NCTS Midterm Report, 2016

National Center for Theoretical Sciences,
Mathematics Division

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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. 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 establish- ment in August, 1997. 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, NCTSs academic activities were impressive domestically and internationally. After serv- ing the Taiwanese mathematical community for nearly two decades, we have launched our first Newsletter and expected a further promotion of mathematical research in Taiwan.

We in fact consider 2016 as a year of collaboration for NCTS, marked by strengthened research collaboration both domestically and globally. We worked with Institute of Mathematics of Academia Sinica, Taiwan, and organized Taipei Postdoc Seminar for postdocs and young researchers. Thanks to the cooperative programs with our neighboring research institutes, such as RIMS in Japan and KIAS in Korea, we sent young researchers to Japan and Korea for international academic exchange. We are initiating cooperative programs and joint activities with MSRI, PIMS, and Fields Institute. We expect these international cooperations will be very helpful for students and young researchers to broaden their horizons and to build up their international connections.

Youth training and youth empowerment have been the major goal of NCTS since its foundation. Many of our new generations, both math majors and non-math majors;

both Taiwanese and international students, have benefited from our large variety of sum-mer courses and boot-camps. This year, we organized 10 summer schools whose topics have covered geometry, elliptic curves, probability, mathematical biology, optimization, etc. Students are highly encouraged to attend the intensive and research-oriented lectures given by both Taiwanese local and international visiting scholars, which are unique and different from their usual curriculum.

Data science has been a very hot topic that theoretical mathematical research could and should play the fundamental and pivotal role. As we promised in the Review Committee last year, a lot of extra efforts were made for development of data science. With the assistance of Prof. Hau-Tieng Wu, University of Toronto, and Weichung Wang, National Taiwan University, we have cooperated with the existing Big and Complex Data Analysis Program and launched a Laboratory of Data Science of National Center for Theoretical Sciences. The main goal of LDS of NCTS is to study the mathematical models for data processing in medical research. The Forum of Data Science is organized every month as a platform for mathematicians, statisticians, physicians and other experts to gather for idea exchange and problem solving. There are already some other collaborations initiated by this program ongoing.

For the year 2017 to come, we aim at consolidating our Topical Programs, with partial restructures proposed and considered. On the 28th and 29 th, December, 2016, we are going to organize International Scientific Advisory Committee meeting. We will then refer the comments and suggestions of the Review Committee and ISAC to the further operations of our scientific programs. We have programs on excellent topics, and we expect to have excellent topical programs.

I.1.2 Brief summary of the year

a. 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 ex-change of idea. Updated to the end of September, it was concluded that we have had 183 seminars this year. 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 40 conferences and workshops, accompanied by 29 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. We have transferred three of the summer courses into official courses o2f NTU, so that students are eligible to get official credits. We considered these courses our path toward to the idea of "Taiwan Mathemtical School".

b. Visitor's Program
NCTS International and domestic visitors have inspired and empowered the activities of NCTS. There are 348 foreign visitors with the total duration of 4289 days, and the both records are the highest throughout NCTS history. As we especially encourage visitors for longer stay, there are 38 visitors visiting NCTS for more than 30 days and another 16 visitors visiting NCTS for more than 20 days.

The improved international collaboration is on the one hand due to the progress of NCTS Scholar Program, based on which we invite world leading experts to visit for the total duration of 3 months or more during the span of three years. On the other hand, based on our Domestic Visiting Scholar Program, we have attracted 3 young researchers for intensive research in summer for more than one month. Besides, based on our Research Pair program, we have approved a research team of 4 scholars, who are from Italy, Japan and China.

We have extended the existing NCTS Scholar Program to recruit more excellent researchers for longer visit. There are 5 NCTS Distinguished Scholars and NCTS Scholars who have visited or will visit NCTS this year: Yujiro Kawamata, Paolo Cascini, Richard Schoen, Horng-Tzer Yau, Nikolas Zygouras. We have 2 more NCTS Scholars: Albert FanJiang (UC Davis) and Yen-Hsi Richard Tsai (UT Texas). The lectures given by NCTS Scholars Yujiro Kawamta and Paolo Cascini were the highlights of the event in algebraic geometry this year. The upcoming activities organized by NCTS Scholar, Nikolaos Zygouras (University of Warwick), and co-organized by NCTS postdoc, Chien-Hao Huang, are exciting for people who work on probability.

c. Cultivation the Youth
An important feature of world leading center is to be a place where fresh Ph.D. would love to start their academic career. Therefore, we have extended our programs for postdoc fellows. We have 20 postdoc fellows currently, and 14 of those are international postdocs from Japan, Korea, China, Hong Kong, Vietnam, Lebanon, India and Romania. Each one of our postdocs is associated to a Topical Program and supervised by a senior member. We also encourage postdoc fellows to build up their own international academic connections. In fact, by cooperating with other prestigious centers or institutes, we have promoted ex- change or visiting programs for postdoc fellows. For example, Heip Dang visited KIAS for a month according to

the MOU between KIAS and NCTS. Also, Mario Chan was invited by J.P Demailly for a visit of two months to Grenoble.

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-training3in each program by organizing student seminars and summer schools, but also promote and inspire more inter-university cooperations. With this mission bore in mind, we are serving a platform for outstanding scholars from different institutes to participate in joint student-training programs. The fact that we held about 20 short courses and summer/winter schools designed for young generations represents our progress to solve the Taiwanese academic situation.

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 Re-search 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. Minor Restructure of Topical Programs

NCTS was moved to the campus of National Taiwan University in 2015, since when the operating structure has been reformulated, and new visions and missions are introduced. Significantly, our Topical Programs had been reformulated and regrouped, and we have 6 Topical Programs and 2 Initiatives currently. The 6 Topical Programs consist of:

(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.

The Topical Programs are structured based on the advice of the I nternational Scientific Advisory Committee held i n July 2014, while the 2 Initiatives are G. Big and Complex Data Analysis and H. Harmonic Analysis.

We understand that the rapidly changing world has produced new problems and challenges i n mathematical sciences. These newly developing topics usually require excellent researchers with broad visions in particular; we therefore encourage cooperation and interactions among various disciplines as our solution. The previous programs of PDE, Dynamical System and Probability were as a result merged into a larger pro-gram: Differential Geometry and Stochastic Analysis. The newly created program, Interdisciplinary Research, was created i n order to promote further theoretical research on newly developed areas i n mathematical sciences. Besides, two programs were developed and they reected important new research topics and emerging new research groups. Through the Open Calls f or Proposals in 2015, we selected two new initiatives: Big and Complex Data Analysis and Harmonic Analysis.

e. Laboratory of Data Science

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 people: 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 latest meeting held on September 22, Dr. David Liao introduced some challenges we now face for diseases of pancreas, 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.

I.2 Summary of demographic data

I.2.1 Summary of activities

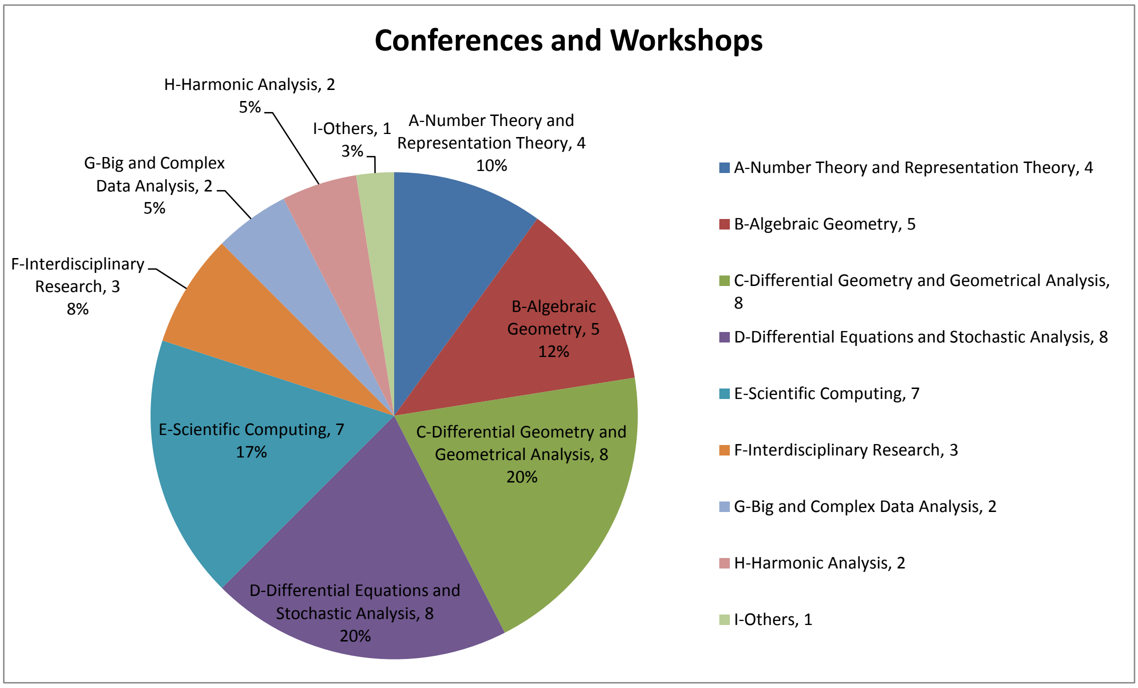


Figure 1. 2016 NCTS Conference and Workshop

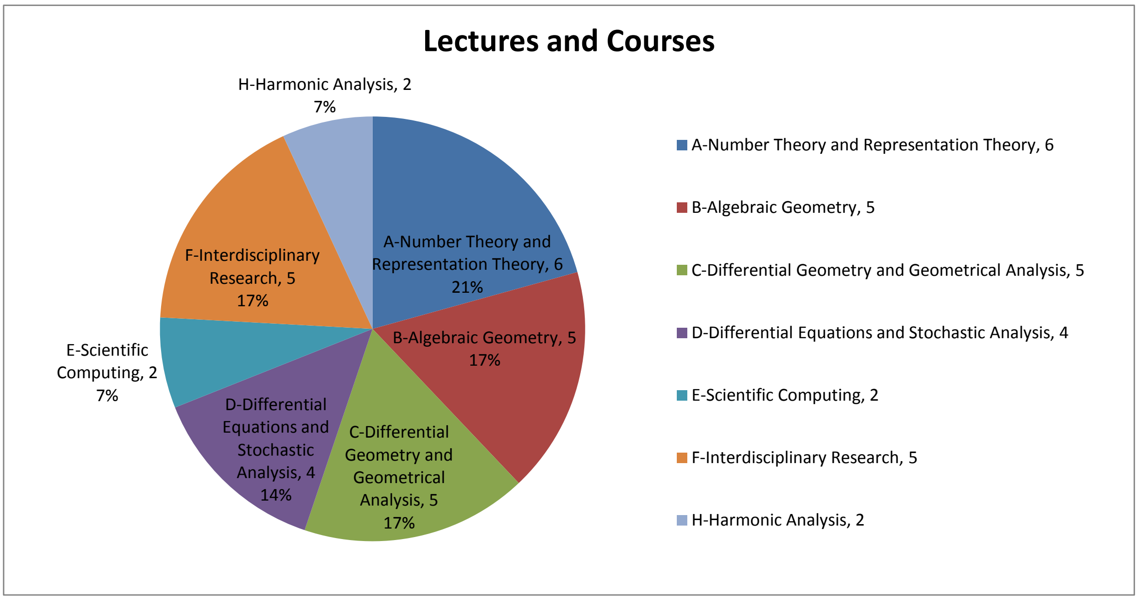


Figure 2. 2016 NCTS Lectures and Courses

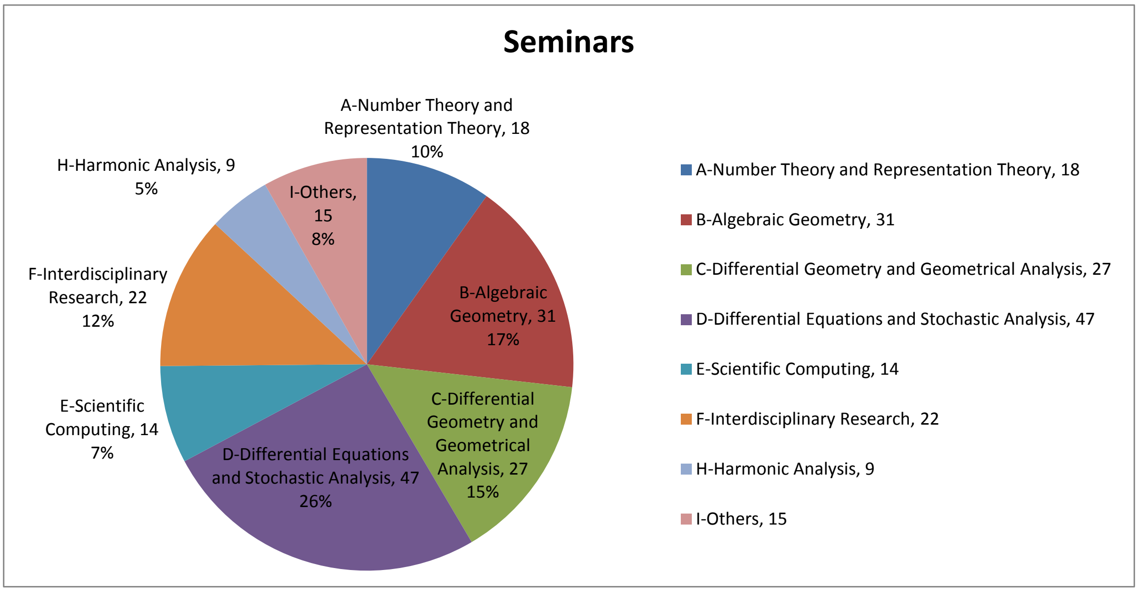


Figure 3. 2016 NCTS Seminars

I.2.2 Summary of visitors

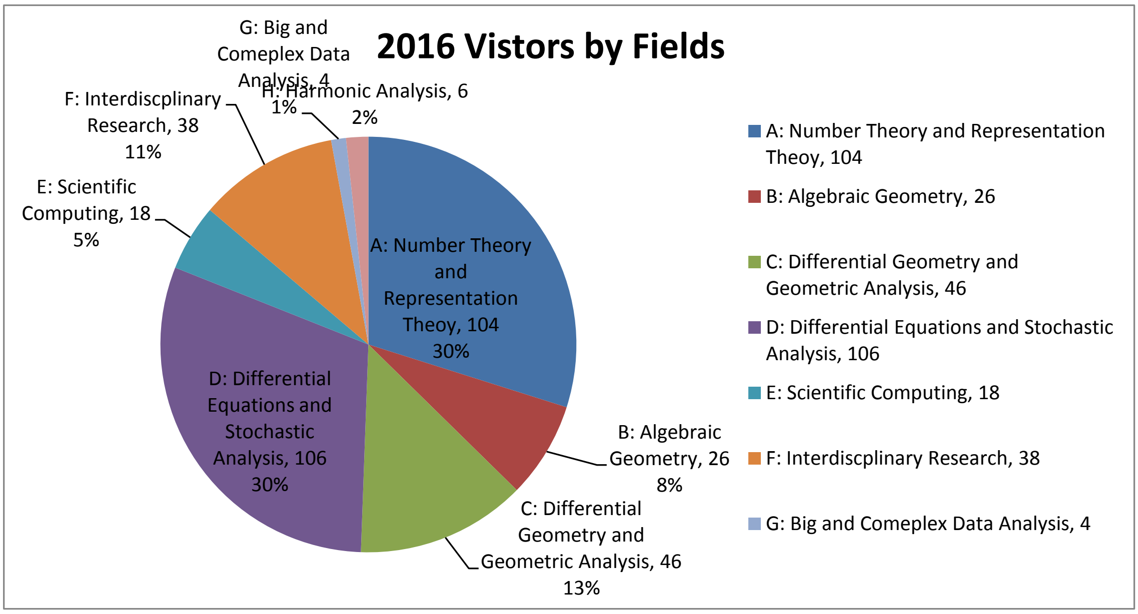


Figure 4. 2016 NCTS Visitors by Fields

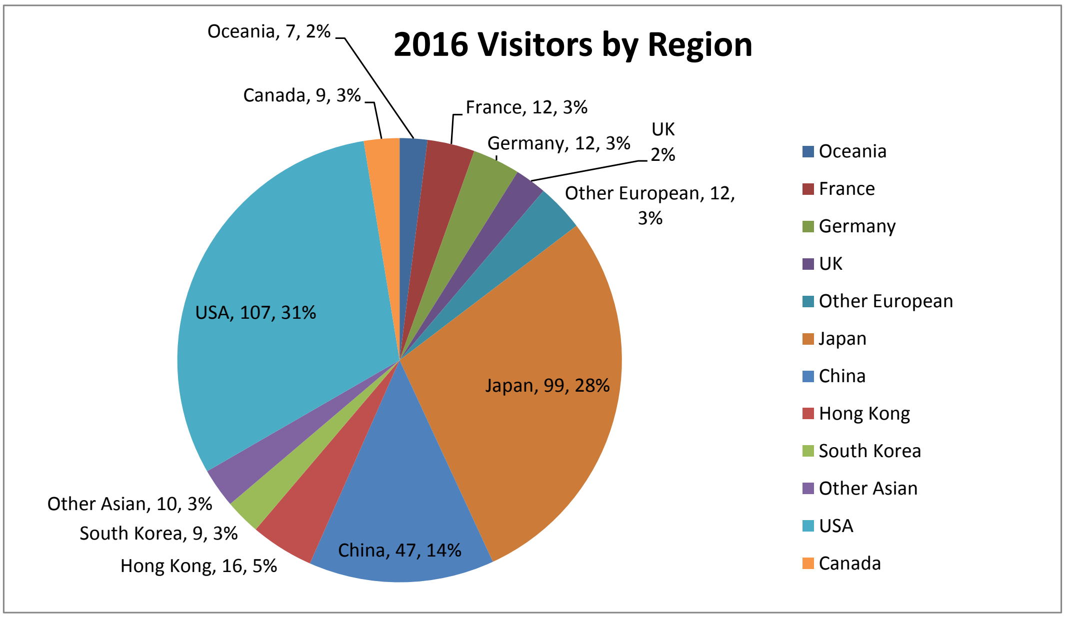


Figure 5. 2016 NCTS Visitors by Region

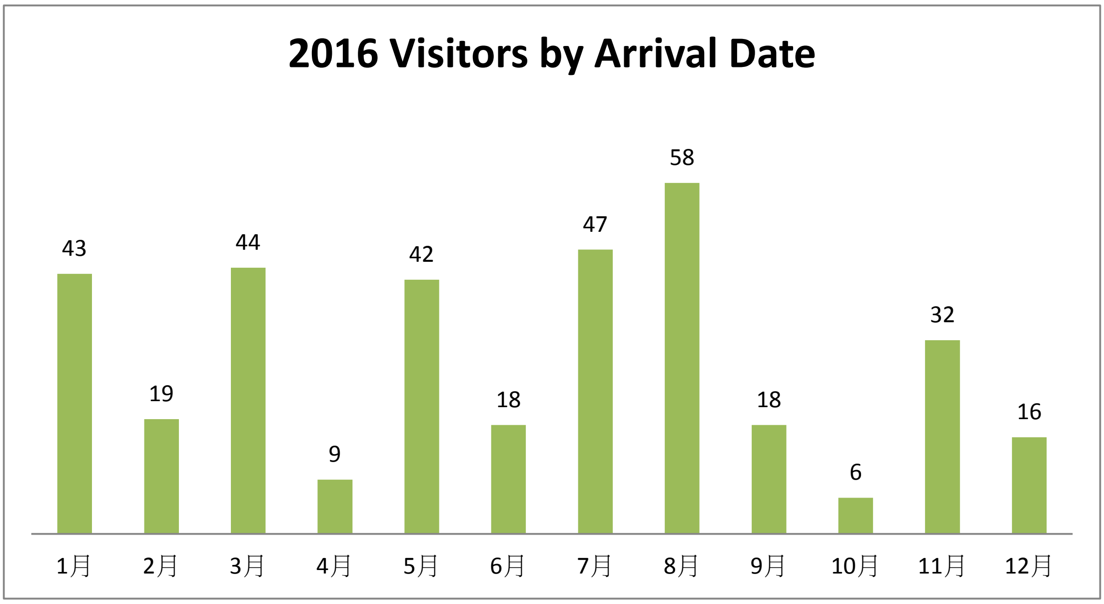


Figure 6. 2016 NCTS Visitors by Arrival Date

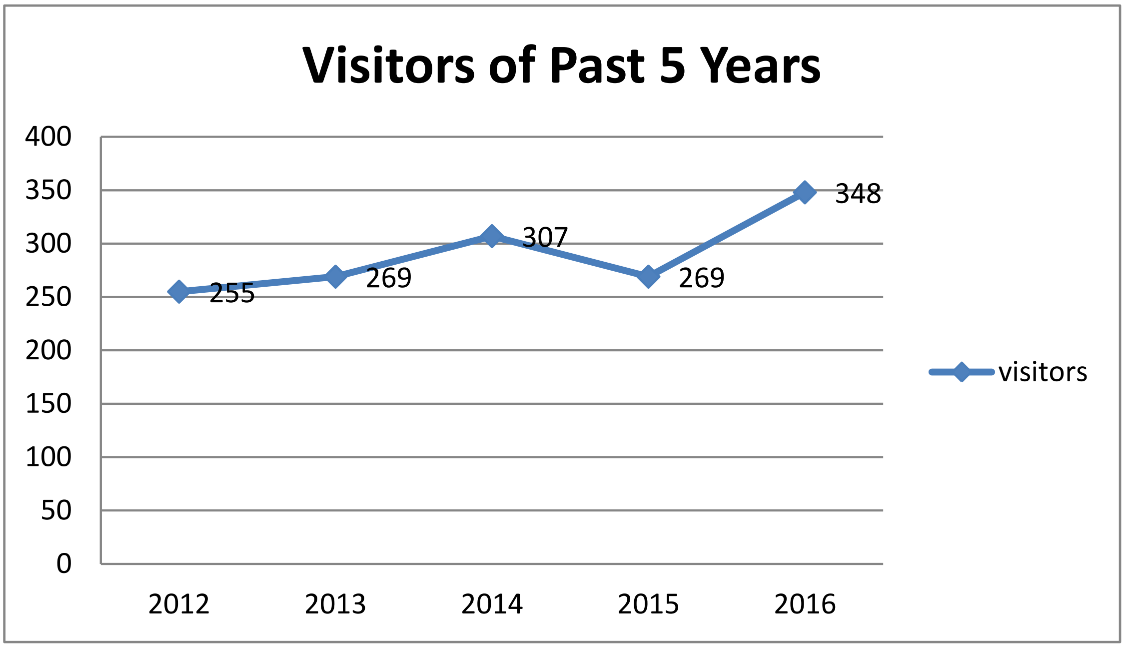


Figure 7. Visitors of Past 5 years

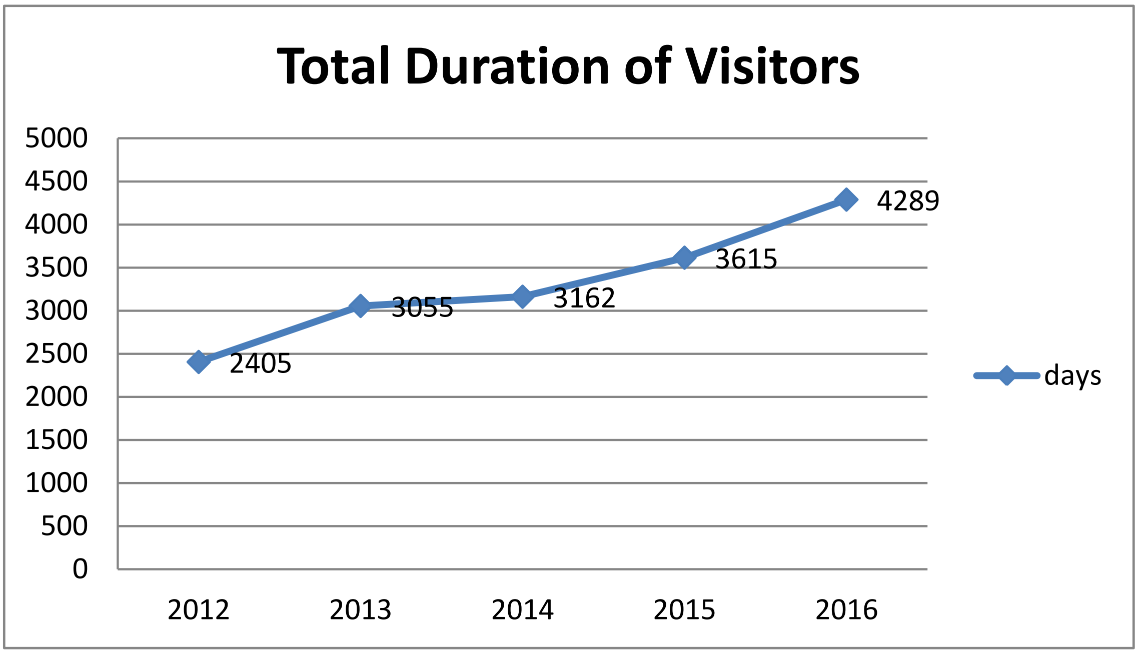


Figure 8. Total Duration of Visitors of Past 5 Years

I.2.3 Summary of publication data

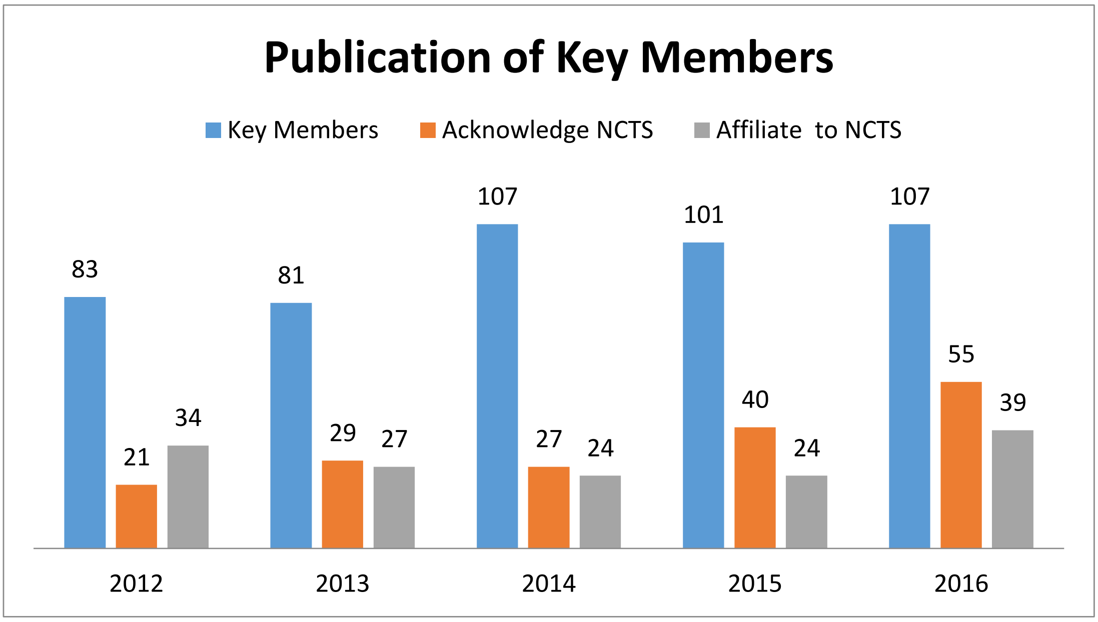


Figure 9. Publication of Key Members of Past 5 years

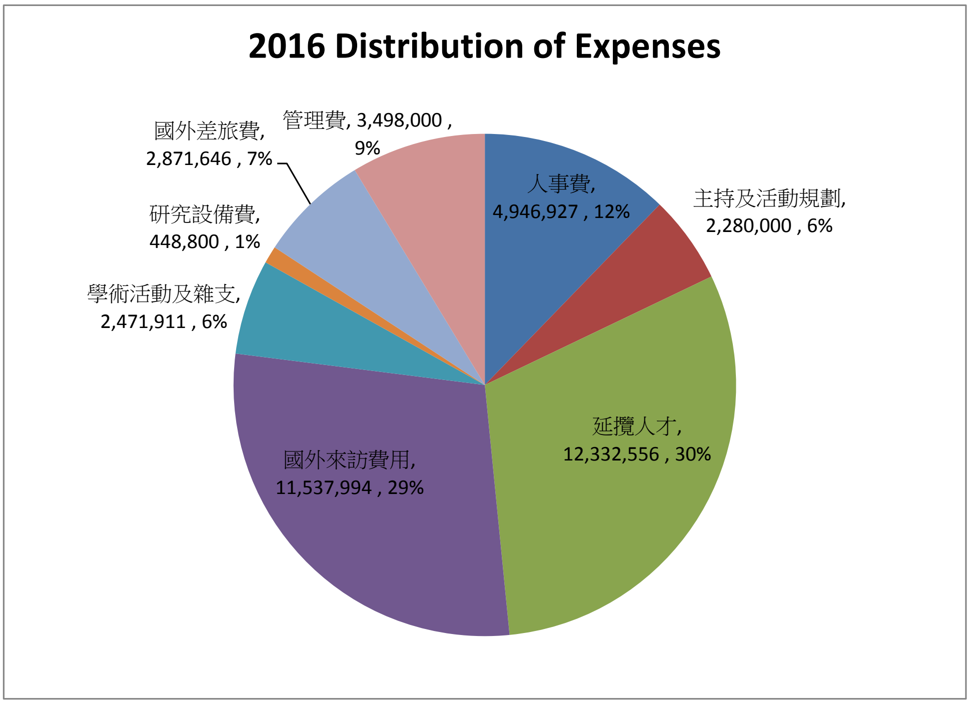


Figure 10. 2016 Distribution of Expenses up to Sep. 20, 2016

II Operation and Achievement of the Center

II.1 Visitor program

II.1.1 Short term and long term visitors

We have hosted 348 foreign visitors with the total duration of stay is 4289 days in 2016, and both the number of visitors and total duration of stay are the highest among all years.

