IBS Center for Geometry and Physics

Report for the Inaugural Year

July 31, 2012 December 31, 2013

Institute for Basic Science

Background and Purpose

The **Center for Geometry and Physics** **(CGP)** was founded in July 2012 as one of the first research centers of the **Institute for Basic Science** **(IBS)**. **IBS** is a newly established research institute in Korea that aims to become a dream research institute for world-class scientists where they can enjoy the utmost freedom in conducting their research projects.

The CGP originated in a government funded award, via IBS, to the research program of its director Yong-Geun Oh. This program aims to help establish and develop the emerging field of symplectic algebraic topology through a collaborative effort by experts in fields such as symplectic geometry, dynamical systems, algebraic geometry and mathematical physics. The center is currently evolving into an international institution with a broader scope, focusing more generally on geometry and mathematical physics.

An ideal scientific research institute should be a place which fosters the disinterested pursuit of learning and the fundamental innovative thinking that advances the individual fields of inquiry of an intellectual community. The center's goal is to enable the research environment at the CGP to achieve this ideal. The center exists to provide an environment for the creation of new mathematics, engagement in international collaboration, and inspiration of young and upcoming leaders to further pursue the fields of geometry and theoretical physics.

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Even though Korea has a long and rich intellectual history, its participation in the modern scientific and mathematical communities is relatively new. In particular, institutes dedicated solely to mathematics are very rare, making the CGP a valuable institution with the potential to serve an important function within the larger Korean scientific community. The center's emphasis on international collaboration will offer a chance for scholars with similar passions to plant ideas together and watch them grow, no matter where they are on the globe, and allow the center to serve as a bridge between Korean mathematicians and the international mathematical community.

The center is loosely organized into multiple research groups, each of which comprises a senior scholar (group leader) and several researchers whose areas of expertise and interest overlap synergistically. The director and group leaders decide collectively on the major scientific activities such as annual thematic programs, conferences, and seminars, and distribute the center's budget accordingly. They also select and work closely with research fellows, visitors and graduate students.

The center is located on the intellectually dynamic campus of **Pohang University of Science and Technology (POSTECH)** in Pohang, Korea. Members and visitors at the Center will immediately be immersed in an intellectual network that reaches beyond the peaceful seaside city.

Director's Note on the Inaugural Year

While I was a post-doc member of the Institute for Advanced Studies (IAS) in Princeton in 1990–1991, I often expressed to Taeim, my wife, how grateful I felt to IAS for providing such a wonderful supportive environment not only for my mathematical research but also for my family life. But I also wondered why. What did I do for them to get treated like this? Just because I did what I liked and enjoyed most? I wished so much that my country, Korea, would have this kind of research institute leaving its members completely free so that they could do what they liked to do most! When I heard the Korean government was going to create basic science institutes aiming to make them dream institutes of this kind, I had little reservation trying to get on board, and luckily, here I am.

It is a great pleasure and privilege to be able to take this journey with Professors Jae-Suk Park and Jihun Park. I very much appreciate their courage to take the challenge of exploring this uncharted territory, at least in the realm of Korean scientific research. I know that it takes some courage and faith in what they are doing to leave what they already have in hand and aim for what we do not see but hope. I also give many thanks to my administrative staff members for their hard work to make the CGP an enjoyable place for research members and visitors. Without their devotion, the launch of the CGP would not have been so successful.

The Inaugural Conference in June was a great success. The topics covered by the speakers did a good job representing the mathematical vision for the CGP that I initially proposed to the IBS Selection and Evaluation Committee. Especially the inclusion of three promising young mathematicians was beautiful. It set the bar for what the CGP should aim for when fostering the younger generation of mathematical researchers under its umbrella.

I am also very happy to see our Inaugural Thematic Program of "Symplectic topology and mirror symmetry" running smoothly so far and hope that by the end of the year and afterwards much fruit will be garnered out of the scientific interactions and collaborations the CGP provided. I am sure that good words about the CGP will be spread out all over the world by the visitors who participated in the program.

I am glad to hear that KTX, the high-speed train, will be connected from Seoul directly to Pohang by the end of 2014, which will make it much simpler to welcome foreign visitors. I am also looking forward to seeing the first shovel for the government-promised permanent research building project in the near future. I am deeply privileged to be the director of one of the IBS institutions and thank the Korean government for providing such an opportunity to me, especially because this is the only math research center so far. I hope to see more of this kind of research institution in mathematics in Korea in the near future.

Awards and Honors

The **Fellows of the American Mathematical Society** program recognizes members who have made outstanding contributions to the creation, exposition, advancement, communication, and utilization of mathematics. Director **Yong-Geun Oh** was selected as one of the inaugural class fellows of the society on November 1, 2012.

