workshop.

c. Training of the PhD students.
NCTS will continue to run Taiwan Mathematics School to offer the courses to well train our PhD students.

d. Encourage domestic young researchers to attend schools and international workshops.
We will continue to encourage young local researchers and PhD students to attend schools and international workshops or to have short/long term visits to major institutes in algebraic geometry.

e. Recruit world leading experts as NCTS distinguished scholars. We will continue to recruit world leading experts as NCTS distinguished scholars. With the help from NCTS distinguished scholars we will continue to have the workshops of high quality as before. It also helps attract more researcher to visit NCTS and build international research cooperations.

III.3 Differential Geometry and Geometric Analysis

1. Core Members

a. Faculty: Jih-Hsin Cheng (AS), River Chiang (NCKU), Nan-Kuo Ho (NTHU), Chin-Yu Hsiao (AS), Chun-Chi Lin (NTNU), Chung-Jun Tsai (NTU), Mao-Pei Tsui (NTU) are the key members. Active associates include: Shu-Cheng Chang (NTU), Chih-Wei Chen (NSYSU), Hung-Lin Chiu (NTHU), Chung-I Ho (NKNU), Rung-Tzung Huang (NCU), Ting-Jung Kuo (NTNU), Yng-Ing Lee (NTU), Kuo-Wei Lee (NCUE), Chih-Chung Liu (NCKU), Chiung-Jue Anna Sung (NTHU), Ryosuke Takahashi (NCKU), Dong-Ho Tsai (NTHU), Ye-Kai Wang (NCKU), Chin-Tung Wu (NPTU), Siye Wu (NTHU), Mei-Lin Yau (NCU), Mei-Heng Yueh (NTNU).

b. Postdoctoral fellows: Jui-En Chang (NTU), Ting-Hui Chang (NTHU), Sheng-Fu Chiu (AS), Ser-We Fu (NCTS), Sin-Hua Lai (NCU), Yang-Kai Lue (NCTS), Taiji Marugame (AS), Ryuma Orita (NCTS), Yi-Sheng Wang (NTU).

c. Long-term visitors: Po-Ning Chen (UC Riverside), Viktor Ginzburg (UC Santa Cruz), Martin Guest (Waseda), Robert Hardt (Rice), Yen-Chang Huang (Xinyang Normal), Shizuo Kaji (Kyushu), Yoshinobu Kamishima (Josai), Hsuan-Yi Liao (Penn State), Kaoru Ono (RIMS), Leon Simon (Stanford), C. Michael Tsau (Saint Louis), Mu-Tao Wang (Columbia).

2. Program Overview

The Program of Differential Geometry and Geometric Analysis covers a broad spectrum of themes, including a more analytic perspective as well as a more topological incarnation of modern geometry. Integration with applications is also recently introduced. Our current research focuses are:

a. Geometric evolution equations

b. Geometry of CR manifolds

c. Mathematical general relativity

d. Symplectic geometry, gauge theory, and mirror symmetry

e. Computational geometry, and manifold learning theory

3. Research Highlights

Our members have always been working vigorously and have produced many interesting and important results. Here we sample a few research highlights in our program:

a. tt*-Toda equations and Lie theory *by Nan-Kuo Ho (NTHU)*

In 1991, Cecotti and Vafa introduced the tt* equations in order to describe deformations of supersymmetric quantum (topological) field theories. Shortly afterwards, Dubrovin (1993) showed that this system is integrable and can be viewed as the equations for harmonic maps with a *similarity condition*. The tt* equations are not only interesting for physicists, but also for mathematicians due to their rich connections to various subjects such as differential equations, geometry and singularity theory. At that time, the only examples where significant information regarding solutions of tt* equations were known were the sinh-Gordon and Tzitzeica equations. After 20+ years, finally more knowledge was obtained regarding the solutions to the "Toda type" equations by Guest–Lin, Guest–Its–Lin, and Mochizuki. Their results also confirmed some of Cecotti–Vafa's predictions made based on physical grounds. Solutions obtained by Guest–Its–Lin have very precise and interesting properties, but due to the nature of the methods, the reasons behind these properties were still unclear. Intrigued by the way the solutions look, we decided to investigate the geometry of the system and hoped to obtain more intrinsic explanations.

Since the system contains equations with irregular singularities, the Stokes Phenomenon comes into play. From the classical differential equations point of view, Stokes data involves explicit matrices. However, from a more abstract point of view, Boalch developed a Lie theoretic way to describe this. Thus, our first goal was to explain the results of Guest–Its–Lin in a Lie theoretic way. This helps us to understand better the mysterious looking symmetry and properties of the data, thus uncovering some of the intrinsic properties of the solutions. This was explained in our paper [1]. The next goal was then to generalize this understanding to other Lie groups. We achieved this by combining some very classical results in Lie theory together with Boalch's approach to the Stokes analysis. To be precise, we used Kostant's theory of Cartan subalgebras in apposition, Steinberg's theory of conjugacy classes of regular elements, and the loop group Iwasawa factorization. This is explained in our preprint [2].

b. Gradient flows of geometric functionals *by Chun-Chi Lin (NTNU)*

Gradient flows of higher-order geometric variational functionals are motivated by the intrinsic mathematical interests and the applications. Here, higher-order geometric functionals include Euler's elastic energy of curves, Kirch-

hoff's elastic energy of rods, Willmore energy of surfaces, thin-plate models of 3-dimensional solids, etc. In geometric analysis, the approach of gradient flows not only provides a method in finding equilibrium configurations but also offers certain dynamic aspects of physical/geometrical objects. The three papers listed below represent some attempts in exploring geometric flows of one-dimensional objects, e.g., curves and/networks, but we only focus on curves so far in these articles.

In [3], we consider closed curves on the sphere moving by the L^2-gradient flow of the elastic energy both with and without penalization of the length and show the short time and long-time existence of the flow. Moreover, when the length is penalized, we prove sub-convergence to critical points. This paper is the first stage in extending some of our previous results to curves in manifolds. We found out new interesting problems and phenomena along this direction.

In [4], we give a brief report on how to evolve planar curves with so-called clamped boundary conditions into the equilibrium by solving a second-order parabolic equation. Namely, for any given C^2-smooth initial open curves with fixed end points and fixed tangent at the end points, we obtain the long-time existence of smooth solutions under the second-order evolution of plane curves. Moreover, the asymptotic limits of a convergent subsequence are inextensible elasticae. This work is an extension of our previous paper, where the boundary condition of curves is called the hinged boundary condition. The mathematical difficulty, due to the difference of boundary conditions, is quite different from the one in the previous article though.

In [5], we consider regular open curves in $\mathbb{R}^n$ with clamped ends subject to a fixed length constraint and moving according to the L^2-gradient flow of the elastic energy. For this flow we prove a long time existence result and sub-convergence to critical points. To the best of our knowledge, the technique we developed for the estimates of deriving the long-time existence is indirect and not found in the literature. The final breakthrough was done when Anna and I were working intensely in Trieste, Italy (during a ICTP workshop held there) for one-week long, after two years of struggling on this project.

We make some remarks on the two approaches in [5] and [4] which work well in different situations. In [4], the equation is second-order thus inherits nice geometric properties, e.g., convexity-preserving, while the approach of fourth-order equations in [5] doesn't have. However, it is still problematic to extend [4] to curves with higher co-dimensions, e.g., space curves, and the so-called networks, while the last situation is what we are now working on by using the approach of [5]. Besides pure mathematical interests, there are some application of problems like the one in [3] to computer graphics.

c. Generalized Lagrangian mean curvature flow *by Mao-Pei Tsui (NTU)*

The main motivation to study the generalized Lagrangian mean curvature flows in cotangent bundle is to study the strong Arnold conjecture: Let Σ be a compact, exact, orientable embedded Lagrangian in T^*M, where M is also compact and orientable. Can Σ be deformed through exact Lagrangian to the zero-section?

Fukaya, Seidel and Smith proved that compact, exact, orientable embedded Lagrangian submanifolds are Floer-cohomologically indistinguishable from the zero-section in cotangent bundle under suitable conditions (triviality of the fundamental group of the cotangent bundle, and of the Maslov class and second Stiefel-Whitney class of the Lagrangian submanifold). Another possible approach to investigate the strong Arnold conjecture is to use the generalized Lagrangian mean curvature flows in cotangent bundle to deform an exact Lagrangian submanifold to zero section in the cotangent bundle of a manifold. In [6], Smoczyk and Wang propose a natural evolution equation to investigate the deformation of Lagrangian submanifolds in almost Kähler manifolds with an Einstein connection. On the cotangent bundle of a Riemannian manifold, there exists a canonical almost Kähler structure with respect to the base metric. In a recent paper of ours ([7]), we first show that the canonical connection on the cotangent bundle of any Riemannian manifold is an Einstein connection (in fact, Ricci flat). Furthermore, we show that if a Lagrangian submanifold Σ is exact and of vanishing Maslov class in the cotangent bundle T^*M then it remains so under the evolution of the generalized Lagrangian mean curvature flows. At the end, we also prove a long time existence and convergence result to demonstrate the stability of the zero section of the cotangent bundle of a Riemannian manifold with positive sectional curvature. This can be regarded as the stability result of the zero section under generalized Lagrangian mean curvature flows in a cotangent bundle.

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4. Highlights of Events

The scientific activities consist of three parts: seminar series; workshops and conferences; lectures and courses. As a whole they help our program maintain diversity, keep focus, support working relations, and develop future possibilities.

In particular this spring we had two lecture series under Taiwan Mathematics School, which inspired follow-up workshops on related topics:

a. An Introduction to Geometric Measure Theory by Leon Simon (Stanford), March 5–May 11, 2018

Geometric measure theory is a very active area of current research and has found applications in many areas of mathematics, far beyond the problem of area minimization. It plays important roles in resolving fundamental problems such as Willmore Conjecture, Positive Mass Theorem, etc.

The course covers the bulk of the first 6 chapters, plus selected materials from Chapters 7, 8, of the text "Introduction to Geometric Measure Theory" by Leon Simon. The main aim of the course is to give a general introduction to the main ideas and techniques of the theory, suitable for anyone, at the upper division undergraduate to graduate level, planning to specialize in any field related to geometry or analysis.

Three preparation seminars were organized at NTU and NCKU during the winter break prior to the course. Then the course was followed up by a workshop on related topics in May.

- Warm Up Seminar, Jan 23–24, 2018
  Tien-Tsan Shieh (NTU), Chun-Chi Lin (NTNU) and Chun-Yen Shen (NTU) gave a series of lectures on the backgrounds and developments.
- Learning Seminar at NCKU, Jan 23–Feb 9, 2018
  The speakers were Liren Lin, Ye-Kai Wang, Jia-Min Liu (NCKU).
- Student Seminar at NTU, Jan 24–Mar 2, 2018

- Workshop on Geometric Measure Theory and Minimal Submanifolds, May 8–10, 2018
  The speakers include Robert Hardt (Rice), Lami Kim (Yonsei), Brian Krummel (UC Berkeley), Ulrich Menne (Leipzig), Daniel Spector (NCTU), Chung-Jun Tsai (NTU), Jiaping Wang (Minnesota), Neshan Wickramasekera (Cambridge).

b. Lectures on Lagrangian Floer theory by Kaoru Ono (RIMS, Kyoto), April 14–28, May 19–June 2, 2018

   Lagrangian Floer theory is one of the main tools of current research in symplectic geometry. For example, it provides a source of symplectic invariants and plays an essential role in the homological mirror symmetry.

   The course starts with basics on Floer theory, and move on to a general theory of A_∞-structures, (weak) Maurer–Cartan equation, potential function, bulk deformations, etc, which is then applied to Lagrangian torus fibers, followed by related topics. The targeted audience are motivated graduate students. Participants also included 7 graduate students from the Chinese University of Hong Kong.

   Following the lectures, we organized a workshop to dive into a variety of related topics such as Fukaya category, quantum cohomology and mirror symmetry:

   - NCTS Symplectic Expedition: Floer theory and beyond, May 27–29, 2018
     The speakers include Manabu Akaho (Tokyo Metropolitan), Kwokwai Chan (CUHK), Siu-Cheong Lau (Boston), Naichung Conan Leung (CUHK), Kaoru Ono (RIMS), Kazushi Ueda (Tokyo), Chien-Hsun Wang (NTU).
     Moreover, "Symplectic Expedition" is intended to be a series of events that aims to explore new territories of symplectic geometry and related fields and to promote academic exchange in Asia and beyond. This workshop is the first installment of such.

We summarize the other activities in 2018 as follows.

a. Seminar Series: NCTS Differential Geometry Seminar; NCTS Seminar on Symplectic Geometry; Sinica-NCTS Geometry Seminar; Sinica-NCTS Reading Seminar on Kapustin–Witten Equations.

b. The 16th Taiwan Geometry Symposium, March 24, 2018

   We started in Fall 2010 this series of regular meetings to foster discussions and interactions within the geometry community in Taiwan. We meet once every semester. This 16th symposium took place at National Changhua University of Education with 4 speakers: Sheng-Fu Chiu (AS), Martin Guest (Waseda),

Leon Simon (NTU & Stanford), and Dong-Ho Tsai (NTHU). The 17th symposium is planned for October 2018.

c. NCTS Workshop on Isometric Embedding and Quasilocal Mass, June 19–22, 2018

The mathematical theory of isometric embedding culminated in Nashs theorem and the solution of Weyls problem by Nirenberg and Pogorelov in the last century. On the other hand, due to the equivalence principle, the definition of mass/energy in general relativity has been a challenging problem since Einsteins time. As there is no mass/energy density for gravitation, one can at best hope to have a quasilocal definition. Isometric embedding into the Euclidean and Minkowski space provides the needed theoretical foundation in defining quasilocal mass through the Hamilton-Jacobi approach. Very recently, there have been important progresses on isometric embeddings into non-homogeneous spacetimes such as the Schwarzschild spacetime and the definition of quasilocal mass with reference to such a spacetime. This workshop gathers researchers working on the frontier of this recent development and aims to supply a platform for exchanging ideas and facilitating future collaborations.

The speakers include Po-Ning Chen (UC Riverside), Kwok-Kun Kwong (NCKU), Chunhe Li (UEST of China), Siyuan Lu (Rutgers), Pengzi Miao (Miami), Mu-Tao Wang (Columbia & CUHK), Ye-Kai Wang (NCKU), Zhizhang Wang (Fudan), Chao Xia (Xiamen).

d. 2018 Summer Courses

- Introduction to 3-manifold Topology with Some Applications to Knot Theory by C. Michael Tsau, July 9–20, 2018
  This course teaches fundamentals of 3-manifold topology, which lays the foundation for further study in this and other areas involving topology and differentiable manifolds. It also provides general knowledge for the techniques used in the study of 3-manifolds topology. This is the Part 2 following the 2017 Summer Course on Introduction to Knot Theory by C. Michael Tsau.
- Image and Shape Manipulation by Shizuo Kaji (Kyushu)and Mei-Heng Yueh (NTNU), July 30–August 17, 2018
  This course is primarily interested in altering shapes and images on computer based on topological and geometrical techniques. Images are vector-valued functions on a rectangular domain, whose values are the color intensity of pixels. A mesh is an imbedding of a polygon into the three-space. Thus, we can manipulate images and shapes by defining operations on these maps. However, these maps are inevitably discrete to be

dealt with on computer. Discrete differential geometry is a relatively new and active area in geometry to handle "smooth" shapes represented in a discrete way. In this course we see how basic notions in calculus are translated in a discrete language and can be applied to manipulate shapes and images. We also discuss concrete algorithms and their implementations.

One of our goals is to create an excellent research environment for differential geometers in Taiwan to work on world class subjects both independently and in collaboration with fellow mathematicians. Our research group has been very active and maintains a high research standard thanks to the consistent support of NCTS. We have formed several working teams in Taiwan as well as internationally. Another important goal of ours is to integrate our activities to attract excellent undergraduate and graduate students and provide new opportunities for the postdoctoral fellows and junior faculty to enrich their research perspectives and prosper.

5. Plan for the Coming Year(s)

Our activities and visitors have broden the perspectives of our program. The NCTS also provides a good platform on research oriented courses that reach out to students in Taiwan and neighboring Hong Kong, Korea, Japan, etc. It is our hope that our program will lead to a steady growth of the math community on differential geometry and geometric analysis.

We are planning to organize the following activities.

a. East Asian Symplectic Conference 2019.

   This series of conferences is jointly organized among China, Hong Kong, Japan, South Korea, and Taiwan. We meet once every two years to provide an opportunity for the researchers in East Asia to meet many new friends in the same or related subjects, and find out their common interests toward prospering future work. The first conference took place in Taipei in 2009 and we welcome the return to Taiwan in 2019.

b. The Second Japan-Taiwan Joint Conference on Differential Geometry organized by Shu-Cheng Chang, River Chiang, Nan-Kuo Ho and Mao-Pei Tsui in November or December, 2019.

c. One Taiwan Geometry Symposium each semester.

d. Workshop on Kapustin–Witten equations organized by Jih-Hsin Cheng and Ryosuke Takahashi.

e. Workshop on moduli spaces from varies perspectives organized by Nan-Kuo Ho.

The idea is that we will have a two weeks activities, the first week being lecture series and second week workshop. In particular, the speakers for the lectures might include Philip Boalch (Orsay), Anton Alekseev (Geneva), and Eckhard Meinrenken (Toronto).

f. Joint workshop with OIST on interdisciplinary topics in differential geometry, mathematical soft matter and computation organized by Chun-Chi Lin.

g. Undergraduate geometry mini-workshop and forum organized by River Chiang, Nan-Kuo Ho, Yng-Ing Lee, Mao-Pei Tsui, Ye-Kai Wang.

   Recruiting excellent undergraduate students to work in geometry area is an important part of our mission at NCTS. Sometime the undergraduate students do not know the importance of differential geometry and are not familiar with the most recent progress in differential geometry. For a one-day mini-worshop we plan to invite Mu-Tao Wang (Columbia University), Siye Wu (NTHU) and Hau-Tieng Wu (Duke) to give talks about the research in geometric analysis , physics and data science.

h. Intensive lectures by Kaoru Ono (RIMS, Kyoto) and Yakov Eliashberg (Stanford).

i. Mini-course on Mathematical General Relativity by Mu-Tao Wang (Columbia), Po-Ning Chen (UC Riverside), Ye-Kai Wang (NCKU) and Mao-Pei Tsui (NTU).