More significantly, there are 38 visitors staying for more than 30 days, and another 16 visitors who staying for more than 20 days. In fact, we encourage our members to invite visitors for longer stay, which helps create more discussions and interactions among visitors and local researchers. We believe that this is an effective way to strengthen and empower our collaboration.

In order to achieve the goal of longer and closer cooperation, we set the principle that airfare reimbursement is applicable to visitors from non-Asian countries (resp. Asian countries) who stay for at least 14 (resp. 10) days.

We have tried our best to encourage the research collaboration by providing financial support; however, we are still facing some difficulties. The most serious one that we would like raise here is the limitation of the per diem for foreign Ph.D. students. It is quite often and reasonable that a long-term visitor would hope to have his/her Ph.D. student(s) around as well. Also, many of our schools encourage foreign students to come and visit, while our MOU with other institutions promote international programs with more visiting students from abroad. However, according to the regulation of MoST, the maximal per diem for each visiting student is 1900 NTD per day, which is not even enough to cover the cost of hotel.

II.1.2 NCTS scholars

NCTS Scholar is a program to recruit world leading experts to work in NCTS for 3 to 6 months during a span of three years, and they are free to choose their period of visit. We have appointed 2 new NCTS Distinguished Scholars and Scholars this year, including: Yen-Hsi Richard Tsai (UT Austin) and ALbert Fan-Jiang. Together with the current Scholars, there are 5 NCTS Scholars visited or will visit the Center this year: Fan Chung Graham (UC San Diego), Gunther Uhlmann (University of Washington), Paolo Cascini (Imperial College London), and Nikolaos Zygouras (University of Warwick).

In the report of NCTS Scholar Caucher Birkar, he said *"I believe NCTS is going in the right direction by appointing scholars who regularly visit the center and who attract other visitors. Scholars are asked to give lectures and organize conferences which is quite reasonable and necessary. A really positive thing about NCTS is the lack of bureaucracy for scholars."*

II.2 Postdoctoral program and cultivation program

II.2.1 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 17 postdocs in 2015, and 5 of them have now received positions from other institutions, 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.

Name	**Gp**	**Adviser**	**Nationality**	**Previous Affiliation**	Next Affiliation
Li-ren Lin**	D	Jenn-Nan Wang	Taiwan	Academia Sinica	NCKU
Kazuaki Miyatani**	A	Jeng-Daw Yu	Japan	Hiroshima University	Hiroshima University
Ru-Lin Kuan**	D	Tai-Chia Lin	Taiwan	Academia Sinica	NCKU
Qi Gao**	F	Tai-Chia Lin	China	University of Minnesota	Wu-Han Univ. Sci. Tech.
Raoul Normand**	D	Chii-Ruey Hwang	France	Academia Sinica	NYU Shanghai
Yu-Yen Chien*	A	Ching-Hung Lam	Taiwan	University of Southampton	
Tsz On Mario Chan*	B	Chen-Yu Chi	Hong Kong	KIAS	
Hiep Dang*	B	Jungkai Chen	Vietnam	Kaiserslautern	
Chien-Hao Huang*	D	Chii-Ruey Hwang	Taiwan	Academia Sinica	
Gyeongha Hwang*	D	Jenn-Nan Wang	Korea	Ulsan Natl Inst. Sci. Tech.	
Yong-jie Wang*	A	Shun-Jen Cheng	China	Univ. Sci. Tech. China	
Catalin Ion Carstea*	D	Jenn-Nan Wang	Romania	Jiaxiang Foreign Lang. Sch	
Jia-rui Fei*	A	Shun-Jen Cheng	China	UC Riverside	
Zheng-yu Hu*	B	Jungkai Chen	China	University of Cambridge	
Tien-Tsan Shieh*	E	I-Liang Chern	Taiwan	NCU	
Chi Kwong Fok*	C	Nan-Kuo Ho	Hong Kong	Cornell University	
Yunchang Seol*	E	Ming-Chih Lai	Korea	Chung-Ang University	
Tomohiro Uchiyama	A	Jungkai Chen	Japan	Univ. Auckland, NZ	
Manas Kar	D	Jenn-Nan Wang	India	Univ. Jyväskylä, FInland	
Edward Ho	G	Weichung Wang	Malaysia	Natl Yang-Ming Univ.	
Nadim Rustom	A	Ming-Lun Hsieh	Lebanon	Univ. Copenhagen	
Chih-Whi Chen	A	Shun-Jen Chen	Taiwan	NTU	
Chih-Wei Chen	C	Mao-Pei Tsui	Taiwan	NTU	
Yang-Kai Lue	C	Mao-Pei Tsui	Taiwan	NTNU	
Yoshinori Jinbo	E	Ker-Ming Shyue	Japan	Hokaido Univ.	

*: Renewal

**: terminated

II.2.2 Graduate and undergraduate program

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.

In the academic year of 2015, we had 5 RAs. Among them, 2 of them was admitted to Ph.D. program in the US and another one went to CUHK for Ph.D. Currently, we have 3 RAs, working on number theory, differential geometry and PDE respectively.

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.

   (1). RIMS, Japan
   For example, base on the MoU with RIMS, we recommend two young researchers: Y. N. Peng (NCU) and Chien-Hung Cho (CCU). 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.

   (3). Berhen, Norway
   We hosted a group of mathematicians from Bergen, Normay, who visited NCTS and we renew the exist MoU with Univ. of Bergen. However, due to the unstable financial situation of Norwegian side, it is not clear whether they are able to organize a joint workshop in Norway this year.

   (4). PMI, Korea
   The joint NCTS-PMI workshop has been held annually for years. This year, it was a joint workshop on number theory that was held in Pohang.

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, and we started to discuss with MSRI this May for possible cooperation. 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). PIMS, Canada

The Pacific Institute of Mathematical Sciences (PIMS) is an Canadian Institute with its hub at University of British Columbia. There are some common interests in the field of analysis an differential geoemtry. An MoU has been signed in order to promote the collaboration between these two research groups and the networking of some other fields are still being developed.

(3). Fields Institute, Canada

We have started an exchange program with the Fields Institute based on the newly signed MoU. According to the program, we will send young researchers as well as senior researchers for exchange and collaborations, and vice versa.

(4). 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 this year, and NCTS is going to host the next meeting in 2018, by cooperating with AIMS.

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, and it's going to be in Seoul in 2017

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 Other programs

We made some effort to make NCTS more well-known to international communities.

1. Newsletter

   After serving the mathematical societies for almost two decades, we have issued our first newsletter, and the newsletter is planned to be released twice a year. It will provide a new channel for researchers to know about our upcoming programs, prospects, and members.

2. Youtube clips

   We made three videos to introduce NCTS, including our research environment, conferences and lectures, reviews from postdocs, and reviews from international scholars. The videos were published on Youtube already.

3. Promotion in the Annual Meeting of MSJ.

   Japan has relative long tradition of mathematical research in East Asia, and it is therefore important to build up a close cooperation with the Mathematical Society in Japan generally. In the annual meeting of the Mathematical Society of Japan organized this Autumn, we arranged a booth to present our introductory video and spread our Newsletter and brochure, aiming to attract more Japanese young researchers to pursue their postdoctoral studies at NCTS.

III Academic Programs

III.1 Number Theory and Representation Theory

1. Core Mambers

a. Faculties: Ming-Lun Hsieh (AS), Chia-Fu Yu (AS), Chieh-Yu Chang (NTHU), Yung-Ning Peng (NCU), Meng-Kiat Chuat (NTHU), Yifan Yang (NCTU)

b. Postdocs: Nadim Rustom, Tse-Chung Yang, Jia-Wei Guo, Zhi Wei Chen, Mounir Hajli

c. Ph.D. students: Yi-Hsuan Lin (NCTU), Yao Cheng, Shi-Yu Chen (NTU), Isao Ishikawa (Kyoto University).

d. Master students: Nai-Heng Hsu (NTU), Wei-Cheng Huang, Kai-Wen Huang, Po-Fong Chang (NTHU).

2. Overview of the Program

The purpose of the number theory and representation theory program at NCTS is to create outstanding research in these areas, establish international cooperation and enhance international visibility of number theory in Taiwan. The research topics cover a wide spectrum of number theory. We focus on the following four areas:

a. Geometry of Shimura varieties and superspecial abelian varieties over finite fields.(Yu);

b. Shimura curves and related topics (Yang);

c. Multiple Zeta Values in Positive Characteristic (Chang);

d. Iwasawa theory and p-adic methods in algebraic number theory and automorphic forms (Hsieh).

Our members organized a number of research activities in NCTS. We have regular NCTS Number theory seminars in Taipei and Hsinchu every Wednesday with local and international speakers. We invited renowned professors in arithmetic geometry and number theory to visit NCTS and deliver distinguished lecture series. For example, Illusie Luc gave four lectures "Nearby Cycles over General Bases and Thom-sebastiani Theorems" in March, 2016., and John Coates gave four lectures "On the Conjecture of Birch and Swinnerton-Dyer for Quadratic Twists of $X_0(49)$" in July, 2016. Important international workshops and conferences supported by NCTS includes

a. PMI-NCTS Joint workshop in Number Theory June 6-8, 2016 organized by YoungJu Choie, Winnie Li and Chia-Fu Yu.

b. 2016 Summer School of Shimura varieties and Related Topics during May 23-27 and Taipei Workshop of Shimura varieties and Related Topics during May 30-June 3 organized by Chiafu Yu, Xuehua He and Kai-Wen Lan

c. Pan Asia number theory conference in July 11-15, 2016 organzied by Chieh-Yu Chang, Winnie Li and Yifan Yang.

Fostering the young generation of Taiwanese number theorists is also an important task in the program. To this end, our members offered several advanced courses and organized summer schools for students interested in number theory. Chia-Fu Yu continued his 2016 NCTS Spring Course: Representation Theory of Finite Groups of Lie type and Abelain Varieties and Related Topics. Yifan Yang gave a series of lectures in NCTS Summer Course on Elliptic Curve during July, 2016. Chieh-Yu Chang and Fu-Tsun Wei organized NCTS Summer Short Course on Number Theory during August, 2016.

Representation theory is the study of realizations of symmetries in mathematics and nature in general. Its main goal is to understand and give explicit realizations of in general abstract mathematical objects in terms of more concrete linear transformations on vector spaces. The focus group on representation theory investigates the representation theory of groups, Lie algebra, Lie superalgebras and vertex operator algebras. Research topics include the representation theory of finite groups and p-adic groups, the investigations of the relationship between the representation theories of classical Lie algebras and Lie superalgebras, the structure theory of vertex operator algebras and their relationship with certain sporadic simple groups and various quantum algebras such as Yangians and W-algebras. Although representation theory has been one of the focus programs at NCTS since its inception in 1997, the number of mathematicians working in related areas is still rather limited. In the last decade, substantially efforts were made in training students in this direction and we have sent many graduate students aboard. Most of them have just recently earned or are about to earn their Ph.D. degree. Some of them have already come back and have found tenure-track positions in national universities. Yung Ning Peng of National Central University is one of the examples. In 2016, we had regular seminars on Representation theory and vertex algebras in Taipei. There were also seminar and colloquium talks from times to time. In March 2016, we organized an international workshop on finite groups and vertex operator algebras at Yilan. There were about 30 participants and about 20 of them were from US, Japan and China which included several students and postdocs from Taiwan and Japan. We believe that it will be very important for establishing a long-term research relationship between the researchers in Taiwan and other countries in Asia. We plan to make this event an annual event. In August 2016, a conference in finite groups and vertex algebras was held in Academia Sinica, Taipei. This conference is dedicated to Robert Griess on the ocassion of his 71st birthday. There were over 23 speakers and over 45 participants.

3. Research Highlights and Reports

a. Anticyclotomic Iwasawa theory for modular forms
During 2015-2016, we successfully extend the work of Bertiloni-Darmon on the anticylotomic main conjecture for elliptic curves to elliptic modular forms. We construct anticyclotomic p-adic L-functions for modular forms and prove the

vanishing of its mu-iinvariants [CH15b]; we prove one-sided divisibility in the anticyclotomic main conjectures for modular forms [CH15a]. In addition, in [CH15c] we construct Euler system for generalized Heegner cycles and prove the corresponding Perrin-Riou's explicit reciprocity law, with which we obtain some new examples of Bloch-Kato conjectures under some p-ordinary hypothesis. We carried out the first step in our project on Yoshida congruences for Siegel modular forms of genus two. In [HN16] prove the non-vanishing modulo p of Yoshida lifts by computing the Bessel peirods of Yoshida lifts and using main results of [CH15b]. As a consequence, we give a new proof of the non-vanshing of Yoshida lifts. Our next step is to elaborate the computation of the Petersson norm of Yoshida lifts by Rallis inner product formula as well as construct Hida families of Yoshida lifts.

Reference:

M. Chida and M.-L Hsieh, On the anticyclotomic Iwasawa main conjecture for modular forms. (with Masataka Chida). Compositio Mathematica, 151(2015), no. 5, 863-897.

M. Chida and M.-L Hsieh, Special values of anticyclotomic L-functions for modular forms. To appear in Crelle's journal.

F.Castella and M.-L. Hsieh, Heegner cycles and p-adic L-functions. Submitted.

M.-L. Hsieh and Kenichi Namikawa, Bessel periods and the non-vanishing of Yoshida lifts modulo a prime. To appear in Mathematische Zeitschrift.

b. Multiple zeta values in positive characteristic

In [CPY15], we consider the positive characteristic analog of the question for classical MZV's: is there any criterion to determine when a given MZV is Eulerian? This question in the classical setting is only known by Brown, who provides a sufficient condition. In the paper [CPY15], we give an effective criterion for the analogous problem in the function field case. In the classical theory of MZV's, computing the dimension of the space of the same weight double zeta values is a very difficult problem. In fact, the dimension is unknown when the weight is higher than 4. In [C15], we establish an effective criterion or algorithm to compute the dimension of the space of double zeta values in positive characteristic. We determine the dimensions via special points and logarithms, which give completely new points of view.

References:

C.-Y. Chang, M. Papanikolas and J. Yu, An effective criterion for Eulerian multizeta values in positive characteristic, to appear in Journal of the European Mathematical Society.

C.-Y. Chang, Linear relations among double zeta values in positive characteristic, to appear in Cambridge Journal of Mathematics.

c. Geometry of Shimura varieties and superspecial abelian varieties over finite fields

Together with Jiangwei Xue and Tse-Chung Yang, I am working on superspecial abelian varieties over finite fields. The goal of our projects is to calculate the number of superspecial abelian surfaces over finite fields. This consists of a series of 4 papers: The first one establishes the generalized Eichler class number formula, and calculate the number of the isogeny correspeonding to Weil number $\sqrt{p}$. The second paper classify the quadratic orders over $\mathbb{Z}[\sqrt{p}]$ which occurs in our generalized Eichler class number formula. The third paper calculates the number of superspecial abelian surfaces over finite fields with odd exponents. The fourth paper handles the case where the finite fields with even exponents, which relates to computing conjugacy classes of elements of finite orders in an arithmetic group. For Shimura varieties, I proved the existence of the basic locus of the reduction modulo p of Shimura varieties.

d. Shimura curves and related topics

Shimura curves are moduli spaces of principally polarized abelian surfaces and can be regarded as a generalisation of classical modular curves. However, because of the lack of cusps on Shimura curves, there are very few explicit methods for Shimura curves. During the year of 2015, our research focused on the method of Borcherds forms, which are certain modular forms on Shimura curves arising from singular theta correspondence. We showed that the problem of constructing Borcherds forms reduces to that of solving certain integer programming problems. By solving these integer programming problems, we can systematically construct Borcherds forms. One immediate application of our method is the determination equations of (hyperelliptic) Shimura curves. A paper on this application has been accepted for publication on the Compositio Mathematica. Another application is an explicit description of quaternionic loci on Siegel's modular threefold (that is, the moduli point in Siegel's modular threefold whose corresponding abelian surface has quaternionic multiplication. We are able to find the modular parameterisation in terms of Hauptmoduls of Shimura curves when the locus is a curve of genus zero. A manuscript on this work is currently under preparation.

e. holomorphic vertex operator algebras

The research team lead by C. H. Lam has made important contributions towards the classification of holomorphic vertex operator algebras with central charge 24 in the recent years. In 1993, Schellekens obtained a list of 71 possible weight one Lie algebras for holomorphic VOAs of central charge 24 and gave extensive computational data to back his claims. He also asserted that this result has applications to the heterotic string. In addition, it was conjectured that there are exactly 71 holomorphic VOAs of central charge 24 and the VOA structures are determined by the Lie algebra structures of their weight one subspaces. However, only 39 of the 71 proposed theories had been constructed in that time. In the last 20 years, Schellekens' conjecture has become one of the main conjectures in VOA theory, for at least two good reasons: (a) there are very few good construction techniques for rational VOAs, and Schellekens' problem is an interesting yardstick by which progress in this direction can be measured, and (b) the parallel result for self-dual positive-definite lattices has had an enormous influence on areas such as algebraic combinatorics, lattice-theory, and various moonshine theories. Therefore, one would expect that knowing the complete list of holomorphic $c = 24$ VOA's will - in the long run - have an even greater impact.

In around 2010, a special class of holomorphic VOAs, called framed VOAs, of central charge 24 were studied by H. Shimakura, H. Yamauchi and C.H. Lam. A complete classification of holomorphic framed VOAs of $c = 24$ has also been achieved by H. Shimakura and C.H. Lam in 2014. In particular, they showed that there exist exactly 56 holomorphic framed VOAs of central charge 24 and they are uniquely determined by the Lie algebra structures of their weight one subspaces under the assumption that they are framed. In addition, a Z3 -orbifold theory associated to lattice VOAs has been developed by Miyamoto in 2013. As an application, a holomorphic VOA whose weight one subspace has the Lie algebra structure E_6,$3G_2$,13 was constructed. By using the similar methods, two other holomorphic VOAs have been constructed by H. Shimakura and T. Sagaki. Recently, van Ekeren, Moller and Scheithauer announced that they have obtained a mathematically rigorous proof for Schellekens' list using modular invariant of trace functions and the theory of Jacobi forms. They also established the Zn-orbifold construction for lattice VOAs for general elements of arbitrary orders using an unpublished result of Miyamoto. As an application, they also claimed to have the constructions of several new VOAs in Schellenkens' list. In 2015, H. Shimakura and C.H. Lam developed a new construction method using Li's Delta operator and inner automorphisms. The technique itself was developed by Dong-Li-Mason nearly 20 years ago (using simple currents and inner automorphisms), but these ideas were never applied to substantial construction problems before. Using this technique, Shimakura and Lam are able to construct 6 new examples of holomorphic VOAs of $c = 24$. In this year, Lam and Lin have constructed the last example and completed the construction program for Schellekens' list. Some new techniques associated with modular tensor category has also been developed. The technique using inner automorphisms and the Delta operator also provide some new insights for proving the uniqueness of the VOA structures. Shimakura and Lam are able to prove that the VOA structures of several holomorphic VOAs of $c = 24$ are uniquely determined by the Lie algebra structures of their weight one subspaces. More cases have also been confirmed by Kawasetsu-Lin-Lam. By using the technique "Reverse orbifold", we discovered that there may be a direct construction of all 71 cases using a cyclic orbifold construction of "mixed type" from the Leech lattice VOA. We also noticed that this approach may lead to a uniform proof for the uniqueness of 70 of the 71 cases. Our method unfortunately does not apply to the famous Moonshine VOA.

f. representation theory of super Yangian
Our group also made important breakthrough towards the theory of super Yangian. Y.N. Peng obtained parabolic presentations for super Yangian $Y(glM|N)$ associated with arbitrary 01-sequences. This work is a generalization of Brandun-Kleshchev's work about the Yangian of gln, in which they gave a presentation of the Yangian associated to an arbitrary composition of n. The main result of Y.N. Peng is that for an arbitrary fixed composition of m+n and an arbitrary fixed 0^m1^n-sequence, a presentation of the super Yangian of $glm|n$ is obtained. It not only covered some earlier results of Brundan-Kleschev, Gow and Peng but it also provided a lot of new presentations that never appeared before due to the use of 01-sequence.

III.2 Algebraic Geometry

1. Core Mambers

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

b. Postdocs: Zheng-Yu Hu (NCTS), Mario Chan (NCTS), Hiep Dang (NCTS)

c. Students: 2 Ph.D./6 Master

2. Overview of the Program

Algebraic geometry has been one of the core theme of modern mathematics. One the other hand, it is the mathematical theory with possible interaction and applications with many other fields, such as, number theory, differential geometry, mathematical physics, analysis as well. There were almost none working in algebraic geometry 20 years ago. Thanks to the consistent support of NCTS, the research group of algebraic geometry in Taiwan not only grew up substantially, but also obtained certain international reputation. Through the strategic planing of seminars courses and workshops, for undergraduate, postdocs, and reseachers, the size of the group grows notably in recent years.

Therefore, the main goal of the Topical Program in Algebraic Geometry is to achieve world leading advances and to cultivate the young generation as well.

In the year of 2016, our focus is on, but on restricted to, the following three topics:

a. Minimal model program and related topics;
b. Homological algebraic methods in algebraic geometry, including derived categories;
c. Positivity in algebraic geometry, in characteristic zero and in positive characteristics.

In fact, Taiwan has strong research group in higher dimensional birational geometry. Almost all renown world experts in the field of birational geoemtry visited NCTS for some period. Not only this, we also attracted world leading experts to visit NCTS for a longer period for research collaboration. This amounts to the following highlights of activities and events in the year 2016.

a. Younger Generation in Algebraic Geometry.
This series of workshop was initiated by some active young Japanese algebraic geometers such as Yoshinori Gongyo for Japanese people. Due to the existing long-term and close collaboration between Japan and Taiwan in this area. It was held in NCTS in the yaer 2016.
b. Mini-courses and mini-workshop in algebraic geometry in March and April.
NCTS Sholars Yujiro Kawamata (Tokyo) and Paolo Cascini (Imperial) visited NCTS in March and April, together with Masayuki Kawakita (RIMS) and Luc Illusie (Paris-Sud). During this occasion, there are 5 minicourses and 1 workshop, which makes the highlight of the activities of the year. The research group of algebraic geometry benefits a lots from this intensive period, especially for those younger generation.
c. NCTS Seminars in Algebraic Geometry
We had regular weekly seminar in NCTS in Algebraic Geometry. Due to the increasing popularity of researchers in NCKU, there are regular seminars in Tainan started from this year.
d. NCTS Algebraic Geometry Day
Other than regular seminars, we initiated NCTS Algebraic Geometry Days every month. Each time there are 4 talks. The first one is on Oct 14 and the second one is on Nov. 16. It serves as a platform for people to share their current project and hence to seek for possible collaboration.
e. NCTS One-Day workshop in Algebraic Geometry
NCTS has built its reputation and became a place that researchers would like to stop-over. In December, since there are several invited visitors and stop-over visitors, we are going to run a workshop for exchange ideas. Speakers includes well-established mathematicians such as Burt Totaro (UCLA) and Lawrence Ein (UIC).

NCTS becomes an tempting places for younger researchers in algebraic geoemtry. Last year, we attracted three new international postdocs: Zhengyu Hu from Cambridge, Mario Chan from KIAS and Dang Hiep from Kaiserlautern. With these international young scholars, our weekly seminars run in English. This seminar also provide some opportunities for our Ph.D students to present their work in English.

3. **Highlights** The research highlights of the program consists of three parts: first, on explicit birational geometry in dimension three; second, the studies on derived categories on special varieties; and third, on the boundedness problem of varieties of Fano-type.

   a. Explicit birational geometry in dimension three
   The research team led by Jungkai Chen, together with Jheng-Jie Chen, Shin-Ku Chen, Ching-Jui Lai is one the leading team in the study of geometry of threefolds, especially in the problem related to three dimensional minimal model programs. The previous work of Jungkai Chen provides a decomposition of flips and divisorial contraction to curve into a set of explicit elementary maps, such as blowups and weighted blowups. Let $f\colon Y \to X$ be a divisorial contraction, or a flip in dimension three. There exists a sequence

   $$Y = X_n \to X_{n-1} \to \ldots \to X_1 \to X_0 = X$$

   such that each map $X_i \to X_{i-1}$ is one of the following explicit maps: a flop, a blowup along a smooth curve, a divisorial contraction to a point, or a weighted blowup over a point. By using the above decomposition and explicit resolution of singularities, one can similarly obtain and explicit elimination of indeterminancies.

   There are several geometric problems solved by such explicit construction. As a consequence, it is proved by Chen and his collaboration Meng Chen of Fudan University that three dimensional version of Noether Inequality holds. This inequality also leads to the foundation of the study of geography of threefolds of general type. By geography, one means the distribution of invariants and relations of invariants. The worst known example of threefolds of general type is a general hypersurface X_{46} of degree 46 in a weighted projective space $\mathbb{P}(4, 5, 6, 7, 23)$. This example with canonical volume $1/420$ is certainly on the boundary of the "map" by geographical consideration. By the above mentioned technique, it is proved that canonical volume $\geq 1/1170$, which is not far from being sharp.

   Similar technique could be applicable to the studies of Fano-type threefolds as well. There is an ongoing project of Jheng-Jie Chen and Ching-Jui Lai on bounding c_2 and c_1^3 of weak $\mathbb{Q}$-Fano threefols. It is expected that $c_1^3 \leq 72$ for all weak $\mathbb{Q}$-Fano threefols and this bound is sharp. It is also expected that c_2 is aways pseudo-effective for all weak $\mathbb{Q}$-Fano threefolds.

It is expected that explicit birational geometry of threefolds will be an indispensible part toward the geometry of threefolds.

The goal is to build up complete classification theory parallel to that of surfaces. A better understanding of threefolds explicitly will be helpful to general higher dimensional varieties

b. Derived categories and homological algebraic geometry

Derived category (of bounded complexes of coherent sheaves on algebraic varieties) draws lots of attention in recent years. The milestone was Mukai's invention of Fourier-Mukai transform, which build up an fantastic equivalence between derived categories of abelian and its dual abelian varieties. Since then, more equivalence including K3 surface, elliptic fibrations and flops were discovered. There are several potential development of the theory of derived categories.

First of all, this might lead to some mysterious connection with minimal model program. It is well-known that two minimal models are connected by flops. Therefore, a flop may be considered as a birational map preserving the same level of K, called K-equivalence. It is proved that two varieties with same derived categories, called D-equivalence must be K-equivalence. One might imagine a derived minimal model theory which assert that a minimal model is the model with minimal derived category. Prof. Kawamata, who is also NCTS distinguished scholar, is the leading expert is this aspect and our local group has ongoing joint project with him.

Secondly, the Fourier-Mukai transform has been an effective and powerful tool for understanding moduli spaces between FM-pairs. Especially, it builds a amazing connection between two moduli spaces arising from Fourier-Mukai pairs. This reveals the hidden symmetry for abelian varieties. Later it was extended to K3 surface and Calabi-Yau threefolds. Many more interesting results was discovered thanks to the work of Bridgeland. Not only he found some moduli interpretation of the Fourier-Mukai transform, but also he built up the theory of stability on the derived categories.

The work of Wu-Yen Chuang was around this circle. His joint work with Jason Lo considered elliptic fibrations with arbitrary base dimensions, extending Lo's previous work on elliptic fibered threefolds. Their joint work gave a criterion under which certain 2-term polynomial semistable complexes are mapped to torsion-free semistable sheaves under a Fourier-Mukai transform. As an application, one can construct an open immersion from a moduli of complexes to a moduli of Gieseker stable sheaves on higher dimensional elliptic fibrations.

Thirdly, derived categories was very useful in understanding certain positive properties. Another 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, follow 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 will be further investigated during the Fall semester.

Moreover, the algebraic properties of D-modules over varieties of positive characteristics are a long-term project of Jen-Chieh Hsiao. Extending his previous joint work with K. Schwade, he is able to characterize fixed ideals over F-split toric varieties. Such studies on positive characteristics is one of the mainstreams in recent algebraic geometry and draw certain international attentions.

c. boundedness problem of Fano-type varieties

In the minimal model program, Fano varieties of Picard number one are the building blocks for varieties with negative Kodaira dimension. It it expected that the set of mildly singular Fano varieties of given dimension forms a bounded family. The challenging Borisov-Alexeev-Borisov Conjecture, which asserts boundedness of the set of ϵ-klt log $\mathbb{Q}$-Fano varieties is one of the fundamental conjecture in minimal model theory. It is believed that BAB conjecture is more or less equivalent to the conjecture of termination of flips. In the previous work of Lai, an effective upper bound of the anticanonical volume for the set of ϵ-klt $\mathbb{Q}$-factorial log $\mathbb{Q}$-Fano threefolds with Picard number one was obtained. He made some progress along this direction by considering threefolds not necessarily of Picard number one. His studies also show that it is possible to obtain an effective Sarkisov Program in dimension three, which factorizes birational maps between Mori fibered spaces into elementary Sarkisov's links.

III.3 Differential Geometry and Geometric Analysis

1. Core Mambers

a. Organizers: Mao-Pei Tsui (NTU), Nan-Kuo Ho (NTHU), Chun-Chi Lin (NTNU), Hong-Lin Chiu (NCU) and River Chiang (NCKU).

b. Faculties: Chung-Jun Tsai, Ziming Nikolas Ma, Suh-Cheng Chang, Yng-Ing Lee (NTU), Jih-Hsin Cheng (Academia Sinica), Siye Wu, Chiung-Jue Sung, Dong-Ho Tsai (NTHU), Mei-Lin Yau, Rung-Tzung Huang (NCU), Kwok-Kun Kwong(NCKU), Ching-Tung Wu (NPU).

c. Postdocs: Kuo-Wei Lee (NTU), Chih-Wei Chen (NCTS), Yang-Kai Lue (NCTS), Yen-Chang Huang, Sin-Hua Lai (NCU), Ting-Huei Chang, Chung-Yi Ho, Chi-Kwong Fok (NCTS), Ching-Hao Chang(AS), Chih-Chung Liu (NCKU).