The **Kyung-Ahm Education & Culture Foundation** recognized Director **Yong-Geun Oh**'s seminal contributions in Floer homology and Hamiltonian mechanics with the **Kyung-Ahm Prize** on September 24, 2012. The Kyung-Ahm Prize is one of the highest honors in art, science, and technology in Korea.

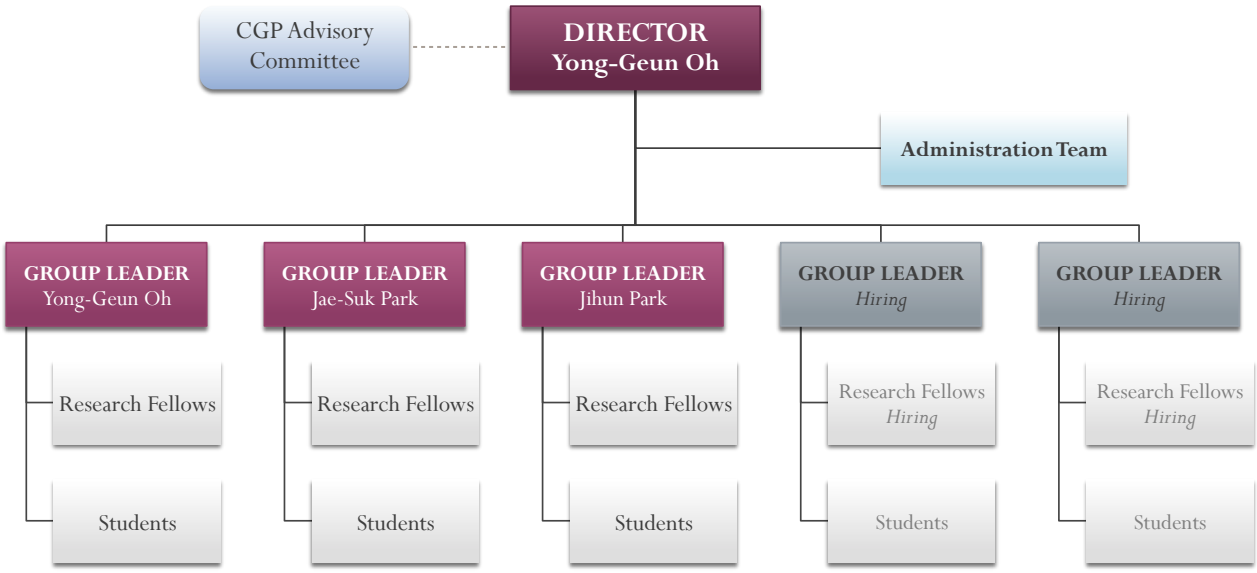
On November 29, 2013, Director **Yong-Geun Oh** was elected as a member of the **Korean Academy of Science and Technology**, Korea's highest integrated think-tank for science and technology.

Organization

The academic body of the center consists of three research groups, including that of the director. Currently, there are twelve research fellows including three tenure-track members. There is also a participating member from the POSTECH faculty as well as ten graduate students. The center has also recruited two distinguished visiting fellows.

In addition to the Selection and Evaluation Committee of IBS, the center has organized the CGP Advisory Committee for additional oversight. The Advisory Committee comprises eight distinguished scholars from Korea and abroad.

The administration unit has six staff members, including a Head and an IT support personnel.



Research Groups

Symplectic Topology, Hamiltonian Dynamics and Mirror Symmetry

Group Leader: **Yong-Geun Oh**

The current status of symplectic topology resembles that of classical topology in the middle of the twentieth century. Over time, a systematic algebraic language was developed to describe problems in classical topology. Similarly, a language for symplectic topology is emerging, but has yet to be fully developed. The development of this language is much more challenging both algebraically and analytically than in the case of classical topology. The relevant homological algebra of A_∞ structures is harder to implement in the geometric situation due to the analytical complications present in the study of pseudo-holomorphic curves or "instantons" in physical terms. Homological mirror symmetry concerns a certain duality between categories of symplectic manifolds and complex algebraic varieties. The symplectic side of the story involves an A_∞ category, called the Fukaya category, which is the categorified version of Lagrangian Floer homology theory. In the meantime, recent developments in the area of dynamical systems have revealed that the symplectic aspect of area preserving dynamics in two dimensions has the potential to further understanding of these systems in deep and important ways. Research themes and research members are as follows:

- Symplectic and contact topology:
  - **Byung Hee An** (*algebraic topology, geometric group theory*)
  - **Juhyun Lee** (*contact geometry, hyperbolic geometry*)
  - **Rui Wang** (*symplectic geometry, contact geometry*)
- Hamiltonian dynamics and dynamical systems:
  - **Youngjin Bae** (*symplectic geometry, dynamics in Hamiltonian systems*)
- Gromov-Witten theory and mirror symmetry:
  - **Jeff Brown** (*mirror symmetry, symplectic geometry*)
  - **Sangwook Lee** (*symplectic geometry, homological mirror symmetry*)
  - **Dongning Wang** (*symplectic topology, mirror symmetry, orbifolds*)