   The goal is to go over the basics of Mathematical General Relativity and discuss some of the recent progress in this area.

j. Lecture series on Poisson geometry and Lie groupoids by Chenchang Zhu (Gottingen), Jiang-Hua Lu (HKU), and Marco Gualtieri (Toronto).

k. Mini-course in the theory of complete, non-compact hyper-Kaehler 4-manifolds.

   The focus is on the geometric evolution equation related to special holonomy and calibrated submanifolds, especially the mean curvature flow and the G_2 Laplacian flow. Potential speakers include: Mu-Tao Wang (Columbia), Pei-Ken Hung (MIT), Yohsuke Imgai (Nagoya), Jason Lotay (UCL), Chengjian Yao (ULB), Kotaro Kawai (Gakushuin).

l. Courses on microlocal analysis, CR and Complex Geometry by Chin-Yu Hsiao (AS) and visitors.

m. Seminar Seires: NCTS Differential Geometry Seminar, NCTS& NTHU joint Geometry and Topology seminar, Symplectic working seminar, etc.

We also plan to invite visitors from abroad for research discussions and collaboration, including but not limited to, Martin Guest (Waseda), Mu-Tao Wang (Columbia University) , Knut Smoczyk (Leibniz University Hannover, Germany) and Huy THE NGUYEN (Queen Mary University of London).

III.4 Differential Equations and Stochastic Analysis

1. Core Members

a. Organizers:Chun-Hsiung Hsia (NTU), Jung-Chao Ban (NDHU), Je-Chiang Tsai (NTHU), Kuo-Chang Chen (NCTU).

b. Faculties:Chiun-Chuan Chen(NTU), I-Kun Chen (NTU), Lung-Chi Chen (NCCU), Kuo-Chang Chen (NTHU), Jann-Long Chern (NCU), Jong-Shenq Guo (TKU), Jin-Cheng Jiang (NTHU), Ru-Lin Kuan (NCKU), Hung-Wen Kuo (NCKU), Chin-Lung Lin (NCKU), Shuenn-Jyi Sheu (NCU), Daniel E. Spector (NCTU), Feng-Bin Wang (Chang Gung U.), Jenn-Nan Wang (NTU), Chang-Hung Wu (Tainan U.), Kung-Chien Wu (NCKU).

c. Long term visitor: Kazuo Aoki (NCTS and NCKU).

d. Postdocs:Gyeongha Hwang (NCTS), Chih-Chiang Huang (NCTS), Manas Kar (NCTS), Haewon Yoon (NCTS).

e. Students:10 Ph.Ds/20 Masters

2. Program Overviews

Thanks to the generous support of NCTS, we have seen a booming development in the research of Differential Equations and Stochastic Analysis in Taiwan. This program of Differential Equation and Stochastic Analysis is the most diverse program in the NCTS. Differential equations and stochastic analysis are usually developed independently. Nonetheless, the main aim of this program is to bridge these two topics. Under this program, we have four subprograms–partial differential equations, dynamical systems, mathematical biology, and stochastic analysis. Each subprogram has its own agenda. However, activities in each subgroups always involved people from different subgroups. Interdisciplinary research is always on the top of our promotion list. Besides of the interdisciplinary studies, we also put our efforts on improving research achievements in each field. Our another goal is to connect other outstanding scholars in the world. Every year, we invited lots of active researchers from all over the world to visit NCTS and interact with our members and students. We also organized many conferences and workshops with speakers from other countries. The program has evolved into a very solid research group in NCTS.

a. In the subprogram on PDEs, based on our core members, we mainly focus on the following topics: the kinetic theory, fluid equations, nonlinear Schrödinger equations, inverse problems, etc. We have made some important progress on the well-posedness of the spatially homogeneous Landau equation with soft potentials, the inhomogeneous Landau equation on the torus in the cases of

hard, Maxwellian and moderately soft potentials. Our members are also devoted to the study the properties of large-scale atmospheric fluids. Among the most popular models in this research fields, we pay our attention to the Navier-Stokes equation and the primitive equation. In inverse problems, we study the reconstruction of singular conductivities and potentials by the full boundary measurements. In addition to the research achievements, we organized workshops and symposia for young scholars in which all of speakers are either postdocs or PhD students, both domestic and international.

b. Dynamical System is one of the major and classical research areas in mathematics and mathematical science. Various activities supported by NCTS are organized to widen the spectrum of research groups on dynamical systems in Taiwan. The aim of these programs is to promote international collaborations and to provide training for young scholars and students. New developments or new breakthroughs and its relation to the program are: Tree sub-shift of finite type; Higher dimensional symbolical dynamical systems; Variational method on n-body problems; Entire solutions for delayed monostable epidemic models.

c. The field of mathematical biology is closely related to PDE. There are many interesting problems arising in studying new phenomena observed in biology and ecology. The program of mathematical biology is to promote interdisciplinary research through the communication between mathematicians, biologists, statisticians, physicists and computational scientists. In recent years, many mathematical problems have been studied for further understanding complicated phenomena appeared in mathematical biology, physiology and ecology. Through the communication between scientists, we intend to develop new mathematical tools from differential equations and dynamical systems to obtain useful information for applications. Some research highlights include the analysis of the long-time behavior of solutions of a susceptible-infectious-susceptible (SIS) epidemiological model, proposed to explain an epidemiological phenomenon that pathogen spread does not necessarily keep pace with its host invasion and the study of the classical Kermack and McKendrick epidemic model with standard incidence and latent period included.

d. In the subprogram of probability and stochastic analysis, the main research topics are: Markov chains and mixing, mathematical problems from finance, stochastic heat equations, phase transitions and critical behavior for some statistical mechanics models, disorder chaos in the spherical mean-field model, branching process, self-interacting random walk and some other applied probability models.

3. Research Highlights

We obtained many important results in 2015-2018. In the following, we list some selective achievements.

a. Partial differential equations

(1) *Chiun-Chuan Chen* and his collaborators studied a prototype model of self-replication in complex reaction-diffusion systems :

$$\Delta u - u + (1 + a|x|^q)u^p = 0.$$

Under certain conditions on p, q, it was previously shown by Chen-Kolokolnikov that the equation has no radial ground state solution when the control parameter a is increased above some threshold. This property is important for the existence of a saddle-node bifurcation proposed in the Nishiura-Ueyema conditions, which is believed to be necessary for an initiation of a self-replication event. They generalized Chen-Kolokolnikov's result to non-radial positive solutions by proving a Liouville-type nonexistence theorem. Furthermore we derive a local version of this nonexistence theorem for solutions defined on a bounded ball. Our result indicates that critical values of q derived in Ding and Ni (1986) are also crucial for the existence and nonexistence problem of positive solutions when the space dimension $N \geq 3$.

(2) *Chun-Hsiang Hsia* and his collaborators, in a series of fluid research projects, they figured the following scenario for the flow patterns driven by time periodic forcing: (1) As the forcing is small, the fluid system would have exactly one globally time asymptotically stable time periodic flow pattern. (2) As the forcing goes beyond first threshold, the system might have more than one locally stable time periodic flow patterns. (3) In case the amplitude of the forcing goes over too much, the system would lose the stabilities of the time periodic flow patterns.

(3) *Jenn-Nan Wang* and his collaborators studied some inverse boundary value problems with singular coefficients. For the Calderón problem in two dimensions with conductivity $\gamma \in W^{1,2}(\Omega)$, the proved a local uniqueness result. Note that the condition allows for the conductivity to be unbounded. They also investigated the inverse boundary value problem for the Schrödinger equation with potential in L^p class, $p > 4/3$. They showed that the potential is uniquely determined by the boundary measurements. Both results aim to find the most optimal conditions in which one has the uniqueness of identifying singular coefficients.

(4) *Kung-Chien Wu* and his collaborators studied the quantitative pointwise behavior of the solutions of the linearized Boltzmann equation for hard

potentials, Maxwellian molecules and soft potentials, with Grad's angular cutoff assumption. More precisely, for solutions inside the finite Mach number region (time like region), they obtained the pointwise fluid structure for hard potentials and Maxwellian molecules, and optimal time decay in the fluid part and sub-exponential time decay in the non-fluid part for soft potentials. For solutions outside the finite Mach number region (space like region), they obtained sub-exponential decay in the space variable.

b. Dynamical systems

(1) *Jung-Chao Ban* and his collaborators studied shifts defined on infinite trees, which are called tree- shifts. Infinite trees have a natural structure of one-sided symbolic dynamical systems equipped with multiple shift maps and constitute an intermediate class between one-sided shifts and multidimensional shifts. They have shown not only an irreducible tree-shift of finite type but also a mixing tree-shift that is chaotic in the sense of Devaney. Furthermore, the graph and labeled graph representations of tree-shifts are revealed so that the verification of irreducibility and mixing of a tree-shift is equivalent to determining the irreducibility and mixing of matrices, respectively. This extends the classical results of one-sided symbolic dynamics.

(2) *Kuo-Chang Chen* and his collaborators considered the challenging problem to determine possible shapes of central configurations which are of special importance in celestial mechanics. They proved the existence of convex but not strictly convex central configurations for the planar five-body and spatial seven-body problems. More recently, they characterized strictly convex planar five-body central configurations in terms of mutual distances.

(3) *Chun-Hsiung Hsia* and his collaborators investigated the collective behavior of synchrony for the Kuramoto and Winfree models. They proved the global convergence of frequency synchronization for the non-identical Kuramoto system of three oscillators. It is known that the uniform boundedness of the diameter of the phase functions implies complete frequency synchronization. In light of this, they showed, under a suitable condition on the coupling strength and deviation of the intrinsic frequencies, that the diameter function of the phases is uniformly bounded. In a similar spirit, they also proved the unconditional phase-locked synchronization for the Winfree model of N oscillators for all $N \geq 2$.

(4) *Cheng-Hsiung Hsu* and his collaborator studied the front propagation for a class of discrete periodic monostable equations with delay and nonlocal

interaction. They first establish the existence of rightward and leftward spreading speeds and prove their coincidence with the minimal wave speeds of the pulsating traveling fronts in the right and left directions, respectively. The dependency of the speeds of propagation on the heterogeneity of the medium and the delay term is also investigated. They found that the periodicity of the medium increases the invasion speed, in comparison with a homogeneous medium; while the delay decreases the invasion speed. Further, they proved the uniqueness of all noncritical pulsating traveling fronts. Finally, they show that all noncritical pulsating traveling fronts are globally exponentially stable, as long as the initial perturbations around them are uniformly bounded in a weight space.

c. Mathematical biology

(1) *Je-Chiang Tsai* and his collaborators investigated the mechanism of how ovarian cancer initiating cells arises and how the cell surface markers (c-KIT) are transcriptionally controlled. It has been experimentally shown that a microRNA, mir-193a, targets c-KIT mRNA, and plays a key role in ovarian cancer development. Their previous modelling studies suggest that estrogen E2F6 protein may inhibit the transcription rate of mir-193a, and, through the ceRNA mechanism, promote the expression of c-KIT mRNA, and thus leading to carcinogenesis. They now experimentally verify this modeling prediction. Also, for modeling studies of this system, the governing equations are very large and the kinetic parameters are in principle unknown. To analytically study this large system, they have developed an efficient way to detect the bifurcation point. The main feature of this approach is that it depends only on the network structure, not neither on the values of parameters nor on the choice of kinetics.

(2) *Chang-Hong Wu* and his collaborator studied the spreading behavior of two invasive species modeled by a Lotka-Volterra diffusive competition system with two free boundaries in a spherically symmetric setting. They showed that, for the weak-strong competition case, under suitable assumptions, both species in the system can successfully spread into the available environment, but their spreading speeds are different, and their population masses tend to segregate, with the slower spreading competitor having its population concentrating on an expanding ball, say B_t , and the faster spreading competitor concentrating on a spherical shell outside B_t that disappears to infinity as time goes to infinity.

d. Probability and Stochastic analysis

(1) *Guan-Yu Chen* and his collaborators considered reversible Markov chains of which L^2-distances can be expressed in terms of Laplace transforms.

The cutoff of Laplace transforms was first discussed by Chen and Saloff-Coste in [J. Funct. Anal. 258 (2010) 2246-2315], while they provided here a completely different pathway to analyze the L^2-distance. Consequently, they obtained several considerably simplified criteria and this allows us to proceed advanced theoretical studies, including the comparison of cutoffs between discrete time lazy chains and continuous time chains. For an illustration, they considered product chains, a rather complicated model which could be involved to analyze using the method in [J. Funct. Anal. 258 (2010) 2246-2315], and derived the equivalence of their L^2-cutoffs.

(2) *Lung-Chi Chen* and his collaborators considered a long-range Domany-Kinzel model proposed by Li and Zhang (1983), such that for every site (i, j) in a two-dimensional rectangular lattice there is a directed bond present from site (i, j) to $(i+1, j)$ with probability one. There are also $m+1$ directed bounds presentfrom (i, j) to $(i - k + 1, j + 1)$, $k = 0, 1, ..., m$ with probability $p_k \in [0, 1)$,where m is a non-negative integer. Let $\tau_m(M, N)$ be the probability that there is at least one connected-directed path of occupied edges from $(0, 0)$ to (M, N). Defining the aspect ratio $\alpha = M/N$, we derive the correct critical value $\alpha_{m,c} \in R$ such that as $N \to \infty$, $\tau_m(M, N)$ converges to $1, 0$ and $1/2$ for $\alpha > \alpha_{m,c}, \alpha < \alpha_{m,c}$ and $\alpha = \alpha_{m,c}$, respectively, and we study the rate of convergence. Furthermore, we investigate the cases in the infinite m limit. Specifically, we discuss in details the case such that $p_n \in [0, 1)$ with $n \in \mathbb{Z}_+$ and $p_n \approx_{n\to\infty} pn^{-s}$ for $p \in (0, 1)$ and $s > 0$. We find that the behavior of $\lim_{m\to\infty} \tau m(M, N)$ for this case highly depends on the value of s and how fast one approaches to the critical aspect ratio. The present study corrects and extends the results given in Li and Zhang (1983).

4. Highlights of Events

We briefly summarize some of the most interesting and important activities held in 2017 as follows.

(a) NCTS Short Course on Landau Kinetic Equation (2017-01-10 / 2017-01-12), organized by Wu Kung-Chien (NCKU).

(b) A Comprehensive Survey of Diffusion Maps (2017-02-06 / 2017-02-07), organized by Wang Jenn-Nan (NTU).

(c) 2017 NCTS Summer School on Dynamical Systems: Symbolic Dynamics (2017-07-21 / 2017-08-11), organized by Ban Jung-Chao (NDHU).

(d) 2017 NCTS Summer Courses on Introduction to Brownian Motion and Partial Differential Equations (2017-08-07 / 2017-08-16), organized by Chen Lung-Chi (NCCU).

(e) Introduction to Mathematics in Modern Technology (2017-09-04 / 2017-09-07), organized by Chern I-Liang (NTU), Hsia Chun-Hsiung (NTU), Wang Jenn-Nan (NTU) and Wang Weichung (NTU).

(f) 2017 NCTS Short Course and Seminar on Dynamical Systems(2017-09-22 / 2017-12-15), organized by Ban Jung-Chao (NDHU).

(g) Taiwan Mathematics School: Kinetic Theory and Introduction to Shock Wave Theory(2017-10-12 / 2017-11-30), organized by Wu Kung-Chien (NCKU)

5. The Future Plan

In the second half of 2018 and in the coming 2019, we will continue focus on several main topics such as the kinetic theory, the traveling wave phenomena, pattern formations, and the symbolic dynamics, etc. Preparation works for many activities are already underway.

a. This coming year, we will continue to focus on the the pointwise (in the space and time variables) behavior of the kinetic equations, such as Fokker-Planck equation, Landau equation or Boltzmann equation with soft potentials. This is a very important subject on kinetic theory. It will let us know the explicit structures of the solution. The main idea is to combine the long wave-short wave decomposition, the wave-remainder decomposition, the weighted energy estimate and the regularization estimate. We plan to organize a regular reading seminar to understand this subject. Moreover, we organize a Taiwan Mathematics School focusing on Kinetic theory and Boltzmann equations from fall, 2018 through Spring, 2019. Meanwhile, we will invite international experts in this research field to give short lectures in this Taiwan Mathematics School.

b. Chun-Hsiung Hsia and his collaborators plan to investigate the synchronization phenomena. A typical model is the Kuramoto model. In particular, we will focus on the time delay effects and the non all-to-all coupling effects. Both the phase synchronization and the frequency synchronization are in view. We plan to organize a workshop in 2019 on this topic.

c. Jung-Chao Ban plans to invite Professor Yunping Jiang(The City University of New York) to NCTS to discuss the recent development of Sarnak Conjecture. Sarnak Conjecture is named after P. Sarnak. It is a conjecture on zero entropy system. Another refined version Sarnak conjecture is equivalent to Riemann Conjecture. On the other hand, Jung-Chao Ban plans to invite Professor David Kerr (Texas A & M University) and Professor Heng-Feng Li (SUNY) to NCTS to give lectures on ergodic theory.

d. Guan-Yu Chen plans to explore the max-L^2-cutoff of random walks on fractal-like graphs. First, we will polish the obtained theoretical framework and apply it to several famous classical infinite graphs with suitable symmetric structures. Random walks on fractal trees and Sierpinski gasket and carpet and are targeted examples. There are many well-developed results on their scaling limits and we shall explore the evolution of well-known inequalities, including Harnack, Poincar?e, Nash and logarithmic Sobolev inequalities, from the discrete time walks to continuous time diffusions.

e. Je-Chiang Tsai plans to (1) explore the relation between the sub-network E2F6-mir193a-c-Kit and the immune system, (2) remove the piecewise-linear assumption in the B-cell project, and (3) include the farming technology as a variable in the farmers and hunter-gatherers model of the Neolithic transition.

f. Regular meetings and talk seminars in each subgroup will be organized as usual.