2. Overview of the Program

The main goal of the differential geometry and geometric analysis group at NCTS is to create an excellent research environment for Taiwanese differential geometers to work on world class research topics and provide necessary resources to conduct both international research cooperation and research cooperation in Taiwan. Our research group has been very active and maintains a high research standard thanks to the consistent support of NCTS. It is also an important focus to integrate our activities to attract excellent undergraduate and graduate students and also provide new opportunities for the postdoc and junior faculty to broaden their research perspectives. We are hoping that our activities will enhance international visibility of differential geometers in Taiwan. The research topics of this program cover a wide spectrum of in differentia geometry. This year we focus on the following four areas:

a. Geometric evolution equations

b. Mathematical general relativity

c. Symplectic geometry and Mirror Symmetry

d. Geometry of CR manifolds

For the moment, there are several working teams in our groups.

a. Mao-Pei Tsui (NTU) and Yng-Ing Lee (NTU) togather with a Ph.D student are working on problems related to minimal surface systems and Lagrangian mean curvature flow

b. Mao-Pei Tsui (NTU) and Chun-Chi Lin (NTNU) are exploring on some geometric problems related to soft matter

c. Chun-Chi Lin (NTNU) and Yang-Kai Lue (NCTS postdoc) are working on higher older geometric flows

d. Jih-Hsin Cheng (AS), Hong-Lin Chiu (NCU) togather with postdoc Yen-Chang Huang (NCU), Sin-Hua Lai (NCU), Ching-Hao Chang(AS) are working on problems related to subriemannian and CR geometry

e. Shu-Cheng Chang (NTU) and Chih-Wei Chen (NCTS postdoc) are working on the classification of CR Yamabe soliton

In this coming year, we are hoping to strengthen these working teams and create more cooperation opportunities between active differential geometers. Our activities and visitors have broaden and strengthen the research topics in our group. This will lead to a steady growth of the differential geometry and geometric analysis group.

3. Highlights

The highlights of the program consists of two parts: first, we describe some important breakthroughs in our group and second, the important activities of this year.

Our group members have been very productive this year. Mao-Pei Tsui and Yng-Ing Lee have obtained a result in the uniqueness of the minimal surface systems, Nan-Kuo Ho and M. Guest have found surprising relations between the solutions to tt*-Toda equations and classical Lie group theory (as in Kostant, Coxeter, and Steinberg), Chun-Chi Lin, Dall'Acqua and P. Pozzi obtained interesting results about the gradient flow for open elastic curves with fixed length and clamped ends, River Chiang, Fan Ding, and Otto Van Koert define symplectic fractional twists, which generalize Dehn twists, and use these in open books to investigate contact structures, Kwok-Kun Kwong obtains sharp Hodge Laplacian and Steklov eigenvalue estimates for differential forms and a functional inequality on the boundary of static manifolds, Ziming Nikolas generalized earlier work on Witten deformation to two interesting cases, namely the Witten deformation of circle valued Morse function and Witten deformation of S^1 equivariant cohomology, Chi-Wei Chen obtained Shi-type estimates and the volume estimate of the Ricci flow. Due to the limited space, we will only describe in detail the works of Chung-Jun Tsai in mean curvature flow and Jih-Hsin Cheng in CR and subriemannian geometry.

a. The stability of the mean curvature flow in manifolds of special holonomy

In the 50s, M. Berger classified the possible irreducible holonomies of a Riemannian manifold. There are some special ones in his list:

holonomy	dimension	geometry
SU(n)	$2n$	Calabi–Yau
Sp(n)	$4n$	hyper-Kähler
G2	7	G2
Spin(7)	8	Spin(7)

Theses geometry can be characterized by the existence of certain parallel forms. The existence of these parallel forms implies that the metric is Ricci-flat. On the other hand, these parallel forms are all *calibration* forms as introduced by

R. Harvey and B. Lawson. From a calibration form, they define the notion of a *calibrated submanifold*. These submanifolds are not just minimal submanifolds, they actually minimize the volume functional in their homology classes.

Of particular interests are special Lagrangians in Calabi–Yau, associatives and coassociatives in G2, and Cayley submanifolds in Spin(7). These geometric objects attracted a lot of attentions in recent years. On the one hand, they are natural generalizations of algebraic subvarieties in algebraic manifolds and thus are of immense geometric interest. On the other hand, they appear in various proposals of string theory such as Mirror Symmetry and the M-theory. However, our understanding of these geometric objects is still rather limited.

Since calibrated submanifolds are minimal, it is a natural attempt to construct calibrated submanifold by the mean curvature flow. Recently, Mu-Tao Wang and Chung-Jun Tsai study the mean curvature flow in the most well-known examples of manifolds with special holonomy. They are the Stenzel metric on the cotangent bundles of spheres, the Calabi metric on the cotangent bundles of complex projective spaces, and the Bryant-Salamon construction of G2 and Spin(7) metrics. These examples are all total space of a vector bundle, and the zero section is a calibrated submanifold. They are believed to serve as the leading order approximation for the neighborhood of a calibrated submanifold. By the work of R. McLean, the zero section is stable in the sense of the second variational formula.

In a joint paper with Mu-Tao Wang, Chung-Jun Tsai proves that the zero section is the unique *compact*, minimal submanifold. In contrast to the result of R. McLean, their result is a *global rigidity* result. Moreover, they use the estimates in the global rigidity to prove the dynamical stability of the zero section. Namely, any submanifold which is C^1-close to the zero section must converge to the zero section under the mean curvature flow. This dynamical stability theorem appears to be the first such result for manifolds of special holonomy.

b. The classification of immersed, connected, umbilic hypersurfaces in the Heisenberg group H_n with $n \geq 2$.

   In a series of papers, Jih-Hsin Cheng, Hung-Lin Chiu, Jenn-Fang Hwang and Paul Yang have showed that such a hypersurface, if closed, must be rotationally invariant up to a Heisenberg translation. Moreover, they proved that, among others, Pansu spheres are the only such spheres with positive constant sigma-k curvature up to Heisenberg translations. This is the first paper dealing with characterization of Pansu spheres in H_n with $n \geq 2$. They are revising the Strong maximum principle (SMP) techniques used in their earlier works and they have extended the SMP to a very general setting including mean curvature operator in subriemannian geometry. It is expected that these tools can be used to studied other problems in subriemannian geometry.

c. Local index theorem for CR manifolds with S^1 action In a recent preprint with Chin-Yu Hsiao and I-Hsun Tsai , Jih-Hsin Cheng established a local index theorem for CR manifolds with S^1 action. Among those transversally elliptic operators initiated by Atiyah and Singer, Kohn's $\Box_b$ operator on CR manifolds with S^1 action is a natural one of geometric significance for complex analysts. Our first main result establishes an asymptotic expansion for the heat kernel of such an operator with values in its Fourier components, which involves an unprecedented contribution in terms of a distance function from the lower dimensional stratum of the S^1-action. Our second main result computes a local index density, in terms of *tangential* characteristic forms, on such manifolds including *Sasakian manifolds* of interest in String Theory, by showing that the non-trivial contributions from the stratum in the heat kernel expansion will eventually cancel out by applying Getzler's rescaling technique to off-diagonal estimates. This leads to a local index theorem on these CR manifolds. As applications of our CR index theorem we can prove a CR version of Grauert-Riemenschneider criterion, and produce many CR functions on a weakly pseudoconvex CR manifold with transversal S^1 action and many CR sections on some class of CR manifolds, answering some long-standing questions raised by Kohn and Henkin respectively. We give examples of these CR manifolds, some of which arise from generalized Brieskorn manifolds. Moreover in some cases, taking an approach which does not rely on the usual one using equivariant cohomology neither on the stratum of the orbifold, we can reinterpret Kawasaki's Hirzebruch-Riemann-Roch formula for a complex orbifold with an orbifold holomorphic line bundle as an index theorem obtained by an integral over a smooth CR manifold which is essentially the circle bundle of this line bundle.

Next we describe the list and describe some of the most important activities this year.

a. Weekly differential geometry seminar at NTU, Sinica - NCTS Geometry Seminar at Academia Sinica

b. 2016 The third Taiwan International Conference on Geometry (2016-01-18–2016-01-22) The main topics of the third Taiwan International Conference on Geometry are on conformal geometry, CR structures, and minimal submanifolds. This is a successful joint conference with Institute of Math, Academia Sinica. The speakers of this conference include some of the most active researchers in differential geometry.

c. NCTS one day workshop on symplectic and poisson geometry at NTHU (June 8, 2016)

   This was organized in the occasion of a visit of Professor Reyer Sjamaar (Cornell University). Professor Reyer Sjamaar (Cornell University) gave a talk on "Convexity properties of presymplectic Hamiltonian actions". Our NCTS postdoc Chi-Kwong Fok and a graduate student Hsuan-Yi Liao from Pennsylvania State University also gave talks on . Equivariant formality of homogeneous spaces and KontsevichDuflo theorem respectively.

d. Two Taiwan Geometry Symposium (24-25, 2015 at NDHU, May 14, 2016 at NTHU)

   This series of Symposium was started in the year 2010 . These two are the 12th and thirteen belong to the series. Each time, we invited some young geometers or world leading experts to talk about the most recent advances in differential geometry.

e. Workshop for young geometers (December 13th, 2015)

f. Special Day on the mathematics of relativity (December 28, 2015) and NCTS Special Day on Isometric Embeddings (July 15, 2016)

g. NCTS Summer Course on Aspects of Geometric Analysis (July 3-12, 2016 at NTU)

   A summer course "Aspects of Geometric Analysis" organized by Mao-Pei Tsui and Mu-Tao Wang took place from July 4th to July 12th, 2016. The course was intended for advanced undergraduate students or beginning graduate students who are interested in the field of Geometric Analysis. The emphasis is on geometric partial differential equations on Riemannian manifolds with elementary four topic lectures: Riemannian manifolds and submanifolds geometry (Mu-Tao Wang), isometric embeddings of surfaces (Ye-Kai Wang), Ricci flows on surfaces (Mao-Pei Tsui), and the Poincaré uniformization theorem (Chung-Jun Tsai). They are followed by an advanced topic lecture "The geometry of the Schwarzschild spacetime" by Mu-Tao Wang. Many undergraduate students have attended this summer course.

h. Summer Course on Fractional Sobolev Spaces in Geometric Knot Theory (August 2-5, at NTU)

   Fractional Sobolev spaces and fractional partial differential equations appear in many areas of current mathematics. In this series of lectures, Simon Blatt (University of Salzburg) give an introduction to the topic and recent applications in geometric knot theory. He started this series of talks with an introduction to geometric knot theory and fractional Sobolev spaces and operators. Then he discussed in two lectures the regularity of critical points of knot energies and their negative gradient flows.

i. NCTS Mini course on Mirror Symmetry (June 18-20, at NTU), Mini Course on Symplectic Fillings and More (July,26–28, 2016)

   In the "Mirror Symmetry" minicourse, Professor Kazushi Ueda will give an introduction to mirror symmetry, with emphasis on explicit examples. Jongil Park talked about symplectic fillings and Milnor fibers of quotient surface singularities and Cheuk Yu Mak discussed ”Symplectic caps and application to symplectic fillings” and ”Symplectic log Calabi-Yau surfaces”

j. NCTS International Workshop on Geometric Analysis and Subelliptic PDEs(May 24-26, 2016)

III.4 Differential Equations and Stochastic Analysis

1. Core Mambers

a. Organizers: Jenn-Nan Wang (NTU), Yuan-Chung Cheu (NCTU), Jung-Chao Ban (NDHU), Chao-Nien Chen (NTHU),

b. Faculties: Chiun-Chuan Chen(NTU), Jann-Long Chern (NCU), Kuo-Chang Chen (NTHU), Kung-Chien Wu (NCKU), Hung-Wen Kuo (NCKU), Jin-Cheng Jiang (NTHU), Lung-Chi Chen (NCCU), Shuenn-Jyi Sheu (NCU), chang-Hung Wu (Tainan U.), Chin-Lung Lin (NCKU), Ru-Lin Kuan (NCKU), Zhi-You Chen (NCUE), Shin-Yuan Huang (NSYSU), Chun-Hsiung Haia (NTU), Feng-Bin Wang (Chang Gung U.)

c. Postdocs: Catelin Castea (NCTS), Li-Ren Lin (NCKU), Manas Kar (NCTS), Chien-Hao Huang (NCTS), Cheng-Fan Su (NCU)

d. Students: 10 Ph.D/ 20 Master

2. Overview of the Program This program is the most diverse program in the NCTS. Differential equations and stochastic analysis are developed independently. But in this program, we aim to bridge the gap between these two topics. On the other hand, mathematical biology and dynamical systems are the most important applied fields of differential equations. The techniques of differential equations may provide essential tools in stochastic analysis and mathematical biology; while problems arising from stochastic analysis, mathematical biology, and dynamical systems motive the development of differential equations. Besides of the interdisciplinary studies, we also put our efforts on improving research achievements in each field.

a. In the subprogram on PDEs, continuing from the focus topics last year, we are mainly concerned with the kinetic theory, fluid equations, nonlinear Schrödinger equations, inverse problems, etc. We have made progress on the Liouville equation with exponential nonlinearity, the Landau equation, and the Carleman estimates for equations with discontinuous coefficients. We also organized a symposium for young scholars in which all of speakers are either postdocs or PhD students.

b. For the subprogram on dynamical systems, in addition to the research achievements on higher dimensional symbolic dynamical systems and tree shifts of finite type (TSFTs), entire solutions for delayed monostable epidemic models, and symbolic embeddings for difference equations, we also organized several activities. First, the one-day workshop "2016 Young Dynamical Day" was held in February. Later, we organized a conference "2016 workshop on dynamical systems & 2016 China, Hongkong, Taiwan joint conference on dynamical systems" in middle August. From 5 Aug to 12 Sep, we organized a summer course for students, the topics of this course are on the topological and arithmetic dynamics.

c. Neuroscience is one of the fastest growing fields in biology in this century. As enormous amount of neural imaging data have been produced in the past decade, informatics tools and data-sharing platforms that provide efficient analysis, modeling and management of these data are urgently needed. With an aim to facilitate interactions between researchers in mathematics and related fields, we organize a workshop in respond to the demand. Through the stimulation of novel ideas from international renowned researchers, local experts across disciplines to share their latest studies. In the mathematical biology subprogram, we have obtained interesting results for the reaction-diffusion equations that improve many existing results. Moreover, we studied the wave phenomena on the sphere and found that the stationary waves for the bistable kinetics on the sphere play a key role in the study of waves on the sphere. We also investigated new phenomena of the 3-species competing system not observed in the 2-species system. Several activities including workshops, tutorials, and special lectures were organized in this year.

d. The group on the stochastic analysis in Taiwan is small, but the members are very close and work very hard in recruiting young scholars and students. Research-wise, we studied topics such as Markov chains and mixing, phase transitions and critical behavior for self-avoiding walk and percolation, and the techniques of diffusion maps, etc. We also organized workshops and summer short courses.

3. Highlights

We obtained many important results in this year's program. In the following, we list some selective achievements.

a. Partial differential equations

(1) In Chiun-Chuan Chen and Chang-Shou Lin's work, they studies the Liouville equation with singular sources and derived the topological degree formula for noncritical values of the total mass. They also give several applications of this formula, including existence of the curvature $+1$ metric with

conic singularities, doubly periodic solutions of electroweak theory, and a special case of self-gravitating strings.

(2) In the study of the kinetic theory, Kung-Chien Wu (joint work with Kleber Carrapatoso and Isabelle Tristani) consider the inhomogeneous Landau equation on the torus in the cases of hard, Maxwellian and moderately soft potentials. They first investigate the linearized equation and prove exponential decay estimates for the associated semigroup. They then turn to the nonlinear equation and use the linearized semigroup decay in order to construct solutions in a close-to-equilibrium setting. Finally, they prove an exponential stability for such a solution, with a rate as close as we want to the optimal rate given by the semigroup decay. It is important to underline the fact that their paper largely improves previous results on the Cauchy theory associated to the Landau equation in a perturbative setting. Indeed, they considerably have enlarged the space in which the Cauchy theory has been developed in two ways: the weight of our space is much less restrictive (it can be a polynomial or stretched exponential weight instead of the inverse Maxwellian equilibrium) and we also require less assumptions on the derivatives, in particular no derivatives in the velocity variable.

(3) Jenn-Nan Wang, collaborating with Michele Di Cristo, Elisa Franchi, Ching-Lung Lin, and Sergio Vessella, derive a local Carleman estimate for second order elliptic equations with a general anisotropic Lipschitz coefficients having a jump at an interface. The argument they use is of microlocal nature. Yet, not relying on pseudodifferential calculus, their approach allows one to achieve almost optimal assumptions on the regularity of the coefficients and, consequently, of the interface. Having proved the Carleman estimate, they then go on to study the size estimate problem when the background materials have jump discontinuities.

b. Dynamical systems

(1) Jung-Chao Ban and Chih-Hung Chang in the paper "Tree-Shifts: Irreducibility, mixing, and the chaos of tree-shifts" (scheduled to appear in the Transaction of AMS) study shifts defined on infinite trees, which are called tree-shifts. Topological behavior, such as chaos, irreducibility, and mixing of a one-sided shift of finite type, is well elucidated. Meanwhile, the investigation of multidimensional shifts, for instance, textile systems is difficult and only a few results have been obtained so far. Infinite trees have a natural structure of one-sided symbolic dynamical systems equipped with multiple shift maps and constitute an intermediate class in 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 are 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. A necessary and sufficient condition for the irreducibility and mixing of tree-shifts of finite type is demonstrated. Most important of all, the examination can be done in finite steps with an upper bound.

(2) In the paper "Stability of symbolic embeddings for difference equations and their multidimensional perturbations" by Hung-Ju Chen and Ming-Chia Li, they study complexity of solutions of a high-dimensional difference equation of the form

$$\Phi(x_{i-m}, \cdots, x_{i-1}, x_i, x_{i+1}, \cdots, x_{i+n}) = 0, \quad i \in \mathbb{Z},$$

where Φ is a C^1 function from $(R^\ell)^{m+n+1}$ to R^ℓ. Their main result provides a sufficient condition for any sufficiently small C^1 perturbation of Φ to have symbolic embedding, that is, to possess a closed set of solutions Λ that is invariant under the shift map, such that the restriction of the shift map to Λ is topologically conjugate to a subshift of finite type. The sufficient condition can be easily verified when Φ depends on few variables, including the logistic and Hénon families. To prove the result, they establish a global version of the implicit function theorem for perturbed equations. The proof of the main result is based on the Brouwer fixed point theorem, and the proof of the global implicit function theorem is based on the contraction mapping principle and other ingredients.

c. Mathematical biology

(1) Je-Chiang Tsai and his collaborators study the reaction-diffusion systems on the sphere. It turns out there are very few works for reaction-diffusion systems on the sphere. However, recent investigation of immune systems suggests that it is necessary to study the wave phenomena on the sphere. On the other hand, due to the boundedness of the sphere, the notion of traveling waves must be adapted. They have found that the stationary waves for the bistable kinetics on the sphere play a key role in the study of waves on the sphere. Indeed, they have used the stationary waves to construct suitable sub/super-solutions to explain the propagating phenomena on the sphere. The difficulty of analysis arises from the lack of the explicit form of the Green function for the Laplace-Beltrami operator.

(2) Chao-Nien Chen, Chiun-Chuan Chen and Chih-Chiang Huang in their paper "Traveling waves for the FitzHugh Nagumo system on an infinite channel", appeared in J. Differential Equations, study the traveling wave solutions of the FitzHughNagumo system on an infinite channel. Based on a

variational formulation in which a non-local term depends on a parameter, the speed of a traveling wave can be selected out. Furthermore, to show the existence of a traveling wave solution with such a speed, we seek a minimizer subject to a constraint.

Interesting activities in this subprogram include (i) 2015 NCTS Workshop on Partial Differential Equations and Applied Mathematics organized by Chiun-Chuan Chen and Chao-Nien Chen featured invited speakers Sze-Bi Hsu (National Tsing Hua University), Shin-Ichiro Ei (Hokkaido University), Li-Chang Hung (National Taiwan University), Zhi-You Chen (National Changhua University of Education), Feng-Bin Wang (Chang Gung University), Shigeru Sakaguchi (Tohoku University); (ii) 2015 NCTS Special lecture on dynamical systems given by Petrus van Heijster (Queensland University of Technology); (iii) 2016 NCTS Special lecture on Analysis delivered by Nicola Fusco (University of Napoli, Italy).

d. Stochastic analysis

(1) Markov chains and mixing (led by Guan-Yu Chen). In the year of 2015-2016, the research on the quantitative analysis of Markov chains focuses on the study of mixing times in the L^2-distance and total variation. Compared with the work by Chen and Saloff-Coste in 2010, we obtain several considerably simplified criteria on the L^2-cutoffs, which allow us to proceed advanced theoretical studies on more complicate models. In the total variation, we introduce a new inequality that identifies cutoffs in the total variation and Hellinger distance and, consequently, provides an easier and more delicate way to study the total variation mixing times of product chains. The results are collected in the following preprints. G.-Y. Chen, J.-M. Hsu and Y.-C. Sheu. The L^2-cutoff of reversible Markov chains, 2016, Submitted.

G.-Y. Chen and T. Kumagai. The cutoff of product chains, 2016, in preparation.

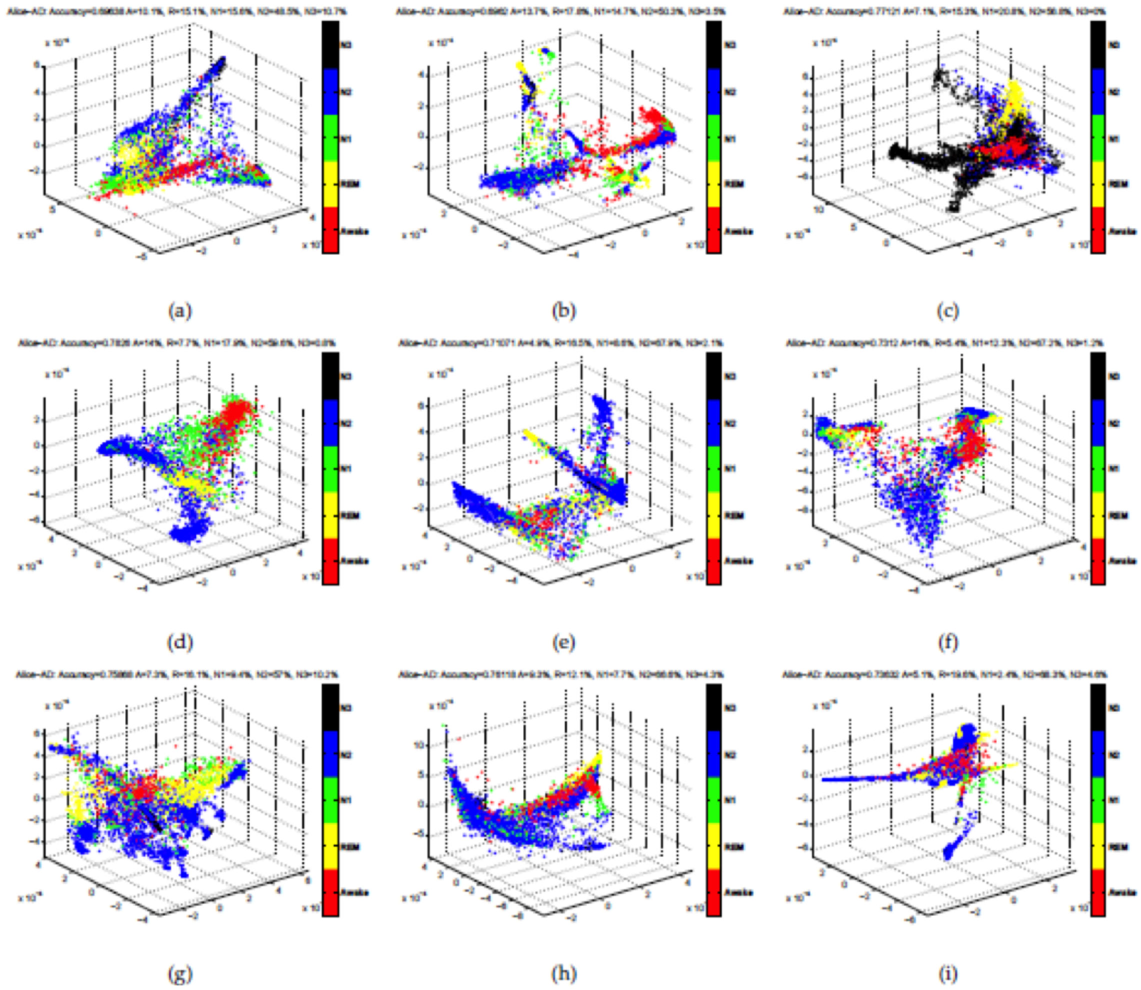
In a recent visit of Guan-Yu Chen to Hokkaido University, Guan-Yu, Kumagai and Sakai have some efficient discussions on the long-range statistical mechanics with power-law decayed potentials. Kumagai provides a brand new analytic proof (Nash inequality and cutoff function) that extends some of Sakais results in 2015 to a more general setting. Chen also provides a different method to conquer this problem using a different cutoff function and the group representation of cycles. For the future collaboration, we will consider the cutoff phenomenon on the long-range statistical mechanics and several famous statistical models, including the Ising model, spin glasses, Glauber dynamics and random walks with random conductances. In Mu-Fa Chen workshop (The 12th workshop on Markov processes and related topics), Guan-Yu Chen has a very good communication with Prof. Yong-Hua Mao and Prof. Yu-Hui Zhang (both from Beijing Normal University) and receive warm invitation to visit them next summer. A possible topic on their joint work could be the mixing time and communicate time of Markov chains and processes and a successful collaboration among them is highly expected.

(2) Assess Sleep Stage by Respiration Signal and the Techniques of Diffusion Maps (led by Gi-Ren Liu, Hau-Tieng Wu *et al.*). They study how to use the respiration signals, including the thoracic (THO) and abdominal (ABD) movement signals during sleep, to predict the time-dependent sleep stages, consisting of Awake, Rapid-Eye-Movement (REM), N1, N2, and N3. The features of the respiration signals within each time slot (5 seconds or 10 seconds) are extracted by the scattering method and the synchrosqueezing transform. They use the diffusion map to re-parameterize the time slots during sleep. Currently, the identification of the sleep stage within each time slot relies on expensive and labor-intensive Polysomnography (PSG). The figure below is the three-dimensional diffusion map of the respiration signals of nine subjects. The color of each point is determined by the corresponding sleep stage, which is identified by the PSG. The figure shows that the time slots with the same sleep stage are roughly clustered together by the diffusion map. After getting the clusters, we apply the support vector machine to separating them into five regions and use the cross validation to assess the performance of prediction. In summary, our simulation results show that the accuracy of prediction can reach around 70% at least. (please see the Figure below).

In addition to the research achievements, in this subprogram, we organized 2016 spring probability workshop and 2016 NCTS Probability summer courses. In the 2016 spring probability workshop, we successfully recruit several famous international speakers to distribute talks on their recent works with subjects on the heat kernel estimate and Harnack inequality, fractional harmonic functions with Marin boundary, the Laplacian on fractals and eigenvalue asymptotics and mean-field bound for Ising ferromagnets with high dimensions. Besides, there are several domestic young probabilists give speeches in closely related subjects or currently popular topics. The informal discussion after the workshop provides a platform for academic and private communications amount the attendees, which implicitly promotes the possible collaboration between the Taiwanese and international probability people in the future. The topics in 2016 NCTS Probability summer courses are (i) Markov chains and mixing times; (ii) Introduction to Stochastic Calculus and Applications .

III.5 Scientific Computing

1. Core Mambers



a. Faculties: Weichung Wang (NTU), I-Liang Chern (NTU), Tsung-Min Huang (NTNU), Ming-Chih Lai (NCTS) Shuh-Yuh Yang (NCU).

b. Postdoc: Zhenchen Guo (ST Yau Center), Wei-Shou Su (ST Yau Center), Xin Liang (NCTU).

c. Students: 3 Ph.D. / 7 Master

d. Long-term Visitors: Zhenyue Zhang (Zhejian Univ.), Tiexiang Li (South-East Univ.)

2. Overview of the Program

Due to the enormous progress in computer technology and numerical software that have been achieved in recent years, the use of numerical simulations in exploring new sciences and engineering gains more and more importance. Scientific computation in many cases offers a cost effective technique, such as numerical linear algebra, computational fluid dynamics and computational electromagnetism, to investigate the real-life sciences which has been regarded equally ubiquitous along with the experiment and theory. A challenging topic in scientific computing is how to design efficient algorithms for numerical PDE, numerical linear algebra, computational electromagnetism, computational fluid dynamics, fluid-structure interaction problems etc., on modern computer systems (CPU/GPU parallelization).

Based on the existing research man power in Taiwan and the current frontier research directions internationally, in this year, our focus is on, but on restricted to, the following topics:

a. Numerical PDEs for solving 3D inextensible vesicle in Navier-Stokes flows, and the electrodeformation and electrohydrodynamics of a vesicle in Navier-Stokes leaky dielectric fluids under a DC electric field;

b. Numerical PDEs for solving singularly perturbed problems, Maxwell's equations with non-H^1 solution, and fluid-structure interaction problems;

c. Matrix computations in three dimensional (3D) dispersive metallic photonic crystals, 3D Maxwell's transmission eigenvalue problems, computing the smallest eigenpair of a large irreducible M-matrix

d. High-performance computing in linear system solver for 3D FDFD photonic device analysis, solving the information-criterion-based optimization problems and rank-revealing.

e. Bayesian uncertainty quantification in sparse representation surrogate modeling, the singular value decomposition of large-scale matrices, experimental designs in computer experiments and optimal designs for mixture models in data science

In this year, we attracted world leading experts to visit NCTS for a longer period, for example, Rio Yokota and Edmond Chow give a short course for fast multipole methods (FMM) and high-performance numerical solvers with applications from March 21 to March 25 and May 3 to May 19, respectively. Not only this, we also invite Daniel B. Szyld who is the Editor-in-Chief of SIAM Journal on Matrix Analysis and Applications to visit NCTS and give a talk in Workshop on Recent Development of Matrix Computations. In order to provide the opportunity of academic discussion for the scientific computing researchers, we also organize 2016 NCTS Workshop on Computational Mathematics for Young Researchers at March 18-19.