Mathematics of Quantum Field Theory

Group Leader: **Jae-Suk Park**

Ideas and principles from quantum field theory have been applied to many important and active areas of mathematics in the last three decades. Typically, such an application begins with a rigorous mathematical framework for the mathematical object in question and a corresponding example of (usually topological) quantum field theory and builds an elaborate dictionary—though the latter side may lack mathematical definition. On the physical side, in all such examples, the quantum field theory comes endowed with a physically natural duality. Via the dictionary, this leads to a duality or correspondence between different mathematical objects, which is generally extremely non-trivial mathematically. Such correspondences are usually studied on a case-by-case basis, separately for each application.

Taken in toto, these phenomena seem to imply that there should be a mathematical unification of those mathematical structures related to quantum field theory. With all the current examples and evidence at hand, it is time to ask the following fundamental question:

What is quantum field theory mathematically and

when is a mathematical quantum field theory physical?

The primary goal of the group's research is to establish an algebraic and mathematically rigorous foundation for quantum field and string theory and pursue its consequences in both pure mathematics and theoretical physics.

The members of this group have diverse backgrounds and interests in mathematics and physics, and each member's area(s) of interest are as follows:

- **Gabriel C. Drummond-Cole** (*algebraic topology*)
- **Calin Iuliu Lazaroiu** (*symplectic and algebraic geometry, category theory, string theory*)
- **Dong Uk Lee** (*arithmetic algebraic geometry*)
- **Jae-Suk Park** (*mathematics of quantum field and string theory*)
- **Jeehoon Park**[1] (*algebraic number theory, arithmetic geometry*)

[1]Participating member from the POSTECH faculty.

Arithmetic, Birational and Complex Geometry of Fano Varieties

Group Leader: **Jihun Park**

For a given smooth variety with pseudo-effective canonical class, the minimal model program produces a birational model of the variety, the so called minimal model, that has mild singularities (terminal and Q-factorial) and whose canonical class is nef. This has been verified in dimension 3 and in all dimensions for varieties of general type.

Meanwhile, if the canonical class is not pseudo-effective, then the minimal model program yields a birational model, a so-called Mori fibred space. It also has terminal and Q-factorial singularities and it admits a fiber structure of relative Picard rank one such that the anticanonical class is ample on fibers. This has been proved in all dimensions. Fano varieties of Picard rank one with at most terminal Q-factorial singularities are important examples of Mori fibred spaces.

Fano varieties are algebraic varieties whose anticanonical classes are ample. They are classical and fundamental varieties that play many significant roles in contemporary geometry. Verified or expected geometric and algebraic properties of Fano varieties have attracted attention from many geometers and physicists. In spite of extensive study of Fano varieties for more than a century, numerous features of Fano varieties are still shrouded in a veil of mist. Contemporary geometry requires a more comprehensive understanding of Fano varieties. This research group is to play a role in broadening comprehensive knowledge about Fano varieties by studying them from various points of view. Currently, the members and their research areas are as follows:

- **Sung Rak Choi** (*algebraic geometry, minimal model program*)
- **Jihun Park** (*algebraic geometry, Fano varieties*)
- **Youngho Yoon** (*algebraic geometry, singularity theory*)

Distinguished Visiting Fellows

The Center for Geometry and Physics invites leading scholars in mathematics and physics for recurring long-term visits to the center as part of the effort to encourage the development of young researchers. Appointees visit the CGP for up to three months a year during their appointment period. The center provides full support for each visit: salary, travel expenses and accommodation. A distinguished visiting fellow may invite her/his own visitors with financial support from the CGP.

The current Distinguished Visiting Fellows are:

Kenji Fukaya
Faculty, Simons Center for Geometry and Physics
Member, Japanese National Academy of Sciences

Dmitry Kaledin
Researcher, Steklov Mathematical Institute
Professor, Independent University of Moscow

CGP Advisory Committee

The CGP Advisory Committee consists of eight distinguished scholars from Korea and abroad. The committee meets once a year and provides advice and input on the operations of the center.

The current members of the Advisory Committee are:

Choe, Jaigyoung
Professor, Korea Institute for Advanced Study

Katzarkov, Ludmil
Professor, University of Miami
Professor, Universität Wien

Kim, Myung-Hwan
Professor, Seoul National University
President, Korean Mathematical Society

Morgan, John
Director, Simons Center for Geometry and Physics

Park, Hyungju
Professor, Pohang University of Science and Technology
Director, NIMS Center for Applications of Mathematical Principles

Park, Kyewon Koh
Professor, Ajou University

Saito, Koiji
Professor, Kavli Institute for the Physics and Mathematics of the Universe

Verlinde, Herman
Professor, Princeton University

Administration

The administrative unit of the CGP works closely with IBS headquarters and POSTECH administration offices and provides administrative services for CGP members and visitors. The main focus of the administration for the inaugural year was to the management of space. This included negotiating with POSTECH to secure space for the center until the planned construction of a research complex as well as the renovation, remodeling, and design of that space.