III.5 Scientific Computing

1. Core Members

a. Faculty: Chieh-Sen Huang (NSYSU), Tsung-Ming Huang (NTNU), Min-Hsiung Lin (NCKU), Wen-Wei Lin (NCTU), Weichung Wang (NTU), Suh-Yuh Yang (NCU), and Mei-Heng Yueh (NTNU).

b. Visitors: So-Hsiang Chou (Bowling Green State University), Jiguang Sun (Michigan Technological University), Hartwig Anzt (Karlsruher Institut fur Technologie) , Kam Chuen Ng (Kodak Research Lab), Eric King-wah Chu (Monash University), Takahiro Katagiri (Nagoya University), Kengo Nakajima (University of Tokyo), Eric K.W. Chu (Monash University), Lek-Heng Lim (University of Chicago), Naoya Nomura (University of Tokyo), Sou-Cheng Choi (Illinois Institute of Technology), Chien-Min Kao (University of Chicago), Takahiro Katagiri (Nagoya University), Jose E. Roman (Universitat Polit?cnica de Val?ncia), Xiaoping Wang (The Hong Kong University of Science and Technology), Xiao-Qing Jin (University of Macau), Hisashi Okamoto (Gakushuin University), Qiang Zhang (City University of Hong Kong), Hau-Tieng Wu (Duke University), Anthony B. Costa (Icahn School of Medicine at Mount Sinai), Eric Oermann (Icahn School of Medicine at Mount Sinai), Andy Choi (IntuitiveX), Shan Zhao (Stealth Health), Rajib Chakravorty (Melbourne Research Laboratory, Melbourne), Holly Oemke (The Mount Sinai Hospital), Analise Rodenberg (University of Minnesota), Volker Mehrmann (Institute of Mathematics at Technische Universität Berlin), Maria Pia Gualdani (George Washington

University).

2. Program Overview

The Scientific Computing Program has achieved several goals in terms of research, education, and reach-ous as shown below . In research, we focus on the Maxwell equations that modeling three dimensional anisotropic photonic crystals, photonics crystals with fourteen Bravais lattices, and complex media. Novel and efficient eigenvalue solvers have been developed to solve some of the most challenging problems. For matrix computations, we also focus on low-rank approximation and matrix equations. Furthermore, we study H1-conforming and mixed H1-conforming finite element method for the numerical computation of Maxwell's equations and stabilized finite element approach of transient problems. We further consider penalty immersed boundary method for simulating the dynamics of inextensible interfaces interacting with solid particles. Finally, several progress on computational conformal geometry have been achieved. In education, we organized several courses in Taiwan Mathematical School, including Scientific Computing on Supercomputer, Numerical linear algebra, High-performance numerical solvers, Scientific Computing and Machine Learning on Multi- and Manycore Architectures, Introduction to Parallel Programming for Multicore/Manycore Clusters, and Introduction to Parallel Computing (II). Advanced Course on Multi-Threaded Parallel Programming using OpenMP/OpenACC for Multicore/Manycore Systems. For reach-out, we organized NCTS Health Hackathon 2018 in collaboration with domestic and international experts in healthcare and mathematics. The competition brought out all kinds of possibilities about the combination of artificial intelligence and healthcare.

3. Research Highlights

a. A finite element based fast eigensolver for three dimensional anisotropic photonic crystals, *by S.-H. Chou, T.-M. Huang, T. Li, J.-W. Lin and W.-W. Lin*.
The standard Yee's scheme for the Maxwell eigenvalue problems places the discrete electric field variable at the midpoints of the edges of the grid cells. It performs well when the permittivity is a scalar field. However, when the permittivity is a Hermitian full tensor field it would generate un-physical complex eigenvalues or frequencies. In this paper, we propose a finite element method which can be interpreted as a modified Yee's scheme to overcome this difficulty. This interpretation enables us to create a fast FFT eigensolver that can compute very effectively the band structure of the anisotropic photonic crystal with SC and FCC lattices. Furthermore, we overcome the usual large null space associated with the Maxwell eigenvalue problem by deriving a null-space free discrete eigenvalue problem which involves a crucial Hermitian positive definite linear system to be solved in each of the iteration steps.

It is demonstrated that the CG method without preconditioning converges in 37 iterations even when the dimension of the matrix is as large as 5,184,000.

b. Electromagnetic field behavior of three-dimensional Maxwell's equations for complex media, *R.-L. Chern, T.-M. Huang, T. Li, W.-W. Lin*.
This article focuses on numerically studying the eigenstructure behavior of the generalized eigenvalue problems (GEPs) arising in the three dimensional (3D) source-free Maxwell's equations with magnetoelectric coupling effects which model 3D reciprocal chiral media. It is a challenging problem to solve such a large-scale GEP efficiently. We combine the null-space free method with the inexact shift-invert residual Arnoldi method and MINRES linear solver to solve the GEP with the matrix dimension being as large as 5,308,416. The eigenstructure behavior is heavily determined by the chirality parameter γ. We show that all the eigenvalues are real and finite for a small chirality γ. For a critical value $\gamma = \gamma^*$, the GEP has 2×2 Jordan blocks at infinity eigenvalues. Numerical results demonstrate that when γ increases from γ^*, the 2×2 Jordan block will split into a complex conjugate eigenpair, and then rapidly collide on the real axis and bifurcate into a new negative eigenvalue and a new positive eigenvalue (resonance mode) smaller than the other existing positive eigenvalues. The resonance band also exhibits an anti-crossing interaction. Moreover, the electric and magnetic fields of the resonance modes are localized inside the structure, with only a slight amount of field leaking into the background (dielectric) material.

c. Solving three dimensional Maxwell eigenvalue problem with fourteen Bravais lattices, *T.-M. Huang, T. Li, W.-D. Li, J.-W. Lin, W.-W. Lin and H. Tian*.
Simulation of band structure of three dimensional photonic crystals amounts to solving large-scale Maxwell eigenvalue problems, which are notoriously challenging due to high multiplicity of zero eigenvalue. In this paper, we try to address this problem in such a broad context that band structure of three dimensional isotropic photonic crystals with all 14 Bravais lattices can be efficiently computed in a unified framework. We uncover the delicate machinery behind several key results of our work and on the basis of this new understanding we drastically simplify the derivations, proofs and arguments in our framework. In this work particular effort is made on reformulating the Bloch boundary condition for all 14 Bravais lattices in the redefined orthogonal coordinate system, and establishing eigen-decomposition of discrete partial derivative operators by systematic use of commutativity among them, which has been overlooked previously, and reducing eigen-decomposition of double-curl operator to the canonical form of a 3×3 complex skew-symmetric matrix under unitary congruence. With the validity of the novel nullspace free method in the broad context, we perform some simulations on one benchmark

system to demonstrate the accuracy and efficiency of our algorithm.

d. An ultrafast GPU eigensolver for three-dimensional photonic crystals band structure, *T.-M. Huang, W.-W. Lin, H.-H. Tsai and W. Wang*.
A null-space free method with the FFT-based matrix-vector multiplications is proposed to efficiently solve the Maxwell equation that models the three-dimensional photonic crystals with 14 Bravais lattices. The most time consuming parts in this method are the FFT-based matrix-vector multiplications. In this article, we rewrite the FFT-based matrix-vector multiplications as highly parallel algorithms and use GPU accelerator to improve the efficiency. Combining matrix transpose with matrix multiplication as a kernel and applying the shared memory on each block of the GPU grid, we propose an efficient method to accelerate the performance of these parallel algorithms again. Integrating all of these techniques, the fast algorithm successfully solves each of a set of generalized eigenvalue problems with 5.184 million dimension within 44 to 63 seconds (45.5 seconds in average) on NVIDIA Tesla K40c GPU. The numerical results also show that we can near real-timely simulate the band structure by using multi-GPUs.

e. Low-rank approximation, *Min-Hsiung Lin*.
Low-rank approximation techniques have been applied by data science to analyze given data and reveal embedded information for a long time. My work in this part is as follows: In [1], we propose how to investigate an integer data set (or discrete data) by solving a series of integer least squares problems to address the integer low-rank approximation. Because integers are discrete in nature, techniques developed so far for real numbers cannot be successfully applied to handle this approximation. We show that at each iteration a global minimum is obtained and finally, a convergent sequence to an integer low-rank approximation is generated. In practice, this method can be directly applied to association rule mining, clustering analysis and pattern extraction of discrete data. From the numerical results presented in the work, it can be seen that our proposed method can obtain a more accurate integer low-rank approximation than other existing processes such as singular value decomposition and non-negative matrix factorization.

f. Matrix equations, *Min-Hsiung Lin*.
While studying low-rank approximation, what I am concerned about also contains the solution to the matrix equations. My research work for this direction includes two results and can be demonstrated as follows: In [2], by constructing particular left null spaces, we propose an iterative method to compute the stable subspace of the matrix pencil A-fB. We show in theory that our proposed method has a semigroup property depending only on the initial matrix pencil. We thus can accelerate our algorithm via a specifically

constructed iterations. Numerically, we apply this accelerated technique to compute the principal square root of a nonsingular and singular matrix. We show that our accelerated method can not only find out the matrix square root but also construct an iterative approach which converges to the square root with any desired order. In [3], we present in theory sufficient conditions for the existence of a positive definite solution for a class of discrete-time algebraic Riccati equations. Numerically, we develop an algorithm with the rate of convergence of any desired order to obtain the positive definite solution. Numerical results show that even in the face of almost critical cases, this accelerated method can maintain its excellent performance. Besides, the theoretical result shows that this method can be used to solve the unique negative definite solution while the only negative solution exists.

g. H1-conforming and mixed H1-conforming finite element method for the numerical computation of Maxwell's equations, *Suh-Yuh Yang*.
We have devised a nodal-continuous H1-conforming finite element method (FEM) and a mixed H1-conforming finite element method for the numerical computation of Maxwell's equations with singular solution in Hr for 0 ¡ r ¡ 1. The key feature of the former FEM is that mass-lumping linear finite element L2 projections act on the curl and divergence partial differential operators so that the singular solution can be sought in a setting of L2 space. We use the nodal-continuous linear finite elements, enriched with one element bubble in each element, to approximate the singular and non- H1 solution. The latter method is a mixed H1-conforming FEM for solving Maxwell's equations in terms of electric field and Lagrange multiplier, where the multiplier is introduced accounting for the divergence constraint. The method is formulated in the stabilized form by adding an additional mesh-dependent stabilization term to the mixed variational formulation. A pair of CP2-P1 elements for electric field and multiplier is studied and its stability and error bounds are derived. Numerical experiments for source problems as well as eigenvalue problems are presented to illustrate the high performance of the proposed methods. These findings have been respectively published in Journal of Computational Physics (2014) and SIAM Journal on Scientific Computing (2018).

h. Stabilized finite element approach of transient problems, *Suh-Yuh Yang*.
We have proposed an efficient stabilized finite element approach to overcome the stability issue, which is commonly encountered in the finite element computations of transient problems with a small diffusivity/viscosity and a small time step. It is very popular to apply finite element stabilization techniques to produce better accuracy and stability in the numerical solution of convection-dominated problems or to circumvent the inf-sup condition in solving saddle-point type problems such as the incompressible Navier-Stokes

equations. However, it has been observed that the small time-step instabilities may be caused in the transient problems when implicit finite difference time integration is applied. Our analysis reveals that the proposed stabilized FEMs are particularly suitable for the transient problems with a small diffusivity/viscosity and a time step, which has never been achieved before in the error analysis of other stabilization methods in the literature. We have numerically confirmed the effectiveness of the proposed stabilized FEMs. These findings have been published in Computer Methods in Applied Mechanics and Engineering (2014 & 2016).

i. Penalty immersed boundary method for simulating the dynamics of inextensible interfaces interacting with solid particles, *Suh-Yuh Yang*.
We have developed a successful penalty immersed boundary method for simulating the dynamics of inextensible interfaces interacting with solid particles. This approach relies on the penalty techniques by modifying the constitutive equation of Stokes flow to weaken the incompressibility condition, relating the surface divergence to the elastic tension to relax the interface's inextensibility, and connecting the particle surface-velocity with the particle surface force to regularize the particle's rigid motion. The resulting semi-implicit discretization scheme has been proved to be unconditionally energy stable and can be applied to rather general fluid-structure interaction problems. Eliminating other unknowns than velocity, the associated linear system can be further reduced to a smaller one, which is symmetric and negative-definite. This finding has been published in Journal of Scientific Computing (2015).

j. Computational conformal geometry, *Mei-Heng Yueh*.
Surface parameterizations have been widely applied to tasks of computer graphics and digital geometry processing, such as surface remeshing, registration and morphing. This year, we have developed efficient energy minimization algorithms for the computations of conformal and area-preserving parameterizations, respectively, for genus-zero surfaces of arbitrary number of boundaries. We have proposed a novel stretch energy minimization (SEM) algorithm for the computation of area-preserving parameterizations of simply connected open surfaces with very small area distortions and highly improved computational efficiencies. In addition, the existence of nontrivial limit points of the SEM algorithm is guaranteed under some mild assumptions of the mesh quality. Numerical experiments indicate that the accuracy, effectiveness, and robustness of the proposed SEM algorithm outperform the other state-of-the-art algorithms.

References

[1] Bo Dong, Matthew M. Lin*, Haesun Park. Integer Matrix Approximation and Data Mining, Journal of Scientific Computing, 75(1), 198-224.

[2] Matthew M. Lin, Chun-Yueh Chiang. An Iterative Method for Solving the Stable Subspace of a Matrix Pencil and Its Application, Linear and Multilinear Algebra, 66(7), 1279-1298, 2018.

[3] Matthew M. Lin and Chun-Yueh Chiang*, An Accelerated Technique for Solving One Type of Discrete-time Algebraic Riccati Equations, Journal of Computational and Applied Mathematics, 338, 91-110.

4. Highlights of Events

In addition to regular meetings and seminars, we have organized the "NCTS 2017/2018 High-Performance Computing for Tomorrow" in Taiwan Mathematical School. The series event includes the following programs.

a. Scientific Computing on Supercomputer, summer school, 6/26-7/7, 2017 (W. Wang, W.-W. Lin, Y.-C. Shu, F.-N. Hwang and T.-M. Huang).
Making good use of high-performance computing can not only solve large scientific or engineering problems, but also develop important industrial application software. In this two-week intensive course, we introduce (A) hands-on math software tools, (B) CUDA GPU programming, and (C) CPU/GPU OpenMP / OpenACC programming. This short-term course offers a very rare opportunity to learn the most advanced language and development environment for the high-performance computing language by using the supercomputer Reedbush in University of Tokyo.

b. Numerical linear algebra, 9/10-12/9, 2017 (T.-M. Huang, M. M. Lin, W.-W. Lin, Y.-C. Shu, W. Wang).
It is a co-teaching platform. Four mathematics departments of Taiwan universities including National Taiwan University, National Taiwan Normal University, National Cheng Kung University, and National Chiao Tung University have cooperated to design the curriculum for this course.

c. High-performance numerical solvers, 2017/12/18-2018/1/5 (T.-M. Huang, W.-W. Lin, Y.-C. Shu, W. Wang).
The mathematical development of modern numerical methods is intimately tied to high-performance computing, particularly for large-scale problems. This short course presents current ideas on high-performance numerical solvers,

as well as foundational concepts necessary to understand the newest methods. The focus will be on numerical linear algebra and parallel computing techniques. Under consideration are parallel iterative solvers that avoid costly communication synchronization, hierarchical matrix representations for kernel-based problems and their relation to fast solvers, multigrid methods for solving extremely large problems in a scalable fashion, and other recent developments. This short course complements and extends the topics presented in the High-Performance Numerical Solvers short course taught in Summer 2016.

d. Scientific Computing and Machine Learning on Multi- and Manycore Architectures, 2018/1/15-2018/1/30 (T.-M. Huang, W.-W. Lin, Y.-C. Shu, W. Wang).
This course covers the fundamentals of designing and implementing numerical linear algebra operations and algorithms on modern multi- and manycore architectures. New trends in the direction of Machine Learning/ Deep Learning will also be covered. The course bridges between mathematical theory on linear solvers, iteration methods, and preconditioning and programming aspects like MPI, OpenMP and CUDA programming. Each day contains two blocks: one morning block (3 hours) and one afternoon block (2 hours). While the morning block covers the more challenging theoretical background, the afternoon block aims at student involvement by containing practical examples, small exercises, and discussions.

e. Introduction to Parallel Programming for Multicore/Manycore Clusters, 2018/2/22-2018/2/25 (T.-M. Huang, W.-W. Lin, Y.-C. Shu, W. Wang).
In order to make full use of modern supercomputer systems with multicore/manycore architectures, hybrid parallel programming with message-passing and multithreading is essential. MPI for message-passing and OpenMP for multithreading are the most popular ways for parallel programming on multicore/manycore clusters. This 4-day tutorial provides essential knowledge and experiences for parallel programming using MPI and OpenMP. Hands-on exercise by the Readbush-U supercomputer at the University of Tokyo (Intel Broadwell-EP) is also given.

f. Introduction to Parallel Computing (II). Advanced Course on Multi-Threaded Parallel Programming using OpenMP/OpenACC for Multicore/Manycore Systems, 2018/7/16-2018/7/19 (T.-M. Huang, W.-W. Lin, Y.-C. Shu, W. Wang).
In order to make full use of modern supercomputer systems with multicore/manycore architectures, hybrid parallel programming with message-passing and multithreading is essential. While MPI is widely used for message-passing, OpenMP for CPU and OpenACC for GPU are the most popular ways for multithreading on multicore/manycore clusters. This 4-day course focus on optimization of single node performance using OpenMP and OpenACC for CPU and GPU.

5. **Plan for the Coming Year(S)**

   In research, we will continue the researches in numerical simulations based on Maxwell's equations, numerical linear algebra, and computational geometry. In education, a joint session of the student's posters for the course 'Numerical Analysis' in National Taiwan University, National Taiwan Normal University and National University of Kaohsiung.