3. Highlights

In recent years, the scientific computing groups in NCTS have yielded significant advances in the topics of numerical PDEs for Navier-Stokes equations, matrix computations for three-dimensional (3D) Maxwell equations, high performance computing and data science. The most significant contributions include the following:

a. Numerical method for 3D vesicle simulations.
The research team led by Ming-Chih Lai extends their previous immersed boundary (IB) method for 3D axisymmetric inextensible vesicle in Navier-Stokes flows

to general three dimensions. Despite a similar spirit in numerical algorithms to the axisymmetric case, the fully 3D numerical implementation is much more complicated and is far from straightforward. A vesicle membrane surface is known to be incompressible and exhibits bending resistance. As in 3D axisymmetric case, instead of keeping the vesicle locally incompressible, they adopt a modified elastic tension energy to make the vesicle surface patch nearly incompressible so that solving the unknown tension (Lagrange multiplier for the incompressible constraint) can be avoided. Nevertheless, the new elastic force derived from the modified tension energy has exactly the same mathematical form as the original one except the different definitions of tension. The vesicle surface is discretized on a triangular mesh where the elastic tension and bending force are calculated on each vertex (Lagrangian marker in the IB method) of the triangulation. A series of numerical tests on the present scheme are conducted to illustrate the robustness and applicability of the method. They perform the convergence study for the immersed boundary forces and the fluid velocity field. They then study the vesicle dynamics in various flows such as quiescent, simple shear, and gravitational flows. Their numerical results show good agreements with those obtained in previous theoretical, experimental and numerical studies.

b. Numerical study for droplet bouncing and coalescence with surfactant.
The research team led by Ming-Chih Lai performs a direct simulation to account for the continuum and short-range flow dynamics of the approaching interfaces, as affected by the soluble surfactant. Based on the immersed-boundary formulation, a conservative scheme is developed for solving the coupled surface-bulk convection-diffusion concentration equations, which presents excellent mass preservation in the solvent as well as conservation of total surfactant mass. They show that the Marangoni effect, caused by non-uniform distributions of surfactant on the droplet surface and surface tension, induces stresses that oppose the draining of gas in the interstitial gap, and hence prohibits merging of the interfaces. In such gas-liquid systems, the repulsion caused by the addition of surfactant, as frequently observed in liquid-liquid systems such as emulsions in the form of an electric double-layer force, was found to be too weak to dominate in the attainable range of interfacial separation distances. These results thus identify the key mechanisms governing the impact dynamics of surfactant-coated droplets in air and imply the potential of using a small amount of surfactant to manipulate impact outcomes, for example, to prevent coalescence between droplets or interfaces in gases.

c. Coupling IB and IIM to study the vesicle electrohydrodynamics.
The research team led by Ming-Chih Lai develops a coupled immersed boundary (IB) and immersed interface method (IIM) to simulate the electrodeformation and electrohydrodynamics of a vesicle in Navier-Stokes leaky dielectric fluids

under a DC electric field. The vesicle membrane is modeled as an inextensible elastic interface with an electric capacitance and an electric conductance. Within the leaky dielectric framework and the piecewise constant electric properties in each fluid, the electric stress can be treated as an interfacial force so that both the membrane electric and mechanical forces can be formulated in a unified immersed boundary method. The electric potential and transmembrane potential are solved simultaneously via an efficient immersed interface method. The fluid variables in Navier-Stokes equations are solved using a projection method on a staggered MAC grid while the electric potential is solved at the cell center. A series of numerical tests have been carefully conducted to illustrate the accuracy and applicability of the present method to simulate vesicle electrohydrodynamics. In particular, we investigate the prolate-oblate-prolate (POP) transition and the effect of electric field and shear flow on vesicle electrohydrodynamics. Their numerical results are in good agreement with those obtained in previous work using different numerical algorithms.

d. 3D dispersive metallic photonic crystals.
The electromagnetic wave propagation through dispersive metallic photonic crystals has been extensively studied over the past few decades. A standard model to study the electromagnetic effects in periodic structures and dispersive isotropic materials is the 3D Maxwell equation. In the numerical simulation of 3D dispersive metallic photonic crystals, one important task is to compute the corresponding band structures. In the computing band structure, the discretized Maxwell equations result in large-scale nonlinear eigenvalue problems, which are very challenging due to a high dimensional subspace associated with the eigenvalue zero and the fact that the desired eigenvalues (with smallest real part) cluster and close to the zero eigenvalues. For the special lossless Drude model, the nonlinear eigenvalue problem can be reformulated as a standard eigenvalue problem. To tackle these computational difficulties in solving standard and nonlinear eigenvalue problems, the research team led by Wen-Wei Lin, together with Tsung-Ming Huang and Weichung Wang proposes a hybrid Jacobi-Davidson method (hHybrid) that integrates harmonic Rayleigh-Ritz extraction, a new and hybrid way to compute the correction vectors, and a FFT-based preconditioner to solve the standard eigenvalue problem. For the solution of the nonlinear eigenvalue problem, the research team led by Wen-Wei Lin, together with Tsung-Ming Huang and Volker Mehrmann propose a Newton-type iterative method and the nullspace-free method is applied to exclude the zero eigenvalues from the associated generalized eigenvalue problem. To find the successive eigenvalue/eigenvector pairs, they propose a new non-equivalence deflation method to transform converged eigenvalues to infinity, while all other eigenvalues remain unchanged. The deflated problem is then solved by the same

Newton-type method, which is used as a hybrid method that combines with the Jacobi-Davidson and the nonlinear Arnoldi methods to compute the clustering eigenvalues. Intensive numerical experiments show that the proposed methods are robust even for the case of computing many clustering eigenvalues in very large problems.

e. 3D Maxwell's transmission eigenvalue problems.
The transmission eigenvalue problem has recently attracted much attention in the area of inverse scattering theory, as it is important for the study of the direct/inverse scattering problem for non-absorbing inhomogeneous media. Transmission eigenvalues can be determined from the far-field pattern of the scattered wave or from the near-field data, and used to estimate the material properties of the scattering object. In addition, transmission eigenvalues are also related to the validity of some recently developed reconstruction methods for scattering problems such as the linear sampling method and factorization method.

Efficient numerical methods to determine transmission eigenvalues are required in estimating the index of refraction. Nonetheless, numerical techniques for solving the transmission eigenvalues are limited and only a few papers have addressed the issues of numerical computation on this topic in the past few years. the research team led by Wen-Wei Lin, together with Tsung-Ming Huang and Wei-Qiang Huang proposes a robust and efficient eigensolver for computing a few smallest positive eigenvalues of the three-dimensional Maxwell's transmission eigenvalue problem. The discretized governing equations by the Nédélec edge element result in a large-scale quadratic eigenvalue problem (QEP) for which the spectrum contains many zero eigenvalues and the coefficient matrices consist of patterns in the matrix form $XY^{-1}Z$, both of which prevent existing eigenvalue solvers from being efficient. To remedy these difficulties, they rewrite the QEP as a particular nonlinear eigenvalue problem and develop a secant-type iteration, together with an indefinite locally optimal block preconditioned conjugate gradient method (LOBPCG), to sequentially compute the desired positive eigenvalues. Furthermore, they propose a novel method to solve the linear systems in each iteration of LOBPCG. Intensive numerical experiments show that our proposed method is robust, although the desired real eigenvalues are surrounded by complex eigenvalues.

f. Positivity preserving algorithms for computing the smallest eigenpair of a large irreducible M-matrix.
Irreducible nonsingular M-matrices are one class of the most important matrices from applications, such as discretized PDEs, Markov chains and electric circuits, and have been studied extensively in the literature. In many applications, one is interested in finding the smallest eigenvalue and the associated eigenvector of an irreducible nonsingular M-matrix. M-matrices are closely related to nonnega-

tive matrices. Nonnegative matrices have important applications in many areas, including economics, statistics and network theory. Based on Perron Theorem, all the entries of the eigenvector associated with the smallest positive eigenvalue of an irreducible nonsingular M-matrix are positive.

The smallest eigenpair of any given matrix can be computed by the Jacobi-Davidson method, the implicitly restarted Arnoldi method and the explicitly restarted Krylov-Schur method. However, all of which cannot guarantee the positivity of approximate eigenvectors if the given matrix is an irreducible nonsingular M-matrix. The positivity of approximations is critical in applications, and if the approximations lose the positivity then they may be meaningless and could not be interpreted. In order to preserve positivity of the eigenvector, the research team led by Wen-Wei Lin, together with Zhongxiao Jia and Ching-Sung Liu presents inexact Noda iterations (INI) to find the smallest eigenvalue and the associated positive eigenvector of a large irreducible nonsingular M-matrix. They propose two different inner tolerance strategies for solving the inner linear systems involved, and prove that the convergence of resulting INI algorithms is globally linear and superlinear with the convergence order $\frac{1+\sqrt{5}}{2}$, respectively. The proposed INI algorithms are structure preserving and maintains the positivity of approximate eigenvectors. They also revisit the exact Noda iteration and establish a new quadratic convergence result. All the above is first done for the problem of computing the Perron root and the positive Perron vector of an irreducible nonnegative matrix and is then adapted to computing the smallest eigenpair of the irreducible nonsingular M-matrix. Numerical examples illustrate that the proposed INI algorithms are practical, and they always preserve the positivity of approximate eigenvectors. Comparing them with the Jacobi-Davidson method and the Arnoldi method, the overall efficiency of the INI algorithms is competitive with and can be considerably higher than the Jacobi-Davidson and Arnoldi methods.

g. Efficient Hardware-Accelerated Direct Linear System Solver for 3D FDFD Photonic Device Analysis.

Frequency-domain computation of Maxwell's equations is very important in various electromagnetic and optical simulations. Among various numerical techniques, finite-difference frequency-domain method (FDFD) is an alternative solution to the popular algorithm of finite-difference time-domain method (FDTD). The FDFD is even more important and efficient to specific photonics analysis such as resonance, sensor, and many spectrum-sensitive applications. The linear system is derived from a vector wave equation with double-curl operator over electric field and discretization based on Yee's scheme, where perfectly-matched layers (PMLs) are employed as absorptive boundary condition. The resulting sparse matrix is complex unsymmetric and ill-conditioned, where direct solver is robust and a good choice for reliable solution. However, the 3D discretization and vector field computing leads to high computation cost and memory requirement for any sparse direct solvers. The research team led by Weichung Wang, together with Cheng-Han Du and I-Hsin Chung, proposes a linear system solver based on compressed hierarchical Schur method (CHiS) for photonics device analysis. The CHiS concept is derived from domain decomposition and nested dissection, while computation redundancy is identified among subdomains and separators based on physical problem, discretization, and relations among hierarchy. The interfaces between subdomains and separators can be greatly reduced by defining of unit face and edge interfaces. For photonic devices with large homogeneous bulks or periodic structures, large portion of redundancy can be identified and removed during numerical factorization. By using customized CHiS, computation time and memory requirement can be significantly reduced compared with direct matrix solver for general matrix problems. Efficiency of the CHiS can be further enhanced by modern accelerators such as GPUs and co-processors. While we use CPU-based general sparse linear system solver in the leaf-level of the Schur hierarchy, the remaining part of computation are many dense matrix operations such as dense linear system solvers and matrix multiplications which can be processed by modern multicore and accelerators with great efficiency. The computation hierarchy can also be exploited for concurrent computing to improve utilization of hardware resources. The proposed CHiS is also tested on a dual-GPU server for performance analysis. The numerical results also demonstrate possible performance tuning considerations based on physical problem properties and computation resources. These new techniques can greatly reduce design timeframe in future development of photonic devices and circuits.

h. Sequential Designs Based on Bayesian Uncertainty Quantification in Sparse Representation Surrogate Modeling.
A numerical method, called overcomplete basis surrogate method (OBSM), was recently proposed, which employs overcomplete basis functions to achieve sparse representations. While the method can handle nonstationary response without the need of inverting large covariance matrices, it lacks the capability to quantify uncertainty in predictions. The research team led by Weichung Wang, together with Ray-Bing Chen and C. F. Jeff Wu addresses this issue by proposing a Bayesian approach that first imposes a normal prior on the large space of linear coefficients, then applies the Markov chain Monte Carlo (MCMC) algorithm to generate posterior samples for predictions. From these samples, Bayesian credible intervals can then be obtained to assess prediction uncertainty. A key application for the proposed method is the efficient construction of sequential designs. Several sequential design procedures with different infill criteria are proposed

based on the generated posterior samples. Numerical studies show that the proposed schemes are capable of solving problems of positive point identification, optimization, and surrogate fitting.

i. Integrating Multiple Random Sketches for Singular Value Decomposition.
The singular value decomposition (SVD) of large-scale matrices is a key tool in data analytics and scientific computing. The rapid growth in the size of matrices further increases the need for developing efficient large-scale SVD algorithms. Randomized SVD based on one-time sketching has been studied, and its potential has been demonstrated for computing a low-rank SVD. Instead of exploring different single random sketching techniques, the research team led by Weichung Wang, together with Ting-Li Chen, Su-Yun Huang, Hung Chen and Chienyao Lin proposes a Monte Carlo type integrated SVD algorithm based on multiple random sketches. The proposed integration algorithm takes multiple random sketches and then integrates the results obtained from the multiple sketched subspaces. So that the integrated SVD can achieve higher accuracy and lower stochastic variations. The main component of the integration is an optimization problem with a matrix Stiefel manifold constraint. The optimization problem is solved using Kolmogorov-Nagumo-type averages. Their theoretical analyses show that the singular vectors can be induced by population averaging and ensure the consistencies between the computed and true subspaces and singular vectors. Statistical analysis further proves a Strong Law of Large Numbers and gives a rate of convergence by the Central Limit Theorem. Preliminary numerical results suggest that the proposed integrated SVD algorithm is promising.

j. A new stabilized linear finite element method for reaction-convection-diffusion equations.
In this work, the research team led by Suh-Yuh Yang proposes a new stabilized linear finite element method for solving reaction-convection-diffusion equations with arbitrary magnitudes of reaction and diffusion. The key feature of the new method is that the test function in the stabilization term is taken in the adjoint-operator-like form $-\varepsilon\Delta v - (\boldsymbol{a}\cdot\nabla v)/\gamma + \sigma v$, where the parameter γ is appropriately designed to adjust the convection strength to achieve high accuracy and stability. They derive the stability estimates for the finite element solutions and establish the explicit dependence of L^2 and H^1 error bounds on the diffusivity, modulus of the convection field, reaction coefficient and the mesh size. The analysis shows that the proposed method is suitable for a wide range of mesh Péclet numbers and mesh Damköhler numbers. More specifically, if the diffusivity ε is sufficiently small with $\varepsilon < \|\boldsymbol{a}\|h$ and the reaction coefficient σ is large enough such that $\|\boldsymbol{a}\| < \sigma h$, then the method exhibits optimal convergence rates in both L^2 and H^1 norms. However, for a small reaction coefficient satisfying

$\|\boldsymbol{a}\| \geq \sigma h$, the method behaves like the well-known streamline upwind/Petrov-Galerkin formulation of Brooks and Hughes. Several numerical examples exhibiting boundary or interior layers are given to demonstrate the high performance of the proposed method. Moreover, they apply the developed method to time-dependent reaction-convection-diffusion problems and simulation results show the efficiency of the approach. The findings of this research just published in a recent issue of the top journal in computational mechanics, *"Computer Methods in Applied Mechanics and Engineering (2016)."*

III.6 Interdisciplinary Research

1. Core Mambers

a. Organizers: Chih-Hao Hsieh (NTU, Institute of Oceanography), Sze-Bi Hsu (NTHU), Tzyy-Leng Horng (FCU), Je-Chiang Tsai (NTNU)

2. Overview of the Program

We have four projects which focus on the following topics.

a. Modeling, simulation and analysis of electric double layers
Continuing from the focus topics of Project I last year, we mainly 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. Models of harmful algae with toxin degradation
Sze-Bi Hsu and his collaborators develop the modeling and mathematical analysis of partial differential equations with fixed yields. It studies the effect of the excessive dioxide in the atmosphere on the competition of phytoplankton in the ocean and lakes. Hsu and his collaborator Ya-Tang develop the modeling and analysis related to the experiments in microfluidic chemostat. Hsu and Feng-Bin Wang study the dynamics of harmful algae in the lakes with seasonal variation in temperature.

d. 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. Highlights

We obtained many important results in this year's program. In the following, we list some selective achievements.

a. Modeling, simulation and analysis of electric double layers

(1). Chiun-Chang Lee and Tai-Chia Lin et al have developed theorems for electric double layers by studying Poisson-Boltzmann type equations which are derived from the system of Poisson-Nernst-Planck equations. Our results may be comparable with experimental results of our colleagues from the school of engineering.

[1]. C. C. Lee, H. Lee, Y. Hyon, T. C. Lin and C. Liu, Boundary layer solutions of charge conserving Poisson-Boltzmann equations: one dimensional case, Comm. Math. Sci. Vol. 14, No.4(2016), 911-940.

(2). Tai-Chia Lin and Zhi-Qiang Wang (2015 NCTS visitor) study the existence and orbital stability of ground states of saturable nonlinear Schrödinger (NLS) equations. They improve the method of Cazenave and Lions (Comm Math Phys, 1982) and use a convexity argument to prove the existence and orbital stability of ground states of saturable NLS equations and intensity functions in $\mathbb{R}^2$. Besides, T.C. Lin derives the energy estimate of ground states of saturable NLS equations with intensity functions using the eigenvalue estimate of saturable NLS equations without intensity function.

[2]. T.C. Lin, X. Wang and Z.Q. Wang, Orbital stability and energy estimate of ground states of saturable nonlinear Schrödinger equations with intensity functions in $\mathbb{R}^2$, submitted.

(3). Tzyy-Leng Horng and Hsisheng Teng study electric double layer supercapacitor in nanotubes by Helmholtz model. Basically, the nanotube is so narrow that it only allows a single array of counter ion in the central axis of circular nanotube. This is just a Stern layer that can be well explained by Helmholtz model. We found the capacitance of supercapacitor, though increasing as the diameter of nanotube decreasing, would saturate below a diameter threshold. It will not go to infinity as predicted by some literatures.

[3]. Wei Hsieh, Tzyy-Leng Allen Horng, Hsin-Chieh Huang, Hsisheng Teng, 2015, Facile simulation of carbon with wide pore size distribution for electric

double-layer capacitance based on Helmholtz model, Journal of Materials Chemistry A, 3:16535-16543, (accepted July 2015, published August 2015).

(4). Tzyy-Leng Horng and Yi-Hsiang Cheng (ITRI) study desalination by nanofiltration (NF) film theoretically using PNP-steric model. We find the computation based on PNP-steric model fits well with traditional DSPM-DE model, which is a popular semi-empirical NF model that has fit well with experiments.

[4]. Tzyy-Leng Horng and Yi-Hsiang Cheng, A charged nanopore model for nanofiltration, submitted.

b. Life history traits and exploitation affect the spatial mean-variance relationship in fish abundance

(1). Fishing is expected to alter the spatial heterogeneity of fishes. As an effective index to quantify spatial heterogeneity, the exponent b in Taylor's power law (V=aMb) measures how spatial variance (V) varies with changes in mean abundance (M) of a population, with larger b indicating higher spatial aggregation. Using 50-year spatiotemporal data from the California Current Ecosystem, we examined fishing and life history effects on Taylor's exponent by comparing spatial distributions of exploited and unexploited fishes living in the same environment. Our results suggest that fishing may increase spatial aggregation of a species, likely through degrading their size/age structure. [5]. Kuo, T. C., S. Mandal, A. Yamauchi, and C. H. Hsieh (2016) Life history traits and exploitation affect the spatial mean-variance relationship in fish abundance. Ecology. 97: 1251-1259

(2). We examine how the size diversity of prey (nano-microplankton) and predators (mesozooplankton) influence trophic transfer efficiency (using biomass ratio as a proxy) in natural marine ecosystems. We reveal an interactive effect of predator and prey size diversities: the positive effect of predator size diversity becomes influential when prey size diversity is high.

[6]. Garcia-Comas, C., A. R. Sastri, L. Ye, C. Y. Chang, F. S. Lin, G. C. Gong, and C. H. Hsieh (2016) Predator size diversity promotes biomass trophic transfer and prey size diversity hinders it in planktonic communities. Proceedings of the Royal Society of London, Series B. 283: 20152129.

(3). We propose a method for detecting evolutionary forces underlying community assembly by quantifying the strength of community-environment relationships hierarchically along taxonomic ranks. This approach explores the potential role of phylogenetic conservatism on habitat preferences: wherein, phylogenetically related taxa are expected to exhibit similar environmental responses.

[7]. Lu, H. P., Y. C. Yeh, A. Sastri, F. K. Shiah, G. C. Gong, and C. H. Hsieh

(2016) Evaluating community-environment relationships along fine to broad taxonomic resolutions reveals evolutionary forces underlying community assembly. ISME Journal. doi:10.1038/ismej.2016.78.

c. Models of harmful algae with toxin degradation

(1). S.B.Hsu and Ya-Tang Yang consider the dynamics of planktonic and biofilm population in a microfluidic chemostat.

[8]. S.B.Hsu and Ya-Tang Yang, *Theory of microfluidic serial dilution for the growth of planktonic and biofilm population.* J.Math. Biology (2016) 1401-1427

(2). S.B.Hsu, Nie Hua and J.P.Grover study the effect of excessive dioxide in the atmosphere on algae competition in a water column.

[9]. S.B.Hsu, Nie Hua and J.P.Grover, *Algae competition in a water column with excessive dioxide in the atmosphere*, J.Math. Biology(2016), p.437-446

(3). S.B. Hsu,Wang Feng-Bin and Wendi Wang study the effect of temperature on the dynamics of harmful algae. With variation of temperature we may have coexistence.

[10]. S.B. Hsu,Wang Feng-Bin and Wendi Wang, *Dynamics of harmful algae with seasonal temperature in the cove-main lake*, DCDS-B (2016) p. 313-335.

(4). S.B. Hsu,Feng-Bin Wang and Zhao XQ study the effect of periodic input of two phytoplankton species in a chemostat with internal storage.

[11]. S.B. Hsu,Feng-Bin Wang and Zhao XQ, *Competition for two essential resources with internal storage and periodic input in a chemostat*, Differential and Integral Equations (2016) p. 601-630

d. Mathematical models of cancer stem cell

We have assumed that the kinetics between E2F6 mRNA and miR-193a and the one between c-KIT mRNA and miR-193a are fast enough, and then applied linear noise approximation to study the dependence of stochastic noise on the strength of the E2F6 protein regulating the transcription rate of miR-193a. Our analysis seems to indicate that the high steady state of the c-KIT level is robust with respect to stochastic noise.

[12]. B.D. Aguda, J.-C. Tsai, T.W. Hwang, and Michael Chan, The role of E2F6 protein regulation on miR-193a in cancer stem cells, submitted.

III.7 Big and Complex Data Analysis (Open Call Program)

1. Core Mambers

a. Faculties: Meihui Guo (NSYSU); Ray-Bing Chen (NCKU),Mong-Na Lo Huang(NSYSU), Yun-Chan Chi (NCKU), Miin-Jye Wen (NCKU), Pei-Fang Su (NCKU), ChingKang Ing (Academia Sinica), Yu-Feng Huang (National Chung Cheng Univ.), Shih-Feng Hunag (NUK)

b. Postdocs: 1
c. Students: 10 Ph.D./80 Master
d. Long-term Visitors: Kerby Shedden (Michigan), Inchi Hu (HKUST)

2. Overview of the Program

In this report we focus on the international cooperation and activities.

a. Workshops and short courses: We organized four workshops and one short course. Several internationally renowned scholars were invited as keynote speakers of the workshops and short course. (a) In last Dec. (2015.12.09), we held the "Workshop on Complex and High-Dimensional Data Analysis". Two academicians of Academia Sinica, Prof. Ruey S. Tsay (Univ. of Chicago) and Prof. Ker-Chau Li (UCLA), Prof. Wei Biao Wu (Univ. of Chicago) and Prof. Henry Horng-Shing Lu (Chiao Tung Univ.) are the four keynote speakers. In addition, there are other 11 international/domestic renowned scholars join the workshop as invited speakers. (b) A mini-workshop, "Big and Small Data in Statistical Quality Control and Reliability Analysis", was held in this May (2016.05). The keynote speakers are Prof. Regina Liu (Rutgers University) and Prof. Jen Tang (Purdue University). In this miniworkshop, we also had two industrial engineers from ITRI and tsmc to share their experiences with us. (c) This summer we invited Prof. Shaw-Hwa Lo and Prof. Tian Zheng (Dept. of Stat., Columbia University) and their research team to give a one-day "Big Data Learning for Prediction" workshop. They introduced the I-score technology for discovering possible function relations among candidate variables in Big Data scenarios. (d) In this December, we will have a workshop on "Experimental Design and Uncertainty Quantification". We are working on inviting several international experts to share their new research results in experimental design and uncertainty quantification with us. Currently the speakers are Prof. Dennis Lin (Penn Stat Univ.); Weng Kee Wong (UCLA) and Prof. Hongquan Xu (UCLA). (e) We invited Prof. Inchi Hu (Hong Kong University of Science and Technology) to give a mini-course on high dimensional data analysis at NCTS in December 2016.

b. Encourage domestic young researchers to attend international conferences and have short term visits: It is important to encourage young faculties to attend international conferences and have short term academic visiting. These activities help young researchers to build their international connections and explore their research fields. In this year, Prof. Pei-Fang Su visited Vanderbilt University on this August. Prof. Ray-Bing Chen attended the 2016 Joint Statistical Meeting and then visit Departments of Statistics and Biostatistics, UCLA, for a few days. Prof. Chieh-Sen Huang visited University of Texas at Austin.

c. Build international research cooperations: The followings are the ongoing international research cooperations.

(1). The joint work with the Vanderbilt Center for Quantitative Sciences (CQS): This research center is led by Dr. Yu Shyr. CQS coordinates and integrates the work of Vanderbilt University and Medical Center quantitative scientists across the disciplines of biostatistics, bioinformatics, biomathematics, computational biology, biomedical engineering, and other related fields. The center is available to all university and medical center investigators, offering collaborative support spanning traditional statistical inputs (e.g., experimental design, sample size determination, power analysis, conventional data analysis and results interpretation), to novel statistical and bioinformatics approaches for modern technologies (e.g., advanced sample size determination for next-generation sequencing, multivariate modeling for high-dimensional data), to systems and computational biology approaches for asking questions and modeling results. Currently Prof. Ray-Bing Chen and Prof. Pei-Fang Su have several joint works with CQS in Vandernilt Univ.

(2). The new joint work on Data Analysis in Experimental Designs: This new joint work was motivated by our one-day workshop (2016.06.30). In this workshop, Prof. S.-H. Lo (Columbia Univ.) introduced the "I-score" method and its applications in bioinformatic data analysis. Currently Prof. Mong-Na Lo Huang; Prof. Shaw-Hwa Lo and Prof. Ray-Bing Chen form a research team, and they target on a novel data analysis approach in experimental designs based on I-score approach. Traditionally in design data analysis, we focus on the main effects and lower-order factor interactions based on the linear additive model and hierarchical assumption. However, it is difficulty to identify the higher-order interaction effects due to the linear additive model assumption. Thus the goal of the joint project is to propose new analysis approaches without linear additive model assumption. We do expect that our new approach will be a breakthrough in experimental design data analysis.

(3). Prof. Meihui Guo invited Prof. Da Zhou (Xiamen University) to visit NSYSU from 2016.06.21 to 2016.06.27. They discussed mathematical biology problem using statistical machine learning method.
4) Prof. Meihui Guo invited Prof. Inchi Hu (Hong Kong University of Science and Technology) to visit NSYSU from 11/15/2016 to 2/15/2017. They will work on the following two research problems (i) Importance Sampling for Conditional Tail Expectation. (ii)Smoothing Spline in Likelihood Inference.

3. Highlights

Our program includes several working groups that address specific issues, but not limited to, such as experiment design, high frequency financial data, scientific computation, biostatistics and etc. In the following we list three hightlighted topics.

a. Efficient Swarm Intelligence Approaches for Experimental Design Generators

In last five years, we have worked on the numerical approaches for experimental design generations. The key idea is to transfer the design generation problem as an optimization problem. Algorithms for obtaining experimental designs have been extensively studied in the literature. In the course of this endeavor, numerous algorithms have been proposed, from Fedorov-Wynn type algorithms to exchange algorithms, mathematical programming, and evolutionary algorithms, to name just a few.

However, the corresponding optimization problems might be very complicate. In the last decade, swarm intelligence optimization has gained momentum and has successfully solved complex optimization problems from various fields, and particle swarm optimization (PSO) is a widely used swarm intelligence optimization method. The popularity of PSO is primarily due to its remarkable simplicity, flexibility and computational efficiency. Thus we have introduced different PSO type methods into design search problems.

At first, we targeted on the "optimal design" generation. In optimal design, a design is a discrete probability measure, ξ. For a specified statistical model and a design criterion, Φ, to identify the best design is to solve the following continuous optimization problem, i.e.,

$$\xi^* = \arg\min_{\xi} \Phi(\xi).$$

Here given a design ξ, a design criterion is a function of the information matrix of the statistical model, for example, D-optimal criterion is the determinant of the inverse information matrix. In optimal design generation problems, sometimes we deal with the problems whose objective functions do not have closed forms. For example, when the maximin design criterion is considered, we face the nested optimization problem, and the objective function of the outer loop is dependent on the solution of the inner problem. Thus we proposed nested PSO for the maximin design search problems. In addition, we studied the generation problems for space-filling designs. The goal of the space-filling design is to find a set of design points such that uniformly fill in the region of interest. To obtain a good space-filling design, we need to solve a discrete optimization problem dependent on the pre-specified criterion, for example, L_2-discrepancy, max-min distance criterion and so on, and it is hard to solve especially when the run sizes and level sizes are large. The efficient discrete PSO type methods, like

LaPSO and DPSO, were proposed for these space-filling design problems. Overall we have several versions of PSO for catering to different experimental design problems.