Staff

Kim, Yeongmi
Head of Administration

Kim, Genn Ia
Guesthouse & CGP library, purchasing, foreign member support, business trips (foreign members)

Kim, Jaekwan
Server & video, network security, IT support

Kim, Min Jeong
Assistant (general affairs)

Park, Soojin
Director's secretary, visitors & events, business trips (Korean members)

Sinn, Elisa
HR (research personnel), performance & evaluation, visitor support

Establishing Research Infrastructure

The **Center for Geometry and Physics** aims to provide a research environment in which new and original ideas are boldly proposed, tested and revised by means of scientific interactions and communication. By doing so, we hope that some of those ideas evolve into a mature form of truly new mathematics. Thus, the goal of the center is to become the birthplace of fundamentally new research areas in addition to carrying out those projects envisioned in its initial proposal.

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실험과학 분야 연구소는 첨단연구장비와 숙련된 실험인력을 갖추는 것이 매우 중요한 것에 비해 수학 연구소에는 우수한 인적교류와 연구방향 및 아이디어의 교환이 상시로 이루어지는 것이 아주 중요하다. 따라서 학문적으로 높은 수준을 지향/유지하고 내부 구성원 전체의 유기적인 상호교류를 활발히 하며, 뛰어난 국내외 학자들이 모두 방문하고 싶어하는 장소를 만드는 것이 본 연구단의 궁극적 목적을 달성하기 위해 없어서는 안될 요소이다.

The CGP Hall & Library

The **CGP Hall** is the central location of the center's academic and social activities.

The hall serves as the venue for most of the **seminars, talks** and **teatimes** hosted by the center. Members and visitors often gather here in small groups for discussions, exchange of ideas or simply for relaxing. It also has several offices for visitors and some members. Other CGP members including the director and the two group leaders are housed in adjacent buildings until the construction of a new research complex is completed.

The CGP hall houses the entire **CGP Library** collection of over 3,500 books published by Springer and Cambridge. There is also a small collection books on the culture and the history of Korea.

In addition, the center has rich archive sources available to its members and visitors thanks to its host institution, POSTECH.

Guesthouse

The CGP aims to facilitate the active creation of new research and the dissemination of recent progress at the boundary of what is known. The center has created a comprehensive visitor programs to attract researchers from both Korea and abroad.

The center operates a fully-furnished apartment-style guesthouse to better accommodate our visitors, especially those who are visiting with their family, and/or visiting for an extended period of time.

Website, Video System, and Computing Facilities

The CGP website (http://cgp.ibs.re.kr) provides schedules and information on events hosted not only by the center but also by the Department of Mathematics and other mathematics centers at POSTECH at a glance. Also available on the website are the preprints of the members of the center and the database for the entire collection of the CGP library which can be searched by title, author, ISBN, or year of publication.