III.6 Interdisciplinary Research

1. **Core Members** Organizers: Chih-Hao Hsieh (NTU, Institute of Oceanography), Tzyy-Leng Horng (FCU), Je-Chiang Tsai (NTHU), Feng-Bin Wang (CGU) and Tai-Chia Lin (NTU)

2. **Program Overview**
   We have four projects which focus on the following topics.

   a. Modeling, simulation and analysis of electric double layers
      Tai-Chia Lin and his group study ion transport through channels and electric double layers with applications on biological ion channels, nanotubes and supercapacitors. New mathematical models have been derived and justified by mathematical theorems and numerical simulations. We have made progress on the analysis and numerical simulation of Poisson-Nernst-Planck type equations. Besides the regular seminar, we organize short courses to introduce scientific backgrounds and mathematical techniques for some specific topics.

   b. Life history traits and exploitation affect the spatial mean-variance relationship in fish abundance
      Chih-hao Hsieh has focused on developing ecological theory and statistical approaches and then testing theory and methods using empirical data. The research topics include fisheries and environmental assessments.

   c. Mathematical models of cancer stem cell
      Je-Chiang Tsai and his collaborators estimate the relative magnitude of binding kinetics between micro-RNA and various oncogenes, with which we can reduce the number of governing equations in the study of ovarian stem cells. The reduced model can facilitate the analysis of stochastic noise.

3. **Research Highlights**
   We obtained many important results in the past five years. In the following, we list some selective achievements.

   a. Mathematical models of cancer stem cell, *by Je-Chiang Tsai*.
      For modelling studies of the ovarian cancer system, the governing equations

are very large and the kinetic parameters are in principle unknown. To analytically study this large system, T. Okada, J.-C. Tsai, and A. Mochizuki (2017 NCTS visitor) developed an efficient way to detect the bifurcation point. The main feature of this approach is that it depends only on the network structure, not neither on the values of parameters nor on the choice of kinetics (published in Phys Rev E, 2018). To link the ovarian cancer to the immune system, S. Bialecki, B. Kazmierczak (2017 NCTS visitor), and J.-C. Tsai studied how the spatial distribution of membrane receptors regulate the generation of ?receptor activation waves in B-cells whose activating states are required for initiating early protective immune response. In mathematical formulation, this corresponds to the study of the separatrix property of stationary waves of a RD systems of bistable type on the sphere. Using the piecewise-linear assumption on the reaction kinetics, we established the existence of stationary waves, and characterized their dynamics (Mathematical Models and Methods in Applied Sciences, in press).

b. Life history traits and exploitation affect the spatial mean-variance relationship in fish abundance, *by Chih-Hao Hsieh*.

1. We developed a series of statistical tools for time series analysis for analyzing and predicting nonlinear dynamical systems. These tools are used to investigate species interactions, system stability, and fisheries managements (published in Nature 2018).

2. Combining techniques of Next Generation Sequencing and Bioinformatics, we developed a series of theory and statistical analyses that allow to incorporate evolutionary information into studying environmental impacts on microbial community ecology. These tools are used to examine community assembly of microbes in the East China Sea and contrast the difference between bacteria and pico-eukaryotes (published in ISME J. 2018, Ecography 2015).

3. We develop automated image analysis systems to study size distribution of and trophic interactions of plankton. These tools can be used as novel bio-indicators to environmental changes, such as how eutrophication affects plankton and how biodiversity affects ecosystem functioning (published in Ecology 2014, Journal of Animal Ecology 2013).

4. Combining life history theory and spatial analysis of populations, I developed new ecosystem indicators to evaluate fishing effects. These indicators are useful for fisheries managements (published in Ecology 2016).

5. We developed an operational now-cast system for predicting fishing grounds using satellite data (accepted by Fisheries Oceanography).

c. Mathematical modeling and numerical simulation of drug transport inside tumor

We investigated the spatiotemporal responses of nanoparticles in tumor tissues and constructed the hydrodynamics model for transmural region by Starling's law and tumor interstitium by Darcy flow, in which a periodic tumor vasculature was employed (published in PLoS One, 2013). Then drug transport model was constructed by kedem-Katchalsky equation for transmural region and convection-diffusion-cell absorption equation for tumor interstitium region. Following our work in 2013, we further developed a mathematical model for drug transport in a spherical tumor (which is applied to a subcutaneous tumor with heterogeneous vascular distributions) and conducted its numerical simulation (published in PLoS ONE, 2017). Our results indicated that the effectiveness of the anti-tumor drug delivery was determined by the interplay of the vascular density and nanoparticle size, which governs the drug transport properties.

d. Models of harmful algae with toxin degradation

We present a PDE system modeling the growth of a single species population consuming inorganic carbon that is stored internally in a poorly mixed habitat. Inorganic carbon takes the forms of "CO2" (dissolved CO2 and carbonic acid) and "CARB" (bicarbonate and carbonate ions), which are substitutable in their effects on algal growth. The main difficulties in mathematical analysis for the model systems are caused by the singularity in the ratio U/u at the extinction steady state (U,u)=(0,0). Thus, standard techniques such as linearization and bifurcation are not applicable. Recently, J. Mallet-Paret and R.D. Nussbaum proposed a Krein-Rutman type theorem involving two separate cones, and hence, the existence of the principal eigenvalue of a nonlinear eigenvalue problem can be proved. Then we are able to establish a threshold type result on the extinction/persistence of the general system in terms of the death rate and the principal eigenvalue associated with a nonlinear eigenvalue problem (published in Journal of Mathematical Biology, 2017).

e. Analysis of nonlinear Schrodinger equations with applications in nonlinear optics

Studying solitons in photorefractive medium described by nonlinear Schrodinger systems, I used methods of mathematical analysis to derive some integral identities and show that beam coupling constant must be greater than or equal to propagation constant (published in the Journal of Optical Society of America B, 2013). Using the energy estimate method, I proved the existence of ground state in (published in JMP 2014) but the eigenvalue problem and the asymptotic behavior of ground state energy should be further investigated. In the paper (published in CVPDE 2017), I used the ratio of kinetic

energy and potential energy to estimate eigenvalues and developed innovative arguments to prove the Virial theorem of the eigenvalue problem of NLS equations. Furthermore, I applied the Virial theorem to derive the asymptotic behavior of ground state energy of NLS equations.

4. Highlight of Events

(a) NCTS workshop on mathematical biology (May 28-June 1, 2018)
This four-day conference is a meeting forum for researchers from mathematical and biological sciences, and aims at suggesting new areas of applications of mathematics in biological sciences and initiating innovative research fields within mathematics itself. As the bridge between mathematical and biological sciences, the topics include Mathematical ecology, Dynamics of Phytoplankton Communities, Disease Spread, Mathematical Physiology, Ion channel analysis, and Inverse problems.

(b) NCTS workshop on nonlinear PDEs (December 12-15, 2017)
In last twenty years we have witnessed great progress in the theory of nonlinear partial differential equations (PDEs) and their applications on physical and biological environments. For example, in the area of diffusions coupled systems of nonlinear PDEs are used to model pattern formation phenomena in biology. With energy dissipation they can also describe complex fluids, electrolytes and liquid crystals. On the mathematical side, coupled systems of nonlinear PDEs may bring about increasing difficulties which requires innovative ideas or techniques of multi-disciplinary approach. During this four-day workshop, we bring analysts in different fields in this workshop, with the goal of catalyzing breakthroughs in developing new theories and techniques on nonlinear PDEs with applications.

5. The Future Plan

1. We propose to organize a Joint Fields-NCTS workshop on modeling and analysis in molecular biology and electrophysiology. The tentative dates will be on December 2019.

2. Mini courses on the topics of interdisciplinary researches

III.7 Harmonic Analysis

1. Core Members

a. Faculties: Xiang Fang (NCU), Ngai-Ching Wong(NSYSU), Ming-Yi Lee (NCU), Chin-Cheng Lin (NCU), Duy-Minh Nhieu (NCU), Chun-Yen Shen (NCU)

b. Postdocs: Hsi-Chun Wu

c. Students: 2 Ph.D./ 9 Master

d. Long-term Visitors: Chao Liu (Ph.D. student, Fudan University), Yongsheng Han (Auburn U.), Heping Liu (Peking University)

2. Program Overview

Many phenomena in nature occur in a periodic fashion. Harmonic analysis is a branch of Mathematics that analyzes and describes such phenomena. Complex problems can be reduced or decomposed in terms of manageable but periodic components. The Fourier series and Fourier transform are of course such well known examples which dated back into the 1800's. This is the time when classical Harmonic Analysis was born. Today, even besides the main development of this field, traces of its principles and thoughts can be found in many other branches of Mathematics. Throughout its history, it has attracted the attention of many great Mathematicians to its development. Despite the fact that it is an old subject, new problems in the field continue to arise, evolve and continue to influence both Pure and Applied mathematics. Given its importance and future prospect, the Harmonic Analysis group in Taiwan (although small) continue its investigation on a wide variety of topics which include the classical two weight problems, singular integral operators, theory of function spaces, operator theory and numerical range.

In the past year, several weekly seminars entitled "Quaternion Heisenberg Group", "Brownian Motion", "Free Probability", "Additive Combinatorics", and "Littlewood-Paley Theory and Hardy Spaces", were held. Also, prominent scholars in the field such as Yongsheng Han, Xuan Thinh Duong visited NCU and gave lectures and workshops. Their visits benefited the mathematical community here at home. The details of our achievement can be found in the publication list and described below. Our upcoming goal is to promote knowledge and development of this field in Taiwan. We outline our forth coming plan and report on activities during the year 2018.

3. Research Highlights

a. Sum-product estimates over various settings:
We recently have proved some strong results on sum-product estimates, and expanding polynomials over matrix rings $M_2(\mathbb{F}_q)$ over finite fields. We also provide similar results in the special linear group $SL_2(\mathbb{F}_q)$. *Sum-product graphs* over both $M_2(\mathbb{F}_q)$ and $SL_2(\mathbb{F}_q)$, and the *special unit-graph* over $M_2(\mathbb{F}_q)$ play a crucial role in our recent studies.

Moreover, we have established that there exists an absolute constant $c > 0$

such that for any finite set A of positive real numbers

$$|AA + A| \gg |A|^{\frac{3}{2}+c}.$$

On the other hand, we also give an explicit construction of a finite set $A \subset \mathbb{R}$ such that $|AA + A| = o(|A|^2)$, disproving a conjecture of Balog.

b. Failure of energy conditions for singular integral operators:
In our solution to the Nazarov-Treil-Volberg conjecture for the two weight Hilbert transform inequality, crucial use was made of the pointwise equivalence for the difference quotients of the Hilbert transform $H\mu$ associated with x, x' in an interval J and a positive measure μ supported outside the double $2J$ with the positive Poisson integral $\mathrm{P}(J,\nu) \equiv \int_{\mathbb{R}} \frac{|J|}{|J|^2+|y-c_J|^2} d\nu(y)$. A striking difference, discovered in our recent results, between the one and higher dimensional settings for singular integrals is that this equivalence fails in both directions $\lesssim$ and $\gtrsim$ for singular integrals in $\mathbb{R}^n$ with $n > 1$. In particular, there is a spectacular failure of the reverse inequality $\gtrsim$, which we refer to as energy reversal. A further counterexample to fail the energy condition has been also constructed in our recent work.

c. $\mathscr{A}_{p,\mathbb{E}}$ weights, maximal operators, Hardy spaces, BMO and Carleson measure spaces associated with a family of general sets:
We establish a theory of weighted maximal function estimates and weighted Hardy spaces associated with a family of open sets on a topological space endowed with a nonnegative Borel measure. The conditions on the family of open sets correspond to standard conditions on families of balls on Euclidean spaces or spaces of homogeneous type. We define weighted atomic Hardy spaces, and characterize the dual space as a weighted BMO type space. Under a stronger assumption of spaces of homogeneous type with polynomial volume growth, we give an equivalent definition of the atomic Hardy space in terms of maximal functions. Our theory recovers well-known results in weighted Hardy space theory. More interestingly, the results give a weighted Hardy space theory related to the Monge-Ampere equation, as previously studied by Caffarelli and Gutierrez in 1996. Other examples of applications include weighted Hardy space theory on open sets in $\mathbb{R}^n$ and on homogeneous groups.

d. (Non-selfadjoint) Random Operator Theory:
It is well known that random matrix theory has evolved into a remarkably sophisticated field, but its infinite dimensional counterpart, which we call random operator theory, is much less studied. Moreover, most references on random operators so far concern with self-adjoint operators, like random Schrodinger operators. This line of research, like random matrices, focuses on

the spectral theory, which is not the focus of non-selfadjoint operators usually. Then the random theory of non-selfadjoint operators seems to be essentially a blank spot in the literature. As far as we know, there is no concrete model which is investigated with reasonable depth so far. Together with G. Cheng at Zhongshan University (Guangzhou) and S. Zhu at Jilin University, we systematically studied the first non-trivial model in non-selfadjoint random operator theory, and many ideas in operator theory and in probability theory are brought together. In particular, we studied the following model.

The unilateral shift is a paradigm for (non-selfadjoint) operator theory. We replace the weights $w_n = 1$ in the unilateral shift $Te_n = w_n e_{n+1}$, where $\{e_n\}_{n=1}^{\infty}$ is an orthonormal basis of a complex Hilbert space, by a sequence of i.i.d. random variables $\{X_n\}_{n\geq 1}$; that is, $w_n = X_n$. We propose to study a generic sample of this new ensemble in parallel to the three well-known weighted shifts (i.e., Hardy, Bergman, Dirichlet) in operator theory. We show that their spectra have a thick boundary (i.e., essential spectrum). They a.s. have invariant subspaces with large indices and their semi-invariant subspaces model arbitrary contractions. We discuss Beurling-type theorems. Their samples are classified up to four equivalences, and this, in particular, helps us characterize when their C^*-algebras contain nonzero compact operators. H^∞ functional calculus is constructed. Von Neumann inequalities for free polynomials are established. Their dynamical properties are clarified. Their iterated Aluthge transforms are shown to converge.

4. Highlights of Events

(a) NCTS-NCU seminar on quaternion Heisenberg group
Organizer: Chin-Cheng Lin
Venue: Room M412, Hong-Jing Building, National Central University
Time: 2017/9/22 – 2018/1/19, Every Friday 3:00 p.m. - 4:00 p.m.

(b) NCTS-NCU seminar on Gaussian free field
Organizer: Xiang Fang
Venue: Center of Math & Theoretic Physics at NCU
Time: 2017/9/22 – 2018/1/19, Every Thursday 4:00 p.m. - 6:00 p.m.

(c) NCTS-NCU seminar on SLE
Organizer: Xiang Fang
Venue: Center of Math & Theoretic Physics at NCU
Time: 2017/9/22 – 2018/1/16, Every Tuesday 4:00 p.m. - 6:00 p.m.

5. Plan for the Coming Year(s)

During 2019, we consider to invite the following mathematicians from abroad to

contribute to our program and to offer either short courses or lectures.

(a) Tuomas Hytonen (University of Helsinki, Finland)

(b) Qingbo Huang (Wright State University, USA)

(c) Eric Sawyer (McMaster University, Canada)

(d) Yongsheng Han (Auburn University, USA)

(e) Xuan Thinh Duong (Macquarie University, Australia)

(f) Sanghyuk Lee (Seoul National University, Korea)

(g) Doowon Koh (Chungbuk National University, Korea)

(h) Akihiko Miyachi (Tokyo Woman's Christian University, Japan)

(i) Naohito Tomita (Osaka University, Japan)

Planed seminars and workshops:

- Weekly seminar
- Organize an International Harmonic Analysis Workshop at NCTS in May 2019

III.8 Laboratory of Data Science

1. **Core Members**

   a. Faculty: Hau-Tieng Wu (Duke), Mei-Hui Guo (NSYSU), Mong-Na Lo Huang (NSYSU), Chieh-Sen Huang (NSYSU), Ray-Bin Chen (NCKU), Shih-Feng Huang (NUK), Sheng-Mao Chang (NCKU), Liang-Ching Lin (NCKU)

   b. Long-term visitor: Yu-Min Chuang (Univ. North Carolina, Greensboro)

   c. Students: 6 Ph.D students, 29 Master students

2. **Program Overview** The recent development of science and technology shows that the increasing importance for people to understand the structure of data in our daily life. The conclusion of the Review Committee in 2015 suggested that there is an immediate need to develop data sciences, and a group to study the mathematical foundation of data science is thus formed.

   We started the Data Science Forum from a group with 7 researchers: Hau-Tieng Wu (Toronto), Weichung Wang (NTU), Su-Yun Chen (AS), Mao-Pei Tsui (NTU), Ting-Li Chen (AS), I-Liang Chern (NTU), Yu-Ting Lin (Hsin-Kuang Hospital). The purpose of this group is to work on mathematical foundation of data sciences with application in medical science. The forum was held every 4 weeks, via the internet meeting with participants from North America through skype.

It attracts more and more participants and therefore we appoint Hau-Tieng Wu as a Center Scientist and also the foundation of *Laboratory of Data Science* was approved by the Executive Committee.

With the collaboration of physicians from NTU Hospital and other hospitals, the group has grown substantially. It is now a group of about 20 researchers, including Yen-Tsung Huang (AS), Dr. Chih-Chieh Albert Yang (Psychiatrist, NYMU, Veteran Hospital), Dr. David Liao (physician, NTUH), Dr Chia-Chun Wang (physician, NTUH), Matthew Lin (NCKU), Hwa-Lung Yu (NTU). In the meeting, some medical challenges are introduced, and the related mathematical solutions were discussed.

The forum has provided a media for people to gather together and share experiences and thoughts, and an active ongoing project is now led by Weichung Wang. We expect to have at least another ongoing project by the end of the year, and we are developing a proposal to arrange an international workshop in data science next year.

On the other hand, we also start the project of building up a database on sleeping signals. The purpose of this project is to build a cross-hospital integrated database so that Taiwanese researchers can have easy access to such database. Currently, it contains about 500 data, thanks to the cooperation of Chang-Gung Memorial Hospital, Taipei Veteran General Hospital, and Tzu Chi Hospital.