Recently we move to the two-level factorial related design problems. We have completed two projects on two-level supersaturated design and two-level orthogonal array with pre-specified model structure. In these two projects, the main challenge is the huge number of the feasible selection of the candidate designs. For example, if we want to find D-optimal orthogonal array of 28 runs for estimating 20 main effects and 3 2fis, then we have $413,040,513,600$ candidates of design structures for this given saturated orthogonal array. Thus, a computationally efficient method is needed.

Target on our two-level design problem. Swarm intelligence approaches were proposed. First for SSD generation problem, a swarm intelligence-based SSD algorithm (SIBSSD in short) was proposed. The SIBSSD starts from a set of initial designs (particles), and the key of the SIBSSD is the MIX operator, which is used to update the current design matrix by exchanging columns with those of other "better" designs. This operator efficiently implements the exchange procedure and makes the SIBSSD quickly converge to the global best supersaturated design. For the two-level orthogonal array problems, we propose a generating algorithm contained two parts, and both parts are based on the SIBSSD. The numerical experiments with large design sizes indicate that the proposed algorithm performs well in terms of the relative D-efficiency.

b. Analysis of High Frequency Financial Data

Thanks to advances in data acquisition and processing techniques, financial data taken at a finer time scale such as tick-by-tick data have become readily available. These high frequency (HF) transaction data provide a rich source of real-time market information as to trading processes and market microstructure. Incorporation of real-time information helps to improve decision making in the rapidly changing markets. However, how to manage the huge real-time data and draw useful information are new challenges to researchers and market practitioners. In Big and Complex Data Analysis Program, we have a team working on the analysis of high frequency financial data including modeling, estimation and testing as well as multi-asset derivative pricing and model risk assessments. Our research outcomes are published in major journals in statistics and quantitative finance such as Annals of the Institute of Statistical Mathematics, Bernoulli Journal, Journal of Multivariate Analysis, TEST, Applied Stochastic Models, Quantitative Finance and etc.

Owing to technology advancement and high frequency trading, markets are now different in many ways from trading strategies, market structure to liquidity and price discovery. The evolution of the market from human involvement to computer control, from operating in time frames of minutes to time scales of microseconds, also change the fundamentals of the market microstructure. Innovative methods and models that can reflect the new realities in the high frequency world are in need. Better understanding of the market microstructure help facilitate the asset pricing as well as market microstructure setup used to attract specific traders. A major challenge in analyzing the HF data arises from the presence of market microstructure noise. Traditionally, the market microstructure noises are deemed as either information or non-information related factors such as bid-ask spread, informational asymmetries, inventory control effects, and others. But in high frequency world, these microstructure factors has taken on different shapes For instance, the HF traders turn speed into information via co-location and other technologies; the algorithmic trading's basic unit of market information are not the trades but the underlying orders.

In the future, our team aims to make breakthroughs in in following studies related to the market microstructure in the HF world: (a) Establish the sparse location dispersion model for microstructure noise. (b) Estimate integrated volatility incorporating the sparse location dispersion model. (c) Propose goodness of fit tests for stochastic volatility model incorporating the sparse location dispersion model. (d) Estimate Self-exciting and cross-exciting integrated volatility and jumps in HF world.

c. High Order Numerical method of Hyperbolic Conservation Laws

Prof. Chieh-Sen Huang and his research team have worked on Eulerian-Lagrangian methods for transport problems for about ten years. In 2006, they published an important modification to the characteristics-mixed method that conserves both mass and volume of the transported fluid regions, leading to the Volume Conserving Characteristics-Mixed Method (VCCMM). This modification leads to a substantial improvement in the monotonicity properties of the solution, much less numerical diffusion, and the practical ability to take time steps many times greater than the CFL constraint. This algorithm handled boundary conditions through a space-time change of variables in the trace-back routines, which allowed the boundary to be treated as if it were interior to the domain. They also presented techniques that allowed one to conservatively implement wells. The method was shown to converge and proven to satisfy maximum/minimum principles and have various monotonicity and stability properties.

They extended and applied the method to a variety of problems, including those with a solenoidal (i.e., divergence free) flow field and a simple one-dimensional two-phase flow problems (as a traceline method). They also improved the method in two significant ways. First, they defined a locally conservative stream-tube method with no numerical cross diffusion (and a projection technique to handle physical diffusion) Second, they defined a locally conservative Eulerian-

Lagrangian finite volume scheme with the weighted essentially non-oscillatory property (EL-WENO) in one-space dimension. This locally conservative method has the advantages of both WENO and Eulerian-Lagrangian schemes. It is formally high-order accurate in space and essentially non-oscillatory. Moreover, it is free of a CFL time step restriction and has small time truncation error. Extension to higher dimensions uses a Strang splitting technique.

They ae most interested in extending the ideas to nonlinear problems. Since the stream-tube and Strang splitting techniques are essentially one-dimensional, they continue to investigate the one-dimensional nonlinear problem. The main difficulty of the nonlinear problem is that the velocity is solution dependent, and thus it is not possible to determine the tracelines a-priori. Their first method for two-phase flow uses a combination of mass and volume balance constraints on the two phases. However, these constraints do not uniquely identify the trace-back regions for transport, and so a local (constrained) optimization step is added which seeks to identify an approximate traceline that has consistency between the previous time-level saturation and the backward traced, dynamically evolved saturation. The method is able to handle very complex shock structures. However, it is relatively computationally expensive and not very robust to solve the optimization problem.

The team was led to consider modifying the old method to incorporate an approximate but known velocity field. In this case, fluid crosses the space-time "sides" of the swept trace-back region, and so must be accounted for. They explored the use of CWENO ideas in the nonlinear context, which effectively approximate fluxes accurately along space-constant approximate tracelines.

The main difficulty in applying WENO ideas in this context is that the trace-back points may or may not have linear weights, needed in the WENO reconstructions.

In 2014, a WENO re-averaging (or re-mapping) technique was developed that converts function averages on one grid to another grid to high order. Nonlinear weighting gives the essentially non-oscillatory property to the re-averaged function values. The new *reconstruction* grid is used to obtain a standard high order WENO reconstruction of the function averages at a select point. By choosing the reconstruction grid to include the point of interest, a high order function value can be reconstructed using only positive linear weights. The re-averaging technique was applied to define two variants of a classic CWENO3 scheme that combines two linear polynomials to obtain formal third order accuracy. Such a scheme cannot otherwise be defined, due to the nonexistence of linear weights for third order reconstruction at the center of a grid element. The new scheme uses a compact stencil of three solution averages, and only positive linear weights are used. Numerical results show that this CWENO3 scheme is third order accurate for smooth problems and gives good results for non-smooth problems, including those with shocks.

The team then developed a formally high order Eulerian-Lagrangian WENO finite volume scheme for nonlinear scalar conservation laws that combines ideas of Lagrangian traceline methods with WENO reconstructions. Particles are transported in the manner of a standard Eulerian-Lagrangian (or semi-Lagrangian) scheme using a fixed velocity v. A flux correction computation accounts for particles that cross the v-traceline during the time step. If $v = 0$, the scheme reduces to a standard WENO5 scheme. The CFL condition is relaxed when v is chosen as either the characteristic or particle velocity. Excellent numerical results are obtained using relatively long time steps. This work is also under review.

In 2015, they presented a general idea to extend the WENO reconstructions to a class of numerical schemes that update different moments simultaneously as the computational variables. The key is to properly devise a re-mapping formulation to convert the multi-moment values to either the cell average or point value, which can be then directly used to generate the WENO reconstructions. The WENO reconstructions in turn provide the numerical approximations for the flux functions and other required quantities.

The numerical tests demonstrate that the presented methods have over fifth-order accuracy as expected and effectively eliminate spurious oscillations. The numerical solutions to all benchmark tests are of good quality and comparable to other existing WENO schemes.

III.8 Harmonic Analysis (Open Call Program)

1. Core Mambers

a. Faculties: Xiang Fang (NCU), Hwa-Long Gau (NCU), Ming-Yi Lee (NCU), Chin-Cheng Lin (NCU), Duy-Minh Nhieu (NCU), Chun-Yen Shen (NCU)

b. Postdocs: Ming-Hsiu Hsu, Zipeng Wang

c. Students: 2 Ph.D./ 11 Master

d. Long-term Visitors: Yongsheng Han (Auburn U.) Denny H. Leung (NUS), Sen Zhu (Jilin U.)

2. Overview of the Program

The research group in Harmonic Analysis in Taiwan is relatively small and mostly concentrated at National Central University. Thanks to the support of NCTS, our group is active and growing and hopefully expanding to researcher all around Taiwan.

Even though we focus on a few topics, our choice of subjects are in the current mainstream of research. In the year of 2016, we obtained results in the following:

a. Hyper-singular cousin of the Bergman projection;

b. Two-weight inequalities for the Cauchy transform;

c. Function spaces associated with a family of sections;

d. Extremality of numerical radii of matrix products.

Our main strategy to expand the group is by inviting well-established visitors for further collaboration. Whenever we have visitors from abroad, a intensive learning seminar will be held at the same time. Then we invite potential collaborators in Taiwan, ranging from Professors to students for participation. By doing this, we are establishing a research collaboration relationship with leading experts in the field in a long term basis as well. This strategy is currently carried out in the following manner this year.

a. Chun-Yen Shen visits Professor Eric Sawyer, McMaster University in Canada, for 2 – 4 weeks every year;

b. Chun-Yen Shen visits Professor Ignacio Uriarte-Tuero, Michigan State University, for 2 – 4 weeks every year;

b. Professor Zipeng Wang, Shaanxi Normal University in China, visits NCU from January to August;

c. Professor Yongsheng Han, Auburn University, visits NCU in spring for a full month;

d. Professors Xuan Thinh Duong and Ji Li, Macquarie University in Australia, visit NCU in autumn for two weeks;

e. Professor Qingbo Huang, Wright State University, visits NCU in summer for two weeks.

3. Highlights

The highlights of the program consists of the following: The hyper-singular cousin of the Bergman projection, the studies on two-weight inequalities for the Cauchy transform, and the boundedness of Monge-Ampère singular integral operators acting on Hardy spaces and their duals and finally, the Extremality of numerical radii of matrix products. In what follows, we summarize the mentioned results.

a. Hyper-singular cousin of the Bergman projection
We completely characterized real numbers α, p, and q such that the integral operator induced by $K_\alpha(z,w) = \frac{1}{1-z\bar{w}}$ is bounded from $L^p(D)$ to $L^q(D)$. This settles a basic issue hanging around for quite many years related to singular integral

operators over the unit disk. These operators may be regarded as variants of the Bergman projection (which corresponds to $\alpha = 2$), and they may appear to be similar to Riesz potential operators (which corresponds to $0 < \alpha < 2$) in some sense. The unexpected new discovery is that there exists a critical exponent $\alpha = 3$ and a hyper-singular theory for $2 < \alpha < 3$, which are hard to predict from existing knowledge of singular integral operators in harmonic analysis.

In summary, we observe two unexpected phenomena:

The boundary curve for the p-q diagram in the hypersingular case is given by a different curve equation which seems to have no counterpart in existing literature. The boundary curve in the hypersingular case is excluded instead of being included as for $0 < \alpha \leq 2$. This is especially interesting when compared with operators considered in harmonic analysis on $\mathbb{R}^N$. Note that the Bergman projection is often studied in analogy with Calderon-Zygmund operators (CZO) on $\mathbb{R}^N$ via the theory of homogeneous spaces. Since for CZO-type operators, the (p, q) range for boundedness usually has no interior points, hence restricted only to the boundary curve, which is missing for K_α when $2 < \alpha < 3$, we say that the hyper-singular theory is "invisible" for CZO.

b. Two-weight for the Cauchy transform in the complex plane, energy conditions and common point masses

We characterize the boundedness for the Cauchy transform:

$$\mathsf{C}_\sigma f(z) \equiv \int_{\mathbb{R}} \frac{f(t)}{t - z} \sigma(dt)$$

as a map between $L^2(\mathbb{R}; \sigma)$ and $L^2(\mathbb{R}^2_+; \tau)$, where σ and τ are two arbitrary weights, i.e. locally finite positive Borel measures. The characterization is in terms of a joint Poisson A_2 condition and a set of testing conditions.

We are motivated by the study of the model space $K_\vartheta = H^2 \ominus \vartheta H^2$, where ϑ is an inner function. These spaces are essential to the Nagy-Foias model for contractions on a Hilbert space. Hence function theoretic properties of the space K_ϑ are therefore of significant interest. As an application of our two weight Cauchy transform, we characterize the Carleson measures for K_ϑ spaces, which in turn settled the problem posed by Cohn in 1982. Previously, Aleksandrov characterized *isometric* Carleson measures, and otherwise definitive results have only been proved in the so-called 'one component' case.

We also characterize the norm of a composition operator from a K_ϑ space to any one of a general class of analytic function spaces, which include Hardy and the entire scale of Bergman spaces. The operator-theoretic properties of composition operators have been of intense interest for 60 years, but the only result concerning composition operators on an arbitrary model space is the elegant characterization of compactness from K_ϑ to H^2 obtained by Lyubarskii-Malinnikova.

In addition we now permit the weights, or measures, to have common point masses, something not permitted in before. As a consequence, we use $\mathcal{A}_2^\alpha$ conditions with holes, together with punctured $A_2^{\alpha,\mathrm{punct}}$ conditions, as the usual A_2^α '*without punctures*' fails whenever the measures have a common point mass. The extension to permitting common point masses uses the dyadic bilinear Poisson inequality to obtain functional energy, together with a delicate adaptation of our previous arguments. In higher dimensions the'punctured' Muckenhoupt $A_2^{\alpha,\mathrm{punct}}$ conditions are typically necessary, and they turn out to be crucial in estimating the backward Poisson testing condition.

As mentioned earlier, the *classical* A_2^α characteristic $\sup_{Q\in\Omega\mathcal{Q}^n}\frac{|Q|_\omega}{|Q|^{1-\frac{\alpha}{n}}}\frac{|Q|_\sigma}{|Q|^{1-\frac{\alpha}{n}}}$ fails to be finite when the measures σ and ω have a common point mass - simply let Q in the $\sup$ above shrink to a common mass point. But there is a substitute that is quite similar in character that is motivated by the fact that for large quasicubes Q, the $\sup$ above is problematic only if just *one* of the measures is *mostly* a point mass when restricted to Q. It turns out proving its necessity is very subtle. Given an at most countable set $\mathfrak{P}=\{p_k\}_{k=1}^\infty$ in $\mathbb{R}^n$, a quasicube $Q\in\Omega\mathcal{P}^n$, and a positive locally finite Borel measure μ define

$$\mu(Q,\mathfrak{P})\equiv|Q|_\mu-\sup\{\mu(p_k):p_k\in Q\cap\mathfrak{P}\},$$

where the supremum is actually achieved since $\sum_{p_k\in Q\cap\mathfrak{P}}\mu(p_k)<\infty$ as μ is locally finite. The quantity $\mu(Q,\mathfrak{P})$ is simply the $\widetilde{\mu}$ measure of Q where $\widetilde{\mu}$ is the measure μ with its largest point mass in Q removed. Given a locally finite measure pair (σ,ω), let $\mathfrak{P}_{(\sigma,\omega)}=\{p_k\}_{k=1}^\infty$ be the at most countable set of common point masses of σ and ω. Then we prove that the weighted norm inequality implies finiteness of the following *punctured* Muckenhoupt conditions:

$$\begin{aligned}A_2^{\alpha,\mathrm{punct}}(\sigma,\omega)&\equiv\sup_{Q\in\Omega\mathcal{P}^n}\frac{\omega\left(Q,\mathfrak{P}_{(\sigma,\omega)}\right)}{|Q|^{1-\frac{\alpha}{n}}}\frac{|Q|_\sigma}{|Q|^{1-\frac{\alpha}{n}}},\\ A_2^{\alpha,*,\mathrm{punct}}(\sigma,\omega)&\equiv\sup_{Q\in\Omega\mathcal{P}^n}\frac{|Q|_\omega}{|Q|^{1-\frac{\alpha}{n}}}\frac{\sigma\left(Q,\mathfrak{P}_{(\sigma,\omega)}\right)}{|Q|^{1-\frac{\alpha}{n}}}.\end{aligned}$$

c. Monge-Ampère singular integral operators

In 1990's the research group led by Caffarelli pioneered real analysis related to the Monge-Ampère equation and introduced a new concept of family of "sections". A family of sections is a collection of bounded convex sets

$$\mathcal{F}=\{S(x,t)\subset\mathbb{R}^n:x\in\mathbb{R}^n\text{ and }t>0\}$$

satisfying certain axioms of affine invariance, which are modeled on the properties of the solutions of the real Monge-Ampère equation. Caffarelli's research group gave a Besicovitch type covering lemma for the family and set up a variant of the Calderon-Zygmund decomposition by applying this covering lemma together with the doubling condition of a Borel measure μ. Such a decomposition plays an important role in the study of the linearized Monge-Ampère equation and the John-Nirenberg inequality. In 1997 Caffarelli's research group introduced the Monge-Ampère singular integral operator H and proved its L^2_μ boundedness. Subsequently, Caffarelli's research group and NCU research group established the L^p_μ boundedness for $1 < p < \infty$, weak type $(1, 1)$ estimate, $H^1_{\mathcal{F}} - L^1_\mu$ boundedness, and $H^1_{\mathcal{F}} - H^1_{\mathcal{F}}$ boundedness of H.

Recently, we keep studying the Hardy spaces $H^p_{\mathcal{F}}$, $\frac{1}{2} < p \leq 1$, and characterize their dual spaces that can be realized as Carleson measure spaces $CMO^p_{\mathcal{F}}$ defined by

$$\sup_{\text{dyadic cube } P} \left\{ \frac{1}{\mu(P)^{2/p-1}} \sum_{Q \subset P} \int_Q |D_Q f(x)|^2 \, d\mu(x) \right\}^{1/2} < \infty,$$

Campanato spaces $\Lambda^\kappa_{q,\mathcal{F}}$ defined by

$$\sup_{S \in \mathcal{F}} \frac{1}{\mu(S)^\kappa} \left(\frac{1}{\mu(S)} \int_S |f(x) - m_S(f)|^q d\mu(x) \right)^{1/q} < \infty,$$

and Lipschitz spaces $\text{Lip}^s_{\mathcal{F}}$ defined by

$$\sup_{\rho(x,y) \leq h} \frac{|f(x) - f(y)|}{h^s} < \infty.$$

The equivalence between the characterization of Littlewood-Paley g-function and atomic decomposition for $H^p_{\mathcal{F}}$ is obtained as well. Then we prove that Monge-Ampère singular operators are bounded on both $H^p_{\mathcal{F}}$ and their dual spaces.

d. Extremality of numerical radii of matrix products

For two n-by-n matrices A and B, it was known before that their numerical radii satisfy the inequality $w(AB) \leq 4w(A)w(B)$, and the equality is attained by the 2-by-2 matrices $A = \begin{bmatrix} 0 & 1 \\ 0 & 0 \end{bmatrix}$ and $B = \begin{bmatrix} 0 & 0 \\ 1 & 0 \end{bmatrix}$. Moreover, the constant "4" here can be reduced to "2" if A and B commute, and the corresponding equality is attained by $A = I_2 \otimes \begin{bmatrix} 0 & 1 \\ 0 & 0 \end{bmatrix}$ and $B = \begin{bmatrix} 0 & 1 \\ 0 & 0 \end{bmatrix} \otimes I_2$. We give a complete characterization of A and B for which the equality holds in each case. More precisely, it is shown that $w(AB) = 4w(A)w(B)$ (resp., $w(AB) = 2w(A)w(B)$ for commuting A and B) if and only if either A or B is the zero matrix, or A and B are simultaneously unitarily similar to matrices of the form $\begin{bmatrix} 0 & a \\ 0 & 0 \end{bmatrix} \oplus A'$ and $\begin{bmatrix} 0 & 0 \\ b & 0 \end{bmatrix} \oplus B'$ (resp.,

$$\left[\begin{array}{cc|c} 0 & a & \\ 0 & 0 & 0_2 \\ \hline & & 0 \quad a \\ \multicolumn{2}{c|}{0_2} & 0 \quad 0 \end{array}\right] \oplus A' \quad \text{and} \quad \left[\begin{array}{c|cc} & b & 0 \\ 0_2 & 0 & b \\ \hline 0_2 & \multicolumn{2}{c}{0_2} \end{array}\right] \oplus B')$$

with $w(A') \leq |a|/2$ and $w(B') \leq |b|/2$. Analogous characterizations for the extremal equalities for tensor products and Hadamard products are also proven.

For doubly commuting matrices, we obtain a unitary similarity model, namely, A and B satisfy $AB = BA$ and $AB^* = B^*A$ if and only if they are simultaneously unitarily similar to matrices of the form $\sum_{j=1}^{k} \oplus(A_j \otimes I_{n_j})$ and $\sum_{j=1}^{k} \oplus(I_{m_j} \otimes B_j)$. For commuting 2-by-2 matrices A and B, we show that $w(AB) = w(A)w(B)$ if and only if either A or B is a scalar matrix, or A and B are simultaneously unitarily similar to $\begin{bmatrix} a_1 & 0 \\ 0 & a_2 \end{bmatrix}$ and $\begin{bmatrix} b_1 & 0 \\ 0 & b_2 \end{bmatrix}$ with $|a_1| \geq |a_2|$ and $|b_1| \geq |b_2|$.

III.9 Laboratory of Data Science

1. **Overview of the Program** As an applied mathematician, Hau-tieng Wu focuses on building up mathematical foundations of massive data analysis, and applies the results to generate reproducible results in medicine. His goal is using sophisticated methods to extract more medically relevant information from data collected in the standard medical environment. As Newton's laws of motion are established to model the real world phenomena, we are facing the same problem in data analysis collected data is nothing but an observation of the world, but what is the underlying rule guiding these observations? Clearly, mathematics is needed to model these observations, fully understand the analysis procedure and quantify the analysis result, but we also need background knowledge about the data so that the analysis results could be well interpreted and applied. To achieve this goal, his work is balanced among different fields, ranging from mathematics, computer science, electrical engineering to medicine. In particular, due to his background knowledge in medicine, he is able to directly communicate between two extreme fields, mathematics and medicine.

   1. Research topics The gap between medicine and mathematics is getting larger and larger in the past few decays. But as the explosive technical development, the need of reuniting these two fields has dramatically increased. Hau-tieng spends time on extracting suitable features reflecting physiological dynamics from different types of datasets, ranging from electrocardiogram (ECG), respiration, contact/non-contact photophlethe- mogram (PPG), electroencephalogram (EEG), clinical questionnaire and charts, medical images, etc. One particular approach to obtaining these features is via nonlinear time-frequency analysis. With these ex- tracted features, he spends time on developing high dimensional data analysis techniques and focuses on the nonlinear low dimensional structure, like manifold or metric measure space. He also spends time on the statistical behavior of the proposed algorithms. These combinations are then applied to predict the outcomes, or be input to the classification or clustering algorithms for different purposes. While the topics seem diverse, the focus is always extracting intrinsic features out of the massive dataset and apply them to study the medical problems.

   The efforts are put in two directions

a. theoretically understand the features we have interest;

b. guarantee that the proposed model and analysis result could be directly applied to resolve the clinical problems.

2. Highlights

a. Development of data analysis techniques– Applied harmonic analysis and nonlinear time frequency analysis.

Time series is universal and fundamental in all fields. One particular feature of the time series we have interest is the time-varying frequency and time-varying amplitude of an oscillatory signal. This feature has been well known to be intimately associated with many physiological/clinical dynamics; for example, the heart rate variability or respiratory rate variability, to name but a few. In the past seven years, a theoretical framework we developed to quantify these necessary dynamics, and several algorithms were proposed and theoretically studied to extract the wanted dynamics [19, 1, 5, 2, 8].

b. Development of data analysis techniques–Applied differential geometry and high dimensional data analysis.

Big data is a hot research area nowadays. However, in addition to "big", the underlying structure/rule guiding the data cannot be ignored. One major work Hau-tieng focuses on is introducing the principal bundle structure to adaptively describe this kind of complicated structure. The main idea is that for a given dataset, where each object inside the dataset might be a vector, a mesh, a time series, a metric space, etc, we would like to extract the "intrinsic structure" hidden inside the dataset. Hau-tieng spent a great portion of time studying how to model this kind of dataset, as well as understanding its noise behavior. The principal bundle structure is considered to organized the data [15, 9], which allows us to capture not only the geometric but also topological structure hidden inside the dataset [14, 12]. In addition to the theoretical study of the model, the high dimensional noise phe- nomenon is also considered and systematically studied [3, 4]. The developed method is directly applied to different problems, like the cryo-electron microscope problem [15, 24], the phase retrieval problem in the ptychography image [12], the vector nonlocal median denoise scheme [7], and multiple oscillatory time series decomposition problem [16]. Furthermore, the manifold model is generalized to the common manifold model to study the sensor fusion problem, and the proposed algorithm, alternating diffusion, is proposed and applied to study the sleep dynamics and other problems [6, 17].

c. Apply the developed methods to medicine. The above developed methods are all motivated and applied to the medical problems. Below are some examples.

(1). Ventilator weaning prediction.
Making a weaning decision for a patient on a mechanical ventilator is an important clinical issue. Unfortunately, on average the weaning failure still occurs in a significant percentage of patients who are judged ready-to-wean. Thus, finding an ideal weaning predictor, which is safe, reproducible, easy to perform, and not subject to confounding inuences, is important. In his work in 2014, a nonlinear time-frequency (TF) analysis called synchrosqueezing transform (SST) is applied to study the respiratory and ECG signals, and a novel weaning index called WIN is proposed to help the physicians. In [21], a preliminary analysis on 68 subjects (45 succeeded the weaning and 23 failed with heterogeneous underlying diseases and intubation reasons), whom are predicted to succeed the weaning procedure based on RSBI, was reported. He shows that with the help of WIN index, the prediction rate increases from 66% to 76% [21]. Based on this result and the abundant information available in the intensive care unit, he conjectured that by taking WIN, suitable HRV analysis and other available signals like EtCO2, SpO2 into account, one could further increase the weaning successful rate. The institutional review board has approved the large scale prospective study, starting from 2016/1/1, and the patients will be prospectively recruited patients with mechanical ventilator on a consecutive basis in the Chang Gang Memorial hospital. A potential commercialization of the proposed index is also under consideration.

(2). Anesthesia.
Anesthesia is definitely the most important medical progress in the 20th century. While there have been several subjective quantifies for physicians to evaluate how well the anesthesia is a lot of information is still left unused. For example, Bispectral Index is applied to monitor the level of hypnosis, but the subcortical activity is rarely monitored due to the lack of suitable tools. Based on clinical observations that deeper anesthetic levels are associated with the more regular oscillatory patterns in the R-to-R peak interval (RRI) time series of electrocardiography, a new index based on the novel multitapered SST, referred to as Nonrhythmic to Rhythmic Ratio (NRR), was introduced to quantify the anesthetic depth [10]. Over 37 subjects, a prospective study shows that NRR well predicts first reaction during the emergence period and NRR correlates with sevourane concentration during spontaneous breathing. These results jointly suggest that momentary information hidden inside RRI and revealed by the tvPS should possess a distinct physiological interpretation of the anesthetic depth compared with the hypnosis measured by surface EEG. In addition to predicting the first reaction, we find that the dynamics hidden in RRI is intimately related to

other physiological activities. Although anesthetized patients falling unconscious do not perceive pain sensation, it is important to counteract the effect of noxious surgical stimulation on human body by using strong analgesics. If observing IHR carefully, we could usually see that transient bradycardia could occur immediately after noxious stimulation, which was never used in the past, again, due to the limitation of the analysis tool. In [9], a preliminary analysis result on 76 homogeneous subjects shows that by replacing the power spectrum in the traditional HRV analysis with the latest nonlinear TF analysis called ConceFT, the time-varying HRV indices provide a correlation greater than 92% with the noxious stimulation in clinical anesthesia. This result is significantly better than any traditional approach. To further confirm this finding, and push it to the clinical usage, a large scale prospective study has been submitted for the institutional review board review. We would expect to get the approval and start the study from 2016/3/1. A potential commercialization of the proposed index is also under consideration.

(3). Sleep.

It is well known that sleep is not a stationary physiological phenomenon. While there are many channels in the polysomnography (PSG), which includes electroencephalography (EEG), elec- tromyogram (EMG), and electrooculogram (EOG), etc, we mainly count on the EEG signal to evaluate the sleep stage. One major limitation is the lack of suitable tools to extract nonstationary dynamics and organize the extracted features from different channels. This is in general the mixup of the nonstationary dynamic extraction problem and the sensor fusion problem. In [23], the dynamical features are properly extracted by SST and diffusion maps, which is proved in 20 subjects without severe sleep apnea–the proposed classification based on the respiratory signal (resp. respiratory and EEG signals) has the overall accuracy 81:7% (resp. 89:3%), which is comparable to human expert classification as the gold standard. In [17], the alternating diffusion maps is proposed and theoretically studied to integrate information from different channels. The clinical results will be reported soon. The problem is more challenging when screening the sleep-disordered breathing (SDB) is considered. For the screening purpose, it is better to have as few channels as possible, which piles on another layer of difficulty. Thus, finding better features is critical. Although there have been many works on this direction, there is no satisfactory solution to simultaneously fulfill all the requirements. In [11], Hau-tieng and his collaborators explore the possibility to achieve the above requirements by taking the abdominal and thoracic movement signals into account. The ConceFT and entropy are applied to extract features from these movement signals and the kernel support vector machine is applied to classify and predict the SDB event. The preliminary result on 47 subjects with different severity levels of SDB confirmed the possibility the prediction rate could be 84:42% on average. This study is currently combined with the 3-G sensor design (hardware design) to improve the final detection accuracy.