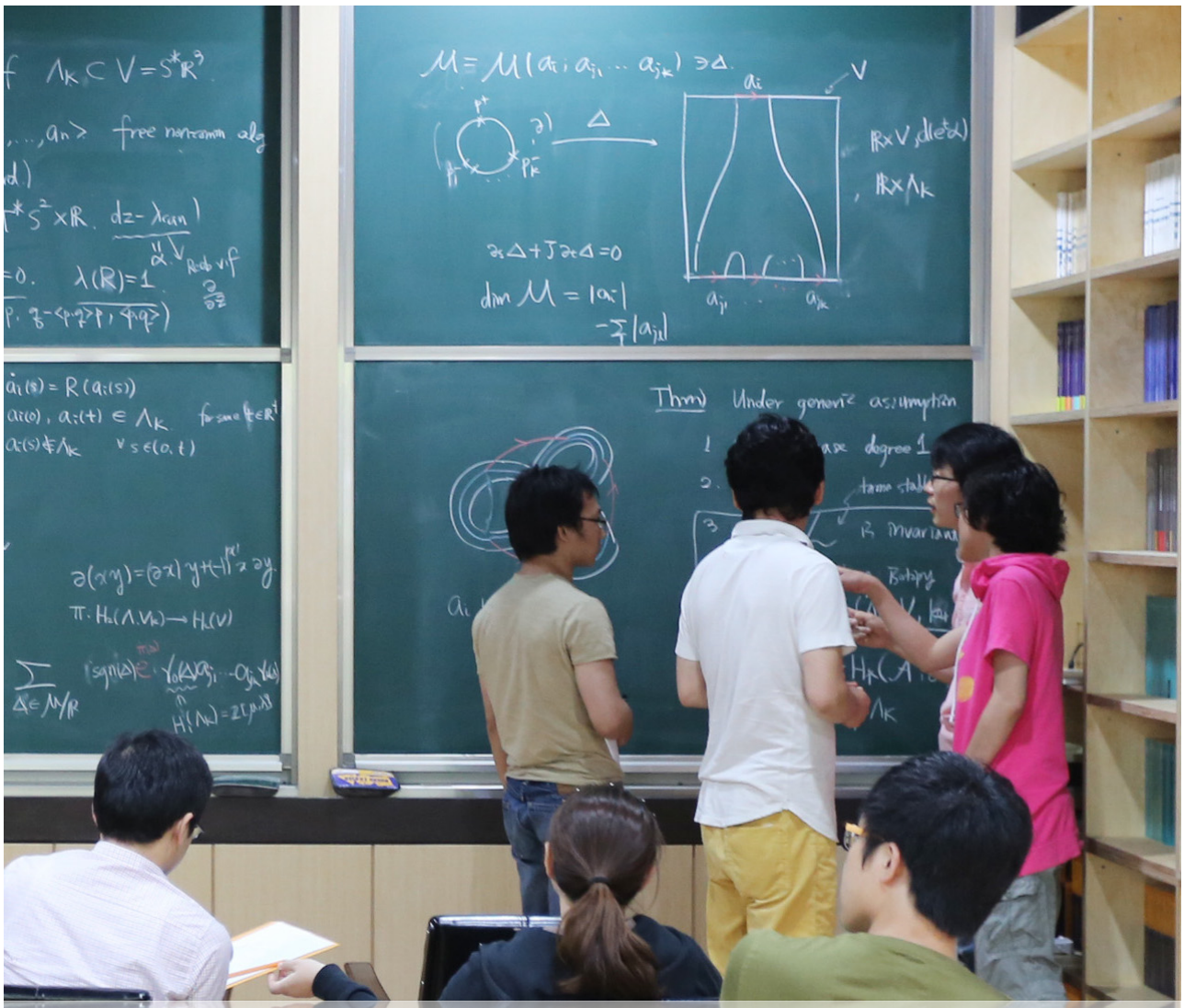
In addition, video recordings of most talks, lectures, and conferences hosted by the CGP are uploaded and made available on the website with the consent of speakers. This feature allows anyone who is interested to access and benefit from the talks regardless of their physical location. The CGP plans to provide live streaming of talks and lectures soon.

For the convenience of visitors and the efficiency of the application process, the center has implemented a visitor application feature on its website. Those who are interested in visiting and conducting collaborative research with the members of the center can apply online at the website.

The CGP Hall, where most of the talks hosted by the center are given, is equipped with a projector system including a Mac computer dedicated for the purpose of presentations and a Windows computer for general use.

The CGP operates a Linux-based high-performance computation server that can be used to run several CAS (computer algebra systems) such as Mathematica and Maple. The center also provides web-publishing services for conferences and seminars as well as research-related materials and personal webpages.