3. Research Highlights

a. massive data, *by Hau-tieng Wu*.
Hau-tieng Wu is an applied mathematician and a medical doctor by training. His research focuses on building up mathematical foundations of massive data analysis, and applying the results to biomedical problems; particular physiological time series analysis, like electrocardiogram, electroencephalogram, respiratory signal, functional MRI, etc. The goal is to establish data-driven and mathematically solid methods to extract intrinsic information from the data-intense clinical environments. The synthesized information will lead to a reliable, consistent, and practical predictive system that describes a patient's current status and can warn the healthcare provider about adverse clinical trajectories. To achieve this goal, his work is balanced among different fields, ranging from mathematics, statistics, electrical engineering, computer science, to medicine. Based on his medical and mathematical training, He is able to to directly communicate between these two extremely diverse fields. The research work of his and his team has drawn a lots of attention, which earned him a tenure-track Associate Professor position at Duke.

b. statistical aspects of big and complex data, *by Ray-Bing Chen*.

In the past few years, the work of Ray-Bing Chen focus on the following research topics.

(1) Numerical generators for the optimal designs: Here we still target on the particle swarm optimization (PSO) approach to be optimal design generators. Due to the different design problems, we would modify the PSO accordingly and improve the corresponding computing efficiency. We did have a paper about orthogonal array construction published in Computational Statistics and Data Analysis(CSDA) this year. In addition, there is another paper about the space-filling designs for the irregular experimental regions which is accepted by Journal of Computational and Graphical Statistics (JCGS). In fact, JCGS is the top journal in Statistical Computing. Currently we do have another revised paper for Technometrics, which is the top journal in Industrial Statistics;

(2) Bayesian structure and variable selection approaches and their applications: Currently we do have a project related to the parameter estimation in vector autoregression (VAR). Due to the huge parameter size, it is a difficulty problem for the parameter estimation in VAR. Based on the prior information, we might divide the parameter matrix into several non-overlapping structure. Thus we transfer the parameter estimation problem as a structure selection problem and here we propose a Bayesian structure selection approach accordingly. The simulation results support that the proposed method can identify the active structures frequently. In this project, we apply the proposed method to deal with a stock market data set. Now we do revise this paper for Journal of Forecasting. There are two other Bayesian related papers published in 2017. The first one is the fast Bayesian factor screening approach which was published in Journal of Statistical Computation and Simulation. Another one is to use Bayesian variable selection approach to identify the possible factors for the 2008 Financial Crisis and this paper was published in Studies in Nonlinear Dynamics & Econometrics.

(3) Machine Learning: (3.1) Independent component analysis (ICA) is an unsupervised learning approach. In the past few years, we focused on how to cooperate the sparse property into the loading matrix of ICA. There are two different approaches. The first one is to assume that the loading matrix involves the sparse property and then a lasso type penalty is involved into the likelihood function. This proposed approach is called the penalized independent factor (PIF) which is a book chapter paper in Applied Quantitative Finance (W. Hardle, C. Y. Chen & L. Overbeck, eds). Another one is to consider the sparse group penalty and the corresponding ICA method is called the sparse group independent component analysis (SG-ICA). Currently we do work on revising this paper for CSDA. (3.2) Active learning is a semi-supervised learn-

ing approach. Unlike supervised learning, in addition to the training set, we do have another unlabeled point set. The key problem is how to smartly select unlabeled points and then label them to update the training set. Here the sequential design procedure is adopted due to the parametric models considered in our works. In addition to the sequential design procedure, we also include the stagy for the variable selection. In our proposed active learning methods, we do not select the proper points for labeling but also update the current learning models. Now we revise two papers for Neurocomputing and CSDA separately.

(4) Uncertainty Quantification (UQ): UQ has been a hot-topic research in the past few years. In 2017, we did have a paper targeted on how to generate the prediction uncertainty for the linear surrogate model and this paper was published in Technometrics. Currently we do work on another related project. The surrogate model considered here is the radial basis function model. We do not only obtain the prediction uncertainty but also update the parameters in the radial basis functions. Then based on the prediction uncertainty, we propose a global optimization approach. Now we still work on few numerical experiments and then will write a paper. In 2018, there is another UQ paper published in Statistica Sinica. In this paper, we apply the UQ approach as an auto-tuning procedure and demonstrate it performance based on a linear equation solver.

4. Highlights of Events

a. In 2018, there are a couple important international visitors, Prof. William Li (University of Minnesota, USA) and Prof. William Wei (Temple University, USA). Prof. William Li is an export in Experimental Design. During his visiting, we came out a joint project related to the numerical generator for the discrimination design. The research of Prof. William Wei is related to the time series analysis.

b. The long-term visitor Yu-Min Chuang is an expert in topology of data. During his stay, he gave a mini-course on topological data analysis. It is the first time to have lectures in this frontier research area.

c. WorkshopsG
(a.1) (Statistical Education in Data Science Era, 2018, 3.9 3.10)GBasically we believe that Statistics should play a key role in Data Science. However, how to teach Statistical courses for Data Science is an important problem. In this workshop, we invited the statisticians who are interested in this topic and from the different ages to share their own experience and thoughts for the related issues. In addition, we also invited Dr. Lan to share her teaching

experience and talk about the key of sharing course martials. Then the second statistical education workshop was held in Academial Sinica and invited more statistical colleagues to join the workshop.

(a.2) 2018 Conference on Advanced Topics and Auto Tuning in High-Performance Scientific Computing (2018, 3.26 3.27)GThis is the first time such that this ATAT conference is not held in Taipei. Basically this is an important conference for the scientific searchers from Japan and Taiwan. Currently, in addition to the scientific computing topics, we also involved the talks related to Machine Learning and Image Analysis. In this year, two keynote speakers were Chien-Min Kao (University of Chicago) and Jose E. Roman (Universitat Politècnica de València).

5. **Plan for the coming year** 1) Enhance international cooperation: In this year, we only had two international visitors. In the next year, we hope to invite more international scholars. The visiting scholars do not only work on the joint research projects but also can help us on the short course or workshop to introduce their own novel research results.

   2) Encourage young researchers and PhD students to attend international conferences and short-term academic visiting: We will continue encouraging young faculties, post-doctors and Ph.D. students to attend international conferences or to have short-term academic visiting. From our experiences, it is really important to build their international connection and also to explore their global view on the current research trend and innovation.

   3) Short course and workshops: We would like to organize the short courses or workshops together with several universities in South of Taiwan. Currently we do plan to co-organize the 2019 Conference on Advanced Topics and Auto Tuning in High-Performance Scientific Computing. In addition, we still think about the possible workshop or short course related to the Data Science.

IV Goals and Planning of Next Year

In the coming year of 2019, there are a few excitements and challenges ahead of us.

1. Joint Summer School with MSRI

   MSRI at Berkeley has long history and is a world leading mathematical research center. Its summer school has very high reputation over the years. It was agreed between MSRI and NCTS to reproduce the popular summer school on Toric Variety, led by David Cox in NCTS in the summer of 2019.

   The long-awaited joint summer school will host 20 graduate students from all over the world selected by MSRI and many more domestic students. The travel of lecturers, TA, and international students will be supported by MSRI. Also the per-diem of lecturers and TA will be covered by funding of MSRI. NCTS will take care of the local supports. The estimated cost-sharing rate is about 60 over 40 from MSRI and from NCTS.

2. Undergraduate Summer Research Program, 2019

   We plan to make 2019 USRP program more internationally, in the following two aspects. For the 2019 USRP program in Taiwan, we will invite proposals from our cooperative international institute, e.g. Fields Institute, Berlin Mathematics School. By doing so, we expect to have program-mentors from abroad. The students in these groups will need to discuss with foreign mentors. And we expect all students in all groups to have their final presentation in English.

   On the other hand, we will cooperate with cooperative institution in order to send a few students to attend their summer research program.

3. Further Collaboration Internationally and Domestically

   With the existing collaboration project with international institutes in Asia and North Ameria, we will seek for further cooperation in Europe in the year 2019. Other than that, we think it is a good idea to build a stronger cooperation in near by countries. For example, there is a proposal to build an alliance among RIMS in Japan, KIAS in Korea, and NCTS in Taiwan. Joint meetings or joint postdoc programs among these institutes will be considered.

   Turning into domestic consideration, he current fact is that each department might have very limited number of faculty members and students. Therefore, it is extremely difficult for each place to build up an outstanding research group. The idea of Taiwan Mathematics School is to bring faculties and students from different places in the same field together. The courses of NCTS school also counted as courses of each individual university. By doing so, faculties members

share the teaching duties so that it is possible to have a better designed curriculum. Also students will be benefits a lot from wider spectrum of the curriculum. There are still many technical and logistic issues ahead of us. We hope to march into a strong liaison in the near future.

V Host institution's commitment

The commitment of Host institution consists of the following aspects: budget, space, and logistic support. From the point of view of budget, the Host institution: National Taiwan University completely fulfill its commitment as we described in the chapter of budgets. Below we will focus on describing the space and other logistic supports.

a. Space of NCTS

   The planned new space in newly-built Cosmology building is delayed. The original expecting date lies in Fall of 2017. Even though, the actual moving date is approaching. We are now working on detailed interior design and decoration. The actual moving date will be around the end of the year or beginning of 2019.

   According to the original commitment, there are 200ping free of charge for NCTS Math to use. The proposed extra space to rent is also reserved for NCTS Math.

   After the reallocation of the Center, the current space in Astro-Math. Building provided by the Department of Mathematics will return to the Department.

b. Logistic support of NTU

   We consider the logistic support of NTU during the past couple years is getting more smooth. At the beginning, we spent considerable effort to explain the special mission of NCTS and to seek for possible solution for some unexpected difficulties. After a couple years of try-and-error, most of the unexpected difficulties has be solved.

   We started the proposal to build up "Taiwan Mathemtics School". The idea was greatly supported by NTU. It is now possible that NCTS offer courses with credits. It is also possible that students in other cooperative universities or cooperative department can take the coursed of NCTS with credits. The list of cooperative universities consists of: National Taiwan Normal University, National Taiwan University of Technology, and National Taipei University of Education. The list of cooperative consists of Department of (Applied) Mathematics of: National Cheng-Chi University, National Central University, National Tsing-Hua University, National Chiao-Tung University, National Chung Cheng University, Naitonal Cheng Kung University, National Sun Yat-sen University, National Dong-Hwa University. Students from other universities or department not on the above list might be possible to get credit recognised, depending on the regulation of his/her own institution.

申請機構配合事項同意書

計畫名稱：國家理論科學研究中心第四階段運作計畫(2015.1.1-2020.12.31)

計畫主持人姓名/職稱：陳榮凱/教授

申請機構配合措施：本計畫業經單位內部審查，同意提供下列配合事項。

一、 配合款：本機構同意提供2000萬之配合款，於執行期間優先使用於計畫所需各項經費（含中心人員薪資、學術活動費用、使用空間的場租、軟硬體設備、裝修維護費、水電雜支等等）。本計畫執行期滿後，收支報告表內需詳細註明配合款支用情形。

二、 員額：提供 5 名供中心延聘中心主任、中心講座、特約中心科學家。

三、 管理費：依本校「建教合作計畫管理費分配處理細則」辦理，以科技部計畫15%管理費計，分配至計畫主持人所屬學院2%，分配至校級中心之管理費約30%。

四、 結餘款：依本校「建教合作計劃結餘款分配、運用及管理要點」辦理，當年度結餘款總額扣除個別使用款項後之餘額，校級中心以分配50%為原則。

五、 中心空間：

1. 現況：

a. 專屬空間共約 361 坪：

天文數學館	二樓 (約 183 坪)	中心行政區，小型研討室(30 人)及大型研討室(120 人)各 1 間，4 間訪問學者辦公室與交誼區；走道公共空間設有沙發及茶水區，為公告區及休息討論區。
	四樓 (約 76 坪)	5 間訪問學者辦公室、1 間視訊會議室、2 間討論室和 1 間辦公室(供研究助理使用)。
數學研究中心	二樓 (約 66 坪)	5 間辦公室(供博士後研究員使用)及休息區。
	三樓 (約 36 坪)	6 間訪問學者辦公室。

b. 共同使用空間共約 255 坪：

天文數學館	一樓 (約 180 坪)	3 間中小型教室(80 人、80 人、20 人)和 1 個國際會議廳(198 人)。
	九樓 (約 75 坪)	接待、交誼、會議或相關學術活動使用空間。

2. 宇宙學大樓於2016年落成之後：

a. 專屬空間共約 502 坪：

宇宙學大樓	4 樓(200 坪) 5 樓(200 坪) (2 層樓 400 坪為數學組與物理組共用)	辦公室、小型會議室與研究室。
	其他樓層 (數學組另行租借 200 坪)	辦公室、小型會議室與研究室。
數學研究中心	二樓 (約 66 坪)	5 間辦公室(供博士後研究員使用)及休息區。
	三樓 (約 36 坪)	6 間訪問學者辦公室。

b. 共同使用空間共約 150 坪：

宇宙學大樓	一樓 (150 坪)	大型演講廳(130 人)。

六、 其它相關配合措施：請詳細說明所提供之各項設備、學人宿舍、裝修維護費、水電雜支、停車、行政支援...等。

1. 中心主任與執行主任因推動中心業務，同意減免教學課程，依本校「教師核減授課時數」規定辦理。
2. 校方提供至少10名博士後研究員名額，以招募優秀年青研究人員。（薪資含配合款中）
3. 提供客座學人宿舍給國內外長期訪問學者。
4. 國內外學生至中心訪問期間的住宿得申請本校學生宿舍。
5. 提供一個月(含)以上中心訪客使用學校體育健身設施收費優惠。
6. 提供參加中心活動的成員停車費優惠。

此致

科技部

申請機構首長（簽章）：　　學校用印

中 華 民 國　103　年　11　月　18　日

VI Appendix

Throughout the Appendix, the Group Codes are used in representing each Topical Programs. The codes are as follows:

- A=Number Theory and Representation Theory
- B=Algebraic Geometry
- C=Differential Geometry and Geometric Analysis
- D=Differential Equation and Stochastic Analysis
- E=Scientific Computing
- F=Interdisciplinary Research
- H=Harmonic Analysis
- L=Laboratory of Data Science

VI.1 Seminar and workshop data

VI.1.1 NCTS seminars, 2018

Seminar Title	**Dates**	**Group**
NCTS Seminar on Number Theory	1/22, 2/12, 3/9, 3/14, 4/20, 4/25, 5/16, 5/30, 6/6, 7/4	A
NCTS Seminar on Arithmetic Geometry and Representation Theory	1/5, 1/12, 3/13, 3/20, 3/27	A
NCTS Seminar in Algebraic Geometry	3/13, 3/20, 3/27, 3/28, 6/1	B
NCTS Lectures in Derived Category	6/21, 6/28	B
NCTS Lecture Series on Moonshine	1/5, 1/12, 1/19	B
NCTS Seminar on Geometry-Physics-Symmetry	2/2,	B
Sinica-NCTS Geometry Seminar	1/5, 1/8, 3/9, 5/25, 6/1,	C
NCTS Differential Geometry Seminar	3/8, 3/14, 3/22, 3/29, 4/19, 4/26, 5/3, 5/31, 6/28, 8/2	C
NCTS Seminar on Symplectic Geometry	2/7, 6/22, 6/25	C
Sinica-NCTS Reading Seminar on Kapustin-Witten Equations	5/20, 5/21, 6/4	C
NCTS GMT Learning Seminar	1/24, 1/30, 2/1, 2/6, 2/8, 2/26, 3/2	C
NCTS GMT Seminar	1/23, 1/24	C

Seminar Title	Dates	Group
NCTS Random Matrices Seminar	1/8, 1/15, 1/22, 2/1, 2/2	D
2018 NCTS Seminar on Dynamical Systems: G-dynamical Systems and Sofic Entropy	3/16, 3/23, 3/30, 5/4, 5/11, 5/25	D
NCTS PDE & Analysis Seminar	1/4, 3/21, 6/4	D
NCTS Reading Seminar on Kinetic Theory	1/26, 2/5, 3/19, 3/26, 4/23, 5/21	D
NCTS Seminar on Analysis	7/2,	D
NCTS Seminar on Celestial Mechanics	3/15, 3/15, 3/22, 3/22, 3/29, 3/29, 4/12, 4/12, 4/19, 4/26, 5/3, 5/17, 5/31	D
NCTS Seminar on Probability	3/14, 3/28, 4/11	D
NCTS Seminar on Modern Control Theory	3/13, 3/15	E
NCTS Seminar on Scientific Computing	3/28, 7/10, 7/16, 7/18, 7/18, 7/20, 7/23	E
NCTS Interdisciplinary Research Seminar	1/5, 1/12, 6/22, 6/29, 6/29, 7/3, 7/10,	F
NCTS Seminar on Mathematical Biology	3/7, 3/23, 5/4, 5/11, 5/18, 5/25, 6/15, 6/22, 6/22, 6/26, 6/26, 6/27, 6/28, 6/29, 7/2, 7/11, 7/12, 7/13	F
Sinica-NCTS Geometry and Quantum Physics Seminar	3/20,	F
NCTS-NCU Seminar on Maximal Operator	3/5, 3/12, 3/19, 3/26, 4/9, 4/16, 4/23, 4/30, 5/7, 5/14, 5/21, 5/28, 9/24, 10/1, 10/8	H
NCTS-NCU Seminar on Stochastic Analysis	3/6, 3/13, 3/20, 3/27, 4/10, 4/17, 4,24, 5/8, 5/15, 5/22, 5/29, 9/25, 10/2, 10/9	H
NCTS Seminar on Machine Learning	3/9, 3/16, 3/23, 3/30, 4/20, 4/26, 4/27, 5/3	L
NCTS Seminar on Data Science	5/11,	L
NCTS Data Sciences Forum	1/2, 1/8	L
Taipei Postdoc Seminar	4/18, 5/2, 5/16, 5/30, 9/20, 10/11, 10/17	All