(4). Cardiac eletrophysiology–J wave analysis.
J-wave, a common finding on the 12-lead electrocardiogram (ECG), has been traditionally considered a benign entity. However, recent reports have implicated early repolarization as a marker for adverse cardiovascular outcomes. Hence, the prognostic significance of the J-wave has become of great interest to clinical researchers. While some reports have shown that the J-wave is a benign finding, others have shown the opposite. Inconsistencies in the observed findings possibly have stemmed from the different methods used to measure the J-wave which have consisted of manual and partially automated techniques. To resolve this issue, he proposed a fully automated technique to detect the presence of the J-wave and has been published in Journal of Electrocardiology [18]. The application of an entirely automated method to measure this hallmark component of early re- polarization eliminates bias and enables researchers to appropriately compare the prognostic significance of this pattern across different populations. In the large scale analysis from the ARIC study [13], our findings suggest that the J-wave is a benign entity that is not associated with an increased risk for sudden cardiac arrest among middle aged, white and black adults in the United States.

(5). Hemodynamics analysis and photoplethysmography signal analysis.
Hemodynamics is an essential ingredient of cardiovascular physiology which not only reflects the forces the heart needs to pump blood through the cardiovascular system, but also reflects the integrity of our physiological system. In addition to the blood pressure and the time-varying heart rate, the pulse wave signal itself contains abundant clinical information, like the stiffness of the artery, the cardiac output, etc. As there is a fruitful information inside the pulse signal, a thoughtful knowledge of the pulse wave is undoubtedly important to fully assess not only the cardiovascular but also the physiological integrity. In [20, 22], Hau-tieng and his collaborators apply the adaptive non-harmonic model based on the wave- shape function, as well as SST to model and analyze the blood pressure signal recorded by different sensors, like contact or non-contact photoplethysmography (PPG) or sphygmomanometer. To demonstrate how the model and algorithm work, he study two aspects of the pulse wave signal. First, in [22], he shows that the instantaneous heart rate could be accurately estimated from different PPG signals, and the accuracy is much better than the existing state of art. Second, by extracting the shape features describing the integrated

blood pressure oscillation, called the spectral pulse signature, based on the functional regression technique, he characterize the hemodynamics from the radial pulse wave signals recorded by the sphygmomanometer. The result is applied to distinguish normal subjects from the patients with congestive heart failure, which serves as a solid foundation for the continuing study. A large scale application of the proposed model and algorithm, as well as solving the partial differential equation to further understand the interaction between hemodynamics and cardiac electrophysiological dynamics have been submitted for the approval of the institutional review board. The data will be directly collected from the A-line signal in the surgery room.

IV Goals and Planning of Next Year

IV.1 Overview

In the coming year of 2017, there are a few excitements and challenges ahead of us.

1. Moving to the New Building

   The construction of Cosmology Building, which locates just next to the current Astro-Math Bldg, is on way smoothly. Since there is no sign of serious delay, we expect its completion at the end of summer of 2017. Therefore, we are the planning the moving will be sometime at the end of 2017.

   It is exciting to use the new facilities to accommodate our visitors, postdocs, members and to run various activities. However, the preassigned space is not sufficient for our active activities and members. We are requesting NTU for more space in the new building.

2. Evaluation and Adjustment of Topical Program

   After two years of operation, we consider it is about time to partially adjust topical programs. In Oct., we are going to have an Executive Committee to discuss the procedure of evaluation and adjustment. Together with the suggestion and comment of International Scientific Advisory Committee, we will start the adjustment from the Spring semester of 2017.

   The adjustment will include focuses of topical programs and organization of topical programs.

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 2017. Domestically, we will build up a prototype of a joint school. The 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 NCTS 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.

IV.2 Academic programs

1. Number Theory of Representation Theory

Number theory. For the future research plan, we continue to broaden and deepen our investigation on the following topics.

a. Geometry of Shimura varieties:
(1) Shimura varieties: hope to complete the following two current projects (a) About the construction of admissible integral models for Shimura varieties of abelian type, and prove the non-emptiness of KR strata for the Pappas-Zhu integral model, the non-emptiness of NP strata as general as possible and the non-emptiness of EO strata for good reduction of Hodge type. (b) Investigate the density and existence of the ordinary locus for type C Shimura varieties. We like to understand the sufficient and necessary condition for the density of the ordinary locus.
(2) Abelian varieties over finite fields (joint with Jiangwei Xue, Tse-Chung Yang, Mounir Hajli). Hope to build as many as possible the cases in which we can compute the number of abelian varieties in a given isogeny class. (a) Superspecial abelian surfaces and Galois cohomolgoy (b) Superspecial abelian surfaces and type numbers (c) Description of polarized abelian varieties over Fp. This tool should help us to determine whether or not certain superspecial polarized abelian varieties over Fp exit. (d) Relation of superspecial abelian surfaces and elliptic fixed points in Hilbert modular surfaces and the conjecture of Peters. (e) Explicit computation of Galois cohomology arising from superspecial abelian varieties and the conjugacy classes of elements of finite orders in quaterionic arithmetic subgroups. (f) Asymptotic behaviors of superspecial abelian varieties over finite fields. (e) The Selberg trace for reduced norm one subgroups.

b. Multiple zeta values in positive characteristic: In this direction of positive characteristic MZV's, our major aim is to prove the function field analogue of Zagier's conjecture. Based on the ideas of [C15], the first step of tackling the dimension problem of higher depth MZV's is to relate MZV's of arbitrary depth to certain coordinate of logarithms of certain t-modules. Currently, Y. Mishiba and I are working on this joint project.

c. p-adic L-functions and congruences among modular forms
(1) Arithmetic of central values of triple product L-functions:
We aim to prove Deligne's conjecture for central values for general triple product L-functions and construct p-adic triple product L-functions (joint with Yao Cheng, Isao IshikawaK). Then we will proceed to investigate some arithmetic problems such as exceptional zeros or p-adic Gross -Zagier formula relating the double derivatives of the balanced p-adic triple L-functions at the weight (2,2,2) to for these p-adic L-functions. With Francesc Castella, we plan to use the work of Darmon and Rotger on the inbalanced p-adic triple product L-functions to give a Euler system construction of anticyclotomic p-adic L-functions for modular form a la Bertolini and Darmom.
(2) Yoshida lifts and congruences among modular forms (joint with Namikawa): we plan to complete the calculation of the Petersson norm formula of Yoshida lifts and study the congruence betweem Hida families of Yoshida lifts and non-Yoshida lifts. The ultimate goal is to prove one side divisibility for the main conjecture for Rankin-Selberg convolution.

d. Future activities
Ming-Lun Hsieh will organize the third Japan-Taiwan Joint conference on number theory at NCTS during September 8-13, 2016. This is the follow-up of the biannual conferences initiated by Yifan Yang and Yamazaki Takao, and the aim is to provide opportunities for young number theorists between Japan and Taiwan to exchange ideas and stimulate the future potential collaboration. There will be more than 20 speakers in this conference. Chia-fu Yu will organize and lecture in "Winter School on Shimura varieties and related topics", December 10-12, 2016 as well as "Cross Strait Workshop on Arithmetic Geometry", December 16-18, 2016, Wuhan University, Wuhan, China. In the year 2017, we will have AS-NCTS Special Lecture Series on Arithmetic Geometry by Prof. Jean-Marc Fontaine. Moreover, Chia-fu Yu will continue advanced courses "NCTS Spring Course Topics on Abelian Varieties", "NCTS Spring Course Modular Representations of Finite Groups" and organize NCTS Summer School on Pecfectroid Spaces and participates in the conference "AGCCT-16 Arithmetic, Geometry, Cryptography and Coding Theory: 30th anniversary", Luminy, France, 19 - 23 June 20 Representation Theory. In the next year, we will continue our program the classification of holomorphic vertex operator algebras (VOA) of central charge 24. It is one of fundamental problem in vertex operator algebra theory and seems to have many applications in mathematical physics and string theory. It also has some possible applications to the theory of modular tensor category. Due to our effort, all 71 theory proposed by Schellekens have been constructed. We will con-

centrate on the uniqueness problem. Our recent work also suggests that there is a uniform construction of all 71 cases using Leech lattice VOA. Reconstructing all 71 cases using a uniform method associated with the Leech lattice will be one of our main focus.

In addition, we will continue our investigation on the two so-called ”strange” series of simple Lie superalgebras, called the queer and the preiplectic Lie superalgebras. They provide some of the most interesting examples of Lie superalgebras. These two series have no classical counterparts in the theory of semisimple Lie algebras, as here one requires the dimensions of the even and the odd space to coincide. It is well-known that the finite-dimensional representation theory of the queer Lie superalgebra has intruiging connections with various areas of classical mathematics, e.g., Lie algebra of type B, symmetric function theory etc. It would be very interesting to study the representation theories of these superalgebras in the general BGG categories, even in the small rank cases. We believe that any insights gained here, even in small rank cases, could be quite significant for further development of Lie superalgebras. We will also study further connections between Lie algebras and Lie superalgebras in the spirit of super duality. An important class of Lie superalgebras so far not covered by super duality is the class of affine Lie superalgebras associated with finite-dimensional classical Lie superalgebras. For these Lie superalgebras representation theory is known to be very difficult. However, as representation theory of affine Lie superalgebras have many applications to other areas of mathematics and physics, we think that their study is a very important future direction. The remarkable connection between Yangians and finite W -algebras are by now well understood. It is therefore expected that there should be a super analogue as well. We would like to establish a realization of the finite W -superalgebras in terms of certain quotients of the so-called shifted super Yangians (both of type A). As an application, this provides a useful tool to the study of the representation theory of the finite W-superalgebras, which we expect to be very rich.

In the coming year, our stress will still be on student training and nurturing young researchers. We will continue to organize weekly reading seminars on recent developments. In addition, we plan to organize a small workshop on finite groups and VOA in the east Taiwan in March 2017.

2. Algebraic Geometry

In the coming year of 2017, we plan to emphasize on the following three aspects. We thus will invite some visitors and organize some activities to achieve the goals, besides the regular seminars

a. higher dimensional algebraic geoemtry

We are going to have two NCTS Scholars: Yujiro Kawamata and Paolo Cascini who will visit in March. During their visits, they are going to lecture some new development in higher dimensional birational geoemtry.

We are also going to organize a workshop "Higher Dimensional Birational Geometry". This series of workshop was initiated in 2004 and has been held 4 times successfully. We plan to have about 20 speakers for this 5 days workshop.

b. new methods in algebraic geoemtry, including arc spaces and Berkovich spaces.

We are organizing a mini-course lectured by active experts such as J. Nicaise or T. de Fernex on Berkovich spaces and arc spaces respectively. We are aiming to introduce these new methods in algebraic geometry to our younger members. We expect these methods will be helpful for younger researchers to develop their work, or at least to broaden their horizon.

c. special varieties, including Fano varieties and Calabi-Yau varieties

Calabi-Yau varieties are compact complex Kahler manifolds with trivial first Chern classes. Research on Calabi-Yau manifolds plays a central role in mathematical physics and mathematics, including differential geometry, complex geometry, algebraic geometry, number theory, representation theory. The algebra-geometric aspects of this rich topic focus on the study of moduli and arithmetic of Calabi-Yau manifolds. Experts in Calabi-Yau varieties will be invited to attend the HDAG workshop scheduled in Aug.

Another special topics in on Fano-type varieties. Fano-type varieties is important in classification theory as well as in minimal model theory. The Russian research group is extremely strong on this topic. We plan to invite some Russian experts in this fields for further interaction and collaboration.

We summarize the events and activities we are organizing:

a. regular seminars

We plan to have regular seminars as we did before.

b. NCTS Algebraic Geometry Day

We plan to have NCTS Algebraic Geometry Day roughly every month for groups member to share their current projects.

c. Mini-courses by NCTS scholars

We are organize mini-courses by Kawamata and Cascini during their visit in March.

d. Workshop on higher dimensional algebraic varieties

We are organizing a one-week workshop at the end of March.

e. mini-workshop on Fano varieties

We plan to invite some Russian experts on Fano varieties on June. Mini-workshop or lectures will be organized.

f. Mini-courses on Berkovich spaces and arc spaces
   We plan to organize these mini-courses in late Aug or Sep.

3. Differential Geometry and Geometric Analysis

In the coming year of 2017, we are hoping to invite NCTS Scholar Professor R. Schoen to visit NCTS and invite him to help organize a international workshop or conference in geometric analysis. Also we are hoping to invite Professor Mu-Tao Wang from Columbia to organize a summer course or workshop in geometric analysis.

Also we are planning to organize the following activities next year.

a. Special day on several topics (2-4 topics)
b. Workshop on the moduli space of connections
c. Mini course on various topics in symplectic geometric
d. A conference on "Mirror symmetry and variation of Hodge structures"
e. A workshop with OIST on some interdisciplinary topics involves differential geometry, Mathematical Soft Matter and computation
f. International conference on symplectic geometry
g. Two Taiwan Geometry Symposium

We also plan to invite the following visitors: Miles Simon, Richard Bamler (U C Berkeley), Peng Lu (Oregon State , Ovidiu Munteanu Teng Fei (Columbia University), Yohsuke Imagi (Kavli IPMU, Boyu Zhang (Harvard Universtiy), Jiro Adachi (Hokkaido), Viktor Ginzburg (UCSC), Hiroshi Iriyeh (Ibaraki), Ely Kerman (UIUC), Hui Ma (Tsinghua), Klaus Niederkrüger (Lyon), Kaoru Ono (RIMS), Kazushi Ueda (Tokyo), Otto van Koert (SNU). Naichung Conan Leung (The Chinese University of Hong Kong), Kwokwai Chan (The Chinese University of Hong Kong), Siu-Cheong Lau (Boston University), Si Li(TsingHua University), Yalong Cao (Kavli institute), Hansol Hong (Harvard University) Wanmin Liu (IBS center for Geometry and Physics), ,Philp Boalch(University of Orsay), Anton Alekseev (University of Geneva), Eckhard Meinrenken (University of Toronto), Chenchang Zhu (University of Gottingen), M. Guest (Waseda University) Eliot Fried (OIST), Giulio Giusteri (OIST), Simon Brendle (Stanford University), Mu-Tao Wang (Columbia University), Jian Song (Rutgers University), Xiao-Dong Cao (Cornell University), Knut Smoczyk (Leibniz Universitat Hannover), Spiro Karigiannis (University of Waterloo), (Hokaido), H. Mikayelyan (Notingham, China) M. Kotani (Tohoku), E. Spadaro (MIS, Germany) and U. Menne (AEI, Germany).

4. Differential Equation and Stochastic Analysis

In the coming year of 2016 and 2017, we will continue focus on several main topics such as the kinetic theory, the traveling wave phenomena, pattern formations, the symbolic dynamics, and the image analysis, etc. Preparation works for many activities are already underway.

(1) In Nov 2016, we will organize at least three workshops: 2nd East Asia Section of IPIA-Young Scholars Symposium (Nov 5-6); Nonlinear Differential Equations: Theory and Applications (Nov 18-19) ; 2016 Japan-Taiwan Joint Workshop on Numerical Analysis and Scientific Computing (Nov 26-28).

(2) Kung-Chien Wu will deliver a regular course: Topics in kinetic theory on 2016 Fall in NCKU; Prof. Kazuo Aoki (Visiting research fellow of NCTS) will visit NTU from 1 October 2016 to 31 January 2017 and Chuin-Chuan Chen of NTU will help host and the organization during Prof. Aoki's stay in Taipei. We plan to invite some visits from Europe and organize the workshops in NTU or NCKU.

(3) For the subprogram in the dynamical systems, our plans include: Lecture of Prof. Yun-Ping Jiang; 2017 Young Dynamics Day (February, 2017); 2017 Workshop on Dynamical Systems (May, 2017); Regular Seminar (Dynamical Diophantine Approximation in Higher Dimension). The organization of the major event "2018 AIMS Annual Meeting" is currently in process.

(4) The 8th Taiwan-Japan Joint Workshop for Young Scholars in Applied Mathematics to held at Hiroshima. This joint workshop is an important event between young people in Taiwan and Japan. We plan to send 15-20 students/postdocs to attend the workshop. In 2018, The 9th Taiwan-Japan Joint Workshop for Young Scholars in Applied Mathematics to held at Taiwan.

(5) ReaDiNet 2017: Reaction-Diffusion Network in Mathematics and Biomedecine will be held in Taiwan. This conference is supported by the CNRS Japan-Korea-Taiwan-France GDRI ReaDiNet, KAIST, NCTS, Meiji University, University of Nice, University Paris-Sud and University of Tokyo. The 2017 conference is sponsored by NCTS.

(6) We will continue organize Spring Workshops on Probability. The next one (2017) will be organized by Lung-Chi Chen. In addition to visitors from Japan and China, some Taiwanese probabilists, Wei-Kuo Chen (Minnesota), Yu-Ting Chen (Tennessee), Yu-Jui Huang (Colorado), Lo-Bin Chang(Ohio), Hau-Tieng Wu (Toronto), and others, will also plan to visit Taiwan next year.

5. Scientific Computing

a. Focuses: According to the current interests of the scientific computing groups, in 2017, we will still focus on the following topics:

(1) Design and analysis of robust numerical methods for multi-scale partial differential equations:
developing efficient numerical methods, such as adaptive methods, homogenization methods, multi-scale methods, and stabilization methods, as well as their rigorous error analysis are important in the future study of numerical partial differential equations.

(2) Developing efficient numerical methods for complex fluid-structure interaction problems:
the most challenging issue is how to develop efficient algorithms for solving 3-D problems. It should also be related to the topic of some computational geometry problems such as how to accurately compute geometric quantities on surfaces.

(3) Studying PDE-based image processing and compressive sensing:
imaging science is a rather young field in the community of applied mathematics, but it grows very fast in the past few years. It is indeed a typical interdisciplinary research area. An important new tool in imaging science is the compressive sensing technique, which was introduced about 10 years ago and had been very hot in the areas of signal processing and data science. It is a general belief that in real-world applications, the information we want to extract from a signal or image is relatively sparse, if properly represented, and thus a compressive sensing is possible if the data can be measured effectively.

(4) Structure-preserving methods for a large sparse nonlinear matrix equation arising in nano research:
The nonlinear matrix equation $X + A^\top X^{-1} A = Q$ arises in Green's function calculations in nano research, where A is a large sparse real square matrix and Q is a large sparse real symmetric matrix. The solution X_* of interest in the nano application is a special weakly stabilizing complex symmetric solution. It is well-known that span($[I,\ X_*^\top]^\top$) is a weakly stable invariant subspace of a real large sparse symplectic pencil $\mathcal{M} - \lambda\mathcal{L}$. The desired eigenpairs, which eigenvalues are near to a given shift value, of $\mathcal{M} - \lambda\mathcal{L}$ can be efficiently solved by the generalized $\top$-skew-Hamiltonian implicity-restarted Arnoldi method with shift value. The main computational challenges of solving the weakly stable invariant subspace of $\mathcal{M} - \lambda\mathcal{L}$ are how to efficiently estimate the distributions of the shift values and the desired eigenvalues, and how to efficiently compute the clustered eigenvalues near to zero. In this work, we will study how to develop (i) an adaptive method to determine the shift values; (ii) structure-preserving methods to estimate the approximated eigenvalues near to the shift value; (iii) a new structure-preserving non-equivalence deflation method

to reduce the number of the duplicated eigenvalues.

(5) Efficient numerical methods for the three-dimensional complex media: Discretized the source-free Maxwell equation with magnetoelectric coupling effects by the Yee's scheme results a generalized eigenvalue problem. It is well-known that the coefficient matrix in this generalized eigenvalue problem is indefinite and degenerate so that it has complex eigenvalues. The main computational challenge is solving the large sparse linear system with a giving shift value because it is difficult to find a suitable preconditioner. In this year, Professors Daniel B. Szyld and Edmond Chow are invited to visit Taiwan and give interesting talks about efficiently solving the linear systems. In this work, we will study how to develop an efficient method for solving the linear system.

(6) Developing structure-preserving method for finding the Perron pair of an inreducible nonnegative third order tensor:
In stochastic process, high-order Markov chain is a very important topic. In many cases, high-order Markov chain can be obtained from the modeling and analysis of big data. In order not to undermine local and global structure of the original data and can maximize their inherent information of the original data, high-order Markov chain can be represented by a tensor, called high-order nonnegative tensor. Therefore, how to determine the steady state of high-order Markov chain is a very important issue. In this work, we will study how to develop a positivity preserving iterative method for computing the largest eigenvalue and the associated positive eigenvector of third-order nonnegative tensor.

(7) Ultra-fast eigenvalue solvers on GPU for full bandgap spectrum of 3D SC and FCC photonic crystals. Full bandgap spectrum is essential to the study of 3D photonic crystals. However, such computation is also time-consuming. We plan to apply the algorithms proposed by the team members and implement the algorithms on multiple GPUs. The algorithms rely on fundamental computations such as FFT and matrix operations and can be performed efficiently on GPUs. Our goal is to develop codes that can solve the eigenvalue problems with millions unknown within one minute, which will be a world leading result.

(8) Monte Carlo numerical linear algebra in big data analysis. For the large matrices arising in big data analysis, SVD and PCA are two important tools. We intend to develop novel algorithms that can compute the approximate leading singular values and the corresponding singular vectors of such matrices by multiple random sketches. We also plan to extend the ideas to tensors via HOSVD and non-negative matrix factorizations. All of such algorithms will be designed to fit parallel computers and will be

used to solve real world problems.

b. The potential visitors:

   (1) Huoyuan Duan (Wuhan University, China), Specialty: stabilized finite element methods
   (2) Eunjung Lee (Yonsei University, Korea), Specialty: least-squares finite element methods
   (3) Ping Lin (University of Dundee, UK), Specialty: multiscale modelling techniques and their applications in biological, medical problems and medical image analysis
   (4) Haijian Yang (Hunan University, China), Specialty: domain decomposition methods
   (5) Michael W. Mahoney (ICSI and Dept of Statistics, UC Berkeley). randomized algorithms, computational statistics.
   (6) Edmond Chow (School of Computational Science and Engineering, Georgia Institute of Technology). High-performance computing and matrix computation.
   (7) Costas Bekas (Foundations of Cognitive Computing, IBM Research-Zurich, Switzerland). High-performance computing and machine learning.

c. The possible workshops:

   (1) 2016 NCTS Workshop on Complex and Biological fluid dynamics with applications organized by Prof. Ming-Chih Lai and Prof. Tai-Chia Lin on 2016.12.18-12.20.
   (2) One-Day Workshop on Numerical Partial Differential Equations
   (3) One-Day Workshop on Numerical Methods for Fluid-Structure Interaction Problems
   (4) 2017 NCTS Workshop on Computational Mathematics for Young Researchers

d. NCTS/NCU Seminar on Scientific Computing: We will organize this regular seminar for the coming academic year.

   Organizer: Suh-Yuh Yang (NCU)

   Time: The seminar will be held almost every week on Monday 10:00-12:00 with a discussion 12:00-13:00

   Venue: Room 107, Hong-Jing Hall, NCU

   Theme: According to the current interests of the scientific computing group at NCU, this seminar will focus on the following topics: (i) finite element stabilization techniques for the incompressible viscous flows; (ii) parameter-uniform difference scheme for strongly coupled systems of singularly perturbed equations; (iii) computational methods for simulating the dynamics of fluid-structure interaction problems; (iv) PDE-based image processing and compressive sensing.

6. Interdisciplinary Studies

In the coming year of 2016 and 2017, we will continue focus on several main topics such as electric double layers (related to ion channels, super-capacitors and desalination by nanofiltration), ecological interaction networks, phytoplankton, drug resistance bacteria and cancer stem cells. Preparation works for many activities are already underway.

(1) On December 2016, we will organize one international workshop on Complex and Biological fluid dynamics with applications (December 18-20).

(2) On December 2017, we will invite Francisco Bezanilla (Chicago U.), Bob Eisenberg (Rush Medical U.), Chun Liu (Penn State U.) and Lijun Shang (Bradford U., UK) to give a short course entitled "Modeling, Simulation and Analysis of ion transport through channels".

In the coming years, Chih-Hao Hsieh aims to further develop new Empirical Dynamic Modeling (EDM) methods to 1) study ecological interaction network, and 2) develop early warning signal for predicting critical transition of systems. These methods will be evaluated using models and real world systems.

In the coming year 2016-2017, we have two subprojects studying models of PDEs and ODEs, respectively. In the first subproject, we shall use PDEs to study the excessive dioxide in the atmosphere on the dynamics of phytoplankton with internal storage. In the second subproject, we shall use ODEs to study the dynamics of drug resistance bacteria in the morbidostat, a modern chemostat with optical devices.

We aim to explore how the spatial distribution of B-cell membrane receptors and its interaction with the membrane kinase molecules regulate the generation of receptors activation waves in immune systems.

7. Big and Complex Data Analysis

In the future, we will continue to the following events:

a. Workshops and short courses: We plan to regularly have a workshop on December. In addition, we would like to organize related mini-workshops or short courses to introduce the new developments in Data Science or the subfields in Statistics, like biostatistics, experimental design, financial statistics and so on. Hopefully these mini-workshop or short courses can provide chances for researchers and graduate students to share their ideas and research experiences.

b. Encourage domestic young researchers to attend international conferences and have short term visits: We will continuous encouraging faculties and PhD students to attend the international conferences or to have short term academical visiting. We believe this would help them to explore their international connections and to find the new cooperation opportunities.

c. Build international research cooperations: In this year, new international research cooperations have been formed in our program. It is always important to catch up these top researches in the world. Thus we would like to have more international visitors. These visitors do not only share their own novel research results with us but also give us chances to have new research cooperations.

8. Harmonic Analysis

In the coming year of 2017, several scholars will visit NCU to contribute to our program, including

a. Yongsheng Han (USA): March.

b. Qingbo Huang (USA): July.

c. Xuan Thinh Duong (Australia): September/October.

d. Sen Zhu (China): June – December.

e. Zipeng Wang (China): January – August.

f. Igor Shparlinski (Australia): inviting

g. Tuomas Hytonen (Finland): inviting

h. Eric Sawyer (Canada): inviting

i. Ignacio Uriarte-Tuero (USA): inviting

For the research subjects in 2017, we will focus on “singular integrals with flag kernels”, the “energy conditions in two weight T1 theory for Calderon-Zygmund operators”, and the “Neumann problem for Hörmander vector fields”.

a. Singular integrals with flag kernels

A new extension of product theory came to light with the proof by Müller, Ricci and Stein [Invent. Math., 1995] for the L^p boundedness, $1 < p < \infty$, of Marcinkiewicz multipliers on the Heisenberg group $\mathbb{H}^n$. This is surprising since Marcinkiewicz multipliers, which are invariant under a two-parameter group of dilations on $\mathbb{C}^n \times \mathbb{R}$, are bounded on $L^p(\mathbb{H}^n)$, despite the absence of a two-parameter automorphic group of dilation on $\mathbb{H}^n$. Müller, Ricci and Stein proved that the Marcinkiewicz multipliers on the Heisenberg groups are not the classical Calderón-Zygmund singular integrals but are singular integrals with flag kernels. Nagel, Ricci and Stein [J. Func. Anal., 2001] studied a class of operators on nilpotent Lie groups given by the convolution with flag kernels. They proved that product kernels can be written as finite sums of flag kernels and that flag kernels have good regularity, restriction and composition properties. Applying the theory of singular integrals with flag kernels to the study of the $\Box_b$-complex on certain quadratic CR submanifolds of $\mathbb{C}^n$, they obtained L^p regularity for certain derivatives of the relative fundamental solution of $\Box_b$ and for the corresponding Szegö projections onto the null space of $\Box_b$ by showing that the distribution kernels of these operators are finite sums of flag kernels. In order to prove the optimal estimates for solutions of the Kohn-Laplacian for certain classes of model domains in several complex variables, Nagel and Stein [Ann. of Math., 2006] applied a type of singular integral operator whose novel features are related to product theory and flag kernels. These operators differ essentially from the more standard Calderón-Zygmund operators that have been used in these problems hitherto. On the Euclidian space convolution with a flag kernel is a special case of product singular integrals. As a consequence, the L^p, $1 < p < \infty$, boundedness of singular integrals with flag kernels follows automatically from the same result for product singular integrals. However, since singular integrals with flag kernels have good regularity, a natural question arises: can one develop an appropriate Hardy space theory for singular integrals with flag kernels, which differs from the classical product Hardy space? Moreover, since the product theory is not available on the Heisenberg groups, it is interesting to ask: can one provide the Hardy space boundedness for the Marcinkiewicz multiplier on the Heisenberg groups?

b. The role of energy conditions in two weight T1 theory for Calderon-Zygmund operators

The energy condition is to capture the mutual distributions of two Borel measures in two weight theory. It has been shown that it is a necessary condition for the two weight norm inequality for the Hilbert transform. Moreover it has played a crucial role in our solution of NTV conjecture, proving the two weight T1 theory for the Hilbert transform. As a result, further investigation of energy conditions for high dimensional C-Z operators is a necessary thing to explore in subsequent work. The two weight T1 theory not only is a profound extension of David-Journe T1 theorem for Lebesgue measures, but also has many important applications, such as :

(i) when a rank one perturbation of a unitary operator is similar to a unitary operator. This could extend to an analogous question for a rank one perturbation of a normal operator T and lead to a two weight inequality for the

Cauchy transform with one measure being the spectral measure of T,

(ii) when a product of two densely defined Toeplitz operators $T_a T_b$ is a bounded operator, which is equivalent to the Birkhoff-Wiener-Hopf factorization for a given function $c = ab$; the same questions for the Bergman space could lead to a two weight problem for the Beurling transform,

(iii) questions regarding subspaces of the Hardy space invariant under the inverse shift operator,

(iv) questions concerning orthogonal polynomials.