Scientific Activities



Statistics

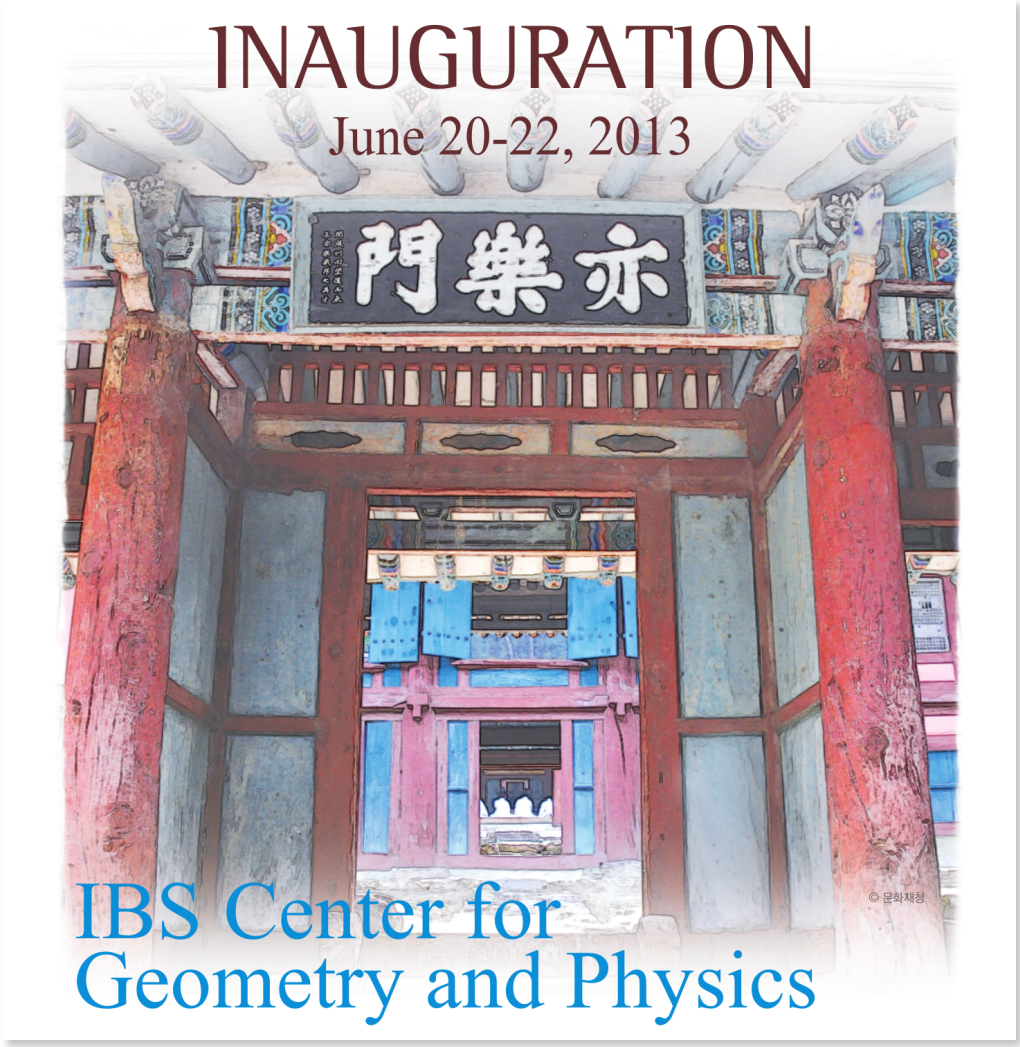
- 3 conferences
- 90 talks and seminars
- 7 tutorials and lecture series
- 3 public events
- 73 visits by 62 visitors

The Inaugural Conference

June 20 – 22, 2013, Auditorium, POSCO International Center

The CGP held its Inaugural Conference with seven distinguished speakers: Jean-Pierre Bourguignon (IHÉS), Kenji Fukaya (Kyoto University, Simons Center), Alexander Givental (UC Berkeley), Ko Honda (University of Southern California), Ludmil Katzarkov (University of Miami, Universität Wien), Bumsig Kim (Korea Institute for Advanced Study) and Gang Tian (Princeton, Peking University).

The CGP took this chance not only to promote the center's aim and vision to the broad mathematical community but also to encourage the younger generation of mathematicians. True to the spirit of this vision, three brilliant mathematics graduate students — Joseph Hirsh (City University of New York), June Huh (University of Michigan), and Sung-Jin Oh (Princeton University), whose research interests are related to those of the Center, were also invited to give talks.



The Inaugural Thematic Program

The thematic programs provide focused and in-depth tutorials, lectures and conferences on themes selected for each thematic year. The topic of the first thematic program, which is from July 2013 to August 2014, is **Symplectic Geometry and Mirror Symmetry**.

Rationale for the program

Symplectic geometry and mirror symmetry are currently some of the most actively researched areas in mathematics. However, they are still comparatively new and unexplored in Korea, especially to students in graduate programs. Only a few young researchers are currently working in these areas at mathematics institutes in Korea. The purpose of this thematic program is to encourage and promote research in these areas and to educate future mathematicians.

Tutorials

The program began with several tutorials by experts designed to be accessible to advanced graduate students.

- *Tutorials on Gromov-Witten theory*, July 8 – 12, 2013,
  Alexander Givental (UC Berkeley)
- *Triangulated category*, August 5 – 9, 2013
  Calin Iuliu Lazaroiu (IBS-CGP)
- *Beginner's guide to homological mirror symmetry*, August 19 – 23, 2013
  Cheol-Hyun Cho (Seoul National University)
- *Lagrangian torus fibration and homological mirror symmetry*, August 26 – 29, 2013
  Kazushi Ueda (Osaka University, Korea Institute for Advanced Study)
- *Symplectic algebraic topology*, September 10 – December 19, 2013
  Yong-Geun Oh (IBS-CGP, POSTECH)
- *Stable homotopy types in Floer theory*, September 30 – October 4, 2013
  Thomas Kragh (Uppsala University)
- *Homological methods in non-commutative geometry*, November 4 – 13, 2013
  Dmitry Kaledin (Independent University of Moscow, Steklov Mathematical Institute)

Conferences and lecture series

In 2014, several conferences and lecture series are scheduled to be hosted by the CGP. The planned conferences are the following:

- *C^0-symplectic topology and dynamical systems*, January 20 – 24, 2014
- *Landau-Ginzburg theory and Fano varieties*, May 26 – 30, 2014
- *Homological mirror symmetry and symplectic topology*, (Seoul ICM 2014 Satellite Conference), August 4 – 8, 2014

Joint Conferences

In an effort to take on a leading role in enriching the mathematical society in Korea, the center works in collaboration with other institutes and organizations to hold conferences for a wider audience of mathematicians and scholars.