VI.1.2 NCTS course, 2018

Dates	Venue	Gp.	Title	Organizers
2018-04-13 / 2018-04-18	AS	A	NCTS Mini-Course on Representations of Algebras and Tilting Modules	Wang Yong-jie (NCTS) Yu Chia-Fu (AS)
2018-01-16 / 2018-01-19	NCTS	A	NCTS Winter School on Automorphic Representations	Hsieh Ming-Lun (AS)
2018-04-27 / 2018-05-11	NCTS	B	NCTS Minicourse in Algebraic Geometry - Birational Geometry of Foliations on Higher Dimensional Varieties	Chen Jungkai (NTU)
2018-01-29 / 2018-02-01	NCTS	B	NCTS-Taiwan Math School-Derived and Homological Algebraic GeometryWinter School, 2018	Chen Jiun-Cheng (NTHU) Chen Jungkai (NTU) Chuang Wu-yen (NTU) Jow Shin-Yao (NTHU) Lai Ching-Jui (NCKU)
2018-07-30 / 2018-08-17	NCTS	C	2018 NCTS Summer Course: Image and Shape Manipulation	Kaji Shizuo (Kyushu) Lin Chun-Chi (NTNU)
2018-07-09 / 2018-07-20	AS	C	2018 NCTS Summer Course: Introduction to 3-manifold Topology with some Applications to Knot Theory	Cheng Jih-Hsin (AS)
2018-04-14 / 2018-06-02	NCTS	C	Taiwan Mathematics School: Lectures on Lagrangian Floer theory	Chiang River (NCKU) Ho Nan-Kuo (NTHU) Yau Mei-Lin (NCU)
2018-03-05 / 2018-05-11	NCTS	C	Taiwan Mathematics School: An Introduction to Geometric Measure Theory	Lee Yng-Ing (NTU) Tsui Mao-Pei (NTU)
2018-01-23 / 2018-02-09	NCKU	C	NCTS GMT Seminar	Wang Ye-Kai (NCKU)
2018-07-31 / 2018-08-21	NCTS	D	2018 NCTS Summer Course: Diffusion Learning Theory and Medical Applications, the first step	Sheu Yuan-Chung (NCTU) Wu Hau-Tieng (Duke)
2018-07-23 / 2018-08-02	NCTS	D	2018 NCTS Summer Course: Random Walks and Related Topics	Chen Guan-Yu (NCKU) Sheu Yuan-Chung (NCTU)

Dates	Venue	Gp.	Title	Organizers
2018-06-26 / 2018-07-04	NCTS	D	2018 NCTS Summer Course: Fluid, Water Wave and Phase Transition Problems	Hsia Chun-Hsiung (NTU)
2018-04-15 / 2018-05-20	NCTS	D	Taiwan Mathematics School: Reaction-Diffusion and Mathematical Sciences	Chen Chiun-Chuan (NTU) Hsia Chun-Hsiung (NTU)
2018-02-26 / 2018-06-30	NCTS	D	Topics in Random Matrix Theory	Tsui Mao-Pei (NTU)
2018-07-16 / 2018-07-19	NCTS	E	2018 NCTS Summer Course: Introduction to Parallel Computing (II)	Wang Weichung (NTU) Lin Wen-Wei (NCTU) Shu Yu-Chen (NCKU) Huang T.-M. (NTNU)
2018-02-22 / 2018-02-25	NCTS	E	Taiwan Mathematics School: Introduction to Parallel Programming for Multicore/Manycore Clusters	Wang Weichung (NTU)
2018-01-15 / 2018-01-30	NCTS	E	Taiwan Mathematics School: HPC for Tomorrow-Scientific Computing and Machine Learning on Multi- and Manycore Architectures	Wang Weichung (NTU)
2018-08-27 / 2018-09-04	NTHU	F	NCTS Summer Course on Mathematical Biology	Hsu Sze-Bi (NTHU) Wang F.-B. (Chang Gung Univ.)
2018-07-16 / 2018-07-30	NCTS	F	2018 NCTS Summer Course: Mathematical Problems Arising in Materials Science	Lin Tai-Chia (NTU)
2018-07-16 / 2018-07-27	NCTS	F	2018 NCTS Summer Course: Mathematical Modeling and Analysis of Infectious Diseases	Lin Tai-Chia (NTU) Lin Hsien-Ho (NTU) Hsieh Y.-H. (China Medical Univ.), Wang F.-B. (Chang Gung Univ.)
2018-04-10 / 2018-05-15	NTNU	F	SOC functions and their applications	Chen Jein-Shan (NTNU)
2018-01-31 / 2018-02-06	NCTS	F	Mini-Course on NekCEMa Numerical PDE Solver	Lin Tai-Chia (NTU)
2018-05-28 / 2018-07-04	NCTS	L	2018 NCTS Summer Course: Theoretical Foundation of Data Science, with Application	Chen Jungkai (NTU) Wu Hau-Tieng (Duke)

VI.1.3 NCTS workshops and conferences, 2018

Title	Gp.	Dates	Venue	Organizers
Special Day on Applied Mathematics - Mathematican in Industry	E	2018-01-16 / 2018-01-16	NCTS	I-L. Chern (NTU)
2018 South-Taiwan Workshop on Scientific Computations Differential Equations and Applications	D, E	2018-02-03 / 2018-02-03	NCKU	M.-H. Chen (NCKU) M. Lin (NCKU) Yu-Chen Shu (NCKU) C.-S. Wang (NCKU)
2018 Young Dynamics Day	D	2018-02-23 / 2018-02-23	Tunghai Univ.	J.-C. Ban (NDHU) K.-C. Chen (NTHU) C.-H. Hsu (NCU) T.-S. Yang (Tunghai)
The 9th Taiwan-Japan Joint Workshop for Young Scholars in Applied Mathematics	D, E	2018-03-03 / 2018-03-05	NCKU	C.-C. Chen(NTU) J.-L. Chern (NCU) J.-S. Guo (Tamkang) et al
Teaching Stats in Big Data Era	L	2018-03-09 / 2018-03-10	NCKU	Ray-Bing Chen (NCKU)
2018 NCTS Spring Day	all	2018-03-17 / 2018-03-17	NCTS	Jungkai Chen (NTU)
International Conference on Nonlinear Analysis and its Applications	D	2018-03-23 / 2018-03-24	Tamkang Univ.	W.-M. Ni (Minnesota) Eiji Yanagida (TIT), Francois Hamel (Aix-Marseille Univ.), J.-S. Guo (Tamkang Univ.)
The 16th Taiwan Geometry Symposium	C	2018-03-24 / 2018-03-24	NCUE	River Chiang (NCKU) Nan-Kuo Ho (NTHU) Yng-Ing Lee (NTU), et al
2018 Conference on Advanced Topics and Auto Tuning in High-Performance Scientific Computing	E, L	2018-03-26 / 2018-03-27	NCKU	Weichung Wang (NTU) Ray-Bing Chen (NCKU) T. Katagiri (Nagoya), et al.
The 5th Taiwan-Japan Conference on Combinatorics and its Applications	A	2018-03-28 / 2018-03-30	NTNU	Sen-Peng Eu (NTNU) F.-H. Chang (NTNU), et al
NCTS Workshop on Computational Mathematics and Applied Analysis	E, F	2018-04-28 / 2018-04-29	NCTS	Ming-Chih Lai (NCTU) Keh-Ming Shyue (NTU) Y.-C. Shu (NCKU), et al

Title	Gp.	Dates	Venue	Organizers
NCTS Health Hackathon 2018	L	2018-05-04 / 2018-05-06	NCTS	Cheyu Hsu (NTUH) Weichung Wang (NTU) A. Costa (Icahn School of Med. at Mt Sinai),
Workshop on Geometric Measure Theory and Minimal Submanifolds	C	2018-05-08 / 2018-05-10	NCTS	Yng-Ing Lee (NTU) Chun-Chi Lin (NTNU) Leon Simon (Stanford)
Mini-workshop on Mathematical Modeling and Computer Simulation for Transmembrane Proteins: Focusing on Ion Channels and Transporters	E	2018-05-18 / 2018-05-18	Feng Chia Univ.	Tai-Chia Lin (NTU) Tzyy-Leng Horng (Feng Chia Univ.)
International workshop on Geometric Analysis and Harmonic Analysis	H	2018-05-25 / 2018-05-28	NCTS	D.-C. Chang (Georgetown) Chun-Yen Shen (NTU)
NCTS Symplectic Expedition: Floer theory and beyond	C	2018-05-27 / 2018-05-29	Kenting Youth Center	River Chiang (NCKU) Kaoru Ono (RIMS) Siye Wu (NTHU)
NCTS Workshop on Mathematical Biology	D, E, F	2018-05-28 / 2018-06-01	NTHU	C.-N. Chen(NTHU) C.-C. Chen (NTU) M.-C. Lai (NCTU) et al.
2018 Spring probability workshop	D	2018-06-04 / 2018-06-08	AS	Guan-Yu Chen (NCTU) Chii-Ruey Hwang (AS) T. Kumagai (RIMS) Y.-C. Sheu (NCTU) Shuenn-Jyi Sheu (NCU)
International Workshop on Algebra	A, B	2018-06-08 / 2018-06-09	NCTS	Jungkai Chen (NTU) Chia-Fu Yu (AS)
2018 Taiwan-Japan Workshop on Scattering, Dispersion, Traveling Waves, and Inverse Problems	D	2018-06-16 / 2018-06-18	NCKU	Yung-fu Fang (NCKU) Kenji Nakanishi (Osaka)
NCTS Workshop on Isometric Embedding and Quasilocal Mass	C	2018-06-19 / 2018-06-22	NCTS	Mao-Pei Tsui(NTU) M.-T. Wang (Columbia) Ye-Kai Wang (NCKU) P.-N. Chen (UC Riverside)

Title	Gp.	Dates	Venue	Organizers
A special day on Applied Mathematics	E	2018-06-25 / 2018-06-25	NCTS	I-Liang Chern (NTU)
International Workshop on Critical Phenomena	D	2018-07-02 / 2018-07-04	NCTU	Daniel Spector (NCTU)
The 12th AIMS Conference on Dynamical Systems, Differential Equations and Applications	D	2018-07-05 / 2018-07-09	NTU	Jung-Chao Ban (NDHU) K.-C. Chen (NTHU), et al.
Taiwan-Japan Joint Workshop on Multiple Zeta Values	A	2018-08-02 / 2018-08-05	NCTS	C.-Y. Chang (NTHU) Jing Yu (NTU) M. Kaneko (Kyushu)
NCTS Interdisciplinary Lectures -Applying physics to mathematics	C	2018-12-07 / 2018-12-07	NCTS	Chun-Chi Lin (NTNU)
Annual Meeting of International Consortium of Chinese Mathematicians	All	2018-12-27 / 2018-12-29	GIS NTU	S.-C. Chang (NTU) S.-J. Cheng (AS) Jungkai Chen (NTU), et al.

VI.2 Visitor data

VI.2.1 NCTS visitors, 2018

Arr. Date	Dep. Date	Days	Name	Gp.	Affiliation	Country	Title
2018/1/1	2018/12/31	365	Kazuo Aoki	D	Kyoto University	Japan	Prof
2018/1/2	2018/1/5	4	Yuan-Nan Young	F	New Jersey Institute of Tech.	USA	Prof
2018/1/2	2018/1/31	30	Guangsheng Wei	D	Shaanxi Normal University	China	Prof
2018/1/4	2018/1/7	4	Bongsuk Kwon	D	Ulsan Nat'l Inst. of Sci. & Tech.	Korea	Prof
2018/1/8	2018/1/12	5	Yen-Hsi Richard Tsai	D	University of Texas at Austin	USA	Prof
2018/1/10	2018/1/21	12	Qing Han	C	University of Notre Dame	USA	Prof
2018/1/13	2018/1/24	12	Hartwig Anzt	E	Karlsruher Institut fur Tech.	Germany	Prof
2018/1/14	2018/1/20	7	Kam Chuen Ng	E	Kodak Research Lab	USA	Prof
2018/1/14	2018/1/28	15	Shanwen Wang	A	Fudan University	China	Prof
2018/1/16	2018/1/25	10	Blair Davey	D	The City College of New York	USA	Prof
2018/1/17	2018/1/31	15	Xianjin Chen	F	Univ. of Sci. & Tech. of China	China	Prof
2018/1/18	2018/7/6	170	Horng-Tzer Yau	D	Harvard University	USA	Prof
2018/1/23	2018/2/22	31	Zhihua Chang	A	South China University of Tech.	China	PD
2018/1/23	2018/2/22	31	Qingqing Liu	A	South China University of Tech.	China	PD
2018/1/29	2018/2/2	5	Yen-Chang Huang	C	Xinyang Normal University	China	Prof
2018/1/31	2018/2/10	11	Morimichi Kawasaki	C	Institute for Basic Science	Korea	PD
2018/2/2	2018/2/5	4	Eric King-wah Chu	E	Monash University	Australia	Prof
2018/2/4	2018/2/11	8	Meng Fai Lim	A	Central China Normal Univ.	China	Prof
2018/2/10	2018/2/12	3	Qing Liu	A	University of Bordeaux	France	Prof
2018/2/17	2018/2/21	5	Bora Moon	D	Seoul National University	Korea	PD
2018/2/21	2018/2/24	4	Takahiro Katagiri	E	Nagoya University	Japan	Prof
2018/2/21	2018/2/26	6	Kengo Nakajima	E	University of Tokyo	Japan	Prof
2018/2/25	2018/3/1	5	Jeff Wu	L	Georgia Institute of Tech.	USA	Prof
2018/2/25	2018/3/24	28	Eric K.W. Chu	E	Monash University	Australia	Prof
2018/2/25	2018/4/20	55	Jiaoyang Huang	D	Harvard University	USA	Stu
2018/2/25	2018/5/3	68	Hirokazu Ninomiya	F	Meiji University	Japan	Prof
2018/2/26	2018/3/9	12	Augusto Ponce	C	Univ. Catholique de Louvain	Belgium	Prof
2018/2/26	2018/5/10	74	Jake Marcinek	D	Harvard University	USA	Stu
2018/2/27	2018/3/30	32	Cécile Armana	A	University of Franche-Comté	France	Prof
2018/3/1	2018/3/29	29	Martin Guest	C	Waseda University	Japan	Prof
2018/3/1	2018/3/14	14	Atsushi Mochizuki	F	Kyoto University	Japan	Prof
2018/3/1	2018/3/31	31	Paul Breutmann	A	University of Münster	Germany	Stu
2018/3/3	2018/5/11	70	Leon Simon	C	Stanford University	USA	Prof
2018/3/5	2018/3/27	23	Benjamin Landon	D	Harvard University	USA	Stu
2018/3/10	2018/3/17	8	Lei Zhang	A	Freie Universität Berlin	Germany	PD
2018/3/11	2018/3/16	6	Misun Min	F	Argonne National Laboratory	USA	Prof
2018/3/12	2018/3/18	7	Lek-Heng Lim	E	University of Chicago	USA	Prof
2018/3/12	2018/3/18	7	Sou-Cheng Choi	E	Illinois Institute of Tech.	USA	Prof
2018/3/12	2018/3/30	19	Yoshinobu Kamishima	C	Josai University	Japan	Prof
2018/3/13	2018/3/16	4	Mu-Tao Wang	C	Columbia University	USA	Prof
2018/3/18	2018/3/25	8	Naoya Nomura	E	University of Tokyo	Japan	Stu
2018/3/19	2018/3/25	7	Francesc Castella	A	Princeton University	USA	Prof
2018/3/19	2018/3/26	8	Victor Isakov	D	Wichita State University	USA	Prof
2018/3/19	2018/3/28	10	Philippe Souplet	D	Université Paris 13	France	Prof
2018/3/20	2018/3/23	4	Jia-Yuan Dai	F	Freie Universität Berlin	Germany	PD
2018/3/22	2018/3/24	3	Francois Hamel	D	Aix-Marseille University	France	Prof
2018/3/22	2018/3/25	4	Yihong Du	D	University of New England	Australia	Prof
2018/3/22	2018/3/25	4	Tetsuya Ishiwata	D	Shibaura Institute of Tech.	Japan	Prof
2018/3/22	2018/3/25	4	Kenichi Namikawa	A	Tokyo Denki University	Japan	Prof
2018/3/22	2018/3/25	4	Masahiko Shimojo	D	Okayama University	Japan	Prof