V Appendix

V.1 Host institution's commitment

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。

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

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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

V.2 List of Courses and Lectures

Code	Title	Dates	Venue	Speaker	Organizer
A1	2016 NCTS Spring Course: Abelian Varieties and Related Topics	2016/02/15-2016/06/21	AS	Chia-Fu Yu	Chia-Fu Yu
A2	2016 NCTS Spring Course: Representation Theory of Finite Groups of Lie type	2016/02/19-2016/06/24	AS	Chia-Fu Yu	Chia-Fu Yu
A3	AS-NCTS Special Lecture Series on Arithmetic Geometry	2016/03/02-2016/03/21	NCTS	Chia-Fu Yu	Chia-Fu Yu
A4	2016 NCTS Summer School on Shimura Varieties and Related Topics	2016/05/23-2016/05/27	NCTS	P. Hamacher, B. Smithling, T. Wedhorn, etc.	Chia-Fu Yu
A5	On the Conjecture of Birch and Swinnerton-Dyer for Quadratic Twists of $X_0(49)$ I/II	2016/07/05-2016/07/07	NCTS	John Coates	Minglun Hsieh
A6	NCTS Summer Short Course on Number Theory I/II	2016/08/02-2016/08/11	NTHU	Chieh-Yu Chang, Fu-Tsun Wei	Chang Chieh-Yu, Fu-Tsun Wei
B5	NCTS Summer Course on Elliptic Curve	2016/07/25-2016/08/12	NCTS	Yi-Fan Yang, Wu-Yen Chuang , Chin-Yu Hsiao	Jungkai Chen
B1	2016 NCTS Minicourse in Algebraic Geometry: minimal log-discrepancy	2016/03/16-2016/03/23	NCTS	Masayuki Kawakita	Jungkai Chen
B2	2016 NCTS Minicourse in Algebraic Geometry: Boundedness in Algebraic Geometry	2016/03/16-2016/03/25	NCTS	Paolo Cascini	Jungkai Chen
B3	NCTS Distinguished Scholar Lectures: Noncommutative Deformations	2016/03/18-2016/03/25	NCTS	Yujiro Kawamata	Jungkai Chen
B4	2016 NCTS Minicourse in Algebraic Geometry: MMP for foliations	2016/04/06-2016/04/08	NCTS	Paolo Cascini	Jungkai Chen
C1	NCTS Mini course on Mirror Symmetry	2016/06/18-2016/06/20	NCTS	Kazushi Ueda	River Chiang, Mao-Pei Tsui
C2	NCTS Summer Course on Aspects of Geometric Analysis	2016/07/04-2016/07/12	NCTS	Mu Tao Wang	Mao-Pei Tsui
C3	Mini Course on Symplectic Fillings and More	2016/07/26-2016/07/28	NCTS	Jongil Park, CheukYu Mak	River Chiang, C.-I Ho
C4	Summer Course on Fractional Sobolev Spaces in Geometric Knot Theory	2016/08/02-2016/08/05	NCTS	Simon Blatt	Mao-Pei Tsui
C5	Sinica-NCTS Distinguished Lecture Series: Steklov Eigenvalues and Free Boundary Minimal Surfaces	2016/08/03-2016/08/03	NCTS	Richard Schoen	Mao-Pei Tsui
D1	Mathematical Theory for Kinetic Equations	2016/02/26-2016/06/24	NCKU	Kazuo Aoki, Tai-Ping Liu, Jin-Cheng Jiang	Kung-Chien Wu
D2	NCTS Seminar in Quantum Random Walks	2016/03/11-2016/03/21	NCTS	Wei-Shih Yang	Chih-Chung Chang, Yuan-Chung Sheu
D3	2016 NCTS Probability Summer Courses	2016/07/25-2016/08/16	NCTS	Tzuu-Shuh Chaing, Shuenn-Jyi Sheu	Sheu Yuan-Chung
D4	NCTS Summer School on Dynamical Systems: Topological and arithmetic dynamics	2016/08/05-2016/09/16	NCTS	W. Abram, Derong Kong, Ai-Hua Fan, etc.	Jung-Chao Ban

E1	NCTS 2016 Short Courses on High-Performance Linear System Solvers	2016/02/23-2016/06/07	NCTS	T.-M. Huang, W.-C. Wang, Rio Yokota, etc.	W.-C. Wang, W.-W. Lin, T.-M. Huang
E2	Big Data Meeting	2016/03/24-2017/06/30	NCTS	Matthew M. Lin	W.-C. Wang
F1	NCTS mini course on Ginzburg-Landau equations and related topics	2016/04/15-2016/05/14	NCTS	Rejeb Hadiji	Tai-Chia Lin
F2	2016 Summer Course on Mathematical Modeling and Analysis of Infectious Diseases	2016/07/04-2016/07/08	NCTS	H. Nishiura, J. Dushoff, Philip Lo (CDC), etc.	Ying-Hen Hsieh, Lin Hsien-Ho
F3	2016 NCTS Summer Course in Modeling for Stochastic Processes in Cell Biology	2016/07/14-2016/09/01	NCTS	Chao-Ping Hsu, Ching-Cher Yan	Chao-Ping Hsu, J.-C. Tsai, C.-C. Yan
F4	2016 NCTS Summer Course in Mathematical Biology	2016/08/01-2016/08/26	NTHU	Feng-Bin Wang, Chang-Hong Wu, Yaping Wu, etc.	Sze-Bi Hsu, J.-C. Tsai, F.-B. Wang
F5	Short Course in Optimization: Theory and Mathematical Models I	2016/08/15-2016/08/19	NCTS	Ruey-Lin Sheu	R.-L. Sheu, J.-S. Chen
H1	NCTS Mini-course on Analysis at NSYSU	2016/04/07-2016/05/26	NSYSU	Denny Leung	Wong Ngai-Ching

V.3 List of Conference and Workshops

	Event	Date	Venue	Organizers
A1	Workshop on Finite Groups, VOA and Algebraic Combinatorics	2016/03/21-2016/03/25	Fo Guang Univ.	Lam Ching-Hung
A2	2016 AS-NCTS Workshop on Shimura Varieties and Related Topics	2016/05/30-2016/06/03	AS	Yu Chia-Fu, He Xuhua, Lan Kai-Wen
A3	Conference in finite groups and vertex algebras	2016/08/22-2016/08/26	AS	Lam Ching-Hung, Dong Chong-Ying, Lyons Richard, Ryba Alex
A4	Japan-Taiwan Joint conference on Number theory 2016	2016/09/08-2016/09/13	NCTS	Hsieh Ming-Lun
B1	Younger Generation in Algebraic Geometry and Complex Geometry	2016/01/11-2016/01/15	NCTS	Chen Jheng-Jie, Chuang Wu-yen, Furukawa Katsuhisa, Gongyo Yoshinori, Jow Shin-Yao, Lai Ching-Jui, Ohashi Hisanori, Okada Takuzo, Watanabe Kiwamu
B2	NCTS Workshop in Algebraic Geometry at CCU	2016/03/29-	CCU	Chen Jungkai
B3	NCTS AG Day	2016/10/14-	NCTS	Chen Jungkai
B4	NCTS AG Day	2016/11/11-	NCKU	Chen Jungkai
B5	One Day workshop in Algebraic Geometry	2016/12/16-	NCTS	Chen Jungkai
C1	2016 The third Taiwan International Conference on Geometry	2016/01/18-2016/01/22	NCTS	Lee Yng-Ing, Chang Sun-Yung Alice
C2	The 12th Taiwan Geometry Symposium	2016/05/14-	NTHU	Tsui Mao-Pei, Lee Yng-Ing, Ho Nan-Kuo, Chiang River
C3	NCTS International Workshop on Geometric Analysis and Subelliptic PDEs	2016/05/24-2016/05/26	NCTS	Chang Der-Chen, Chang Shu-Cheng, Tsui Mao-Pei
C4	NCTS one day workshop on symplectic and poisson geometry	2016/06/08-	NTHU	Ho Nan-Kuo, Tsui Mao-Pei

C5	NCTS Mini Course on Mirror Symmetry	2016/06/18-2016/06/20	NCTS	Tsui Mao-Pei, Chiang River
C6	NCTS Special Day on Isometric Embeddings	2016/07/15-	NCTS	Tsui Mao-Pei
C7	Mini Course on Symplectic Fillings and More	2016/07/26-2016/07/28	NCTS	Tsui Mao-Pei
D1	2016 NCTS Young Dynamics Day	2016/02/19-	NCTS	Ban Jung-Chao, Chen Kuo-Chang, Hsu Cheng-Hsiung
D2	Workshop on Recent Development in Reaction-Diffusion Equations	2016/02/26-	NCTS	Chen Chiun-Chuan, Chern Jann-Long, Fang Yung-fu, Guo Jong-Shenq, Mimura Masayasu, Morita Yoshihisa, Yotsutani Shoji
D3	The 7th Taiwan-Japan Joint Workshop for Young Scholars in Applied Mathematics	2016/02/27-2016/02/29	NCKU	Chen Chiun-Chuan, Chern Jann-Long, Fang Yung-fu, Guo Jong-Shenq
D4	Spring Probability Workshop in 2016	2016/03/07-2016/03/09	AS	Chen Guan-Yu
D5	2016 NCTS Workshop on Applied Mathematics at Tainan	2016/03/28-	Nat'l Univ. Tainan	Guo Jong-Shenq, Wu Chang-Hong, Ishiwata Tetsuya, Yeh Tzung-Shin, Huang Yin-Liang
D6	2016 NCTS Workshop on Dynamical Systems	2016/08/15-2016/08/18	NCTS	Ban Jung-Chao, Chen Kuo-Chang, Hsu Cheng-Hsiung, Fan Ai-Hua, Jiang Yunping
D7	2nd East Asia Section of IPIA-Young Scholars Symposium	2016/11/05-2016/11/06	NCTS	Wang Jenn-Nan
D8	NCTS Workshop on Nonlinear Differential Equations: Theory and Application	2016/11/18-2016/11/19	NCTS	Wang Jenn-Nan, Chen Chiun-Chuan, Tsai Je-Chiang, Fu Sheng-Chen, Wu Chang-Hong
E1	Water Waves: Theory, Simulations & Experiments A Communication Between Mathematics & Engineering	2016/03/13-	NCTS	Hsia Chun-Hsiung, Yuan Juan-Ming, Chern I-Liang
E2	2016 NCTS Workshop on Computational Mathematics for Young Researchers	2016/03/18-2016/03/19	NCTU	Yang Suh-Yuh, Lin Wen-Wei, Chern I-Liang, Lai Ming-Chih, Wang Weichung
E3	NCTS workshop on Compressive Sensing + Signal Processing	2016/04/15-	NCTS	I-Liang Chern
E4	NCTS Workshop on Compressive Sensing + Brain Science through MRI	2016/04/22-	NCTS	Chern I-Liang
E5	Workshop on Recent Development of Matrix Computations	2016/05/13-	NCTS	Huang Tsung-Ming, Lin Wen-Wei, Wang Weichung
F1	2016 NCTS International Workshop in Mathematical Biology	2016/05/21-2016/05/23	NTHU	Hsu Sze-Bi, Tsai Je-Chiang, Wang Feng-Bin, Zhao Xiaoqiang
F2	2016 Summer Course on Mathematical Modeling and Analysis of Infectious Diseases	2016/07/04-2016/07/08	NCTS	Hsieh Ying-Hen, Lin Hsien-Ho
F3	2016 Optimization Workshop	2016/02/26-	NTNU	Sheu Ruey-Lin, Chen Jein-Shan
G1	Big and Small Data in Statistical Quality Control and Reliability Analysis	2016/05/20-	NCKU	Jeng Shuen-Lin, Chen Ray-Bing
G2	Big Data Learning for Prediction	2016/06/30-	NCTS	Wang Wei-Chung
H1	NCTS One-day Workshop on Analysis	2016/02/16-	NCTS	Lin Chin-Cheng
H2	2016 Analysis Young Scholars Symposium	2016/05/06-	NCU	Lin Chin-Cheng, Lee Ming-Yi
Z1	NCTS 2016 Spring Day	2016/03/27-	NCTS	Chen Jungkai

V.4 List of Seminars

Title	Dates	Gp.	Place
NCTS Number Theory Seminar at Hsinchu	4/13, 4/27, 6/1, 6/15, 9/1	A	NTHU
NCTS Seminar on Arithmetic Geometry	2/15, 2/18, 2/25, 3/3	A	NCTS
NCTS Seminar on Arithmetic Geometry and Representation Theory	3/17, 3/24	A	NCTS
Number Theory Seminar of NCTS	2/22, 2/23, 2/24, 3/17, 3/18, 7/8	A	NCTS
NCTS seminar of Algebra	8/31,	A	NCTS
NCTS Seminar in Algebraic Geometry	3/4, 4/15, 4/22, 4/29, 5/6, 5/13, 5/20, 5/27, 6/3, 6/17, 7/1, 7/25, 9/23, 9/30	B	NCTS
NCTS Seminar of Cryptography	6/14, 6/15, 6/17	B	NCTS
NCTS Algebraic Geometry Seminar at NCKU	3/22, 4/19, 5/3, 5/17, 5/31, 7/5, 7/12, 7/19, 7/20, 7/26, 8/2, 8/17, 8/29, 9/26	B	NCKU
NCTS Differential Geometry Seminar	2/18, 3/3, 3/10, 3/17, 3/24, 3/31, 4/14, 4/25, 4/28, 5/12, 5/26, 6/2, 6/16, 6/23, 7/21, 8/2, 8/24, 9/27, 10/4	C	NCTS
Sinica-NCTS Geometry Seminar	4/8, 4/11, 8/26, 9/2, 9/9	C	NCTS
NCU-Sinica-NCTS Geometry Seminar	9/30,	C	NCU
Sinica-NCTS Seminar on Geometry and Several Complex Variables	4/15,	C	NCTS
NCTS Seminar of Topology	6/21,	C	NCTS
2016 NCTS & NCU Probability Seminar	6/3,	D	NCU
2016 NCTS & NCU Stochastic Seminar	6/3,	D	NCU
NCTS/CMMSC Seminar on PDEs	3/9, 3/16, 4/15, 4/22, 4/29, 5/13, 5/20	D	NCTU
NCTS & NCU PDE Seminar	1/6, 1/22, 5/13, 5/27, 6/3	D	NCU
NCTS & NUK Seminar on Dynamical Systems	4/22, 5/13, 5/27	D	NUK
NCTS / CMMSC Seminar on Probability and Statistics	1/7	D	NCTU
NCTS Seminar on Probability with Applications	10/7	D	NCTU
NCTS and NCUE PDE Seminar	3/31, 4/21, 4/28, 5/5, 5/26	D	NCUE
NCTS PDE seminar at NCKU	6/2, 6/3	D	NCKU
NCTS Probability Seminar at NCCU	3/28, 4/25, 5/9, 5/23, 6/6	D	NCCU
NCTS Seminar in Dynamical Systems	1/12	D	NUK
NCTS Seminar in Quantum Random Walks	3/12, 3/14, 3/21	D	NCTS
NCTS/Academia Sinica Joint Seminar on Probability Theory and Related Topics	7/4, 7/11	D	NCTS
Seminar on Inverse Problems	4/15, 5/20	D	NCTS
NCTS Seminar on PDE and Analysis	1/7, 1/26, 3/24, 4/14, 4/28, 5/2, 5/5, 5/12, 5/19, 8/19, 10/5	D, F	NCTS
NCTS / NTU / NCU / NTUST Joint Seminar on Compressive Sensing and Its Applications	1/8, 1/15	E	NCTS
NCTS Seminar on Compressive Sensing + Signal Processing	4/15	E	NCTS
NCTS Seminar on High Frequency Approximations	6/13, 6/14	E	NCTS
NCTS/NCU Seminar on Scientific Computing	9/19, 10/3	E	NCU
NCTS Seminar on Applied Mathematics	3/4, 4/15, 5/16, 5/24	E, F	NCTS
NTHU-NCTS Seminar on Mathematical Biology	1/8, 3/16, 5/11, 5/20, 5/24, 6/3, 6/17, 8/9, 10/7	F	NTHU
NCTS Interdisciplinary Research Seminar	3/11	F	NCTS
NCTS Mathematical Modeling Seminar	3/9, 3/10, 6/13	F	NCTS
NCTS Seminar on Nonlinear Schrodinger Equations	7/14	F	NCTS
NCTS & NCU Harmonic Analysis Seminar	3/25, 9/27, 9/29	H	NCU
NCTS Learning Seminar in Singular Integral Operators	3/8, 3/15, 3/22, 3/29	H	NCU
NCTS Seminar on Harmonic Analysis	1/7, 1/14	H	NCU
NCTS Forum in Data Sciences	3/24, 4/21, 5/19, 6/8, 7/21, 8/25, 9/22, 10/27, 11/22	L	NCTS
NCTS Seminar on Data Sciences	7/28	L	NCTS
Taipei Postdoc Seminar	9/14, 9/21, 9/27, 10/5, 10/12	All	AS

V.5 List of Visitors

Arr. Date	Dep. Date	Name	Gp.	Affiliation	Country	Title
2016/1/1	2016/1/18	Hau-Tieng Wu	E	University of Toronto	Canada	Prof
2016/1/3	2016/1/7	Kenichi Namikawa	A	Tokyo Denki University	Japan	Prof
2016/1/10	2016/1/23	Nicola Fusco	D	University of Naples	Italy	Prof
2016/1/10	2016/1/22	Rupert McCallum	A	University of Tbingen	Germany	PD
2016/1/11	2016/1/31	Xiongtao Zhang	D	Seoul National University	South Korea	PD
2016/1/11	2016/2/29	Fang-Ting Tu	A	Inst. Comput. Exp. Res. Math.	USA	PD
2016/1/11	2016/1/21	Rita Fioresi	A	University of Bologna	Italy	Prof
2016/1/11	2016/1/15	Tatsuki Hayama	C	Sensui University	Japan	Prof
2016/1/11	2016/1/15	Kiwamu Watanabe	B	Saitama University	Japan	Prof
2016/1/11	2016/1/15	Takuzo Okada	B	Saga University	Japan	Prof
2016/1/11	2016/1/15	Hisanori Ohashi	B	Tokyo University of Science	Japan	Prof
2016/1/11	2016/1/15	Yoshinori Gongyo	B	University of Tokyo	Japan	Prof
2016/1/11	2016/1/15	Akihiro Kanemitsu	C	University of Tokyo	Japan	Prof
2016/1/11	2016/1/15	Sho Ejiri	C	University of Tokyo	Japan	Ph.D.
2016/1/11	2016/1/15	Kento Fujita	C	Kyoto University	Japan	Prof
2016/1/11	2016/1/15	Kenji Hashimoto	C	Max Planck Institute	Germany	Ph.D.
2016/1/11	2016/1/15	Nobuo Hara	C	Tokyo Univ of Agr. and Tech.	Japan	Prof
2016/1/11	2016/1/15	Hajime Kaji	B	Waseda University	Japan	Prof
2016/1/12	2016/1/19	Chi-Kun Lin	D	Xi'an Jiaotong-Liverpool Univ.	China	Prof
2016/1/13	2016/1/22	Man-Chun Lee	C	CUHK	Hong Kong	Ph.D.
2016/1/15	2016/2/15	Ting-Hui Yang	D	Tamkang University	Taiwan	Prof
2016/1/15	2016/1/22	Eugene Zhu Xia	B	National Cheng Kung University	Taiwan	Prof
2016/1/18	2016/2/18	Feng-Bin Wang	F	Chang Gung University	Taiwan	Prof
2016/1/18	2016/1/22	Shih-Cheng Kang	B	National Cheng Kung University	Taiwan	Ph.D.
2016/1/18	2016/1/28	Man-Kam Kwong	D	The Hong Kong Poly. Univ.	Hong Kong	Prof
2016/1/18	2016/1/22	Qing Han	C	University of Notre Dame	USA	Prof
2016/1/18	2016/1/22	Robin Graham	C	University of Washington	USA	Prof
2016/1/18	2016/1/22	John Bland	C	University of Toronto	Canada	Prof
2016/1/18	2016/1/22	Olivier Biquard	C	Université Pierre et Marie Curie	France	Prof
2016/1/18	2016/1/22	Kengo Hirachi	C	University of Tokyo	Japan	Prof
2016/1/18	2016/1/22	John M.Lee	C	University of Washington	USA	Prof
2016/1/18	2016/1/22	Tongzhu Li	C	Beijing Institute of Technology	China	Prof
2016/1/18	2016/1/22	Andrea Malchiodi	C	Scuola Normale Superiore	Italy	Prof
2016/1/18	2016/1/22	Fernando Marques	C	Princeton University	USA	Prof
2016/1/18	2016/1/22	Davi Maximo	C	Stanford University	USA	Prof
2016/1/18	2016/1/22	Ana Menezes	C	Princeton University	USA	Prof
2016/1/18	2016/1/22	Jie Qing	C	UC Santa Cruz	USA	Prof
2016/1/18	2016/1/22	Tristan Riviere	C	ETH Zrich	Switzerland	Prof
2016/1/18	2016/1/22	Yuguang Shi	C	Peking University	China	Prof
2016/1/18	2016/1/22	Peter Topping	C	University of Warwick	UK	Prof
2016/1/18	2016/1/22	Yi Wang	F	Univ. of Sci. and Tech. of China	China	Prof
2016/1/18	2016/1/22	Xiaodong Wang	C	Michigan State University	USA	Prof
2016/1/18	2016/1/22	Paul Yang	C	Princeton University	USA	Prof
2016/2/11	2016/2/25	Shinichi Kobayashi	A	Tohoku University	Japan	Prof
2016/2/15	2016/2/20	Xing-Bin Pan	D	East China Normal University	China	Prof
2016/2/17	2016/2/24	Mikiya Masuda	C	Osaka City University	Japan	Prof
2016/2/18	2016/2/19	Wen-Guei Hu	C	Sichuan University	China	Prof
2016/2/24	2016/2/26	Masayasu Mimura	D	Meiji University	Japan	Prof
2016/2/24	2016/2/26	Yotsutani Shoji	F	Ryukoku University	Japan	Prof
2016/2/25	2016/2/29	Yoshihisa Morita	D	Ryukoku University	Japan	Prof
2016/2/26	2016/3/1	Mayuko Iwamoto	F	Meiji University	Japan	Prof
2016/2/26	2016/3/1	Akiyasu Tomoeda	F	Musashino University	Japan	Prof
2016/2/26	2016/3/1	Shuichi Kinoshita	F	Musashino University	Japan	Prof
2016/2/26	2016/3/1	Daishin Ueyama	F	Meiji University	Japan	Prof
2016/2/26	2016/3/1	Tomoyuki Miyaji	D	Meiji University	Japan	Prof

2016/2/26	2016/2/26	Kota Ikeda	D	Meiji University	Japan	Prof
2016/2/26	2016/2/26	Masayasu Mimura	D	Meiji University	Japan	Prof
2016/2/26	2016/2/26	Yoshihisa Morita	D	Ryukoku University	Japan	Prof
2016/2/26	2016/2/26	Shoji Yotsutani	D	Ryukoku University	Japan	Prof
2016/2/26	2016/2/26	Hirokazu Ninomiya	F	Meiji University	Japan	Prof
2016/2/28	2016/3/4	François Loeser	B	Université Pierre et Marie Curie	France	Prof
2016/2/29	2016/3/12	Christian Klingenberg	F	Wrzburg University	Germany	Prof
2016/3/1	2016/3/31	Wei-Shih Yang	D	Temple University	USA	Prof
2016/3/1	2016/3/31	Yongsheng Han	H	Auburn University	USA	Prof
2016/3/4	2016/3/19	Kenichi Namikawa	A	Tokyo Denki University	Japan	Prof
2016/3/5	2016/3/13	Matt Holzer	F	George Mason University	USA	Prof
2016/3/6	2016/3/31	Masayuki Kawakita	B	RIMS	Japan	Prof
2016/3/7	2016/3/29	Jerry L. Bona	D	University of Illinois at Chicago	USA	Prof
2016/3/7	2016/3/29	Hongqiu Chen	D	University of Memphis	USA	Prof
2016/3/7	2016/3/9	Naotaka Kajino	D	Kobe University	Japan	Prof
2016/3/7	2016/3/9	Panki Kim	D	Seoul National University	South Korea	Prof
2016/3/7	2016/3/9	Takashi Kumagai	D	RIMS	Japan	Prof
2016/3/7	2016/3/9	Akira Sakai	D	Hokkaido University	Japan	Prof
2016/3/7	2016/3/9	Jian Wang	D	Fujian Normal University	China	Prof
2016/3/10	2016/3/18	Hiroshi Fujiwara	E	Kyoto University	Japan	Prof
2016/3/13	2016/3/13	Jerry L. Bona	D	University of Illinois at Chicago	USA	Prof
2016/3/13	2016/3/13	Hongqiu Chen	D	University of Memphis	USA	Prof
2016/3/14	2016/3/16	Mu-Tao Wang	C	Columbia University	USA	Prof
2016/3/14	2016/4/2	Yujiro Kawamata	B	University of Tokyo	Japan	Prof
2016/3/14	2016/4/8	Eric K.-w Chu	E	Monash University	Australia	Prof
2016/3/15	2016/4/9	Paolo Cascini	B	Imperial College London	UK	Prof
2016/3/15	2016/4/15	Tie-Xiang Li	E	Southeast University	China	Prof
2016/3/15	2016/4/13	King Fai Lai	A	Capital Normal University	China	Prof
2016/3/20	2016/3/28	Rio Yokota	E	Tokyo Institute of Technology	Japan	Prof
2016/3/20	2016/3/26	Richard Pasquetti	E	Université Nice Sophia Antipolis	France	Prof
2016/3/21	2016/3/25	Masahiko Miyamoto	A	University of Tsukuba	Japan	Prof
2016/3/21	2016/3/25	Hiroshi Yamuchi	A	Tokyo Woman's Christian Univ.	Japan	Prof
2016/3/21	2016/3/25	Chong-Ying Dong	A	UC Santa Cruz	USA	Prof
2016/3/21	2016/3/25	CuiPo Jiang	A	Shanghai Jiao Tong University	China	Prof
2016/3/21	2016/3/25	Hiroki Shimakura	A	Kyoto University	Japan	Prof
2016/3/21	2016/3/25	Hiromichi Yamada	A	University of Tokyo	Japan	Prof
2016/3/21	2016/3/25	Yusuke Arike	A	University of Tsukuba	Japan	Prof
2016/3/21	2016/3/25	Koichiro Harada	A	University of Tokyo	Japan	Prof
2016/3/21	2016/3/25	Koichi Betsumiya	A	Hirosaki University	Japan	Prof
2016/3/21	2016/3/25	Kuwabara Toshiro	A	University of Tsukuba	Japan	Ph.D.
2016/3/21	2016/3/25	Tanabe Kenichiro	A	Hokkaido University	Japan	Prof
2016/3/23	2016/3/27	Brian Smithling	A	Johns Hopkins University	USA	Prof
2016/3/23	2016/3/27	Torsten Wedhorn	A	Technische Universität Darmstadt	Germany	Prof
2016/3/24	2016/3/26	Jishan Hu	D	HKUST	Hong Kong	Prof
2016/3/24	2016/3/26	Yutian Li	D	Hong Kong Baptist University	Hong Kong	Prof
2016/3/24	2016/3/26	Wei Wang	D	Zhejiang University	China	Prof
2016/3/24	2016/3/26	Chisato Iwasaki	D	Osaka University	Japan	Prof
2016/3/26	2016/3/27	Feng-Bin Wang	F	Chang Gung University	Taiwan	Prof
2016/3/27	2016/3/31	Yoshinori Gongyo	B	University of Tokyo	Japan	Prof
2016/3/28	2016/3/28	Tetsuya Ishiwata	D	Shibaura Institute of Technology	Japan	Prof
2016/4/1	2016/5/31	Denny H. Leung	H	National University of Singapore	Singapore	Prof
2016/4/1	2016/6/30	Gen Nakamura	D	Inha University	South Korea	Prof
2016/4/11	2016/4/16	Yau Shu Wong	E	University of Alberta	Canada	Prof