In 2013, the center jointly organized the following two conferences:

Symposium on Projective Algebraic Varieties & Moduli

February 18 – 21, 2013, The MVL Hotel, Yeosu, Korea

The symposium was co-organized with Seoul National University. Sixteen speakers from Korea, China, France, Italy, Japan, Russia, Taiwan, the United Kingdom, and the United States were invited to give talks, and approximately 50 participants from Korea and abroad attended the symposium.

The Asian Mathematical Conference 2013

June 30 – July 4, 2013, BEXCO, Busan, Korea

The AMC 2013 was hosted by the Southeast Asian Mathematical Society and the Korean Mathematical Society and was organized by the CGP, the Korea Insitute for Advanced Study, the National Institute for Mathematical Sciences, and the Organizing Committee for Seoul ICM 2014. The AMC is the biggest mathematics conference in Asia and has been held every four to five years since 1990. The regional focus of the conference expanded from Southeast Asia to all of Asia, and the AMC 2013 in Busan, Korea was the first one held since the expansion.

A total of 575 speakers, including the Fields Medalist Bảo Châu Ngô, presented their research, and approximately 1,000 participants attended the conference from Korea and abroad.

Seminars

The CGP hosts various regular and irregular seminars given both by visiting scholars and the members of the Center.

The Center for Geometry and Physics Seminar on every Thursday afternoon is the most important regular event of the CGP, and generally all members of the center participate. The seminars are formatted to encourage robust and dynamic interactions among participants. The seminar is structured as a two-hour talk by a designated speaker with a thirty minute intermission with tea and snack. The first half is intended to be a colloquium-level talk suitable for a general mathematical audience, while the second half can be more specialized. Discussions may continue over dinner.

Quantum Monday is an evening seminar focusing on various topics in mathematical physics. This seminar has no fixed format or time constraint, and discussions sometimes continue as late as midnight.

The **Algebraic Geometry Seminar** meets on Friday afternoons and usually hosts talks by young mathematicians.

There are also numerous **Irregular Seminars** on diverse topics given by visiting scholars. These seminars organized by the various members of the center.

List of All Talks

Localized mirror functors for Lagrangian immersions
Hansol Hong (Seoul National University)
16:00 – 18:00, December 21, 2013

Integrable systems and non-minimal rational elliptic surfaces
Stefan Adrian Carstea (Horia Hulubei National Institute of Physics and Nuclear Engineering)
16:00 – 18:00, December 19, 2013

Survey on birational rigid Fano complete intersections
Joonyeong Won (Korea Institute for Advanced Study)
16:00 – 18:00, December 17, 2013

Semi-terminal modifications of demi-normal pairs
Kento Fujita (Research Institute for Mathematical Sciences)
14:00 – 15:30, December 13, 2013

An overview of Lagrangian cobordism in symplectic geometry
Wenfeng Jiang (Nanjing University)
16:00 – 18:00, December 12, 2013

Intrinsically knotted graphs with 21 edges
Hwa Jeong Lee (Korea Advanced Institute of Science and Technology)
10:00 – 12:00, December 11, 2013

Arc presentations of knots and links
Hwa Jeong Lee (Korea Advanced Institute of Science and Technology)
16:00 – 18:00, December 10, 2013

What is homotopy probability space?
Jae-Suk Park (IBS-CGP, POSTECH)
19:00 – 21:00, December 9, 2013

Algebraic cycles and crystalline cohomology
Jinhyun Park (Korea Advanced Institute of Science and Technology)
19:00 – 21:00, December 2, 2013

Introduction to operads III
Gabriel C. Drummond-Cole (IBS-CGP)
19:00 – 21:00, November 25, 2013

Bergman Kernel asymptotics for lower energy forms
Chin-Yu Hsiao (Institute of Mathematics, Academia Sinica)
16:30 – 17:30, November 25, 2013

Geometry of the beta-deformation
Daniel Krefl (Seoul National University)
17:00 – 18:00, November 22, 2013

The surjectivity of the reduction map for Alexeev's space
Jaeho Shin (Korea Institute for Advanced Study)
14:00 – 15:30, November 22, 2013

Introduction to operads II
Gabriel C. Drummond-Cole (IBS-CGP)
19:00 – 21:00, November 18, 2013

Toward an E_infty minimal model
Gabriel C. Drummond-Cole (IBS-CGP)
16:00 – 18:00, November 14, 2013

Introduction to operads
Gabriel C. Drummond-Cole (IBS-CGP)
19:00 – 21:00, November 11, 2013