Arr. Date	Dep. Date	Days	Name	Gp.	Affiliation	Country	Title
2018/3/22	2018/3/27	6	Wei-Ming Ni	D	University of Minnesota	USA	Prof
2018/3/22	2018/3/28	7	Masayasu Mimura	D	Musashino University	Japan	Prof
2018/3/22	2018/3/28	7	Chien-Min Kao	E	University of Chicago	USA	Prof
2018/3/22	2018/3/28	7	Yoshihisa Morita	D	Ryukoku University	Japan	Prof
2018/3/25	2018/3/27	3	Takahiro Katagiri	E	Nagoya University	Japan	Prof
2018/3/25	2018/3/27	3	Reiji Suda	L	University of Tokyo	Japan	Prof
2018/3/25	2018/3/30	6	Jose E. Roman	E	Univ. Politécnica de Valéncia	Spain	Prof
2018/3/25	2018/4/20	27	Nikolaos Zygouras	D	University of Warwick	UK	Prof
2018/3/25	2018/4/20	27	Jingfang Huang	F	Univ. North Carolina, Chapel Hill	USA	Prof
2018/3/28	2018/3/30	3	Hongyu Liu	D	Hong Kong Baptist Univ.	HK	Prof
2018/3/30	2018/4/5	7	Takashi Okada	F	RIKEN	Japan	PD
2018/4/9	2018/4/21	13	Changchang Xi	A	Capital Normal University	China	Prof
2018/4/12	2018/6/3	53	Kaoru Ono	C	RIMS , Kyoto University	Japan	Prof
2018/4/13	2018/5/21	39	Wei-Ming Ni	D	University of Minnesota	USA	Prof
2018/4/25	2018/4/29	5	Mu-Tao Wang	C	Columbia University	USA	Prof
2018/4/26	2018/4/29	4	Hailiang Li	D	Capital Normal University	China	Prof
2018/4/26	2018/5/16	21	Paolo Cascini	B	Imperial College London	UK	Prof
2018/4/27	2018/4/29	3	Zhou Ping Xin	D	CUHK	HK	Prof
2018/4/27	2018/4/29	3	Xiaoping Wang	E	HKUST	HK	Prof
2018/4/27	2018/4/30	4	Xiao-Qing Jin	E	University of Macau	China	Prof
2018/4/27	2018/4/30	4	Hisashi Okamoto	E	Gakushuin University	Japan	Prof
2018/4/27	2018/5/1	5	Qiang Zhang	E	City Univ. of Hong Kong	HK	Prof
2018/4/27	2018/5/25	29	Robert Hardt	C	Rice University	USA	Prof
2018/4/28	2018/5/1	4	Yen-Hsi Richard Tsai	D	University of Texas at Austin	USA	Prof
2018/4/28	2018/6/9	43	Hau-Tieng Wu	E	Duke University	USA	Prof
2018/4/29	2018/5/5	7	Ying Su	F	Harbin Institute of Tech.	China	Prof
2018/4/29	2018/5/30	32	Jian Fang	F	Harbin Institute of Tech.	China	Prof
2018/4/30	2018/5/5	6	Hiroyuki Osaka	F	Ritsumeikan University	Japan	Prof
2018/4/30	2018/5/8	9	Anthony B. Costa	E	Icahn School of Med. at Mt. Sinai	USA	Prof
2018/4/30	2018/5/14	15	Matt Sourisseau	L	Duke University	USA	Stu
2018/4/30	2018/5/15	16	Chao Shen	L	Duke University	USA	Stu
2018/4/30	2018/5/21	22	John Rajiv Malik	L	Duke University	USA	Stu
2018/4/30	2018/7/3	65	Pei-Chun Su	L	Duke University	USA	Stu
2018/5/2	2018/5/4	3	William Li	L	University of Minnesota	USA	Prof
2018/5/2	2018/5/7	6	Eric Oermann	E	Icahn School of Med. at Mt. Sinai	USA	Prof
2018/5/2	2018/5/8	7	Andy Choi	E	IntuitiveX	USA	Prof
2018/5/2	2018/5/8	7	Shan Zhao	E	Stealth Health	USA	Prof
2018/5/2	2018/5/8	7	Rajib Chakravorty	E	Melbourne Research Laboratory	Australia	Prof
2018/5/2	2018/5/8	7	Holly Oemke	E	The Mount Sinai Hospital	USA	Prof
2018/5/6	2018/5/13	8	Brian Krummel	C	Univ. of California, Berkeley	USA	Prof
2018/5/6	2018/5/29	24	Satoshi Handa	D	Hokkaido University	Japan	Stu
2018/5/7	2018/5/11	5	Lami Kim	C	Yonsei University	Korea	PD
2018/5/7	2018/5/11	5	Ulrich Menne	C	University of Leipzig	Germany	PD
2018/5/7	2018/5/12	6	Neshan Wickramasekera	C	University of Cambridge	UK	Prof
2018/5/7	2018/5/18	12	Jiaping Wang	C	University of Minnesota	USA	Prof
2018/5/9	2018/5/16	8	Harunori Monobe	D	Okayama University	Japan	Prof
2018/5/14	2018/7/14	62	Yu-Min Chung	L	Univ. North Carolina, Greensboro	USA	Prof
2018/5/15	2018/6/12	29	Yoshinori Kamijima	D	Hokkaido University	Japan	Stu
2018/5/16	2018/5/31	16	Simone Furini	F	University of Siena	Italy	Prof
2018/5/18	2018/5/27	10	Yat Hin Marco Suen	C	CUHK	HK	Stu
2018/5/18	2018/5/27	10	Yan Lung Leon Li	C	CUHK	HK	Stu
2018/5/18	2018/5/27	10	Chi Hong Jimmy Chow	C	CUHK	HK	Stu
2018/5/18	2018/5/27	10	Yu Tung Tony Yau	C	CUHK	HK	Stu
2018/5/18	2018/7/31	75	Analise Rodenberg	E	University of Minnesota	USA	Stu
2018/5/21	2018/5/30	10	Sanghyuk Lee	H	Seoul National University	Korea	Prof
2018/5/21	2018/6/1	12	Xing Liang	F	Univ. of Sci. & Tech. of China	China	Prof
2018/5/22	2018/5/31	10	Der-Chen Chang	C	Georgetown University	USA	Prof
2018/5/23	2018/6/1	10	Kenro Furutani	C	Tokyo University of Science	Japan	Prof
2018/5/24	2018/5/29	6	Sheng-Ya Feng	H	Fudan University	China	Prof

Arr. Date	Dep. Date	Days	Name	Gp.	Affiliation	Country	Title
2018/5/24	2018/5/29	6	Wei Wang	D	Zhejiang University	China	Prof
2018/5/24	2018/6/2	10	Masayasu Mimura	D	Musashino University	Japan	Prof
2018/5/24	2018/6/5	13	Mahdi H. Mahmoudi	H	University of Potsdam	Germany	PD
2018/5/24	2018/6/5	13	Wolfgang Schulze	D	University of Potsdam	Germany	Prof
2018/5/25	2018/5/28	4	Jixiang Yang	H	Wuhan University	China	Prof
2018/5/25	2018/6/1	8	Volker Mehrmann	E	Technische Universität Berlin	Germany	Prof
2018/5/26	2018/5/31	6	William W.S. Wei	L	Temple University	USA	Prof
2018/5/26	2018/6/1	7	Xiaoqiang Zhao	F	Memorial Univ. of Newfoundland	Canada	Prof
2018/5/26	2018/6/2	8	Yuan Lou	F	Ohio State University	USA	Prof
2018/5/26	2018/6/3	9	Yang Kuang	F	Arizona State University	USA	Prof
2018/5/26	2018/6/15	21	Pierre Magal	F	University of Bordeaux	France	Prof
2018/5/27	2018/5/29	3	Manabu Akaho	C	Tokyo Metropolitan University	Japan	Prof
2018/5/27	2018/5/29	3	Kwokwai Chan	C	CUHK	HK	Prof
2018/5/27	2018/5/29	3	Siu-Cheong Lau	C	Boston University	USA	Prof
2018/5/27	2018/5/29	3	Conan Nai Chung Leung	C	CUHK	HK	Prof
2018/5/27	2018/5/29	3	Kazushi Ueda	C	University of Tokyo	Japan	Prof
2018/5/27	2018/5/31	5	Yi Wang	C	Univ. of Sci. & Tech. of China	China	Prof
2018/5/27	2018/6/1	6	Shigui Ruan	C	University of Miami	USA	Prof
2018/5/27	2018/6/1	6	Junping Shi	F	College of William and Mary	USA	Prof
2018/5/27	2018/6/1	6	Xingfu Zou	F	University of Western Ontario	Canada	Prof
2018/5/27	2018/6/2	7	Xiaoqing He	F	East China Normal University	China	PD
2018/5/27	2018/6/2	7	Michael Y. Li	D	University of Alberta	Canada	Prof
2018/5/27	2018/7/10	45	Yu Jin	F	Univ. of Nebraska-Lincoln	USA	Prof
2018/5/28	2018/6/1	5	Yihong Du	D	University of New England	Australia	Prof
2018/5/29	2018/6/1	4	Martin J. Bridgeman	C	Boston College	USA	Prof
2018/5/29	2018/6/1	4	Richard Douglas Canary	C	University of Michigan	USA	Prof
2018/5/29	2018/6/15	18	Philippe Sosoe	D	Cornell University	USA	Prof
2018/5/30	2018/6/7	9	Panki Kim	D	Seoul National University	Korea	Prof
2018/5/31	2018/6/2	3	Akira Ishii	B	Nagoya University	Japan	Prof
2018/6/1	2018/7/31	61	Wei-Hsuan Yu	A	Michigan State University	USA	PD
2018/6/2	2018/6/9	8	Satoshi Ishiwata	D	Yamagata University	Japan	Prof
2018/6/2	2018/6/11	10	Mathav Murugan	D	The Univ. of British Columbia	USA	Prof
2018/6/3	2018/6/7	5	Narutaka Ozawa	D	Kyoto University	Japan	Prof
2018/6/3	2018/6/7	5	Akira Sakai	D	Hokkaido University	Japan	Prof
2018/6/3	2018/6/8	6	Ru-Yu Lai	D	University of Minnesota	USA	Prof
2018/6/3	2018/6/8	6	Andrzej Zuk	D	Universit Paris 7	France	Prof
2018/6/3	2018/6/9	7	Jun Kigami	D	Kyoto University	Japan	Prof
2018/6/3	2018/6/9	7	Jun Masamune	D	Hokkaido University	Japan	Prof
2018/6/3	2018/6/9	7	Ryokichi Tanaka	D	Tohoku University	Japan	Prof
2018/6/3	2018/6/10	8	Naotaka Kajino	D	Kobe University	Japan	Prof
2018/6/3	2018/6/14	12	Matthew Papanikolas	A	Texas A&M University	USA	Prof
2018/6/4	2018/6/15	12	So-Hsiang Chou	E	Bowling Green State University	USA	Prof
2018/6/4	2018/7/12	39	Maria Pia Gualdani	E	George Washington University	USA	Prof
2018/6/4	2018/7/12	39	Yen-Hsi Richard Tsai	D	University of Texas at Austin	USA	Prof
2018/6/7	2018/6/10	4	Akinari Hoshi	B	Niigata University	Japan	Prof
2018/6/7	2018/6/10	4	Boris Kouniavski	B	Bar-Ilan University	Israel	Prof
2018/6/7	2018/6/10	4	Aiichi Yamasaki	B	Kyoto University	Japan	Prof
2018/6/13	2018/6/19	7	Chi-Kun Lin	D	Xi'an Jiaotong-Liverpool Univ.	China	Prof
2018/6/13	2018/6/26	14	Albert Fannjiang	E	University of California, Davis	USA	Prof
2018/6/14	2018/6/24	11	Mu-Tao Wang	C	Columbia University	USA	Prof
2018/6/15	2018/6/18	4	Masahito Ohta	D	Tokyo University of Science	Japan	Prof
2018/6/15	2018/6/19	5	Satoshi Masaki	D	Osaka University	Japan	Prof
2018/6/15	2018/6/19	5	Haruya Mizutani	D	Osaka University	Japan	Prof
2018/6/15	2018/6/22	8	Pengzi Miao	C	University of Miami	USA	Prof
2018/6/15	2018/7/4	20	Po-Ning Chen	C	Univ. of California, Riverside	USA	Prof
2018/6/16	2018/6/30	15	Viktor Ginzburg	C	Univ. of California, Santa Cruz	USA	Prof
2018/6/17	2018/6/23	7	Chunhe Li	C	Univ. of Elec. Sci. & Tech.	China	Prof

Arr. Date	Dep. Date	Days	Name	Gp.	Affiliation	Country	Title
2018/6/17	2018/6/23	7	Chao Xia	C	Xiamen University	China	Prof
2018/6/17	2018/6/24	8	Zhizhang Wang	C	Fudan University	China	Prof
2018/6/17	2018/6/30	14	Yujiro Kawamata	B	University of Tokyo	Japan	Prof
2018/6/18	2018/6/23	6	Siyuan Lu	C	Rutgers University	USA	Prof
2018/6/19	2018/7/4	16	Eduard-Wilhelm Kirr	F	UIUC	USA	Prof
2018/6/19	2018/7/11	23	Ching-Shan Chou	E	Ohio State University	USA	Prof
2018/6/20	2018/6/24	5	Eiji Yanagida	D	Tokyo Institute of Technology	Japan	Prof
2018/6/20	2018/7/10	21	Shouhong Wang	D	Indiana University	USA	Prof
2018/6/21	2018/6/23	3	Phillipo Lappicy	F	Universidade de São Paulo	Brazil	PD
2018/6/21	2018/6/26	6	Hiroaki Hata	D	Shizuoka University	Japan	Prof
2018/6/21	2018/12/4	167	Steven Lu	B	Université du Québec Montréal	Canada	Prof
2018/6/22	2018/7/8	17	Hau-Tieng Wu	L	Duke University	USA	Prof
2018/6/22	2018/7/9	18	Jun Andrew Kitagawa	L	Michigan State University	USA	Prof
2018/6/26	2018/7/4	9	Yaping Wu	F	Capital Normal University	China	Prof
2018/6/27	2018/7/4	8	Teng Fei	C	Columbia University	USA	Prof
2018/6/30	2018/7/9	10	Joan Verdera	D	Univ. Auténoma de Barcelona	Spain	Prof
2018/7/1	2018/7/15	15	Haitao Wang	D	Shanghai Jiao Tong University	China	Prof
2018/7/1	2018/7/28	28	Mihran Papikian	A	Pennsylvania State Univ.	USA	Prof
2018/7/1	2018/7/31	31	Guowei Yu	D	Université di Torino	Italy	PD
2018/7/2	2018/7/10	9	Thomas Giletti	D	Institut Elie Cartan in Nancy	France	Prof
2018/7/2	2018/7/14	13	Weishi Liu	F	University of Kansas	USA	Prof
2018/7/3	2018/7/10	8	Shigeki Akiyama	D	University of Tsukuba	Japan	Prof
2018/7/3	2018/7/16	14	Yiqian Wang	D	Nanjing University	China	Prof
2018/7/4	2018/7/10	7	Wei-Kuo Chen	D	University of Minnesota	USA	Prof
2018/7/4	2018/7/10	7	Antonio Auffinger	D	Northwestern University	USA	Prof
2018/7/4	2018/7/10	7	Yoshitsugu Kabeya	D	Osaka Prefecture University	Japan	Prof
2018/7/4	2018/7/13	10	Gavish Nir	F	Technion-Israel Institute of Tech.	Israel	Prof
2018/7/4	2018/7/14	11	Sergey Gavrilyuk	F	Aix-Marseille University	France	Prof
2018/7/4	2018/8/13	41	C. Michael Tsau	C	Saint Louis University	USA	Prof
2018/7/5	2018/7/8	4	Shing-Tung Yau	C	Harvard University	USA	Prof
2018/7/5	2018/7/8	4	Toshiyuki Ogawa	D	Meiji University	Japan	Prof
2018/7/5	2018/7/9	5	Ozawa Tohru	F	Waseda University	Japan	Prof
2018/7/9	2018/7/31	23	Miao-Jung Yvonne Ou	F	University of Delaware	USA	Prof
2018/7/9	2018/7/31	23	Petr Plechac	F	University of Delaware	USA	Prof
2018/7/10	2018/7/12	3	Yueyuan Gao	D	Tohoku University	Japan	PD
2018/7/10	2018/7/13	4	Elaine Crooks	F	Swansea University	UK	Prof
2018/7/10	2018/7/15	6	Jiguang Sun	E	Michigan Technological Univ.	USA	Prof
2018/7/13	2018/7/19	7	Qi Gao	D	Wuhan University of Tech.	China	Prof
2018/7/14	2018/7/28	15	Don Klinkenberg	F	The Dutch National Inst. for Public Health & Envir. (RIVM)	Netherlands	Prof
2018/7/15	2018/7/20	6	Kengo Nakajima	E	University of Tokyo	Japan	Prof
2018/7/15	2018/7/25	11	Francesc Castella	A	Princeton University	USA	Prof
2018/7/16	2018/7/19	4	Hiroshi Nishiura	F	Hokkaido University	Japan	Prof
2018/7/16	2018/7/27	12	So-Hsiang Chou	E	Bowling Green State Univ.	USA	Prof
2018/7/16	2018/7/30	15	Yunqing Yang	F	Zhejiang Ocean University	China	Prof
2018/7/16	2018/8/17	33	Yen-Chang Huang	C	Xinyang Normal University	China	Prof
2018/7/17	2018/7/20	4	Tetsuya Hoshino	E	University of Tokyo	Japan	Prof
2018/7/19	2018/7/20	2	Robert Bruce Findler	D	Northwestern University	USA	Prof
2018/7/21	2018/7/28	8	Nimalan Arinaminpathy	F	Imperial College London	UK	Prof
2018/7/21	2018/8/12	23	Nathan Grieve	B	Michigan State University	USA	PD
2018/7/22	2018/7/28	7	Joseph T Wu	F	University of Hong Kong	HK	Prof
2018/7/24	2018/8/10	18	Minoru Hirose	A	Kyushu University	Japan	PD
2018/8/1	2018/8/3	3	Pei-Ken Hung	C	MIT	USA	Prof
2018/8/1	2018/8/5	5	Hidekazu Furusho	A	Nagoya University	Japan	Prof