2016/4/11	2019/3/31	Kazuo Aoki	F	Kyoto Univ./ NCTS	Japan	Prof
2016/4/12	2016/4/26	Viktor Ginzburg	C	UC Santa Cruz	USA	Prof
2016/4/15	2016/5/14	Rejeb Hadiji	F	Universitá Paris-Est Créteil	France	Prof
2016/4/20	2016/7/18	Isao Ishikawa	A	Kyoto University	Japan	Ph.D.
2016/4/27	2016/5/5	Pen-Yuan Hsu	F	University of Tokyo	Japan	PD
2016/4/28	2016/5/3	Manabu Machida	D	Hamamatsu Univ, School of Med.	Japan	Prof
2016/5/1	2016/5/20	Edmond Chow	E	Georgia Institute of Technology	USA	Prof
2016/5/2	2016/5/10	Hirokazu Ninomiya	F	Meiji University	Japan	Prof
2016/5/10	2016/5/15	Miyuki Koiso	C	Kyushu University	Japan	Prof
2016/5/11	2016/5/19	Daniel B. Szyld	E	Temple University	USA	Prof
2016/5/12	2016/5/19	Eric Chu	D	Monash University	Australia	Prof
2016/5/13	2016/5/26	Shuanglin Shao	H	University of Kansas	USA	Prof
2016/5/17	2016/5/30	Der-Chen Chang	C	Georgetown University	USA	Prof
2016/5/19	2016/5/28	Stephen Schecter	F	North Carolina State University	USA	Prof
2016/5/19	2016/5/25	Wei-Ming Ni	D	University of Minnesota	USA	Prof
2016/5/20	2016/5/24	Yijun Lou	F	The Hong Kong Poly. Univ.	Hong Kong	Prof
2016/5/20	2016/5/24	Keng Deng	F	Univ. Louisiana at Lafayette	USA	Prof
2016/5/20	2016/5/20	Regina Liu	F	Rutgers University	USA	Prof
2016/5/21	2016/6/26	Yu Jin	F	University of Nebraska-Lincoln	USA	Prof
2016/5/21	2016/5/23	Jian Fang	F	Harbin Institute of Technology	China	Prof
2016/5/21	2016/5/23	Kohei Yoshiyama	F	Gifu University	Japan	Prof
2016/5/21	2016/5/23	Xiaoqiang Zhao	F	Memorial Univ. Newfoundland	Canada	Prof
2016/5/23	2016/5/25	Qin Tim Sheng	E	Baylor University	USA	Prof
2016/5/23	2016/5/27	Paul Hamacher	A	Technische Universität München	Germany	Prof
2016/5/24	2016/5/27	Wolfgang Schulze	D	University of Potsdam	Germany	Prof
2016/5/24	2016/5/26	Alex Vasiliev	D	University of Bergen	Norway	Prof
2016/5/24	2016/5/26	Irina Markina	D	University of Bergen	Norway	Prof
2016/5/24	2016/5/26	Wolfram Bauer	D	Leibniz Universität Hannover	Germany	Prof
2016/5/24	2016/5/26	Kenro Furutani	D	Tokyo University of Science	Japan	Prof
2016/5/26	2016/6/1	Hans G. Kaper	E	Georgetown University	USA	Prof
2016/5/27	2016/6/3	Matthew Papanikolas	A	Texas A&M University	USA	Prof
2016/5/30	2016/6/3	Miaofen Chen	A	East China Normal University	China	Prof
2016/5/30	2016/6/3	Laurent Fargues	A	CNRS	France	Prof
2016/5/30	2016/6/3	Ruochuan Liu	A	Peking University	China	Prof
2016/5/30	2016/6/3	Sian Nie	A	Chinese Academy of Sciences	China	Prof
2016/5/30	2016/6/3	Mao Sheng	A	Univ. of Sci. and Tech. of China	China	Prof
2016/5/30	2016/6/3	Xu Shen	A	Chinese Academy of Sciences	China	Prof
2016/5/30	2016/6/3	Rong Zhou	A	Harvard University	USA	Prof
2016/5/30	2016/6/3	Xinwen Zhu	A	California Institute of Technology	USA	Prof
2016/5/30	2016/6/3	Sug Woo Shin	A	UC Berkeley	USA	Prof
2016/5/30	2016/6/3	Brian Smithling	A	Johns Hopkins University	USA	Prof
2016/5/30	2016/6/3	Yoshinori Mishiba	A	Oyama College	Japan	Prof
2016/5/30	2016/6/3	Keerthi Madapusi Pera	A	University of Chicago	USA	Prof
2016/5/30	2016/6/3	Paul Hamacher	A	Technische Universität München	Germany	Prof
2016/5/30	2016/6/3	Ulrich Görtz	A	Universität Duisburg-Essen	Germany	Prof
2016/5/30	2016/6/3	Ana Caraiani	A	Princeton University	USA	Prof
2016/5/31	2016/6/5	Satoshi Sasayama	D	Hokkaido University	Japan	PD
2016/6/1	2016/7/31	Ye-Kai Wang	C	Michigan State University	USA	Prof
2016/6/3	2016/6/7	Martin Guest	C	Waseda University	Japan	Prof
2016/6/5	2016/6/17	Olof Runborg	E	KTH Royal Institute of Tech.	Sweden	Prof
2016/6/6	2016/6/11	Reyer Sjamaar	C	Cornell University	USA	Prof
2016/6/7	2016/6/16	Xudong Chen	D	National University of Singapore	Singapore	Prof

2016/6/8	2016/6/8	Hsuan-Yi Liao	D	Pennsylvania State University	USA	Ph.D.
2016/6/10	2016/6/19	Ming-Deh A. Huang	B	University of Southern California	USA	Prof
2016/6/15	2016/6/30	Yung-Sze Choi	D	University of Connecticut	USA	Prof
2016/6/16	2016/6/21	Kazushi Ueda	C	University of Tokyo	Japan	Prof
2016/6/17	2016/6/24	Stephen S-T. Yau	A	Tsinghua University	China	Prof
2016/6/19	2016/8/14	Mu-Tao Wang	C	Columbia University	USA	Prof
2016/6/20	2016/7/31	Hau-Tieng Wu	E	University of Toronto	Canada	Prof
2016/6/21	2016/6/27	Da Zhou	G	Xiamen University	China	Prof
2016/6/21	2016/7/27	Chi-Jen Wang	F	Georgia Institute of Technology	USA	Prof
2016/6/24	2016/7/16	John H. Coates	A	University of Cambridge	UK	Prof
2016/6/26	2016/7/12	Horng-Tzer Yau	D	Harvard University	USA	Prof
2016/6/30	2016/6/30	Shaw-Hwa Lo	D	Columbia University	USA	Prof
2016/6/30	2016/6/30	Tian Zheng	G	Columbia University	USA	Prof
2016/7/1	2017/1/31	Yunping Jiang	D	The City University of New York	USA	Prof
2016/7/1	2016/7/31	Gi-Ren Liu	D	National Tsing Hua University	Taiwan	Prof
2016/7/2	2016/8/1	Yen-Hsi Richard Tsai	D	University of Texas at Austin	USA	Prof
2016/7/3	2016/7/17	Romyar T. Sharifi	A	University of Arizona	USA	Prof
2016/7/6	2016/7/13	Yu-Ting Chen	D	Harvard University	USA	PD
2016/7/6	2016/7/18	Meng Fai Lim	A	Central China Normal University	China	Prof
2016/7/8	2016/7/31	Jordan Keller	C	Columbia University	USA	Ph.D.
2016/7/10	2016/8/10	Yibin Ren	C	Zhejiang Normal University	China	PD
2016/7/10	2016/7/15	Shuyang Cheng	A	University of Chicago	USA	Prof
2016/7/11	2016/8/5	Damin Wu	C	University of Connecticut	USA	Prof
2016/7/11	2016/8/5	Lan-Hsuan Huang	C	University of Connecticut	USA	Prof
2016/7/11	2016/7/15	Wen-Ching Winnie Li	A	Pennsylvania State University	USA	Prof
2016/7/11	2016/7/15	Raphael Beuzart-plessis	A	National University of Singapore	Singapore	Prof
2016/7/11	2016/7/15	Soumya Das	A	Indian Institutes of Technology	India	Prof
2016/7/11	2016/7/15	Radhika Ganapathy	A	Tata Institute	India	Prof
2016/7/11	2016/7/15	Hiraku Atobe	A	Kyoto University	Japan	PD
2016/7/11	2016/7/15	Tong Liu	A	Purdue University	USA	Prof
2016/7/11	2016/7/15	Guangshi Lü	A	Shandong University	China	Prof
2016/7/11	2016/7/15	Chol Park	A	KIAS	South Korea	Prof
2016/7/11	2016/7/15	Takeshi Saito	A	University of Tokyo	Japan	Prof
2016/7/11	2016/7/15	Romyar T. Sharifi	A	University of Arizona	USA	Prof
2016/7/11	2016/7/15	Florian Sprung	A	Princeton University	USA	Prof
2016/7/11	2016/7/15	Zhiren Wang	A	Pennsylvania State University	USA	Prof
2016/7/11	2016/7/15	Peng-Jie wong	A	Queen's University	Canada	Prof
2016/7/11	2016/7/15	Hang Xue	A	Max Planck Institute	Germany	Prof
2016/7/11	2016/7/15	John Coates	A	University of Cambridge	UK	Prof
2016/7/11	2016/7/15	Wee Teck Gan	A	National University of Singapore	Singapore	Prof
2016/7/11	2016/7/15	Tamotsu Ikeda	A	Kyoto University	Japan	Prof
2016/7/11	2016/7/15	Kazuya Kato	A	University of Chicago	USA	Prof
2016/7/11	2016/7/15	Minhyong Kim	A	University of Oxford	UK	Prof
2016/7/11	2016/7/15	Bào Châu Ngô	A	University of Chicago	USA	Prof
2016/7/11	2016/7/15	Sujatha Ramdorai	A	University of British Columbia	Canada	Prof
2016/7/11	2016/7/15	Ye Tian	A	Chinese Academy of Sciences	China	Prof
2016/7/14	2016/7/16	Zhizhang Wang	C	Fudan University	China	Prof
2016/7/15	2016/8/22	Chun-Hung Liu	A	Princeton University	USA	PD
2016/7/15	2016/8/2	Xuding Zhu	A	Zhejiang Normal University	China	Prof
2016/7/23	2016/8/8	Qingbo Huang	H	Wright State University	USA	Prof
2016/7/24	2016/7/30	Cheuk Yu Mak	B	University of Minnesota	USA	PD
2016/7/24	2016/7/29	Pei-Ken Hung	C	Columbia University	USA	Ph.D.
2016/7/24	2016/7/30	Jongil Park	C	Seoul National University	South Korea	Prof
2016/7/25	2016/8/9	Di-Ming Lu	B	Zhejiang University	China	Prof
2016/7/25	2016/8/3	Daphne Der-Fen Liu	A	Cal. State Univ., Los Angeles	USA	Prof

2016/7/26	2016/7/26	Ivan Davydov	E	Sobolev Institute of Mathematics	Russia	Prof
2016/7/26	2016/7/26	Yuri Kochetov	E	Sobolev Institute of Mathematics	Russia	Prof
2016/7/28	2016/8/13	Pengzi Miao	C	University of Miami	USA	Prof
2016/7/30	2016/8/6	Simon Blatt	C	University of Salzburg	Austria	PD
2016/8/1	2016/8/31	Hua Nie	F	Zhejiang University	China	Prof
2016/8/1	2016/8/31	Tomoya Wada	D	Tokyo Univ. of Agr. and Tech.	Japan	Ph.D.
2016/8/1	2016/8/31	Xiwu Han	D	Beijing Institute of Technology	China	Ph.D.
2016/8/1	2016/8/31	Jing Wang	D	Beijing Institute of Technology	China	Ph.D.
2016/8/1	2016/8/30	Simone Fiori	D	Marche Polytechnic University	Italy	Prof
2016/8/3	2016/8/26	William C. Abram	D	Hillsdale College	USA	Prof
2016/8/5	2016/8/19	Wen-Xin Qin	D	Suzhou University	China	Prof
2016/8/5	2016/9/16	Tomohiro Uchiyama	B	The University of Auckland	New Zealand	PD
2016/8/9	2016/8/19	Derong Kong	D	Yangzhou University	China	Prof
2016/8/10	2016/9/25	Akinari Hoshi	A	Niigata University	Japan	Prof
2016/8/10	2016/8/30	Yun Zhao	D	Suzhou University	China	Prof
2016/8/10	2016/8/19	Yaping Wu	F	Capital Normal University	China	Prof
2016/8/11	2016/8/16	Tomoki Kawahira	D	Tokyo Institute of Tech.	Japan	Prof
2016/8/12	2016/8/26	Yongluo Cao	D	Suzhou University	China	Prof
2016/8/13	2016/8/17	Doowon Koh	H	Chungbuk National University	South Korea	Prof
2016/8/14	2016/8/23	Ai-Hua Fan	D	Université de Picardie	France	Prof
2016/8/14	2016/8/23	Wen Huang	D	Sichuan University	China	Prof
2016/8/14	2016/8/22	Shi-Liang Wu	D	Xidian University	China	Prof
2016/8/14	2016/8/31	I-Kun Chen	D	Kyoto University	Japan	PD
2016/8/14	2016/8/19	Shilei Fan	D	Central China Normal University	China	Prof
2016/8/14	2016/8/19	Ercai Chen	D	Nanjing Normal University	China	Prof
2016/8/15	2016/8/18	Yunping Jiang	D	The City University of New York	USA	Prof
2016/8/15	2016/8/18	Wen-Guei Hu	C	Sichuan University	China	Prof
2016/8/15	2016/8/18	Hui Rao	D	Central China Normal University	China	Prof
2016/8/15	2016/8/18	Dejun Feng	D	CUHK	Hong Kong	Prof
2016/8/15	2016/8/18	Kasing Lau	D	CUHK	Hong Kong	Prof
2016/8/15	2016/8/18	Yang Wang	D	HKUST	Hong Kong	Prof
2016/8/15	2016/8/18	Zhou Ping Xin	D	CUHK	Hong Kong	Prof
2016/8/15	2016/8/18	Tomoki Kawahira	D	Tokyo Institute of Technology	Japan	Prof
2016/8/15	2016/8/18	Mansoor Saburov	D	Int'l Islamic Univ. Malaysia	Malaysia	Prof
2016/8/15	2016/8/18	William C. Abram	D	Hillsdale College	USA	Prof
2016/8/15	2016/8/18	Lingmin Liao	D	Université Paris-Est Créteil	France	Prof
2016/8/18	2016/9/3	Yoshinori Mishiba	A	Oyama College	Japan	Prof
2016/8/20	2016/12/20	Yung-Sze Choi	D	University of Connecticut	USA	Prof
2016/8/22	2016/8/26	Tomoyuki Arakawa	A	Kyoto University	Japan	Prof
2016/8/22	2016/8/26	Chong-Ying Dong	A	UC Santa Cruz	USA	Prof
2016/8/22	2016/8/26	John Duncan	A	Emory University	USA	Prof
2016/8/22	2016/8/26	Daniel Frohardt	A	Wayne State University	USA	Prof
2016/8/22	2016/8/26	Terry Gannon	A	University of Alberta	Canada	Prof
2016/8/22	2016/8/26	George Glauberman	A	University of Chicago	USA	Prof
2016/8/22	2016/8/26	Jonathan Hall	A	Michigan State University	USA	Prof
2016/8/22	2016/8/26	Koichiro Harada	A	University of Tokyo	Japan	Prof
2016/8/22	2016/8/26	Gerald Höhn	A	Kansas State University	USA	Prof
2016/8/22	2016/8/26	CuiPo Jiang	A	Shanghai Jiao Tong University	China	Prof
2016/8/22	2016/8/26	Naihuan Jing	A	North Carolina State University	USA	Prof
2016/8/22	2016/8/26	Haisheng Li	A	Rutgers University	USA	Prof
2016/8/22	2016/8/26	Kay Magaard	A	University of Birmingham	UK	Prof
2016/8/22	2016/8/26	Masahiko Miyamoto	A	University of Tsukuba	Japan	Prof
2016/8/22	2016/8/26	Alex Ryba	A	City University of New York	USA	Prof
2016/8/22	2016/8/26	Leonard Scott	A	University of Virginia	USA	Prof

2016/8/22	2016/8/26	Yoav Segev	A	Ben-Gurion Univ. of the Negev	Israel	Prof
2016/8/22	2016/8/26	Peter Sin	A	University Of Florida	USA	Prof
2016/8/22	2016/8/26	Hiroki Shimakura	A	Kyoto University	Japan	Prof
2016/8/22	2016/8/26	Stephen Smith	A	University of Illinois at Chicago	USA	Prof
2016/8/22	2016/8/26	Pham Huu Tiep	A	University of Arizona	USA	Prof
2016/8/25	2016/9/23	Aiichi Yamasaki	A	Kyoto University	Japan	Prof
2016/8/25	2016/8/31	Ryo Okawa	B	RIMS	Japan	Prof
2016/9/1	2016/9/30	Bing Li	D	South China University of Tech.	China	Prof
2016/9/1	2017/1/31	Frances Y. Kuo	F	Univ. of New South Wales	Australia	Prof
2016/9/5	2016/9/16	Paul Binding	D	University of Calgary	Canada	Prof
2016/9/8	2016/9/13	Masataka Chida	A	Tohoku University	Japan	Prof
2016/9/8	2016/9/13	Wataru Kai	A	Universität Duisburg-Essen	Germany	PD
2016/9/8	2016/9/13	Yoichi Mieda	A	University of Tokyo	Japan	Prof
2016/9/8	2016/9/13	Kentaro Nakamura	A	Saga University	Japan	Prof
2016/9/8	2016/9/13	Yuji Odaka	A	Kyoto University	Japan	Prof
2016/9/8	2016/9/13	Yoshiyasu Ozeki	A	Kyoto Institute of Technology	Japan	Prof
2016/9/8	2016/9/13	Kanetomo SATO	A	Chuo University	Japan	Prof
2016/9/8	2016/9/13	Shunsuke Yamana	A	Kyoto University	Japan	PD
2016/9/8	2016/9/13	Shuji Yamamoto	A	Keio University	Japan	Prof
2016/9/8	2016/9/13	Takao Yamazaki	A	Tohoku University	Japan	Prof
2016/9/8	2016/9/13	Ren-He Su	A	Kyoto University	Japan	Prof
2016/9/11	2016/9/23	Shigeki Akiyama	D	University of Tsukuba	Japan	Prof
2016/9/18	2016/9/30	Xuan Thinh Duong	H	Macquarie University	Australia	Prof
2016/9/22	2016/9/26	Martin Guest	C	Waseda University	Japan	Prof
2016/9/30	2016/10/9	Lingbing He	D	Tsinghua University	China	Prof
2016/10/1	2016/11/30	Yuuji Tanaka	C	Nagoya University	Japan	PD
2016/10/2	2017/1/24	Khai Ching Ng	F	Universiti Tenaga Nasional	Malaysia	Prof
2016/10/5	2016/10/17	Tu Nguyen	D	Vietnam Academy of Sci. Tech.	Vietnam	Prof
2016/10/11	2016/10/18	Danielle Hilhorst	D	Université Paris-Sud	France	Prof
2016/10/28	2016/11/6	Boniface Nkonga	E	Université Nice Sophia Antipolis	France	Prof
2016/10/29	2016/11/6	Sergey Gavrilyuk	F	Aix-Marseille University	France	Prof
2016/11/4	2016/11/7	Hongyu Liu	D	Hong Kong Baptist Univ.	Hong Kong	Prof
2016/11/5	2016/11/6	Jun-Yong Eom	D	Inha University	South Korea	Ph.D.
2016/11/5	2016/11/6	Hiromichi Itou	D	Tokyo University of Science	Japan	Prof
2016/11/5	2016/11/6	Manas Kar	D	University of Jyväskylä	Finland	Prof
2016/11/5	2016/11/6	Atsushi Kawamoto	D	University of Tokyo	Japan	Ph.D.
2016/11/5	2016/11/6	Xiaofei Li	D	Inha University	South Korea	Ph.D.
2016/11/5	2016/11/6	Yikan Liu	D	University of Tokyo	Japan	Ph.D.
2016/11/5	2016/11/6	Hisashi Morioka	D	Shibaura Institute of Technology	Japan	Ph.D.
2016/11/5	2016/11/6	Yuliang Wang	D	Hong Kong Baptist University	Hong Kong	Prof
2016/11/5	2016/11/6	Haibing Wang	D	Southeast University	China	Prof
2016/11/5	2016/11/6	Jing-Ni Xiao	D	Hong Kong Baptist University	Hong Kong	Ph.D.
2016/11/5	2016/11/6	Xiang Xu	D	Zhejiang University	China	Prof
2016/11/5	2016/11/6	Jiaqing Yang	D	Xi'an Jiaotong University	China	Prof
2016/11/5	2016/11/6	Sang Hyeon Yu	D	ETH Zrich	Switzerland	Ph.D.
2016/11/5	2016/11/6	Hai Zhang	D	HKUST	Hong Kong	Prof
2016/11/5	2016/11/6	Hongyu Liu	D	Hong Kong Baptist University	Hong Kong	Prof
2016/11/5	2016/11/6	Bo Zhang	D	Chinese Academy of Sciences	China	Prof
2016/11/5	2016/11/6	Gunther Uhlmann	D	University of Washington	USA	Prof
2016/11/5	2016/11/6	Jun Zou	D	CUHK	Hong Kong	Prof
2016/11/12	2016/12/1	Ansgar Jüngel	F	Vienna Univ. of Tech.	Austria	Prof
2016/11/13	2016/11/26	Chen Jiang	B	IPMU	Japan	Prof
2016/11/15	2017/2/15	Inchi Hu	G	HKUST	Hong Kong	Prof
2016/11/18	2016/11/19	Francois Hamel	D	Aix-Marseille University	France	Prof
2016/11/18	2016/11/19	Bei Hu	D	University of Notre Dame	USA	Prof

2016/11/18	2016/11/19	Hiroshi Matano	D	University of Tokyo	Japan	Prof
2016/11/18	2016/11/19	Masayasu Mimura	D	Meiji University	Japan	Prof
2016/11/18	2016/11/19	Philippe Souplet	D	Universit Paris 13	France	Prof
2016/11/18	2016/11/19	Hirokazu Ninomiya	D	Meiji University	Japan	Prof
2016/11/18	2016/11/19	Yoshihisa Morita	D	Ryukoku University	Japan	Prof
2016/11/18	2016/11/19	Shoji Yotsutani	D	Ryukoku University	Japan	Prof
2016/11/18	2016/11/19	Xinfu Chen	D	University of Pittsburgh	USA	Prof
2016/12/4	2016/12/18	Weng Kee Wong	D	UC Los Angeles	USA	Prof
2016/12/10	2017/1/10	Nikolaos Zygouras	D	University of Warwick	UK	Prof
2016/12/10	2017/1/10	Anatol N. Kirillov	D	RIMS	Japan	Prof
2016/12/14	2016/12/21	Burt Totaro	B	UC Los Angeles	USA	Prof
2016/12/14	2016/12/18	Lawrence Ein	B	University of Illinois at Chicago	USA	Prof
2016/12/15	2017/1/5	Yen-Hsi Richard Tsai	D	University of Texas at Austin	USA	Prof
2016/12/17	2016/12/24	Hajime Koba	F	Osaka University	Japan	Prof
2016/12/18	2016/12/19	Michael Miksis	F	Northwestern University	USA	Prof
2016/12/18	2016/12/19	Chaouqi Misbah	F	Universit Joseph-Fourier	France	Prof
2016/12/18	2016/12/19	Xiaofan Li	F	Illinois Institute of Technology	USA	Prof
2016/12/18	2016/12/19	Shuwang Li	F	Illinois Institute of Technology	USA	Prof
2016/12/18	2016/12/19	Zhilin Li	F	North Carolina State University	USA	Prof
2016/12/18	2016/12/19	Yuan-Nan Young	F	New Jersey Institute of Tech.	USA	Prof
2016/12/18	2016/12/19	Yoichiro Mori	F	University of Minnesota	USA	Prof
2016/12/18	2016/12/19	Qi Wang	F	University of Southern California	USA	Prof
2016/12/18	2016/12/19	Xiu Ye	F	University of Arkansas	USA	Prof
2016/12/18	2016/12/23	Sheng-Chi Liu	A	Washington State University	USA	Prof
2016/12/27	2016/12/30	Shigefumi Mori	B	Kyoto University	Japan	Prof
2016/12/27	2016/12/30	Hélèene Esnault	B	Berlin	Germany	Prof
2016/12/27	2016/12/30	Shing-Tung Yau	C	Harvard University	USA	Prof
2016/12/27	2016/12/30	Horng-Tzer Yau	D	Harvard University	USA	Prof
2016/12/27	2016/12/30	Thomas Hou	E	Cal Tech	USA	Prof
2016/12/27	2016/12/30	Russell Calflisch	E	UCLA	USA	Prof

V.6 Publication data of Key Members

	2012	2013	2014	2015	2016
Adv. Applied Mathematics and Mechanics			2		
Adv. Calc. Var.				1	
Adv. Differential Equations					1
Adv. Math.			1	2	
Adv. Studies in Pure Mathematics				1	
Adv. Theoretical and Mathematical Physics			2		
Algebr. Represent. Theory				1	
Algoritmica		1			
Amer. J. Math.	1		1	1	
Ann. Sc. Norm. Super. Pisa Cl. Sci		1	1		2
Appl. Anal.				1	
Appl. Math. Lett.		1			
Appl. Mathematical Finance				2	
Appl. Mathematical Modelling				2	
Appl. Mathematics and Computation		2		1	
Appl. Stochastic Models in Business and Industry	1			1	
Arch. Rational Mech. Anal	1			1	1
Asian J. Mathematics					1
Bernoulli Journal					1
Biogeosciences		2			
BIT Numer. Math.				1	
BMC Genomics	1				
Boundary Value Problems		1			
Bull. Institute of Mathematics, Academia Sinica		1	3		
Bulletin of Mathematical Biology		1			
Calc. Var. Partial Differential Equations 54			1	3	1
Cambridge J. Mathematics					2
Comm. Algebra					
Comm. Analysis and Geometry				1	2
Comm. Computational Physics	1	1	1	1	2
Comm. Inf. System			2		
Comm. Math. Sci.					1
Comm. Mathematical Physics			1	1	3
Comm. Nonlinear Science and Numerical Simulation	2		2		
Comm. Partial Differential Equations				1	1
Comm. Pure and Applied Analysis				1	1
Comm. Statistics - Simulation and Computation					1
Complex Systems				1	
Compositio Mathematica		1	3	2	
Computational and Numerical Simulations			1		
Computational Economics		1			
Computational Statistics and Data Analysis		2	3		1
Computer Methods in Applied Mechanics and Engineering	2		2		2
Computer Physics Communications	1				2
Computers and Mathematics with Applications		1			
Contemporary Mathematics		1	1		
Differential & Difference Equations and Applications		1			
Differential and Integral Equations					1
Differential Geometry and its Applications	1				
Discrete and Continuous Dynamical Systems - Series A		1	1		1
Discrete and Continuous Dynamical Systems - Series B	5	1	1		5
Discrete Appl. Math.	4	5	2	1	
Discrete Math.	4	1		1	
Discrete Math. Theor. Comput. Sci.	1				
Discussiones Mathematicae Graph Theory			1		
Documenta Mathematica			1		

Duke Math. J.	1				
East Asian Journal on Applied Mathematics		1			
Ecological Modelling	1				
Ecology			2		1
Elec. J. Comb				1	
Elect. Comm. in Probab.		2			
Fisheries Oceanography	1			1	
Forum Mathematicum	3				1
Functional Ecology					1
Geom. Imag. Comput.			1		
Geometry & Topology	1				
Graph Comnbin					2
Hydrological Processes			2		
IEEE Transactions on Information Theor		1			
IMA J. Numerical Analysis			1	2	
Indiana Univ. Math. J.		1			
Inform. Process. Letters		1			
Int. J. Mach. Learn. & Cyber			1		
Int. J. Number Theory		1			
Internat. J. Math.			1		
International Mathematics Research Notices		1		2	
Inverse Problems	1	2	2		
Inverse Problems and Imaging			1		
Israel J. Math.			1		
J. Algebra	3			4	3
J. American Mathematical Society	2		1		
J. Animal Ecology		1			
J. Applied Probability	2				
J. Applied Statistics				1	
J. Chinese Statistical Association					
J. Combin. Optim				1	
J. Combin. Theory	3	2	2		
J. Computational and Applied Mathematics		1	2		
J. Computational and Graphical Statistics					1
J. Computational Physics		1	7	1	5
J. Data Science	1				
J. Differential Equations	3		2	3	3
J. Dynamics. Differential Equation				1	
J. Elasticity			1	1	
J. European Mathematical Society					1
J. Evolution Equations	1		1		
J. Fixed Point Theory Appl.				1	
J. Fluid Mechanics					1
J. Functional Analysis			2	1	
J. Geometric Analysis			2		2
J. Geometric Mechanics					1
J. Geometry and Physics	1				
J. Global Optimization			1		
J. Graph Theory		1			
J. Inequalities and Applications		1			
J. Korean Statistical Society			1		
J. Math. Biology					2
J. Math. Phys				1	
J. Math. Pures Appl		1			1
J. Math. Soc. of Japan				1	
J. Mathematical Analysis and Applications			1		2
J. Mathematical Physics		1	1		
J. Matrix Analysis and Applications					
J. Multivariate Analysis		1			

J. Number Theory	1				
J. Pure Appl. Algebra	1	1		1	
J. Scientific Computing	1	1	1	6	1
J. Statistical Physics				3	
J. Symplectic Geom.					1
Jour. Reine Angew. Math.			2	1	4
Kodai Math. J.					2
Letters in Mathematical Physics		1	1		1
Linear Algebra Appl.	1		2		
Linear and Multilinear Algebra			1		
Manuscripta Mathematica			1		
Mathematical and Computer Modelling		1			
Mathematical Proc. Cambridge Philosophical Soc.					1
Mathematical Research Letters	1	2		1	
Mathematische Annalen	3	1			
Mathematische Zeitschrift	1	3	1		2
Memoirs of the Amer. Math. Soc.		1			
Nagoya Math. J.		1	2		
Neural Networks		1		1	1
Neural Processing Letters			1		
New York J. Mathematics				2	
Nonlinearity				1	
Num. Algorithms			1		
Num. Lin. Alg. Appl.					1
Num. Method for PDE			1		
Numer. Math.				1	1
Optimization Methods and Software	1				
Pacific J. Mathematics	1		1		
Parallel Computing			2		
Physical Review A					1
Physical Review E	1				1
Physics Letters A			2	2	
PLoS ONE	3	1		3	
Proc. National Academy of Sciences		1		1	
Proc. Amer. Math. Soc	3		1	2	2
Proc. Royal Society of London					1
Pure Appl. Math. Q	2		2	1	
Quality and Reliability Engineering International		1			
Quantitative Finance		2		1	
Rapid Communications				1	
Science	1				
SIAM J. Scientific Computing	1				
SIAM J. Discrete Math.	1				
SIAM J. Imaging Sciences		1			
SIAM J. Math. Anal.	1	1	2	2	1
SIAM J. Matrix Anal. Appl.				2	2
SIAM J. Sci. Comp.				2	2
Statistica Sinica					1
Statistics and Computing		2		4	
Statistics and Probability Letters.					1
Stochastic Processes and Their Applications	2				
Symmetry, Integrability and Geometry: Methods and Appl.			1	1	
Taiwanese J. Math				2	1
Technometrics					4
The Ramanujan Journal	1			1	
Theor. Compt. Sci.	1	1			
Topology and its Applications					1
Trans. Amer. Math. Soc	2	1	1	1	3
Zoological Studies		1		1	