Arr. Date	Dep. Date	Days	Name	Gp.	Affiliation	Country	Title
2018/8/1	2018/8/5	5	Kenji Sakugawa	A	Kyoto University	Japan	Prof
2018/8/1	2018/8/5	5	Koji Tasaka	A	Nagoya University	Japan	Prof
2018/8/1	2018/8/5	5	Takashi Nakamura	A	Tokyo University of Science	Japan	Prof
2018/8/1	2018/8/6	6	Noriyuki Abe	A	University of Tokyo	Japan	Prof
2018/8/1	2018/8/6	6	Tatsushi Tanaka	A	Kyoto Sangyo University	Japan	Prof
2018/8/1	2018/8/6	6	Ryotaro Harada	A	Nagoya University	Japan	Stu
2018/8/1	2018/8/6	6	Masataka Ono	A	Keio University	Japan	PD
2018/8/1	2018/8/6	6	Shinichiro Seki	A	Tohoku University	Japan	PD
2018/8/1	2018/8/6	6	Yasuo Ohno	A	Tohoku University	Japan	Prof
2018/8/1	2018/8/6	6	Yoshinori Yamasaki	A	Ehime University	Japan	Prof
2018/8/1	2018/8/6	6	Henrik Bachmann	A	Nagoya University	Japan	Prof
2018/8/1	2018/8/6	6	Ryota Umezawa	A	Nagoya University	Japan	Stu
2018/8/1	2018/8/6	6	Takashi Hara	A	Tokyo Denki University	Japan	Stu
2018/8/1	2018/8/6	6	Yoshitaka Sasaki	A	Osaka University	Japan	Prof
2018/8/1	2018/8/6	6	Nils Matthes	A	Kyushu University	Japan	Stu
2018/8/1	2018/8/7	7	Masanobu Kaneko	A	Kyushu University	Japan	Prof
2018/8/1	2018/8/17	17	Yoshinori Mishiba	A	Fukuoka Institute of Tech.	Japan	Prof
2018/8/1	2018/8/19	19	Shizuo Kaji	C	Kyushu University	Japan	Prof
2018/8/3	2018/8/5	3	Shingo Saito	A	Kyushu University	Japan	Prof
2018/8/3	2018/8/11	9	Kenichi Namikawa	A	Tokyo Denki University	Japan	Prof
2018/8/6	2018/8/20	15	Ryotaro Harada	A	Nagoya University	Japan	Stu
2018/8/6	2018/9/5	31	Mingjing Zhang	A	Sun Yat-Sen University	China	Prof
2018/8/9	2018/8/16	8	Makoto Kawashima	A	Osaka University	Japan	PD
2018/8/9	2018/8/23	15	Meng Fai Lim	A	Central China Normal Univ.	China	Prof
2018/8/17	2018/9/7	22	Nurcan Argaé	A	Ege University	Turkey	Prof
2018/8/30	2018/9/28	30	Hsuan-Yi Liao	C	Pennsylvania State University	USA	PD
2018/9/5	2018/9/12	8	Chengbo Wang	D	Zhejiang University	China	Prof
2018/9/29	2018/10/10	12	Jean Dolbeault	F	Université Paris-Dauphine	France	Prof
2018/10/7	2018/11/7	32	Jean-Marc Fontaine	A	Université Paris-Sud	France	Prof
2018/10/28	2018/11/1	5	Christopher D. Sogge	D	Johns Hopkins University	USA	Prof
2018/11/1	2018/11/30	30	Suman Kumar sahoo	D	Tata Inst. of Fund. Research	India	Prof
2018/11/7	2018/11/13	7	Lingbing He	D	Tsinghua University	China	Prof
2018/11/14	2018/11/19	6	Bochen Liu	H	CUHK	HK	PD
2018/11/16	2018/12/1	16	Eduard-Wilhelm Kirr	F	UIUC	USA	Prof
2018/12/6	2018/12/12	7	Tadashi Tokieda	C	Stanford University	USA	Prof
2018/12/6	2018/12/13	8	Yongdo Lim	F	Sungkyunkwan University	Korea	Prof
2018/12/7	2018/12/11	5	Fang Hua Lin	F	NYU	USA	Prof
2018/12/7	2018/12/18	12	Paolo Cascini	B	Imperial College London	UK	Prof
2018/12/10	2018/12/14	5	Navid Nabijou	B	University of Glasgow	UK	PD
2018/12/16	2019/1/5	21	Nikolaos Zygouras	D	University of Warwick	UK	Prof
2018/12/16	2019/1/6	22	Hau-Tieng Wu	E	Duke University	USA	Prof
2018/12/22	2019/1/1	11	Xiaohua Yao	H	Central China Normal Univ.	China	Prof
2018/12/23	2018/12/30	8	Chen Jiang	B	University of Tokyo	Japan	PD
2018/12/26	2019/1/2	8	Hojoo Lee	C	KIAS	Korea	Prof
2018/12/26	2019/1/2	8	Yong Wei	C	Australian National University	Australia	PD
2018/12/28	2019/1/6	10	Yun Zhao	D	Suzhou University	China	Prof

VI.2.2 NCTS visitors covered by their own grants, 2017-2018

Name	Affiliation	Period	Gp.
Jifa Jiang	Shanghai Normal University	20161210-20170107	F
Yohsuke Imagi	Kavli IPMU	20170305-20170318	C
Loring Tu	Tufts University	20170608-20170619	B
LieJune Shiau	University of Houston	20170612-20170629	D
Frances Y. Kou	University of New South Wales	20170904-20170922	E
Holger Roth	Nagoya University	20171211-20171215	E
Anthony B. Costa	Icahn School of Medicine at Mount Sinai	20171211-20171215	E
Eric Oermann	Icahn School of Medicine at Mount Sinai	20171211-20171215	E
Senhuei Chen	Howard Universtiy	20171212-20171227	E
Martin Guest	Waseda University	20171216-20171219	C
Yoshinori Gongyo	University of Tokyo	20171228-20180104	B
Bora Moon	Seoul National University	20180217-20180221	D
Martin Guest	Waseda University	20180301-20180329	C
Lei Zhang	Freie Universitat Berlin	20180310-20180317	A
Lek-Heng Lim	University of Chicago	20180312-20180318	E
Sou-Cheng Choi	Illinois Institute of Technology	20180312-20180318	E
Naoya Nomura	University of Tokyo	20180318-20180325	E
Takashi Okada	RIEKEN	20180330-20180405	F
Ying Su	Harbin Institute of Technology	20180429-20180505	F
Teng Fei	Columbia University	20180627-20180704	C
Noriyuki Abe	University of Tokyo	20180801-20180806	A
Ryotaro Harada	Nagoya University	20180806-20180820	A
Meng Fai Lim	Central China Normal University	20180809-20180823	A
Nurcan Argac	Ege University	20180817-20180907	A

VI.3 Publication data

VI.3.1 Summary of publications of key members, 2017-2018

Journal Title	2017 ACK	2017 AFF	2018 ACK	2018 AFF	pre-print
Acta Arithmetica		1			
Acta Mathematica Scientia					1
Acta Mathematica Sinica, English Series					1
Adv. Differential Equations				2	
Advances in Mathematics	1		1		1
American Journal of Mathematics	1				1
Ann. Appl. Probab.	1				
Ann. Scuola Norm. Sup. Pisa Cl. Sci	1	1			
Annals of Global Analysis and Geometry	1	1			
Applied Mathematics Letters	1	1			
Asian J. Math					1
Buelltin of Mathematical Biology			1	1	
Bull. Inst. Math. Acad. Sin.		1			
Bull. Lond. Math. Soc.		1			
C. R. Math. Acad. Sci. Paris		1			
Calc.Var. Partial Differential Equations	1		1		1
Canad. J. Math.			1	1	
Chemometrics and Intell. Lab. Systems	1				
Comm. Pure Appl. Anal.		1			1
Commun. Contemp. Math.					1
Commun. in Algebra		2			
Commun. in Computational Physics			1	1	
Commun. in Contemporary Mathematics					1
Commun. in Mathematical Physics		1			
Commun. in Partial Differential Equations	1	1			
Compositio Math.					1
Computers and Fluids			2	1	
Discrete Contin. Dyn. Syst. Ser.				1	
East Asian Journal on Applied Math.	1	1			
Ecological Research	1	6	1	1	
Environmental Microbiology	1	2			
Ergodic Theory and Dynamical Systems	1				
Eur. J. Math.		1			

Journal Title	**2017 ACK**	**2017 AFF**	**2018 ACK**	**2018 AFF**	**pre-print**
Forum Math	1	1	1		
Frontiers in Microbiology				1	
Geom. Dedicata					1
Geometric Flows			1	1	
IEEE Trans. Compon. Packag. Technol	1		1		
Indiana Univ. Math. J.		1			
International Journal of Mathematics					1
International Math. Research Notices					1
Inverse Problems	1				
Inverse Problems and Imaging		1	1		
ISME Journal			2	2	
J. Mod. Dyn.		1			
J. Stat. Mech	1	1			
J. Symplectic Geom.	1				
J. Th'eor. Nombres Bordeaux	1				
J. fur die reine und angew. Math.					1
Journal of Algebra	1	2	1		
Journal of Comput. and Applied Math.			1		
Journal of Comput. and Graphical Stat.			1		
Journal of Comput. Mathematics				1	
Journal of Comput. Physics			2		
Journal of Differential Equations	2		1		
Journal of Differential Geometry	1	1	1		1
Journal of Dynamics and Diff. Equations	1				
Journal of European Mathematical Society					1
Journal of Evolution Equations			1		
Journal of Functional Analysis		1			
Journal of Geometric Analysis	1		1	1	
Journal of Geometric Flows				1	
Journal of Group Theory		1			
Journal of Math. Analysis and Appl.	2		2		
Journal of Math. Biology	2				
Journal of Mathematical Physics	1				
Journal of Non-Newtonian Fluid Mech.			1		
Journal of Scientific Computing			2	2	
Journal of Statistical Physics	1	1	1	1	
Journal of the London Math. Society			2		

Journal Title	**2017 ACK**	**2017 AFF**	**2018 ACK**	**2018 AFF**	**pre-print**
Journal of the Royal Society Interface	1				
Journal of Theoretical Biology	1				
Linear Algebra Appl.				1	
Math. Annalen			1		
Math. Res. Lett.	1				
Math. Models and Methods in Applied Sci.	1	1	1	1	
Mathematical Research Letters	1	1			
Mathematische Annalen	2	1			
Mathematische Zeitschrift	1		1	1	
Memoirs of the Amer. Math. Soc.			1	1	
Nature			1	1	
Nonlinear Anal.					1
Nonlinearity	2		1	1	
Numer. Math.		1		1	
Numerical Methods for Partial Diff. Equa.				1	
Phys. Rev. Fluids		1		2	
Physical Review E	1				
PloS ONE	1	1			
Proc. Amer. Math. Soc.		1		1	
Proceedings of London Mathematical Society	1				
Publ. Res. Inst. Math. Sci.				1	
Pure and Applied Mathematics Quarterly	1	1		1	
Rev. Mat. Iberoam.	1				
Sci. China Math		1			
Scientific Reports			1	1	
SIAM Journal on Applied Mathematics		2			
SIAM Journal on Mathematical Analysis	2	1			
SIAM Journal on Numerical Analysis			1		
SIAM Journal on Scientific Computin				1	
Signal Processing				1	
Statistica Sinica			1		
Stochastic Processes and their Applications			1		
Tohoku Mathematical Journal	1				
Tokyo J. Math.		1		1	
Trans. Amer. Math. Soc		1			

VI.3.2 Publications of NCTS postdocs, 2017-2018

Author	Title	Journal	Year
Catalin Carstea	Uniqueness for the two dimensional Calderóns problem with unbounded conductivity		2017
Catalin Carstea	Quantitative uniqueness estimates for second order elliptic equations with complex coefficients and applications		2017
Chia-Yu Hsieh	Global Existence for an Attraction-Repulsion Chemotaxis Model		preprint
Chia-Yu Hsieh	Global Existence of Solutions for Drift-Diffusion Systems with Steric Effects		preprint
Chia-Yu Hsieh	Stability of Radial Symmetric Solutions of the Poisson-Nernst-Planck System in Annular Domains		preprint
Chien-Hao Huang	Asymptotic behavior for a generalized Domany-Kinzel model.		2017
Chih-Wei Chen	A note on geodesic loops in complete non-compact Ricci solitons	Acta Mathematica Scientia	preprint
Chih-Wei Chen	Shi-type estimates along the Ricci flow based on Ricci curvature		preprint
Chih-Whi Chen	Quantum group of type A and representations of queer Lie superalgebra	Journal of Algebra	2017
Guanghui Jin	Standing waves of generalized Chern-Simons-Schrodinger equations		preprint
Guanghui Jin	Existence of the standing wave solutions for the Chern-Simons gauged $O(3)$ sigma equations		preprint
Guanghui Jin	Low regularity well-posedness of the gauged $O(3)$ sigma model with Chern-Simons term		preprint
Gyeongha Hwang	Corrigendum to "On small data scattering of Hartree equations with short-range interaction	Commun. Pure Appl. Anal.	2017
Gyeongha Hwang	On the modified scattering of 3-D Hartree type fractional Schröinger equations with Coulomb potential	Adv. Differential Equations	2018
Gyeongha Hwang	On the focusing energy-critical fractional nonlinear Schröinger equations	Adv. Differential Equations	2018
Gyeongha Hwang	Almost Sure Well-Posedness of Fractional Schröinger Equations with Hartree Nonlinearity	Publ. Res. Inst. Math. Sci.	2018
Gyeongha Hwang	Probabilistic well-posedness of generalized KdV	Proc. Amer. Math. Soc.	2018
Gyeongha Hwang	On the Neumann problem of Hardy-Sobolev critical equations with the multiple singularities		2018
Gyeongha Hwang	Probabilistic well-posedness of the NLS with radial data below $L^2(\mathbb{R}^d)$		2018
Gyeongha Hwang	Well-posedness and scattering for the critical fractional Schröinger equations		2018
Gyeongha Hwang	Probabilistic global well-posedness of generalized KdV		2018
Haewon Yoon	Normal form approach to near-linear dynamics of modified KdV equation		2018
Haewon Yoon	Normal form approach to unconditional well-posedness of nonlinear dispersives PDEs on the real line		2018
Haewon Yoon	Global existence versus finite time blowup dichotomy for the system of nonlinear Schröodinger equations		2018
Hang Fu	Torsion of elliptic curves and unlikely intersections	Geometry and Physics: A Festschrift in Honour of Nigel Hitchin	2017
Hang Fu	Elliptic curves with large intersection of projective torsion points	Eur. J. Math.	2017
Hang Fu	Projectively equivalence for the roots of unity		2018
Hang Fu	A variant of KuniyoshiGGaschütz theorem with applications to Noethers problem		2018

Author	Title	Journal	Year
Hiep Dang	An identity involving symmetric polynomials and the geometry of Lagrangian Grassmannians		2017
Hiep Dang	Identities involving (doubly) symmetric polynomials and integrals over Grassmannians		2017
Hiep Dang	Numerical invariants of Fano schemes of linear subspaces on complete intersections		2017
Hiep Dang	Representations of non-negative polynomials via critical ideals		2017
Hiep Dang	Computing Serre's intersection multiplicities		2017
Jia-Rui Fei	Moduli of representations I. Projection from quivers		2017
Jia-Rui Fei	Moduli of representations II. Extensions from quivers		2017
Jia-Rui Fei	Categorical homotopy I. Quivers		2017
Jia-Rui Fei	Counting using Hall algebras III. Quivers with potentials		2017
Jia-Rui Fei	Cluster algebras and semi-invariant rings I. Triple flags		2017
Jia-Rui Fei	Cluster algebras, invariant theory, and Kronecker Coefficients I.		2017
Jia-Rui Fei	Cluster algebras, invariant theory, and Kronecker Coefficients II.		2017
Jia-Rui Fei	The upper cluster algebras of iARt quivers I. Dynkin		2017
Kian Chuan Ong	Convergence of the MAC scheme for the Stokes/Darcy coupling problem	Journal of Scientific Computing	2018
Kian Chuan Ong	A unified wall function for compressible turbulent modelling	Journal of Turbulence	preprint
Kian Chuan Ong	A simple projection method for the coupled Navier-Stokes and Darcy flows		preprint
Manas Kar	Monotonicity and enclosure methods for the p-Laplace equation	SIAM Journal on Applied Mathematics	2017
Manas Kar	Superconductive and insulating inclusions for linear and non-linear conductivity equations	Inverse Problems and Imaging	2017
Nadim Rustom	Filtrations of dc-weak eigenforms	Acta Arithmetica	2017
Nadim Rustom	Congruences modulo prime powers of Hecke eigenvalues in level 1		2017
Nadim Rustom	Dihedral group, 4-torsion on an elliptic curve, and a peculiar eigenform modulo 4		2018
Nobuo Sato	A Lower Bound of the Dimension of the Vector Space Spanned by the Special Values of Certain Functions	Tokyo Journal of Mathematics	2018
Ryuma Orita	Non-contractible periodic orbits in Hamiltonian dynamics on tori	Bull. Lond. Math. Soc.	2017
Ryuma Orita	Computation of annular capacity by Hamiltonian Floer theory of non-contractible periodic trajectories,	J. Mod. Dyn.	2017
Ryuma Orita	Morse-Bott inequalities for manifolds with boundary	Tokyo J. Math.	2017
Ryuma Orita	On the existence of in nitely many non-contractible periodic trajectories in Hamiltonian dynamics on closed symplectic manifolds		2017
Ryuma Orita	Disjoint superheavy subsets and fragmentation norms		2018
Tien-Tsan Shieh	Ground state patterns of spin-1 Bose-Einstein condensates via G-convergence		2017
Tien-Tsan Shieh	Asymptotic behaviour of equilibrium states of reaction-diffusion systems with mass conservation		2017
Tomohiro Uchiyama	Complete reducibility, Külshammer question, conjugacy classes: a D4 example	Communications in Algebra	2017
Tomohiro Uchiyama	Complete reducibility of subgroups of reductive algebraic groups over nonperfect fields II	Communications in Algebra	2017
Tomohiro Uchiyama	Non-separability and complete reducibility: En examples with an application to a question of Klshammer	Journal of Group Theory	2017

Author	Title	Journal	Year
Tsz On Mario Chan	On analytic adjoint ideal sheaves		2017
Tsz On Mario Chan	Extension from the mlc and the extension theorem of Demailly but with estimates		2017
Tsz On Mario Chan	An extension theorem for dlt pairs via the L^2-extension theorem of Demailly		2018
Yang-Kai Lue	Evolving inextensible and elastic curves with clamped ends under the second-order evolution equation in R2	Journal of Geometric Flows	2018
Yong-Jie Wang	A family of representations of the general linear affine Lie superalgebra gldm—n(C[t, t-1])	J. Algebra	2017
Yong-Jie Wang	Central extensions of generalized orthosymplectic Lie superalgebras	Sci. China Math	2017
Yong-Jie Wang	$\mathbb{Z}/2\mathbb{Z}$-graded dihedral homology and central extensions of generalized periplectic Lie superalgebras		2017
Yong-Jie Wang	Second homology of generalized periplectic Lie superalgebras	Linear Algebra Appl.	2018
Zheng-yu Hu	Log canonical thresholds of anti-log canonical systems of Fano pairs	BAB volume	2018
Zheng-yu Hu	Log canonical pairs over varieties with maximal Albanese dimension	Pure and Applied Mathematics Quarterly	2018
Zheng-yu Hu	On log canonical pairs of weak Fano type		2018
Zheng-yu Hu	Log canonical pairs with boundaries containing ample divisors		2018