Log canonical thresholds of complete intersection log del Pezzo surfaces
In-kyun Kim (POSTECH)
11:00 – 12:00, November 8, 2013

Gromov-Witten invariants of toric fibrations (and beyond)
Jeff Brown (IBS-CGP)
16:00 – 18:00, November 7, 2013

Introduction to the method of descent III
Dohyeong Kim (POSTECH)
19:00 – 21:00, November 4, 2013

Hochschild-Witt complex
Dmitry Kaledin (Independent University of Moscow, Steklov Mathematical Institute)
16:00 – 18:00, October 31, 2013

Enriques K3 surfaces over odd characteristic
Junmyeong Jang (University of Ulsan)
10:30 – 12:00, October 31, 2013

Optimistic limits of quantum invariants and volume potential functions for knotted graphs
Seonhwa Kim (Seoul National University)
10:00 – 12:00, October 31, 2013

An introduction to volume conjecture, its generalizations and related topics
Seonhwa Kim (Seoul National University)
14:00 – 16:00, October 30, 2013

Introduction to the method of descent II
Dohyeong Kim (POSTECH)
19:00 – 22:00, October 28, 2013

Introduction to the method of descent
Dohyeong Kim (POSTECH)
19:00 – 22:00, October 21, 2013

Hodge structure and arithmetic of abelian varieties: around the Morita conjecture
Dong Uk Lee (IBS-CGP)
16:00 – 18:00, October 17, 2013

Non-Markovian categories of open quantum systems
Calin Iuliu Lazaroiu (IBS-CGP)
19:00 – 21:00, October 14, 2013

Torus localization and the stable pairs
Jinwon Choi (Korea Institute for Advanced Study)
14:00 – 15:30, October 11, 2013

The uniqueness of the Fisher metric as information metric
Hông Vân Lê (Institute of Mathematics of ASCR)
16:00 – 18:00, October 10, 2013

Hodge spectrum of hyperplane arrangements
Youngho Yoon (IBS-CGP)
14:00 – 15:30, October 4, 2013

A_∞ algebras and morphisms arising in group representations II
Jeehoon Park (POSTECH)
19:00 – 21:00, September 30, 2013

Log canonical threshold in positive characteristic
Zhixian Zhu (Korea Institute for Advanced Study)
14:00 – 15:30, September 27, 2013

Log minimal model program for the moduli space of curves
Donghoon Hyeon (POSTECH)
16:00 – 18:00, September 26, 2013

A basic concept of geometric group theory
Hyowon Park (Korea Advanced Institute of Science and Technology)
14:00 – 15:30, September 25, 2013

Nakamaye theorem, Moriwaki divisors
Sung Rak Choi (IBS-CGP)
14:00 – 15:30, September 13, 2013

Singularity invariants related to Milnor fiber
Youngho Yoon (IBS-CGP)
16:00 – 18:00, September 12, 2013

A_∞ algebras and morphisms arising in group representations
Jeehoon Park (POSTECH)
19:00 – 21:00, September 9, 2013

Introduction to birational geometry: 1. The minimal model program 2. Positivity of divisors
Sung Rak Choi (IBS-CGP)
14:00 – 16:00, September 5, 2013

On Seidel representation
Dongning Wang (IBS-CGP)
16:00 – 18:00, August 29, 2013

The analysis of pseudo-holomorphic curves in contact manifolds
Rui Wang (IBS-CGP)
16:00 – 18:00, August 22, 2013

Quantization in a magnetic field
Radu Purice (Simion Stoilow Mathematics Institute of the Romanian Academy)
11:00 – 12:00, August 20, 2013

Vector bundles on non-Kaehler elliptic principal bundles
Vasile Brinzanescu (Simion Stoilow Mathematics Institute of the Romanian Academy)
11:00 – 12:00, August 19, 2013

A revisit on knot-surgery 4-manifolds
Jongil Park (Seoul National University)
16:00 – 17:30, August 16, 2013

Braid groups on CW complexes
Byunghee An (IBS-CGP)
14:00 – 16:00, August 1, 2013

Orbifolds and topological defects
Nils Carquville (Simons Center for Geometry and Physics)
16:00 – 18:00, July 25, 2013

Matrix factorizations, disk instantons and mirror symmetry
Wolfgang Lerche (CERN, University of Heidelberg)
11:00 – 12:00, July 5, 2013

Review of Hodge theory V
Dong Uk Lee (IBS-CGP)
16:45 – 18:45, June 24, 2013

Classification of tight contact 3-manifolds
Juhyun Lee (IBS-CGP)
16:00 – 18:00, June 19, 2013

Review of Hodge theory IV
Dong Uk Lee (IBS-CGP)
16:45 – 18:45, June 17, 2013

Introduction to knot contact homology II
Youngjin Bae (IBS-CGP)
16:00 – 18:00, June 12, 2013

Higher-dimensional Heegaard Floer homology
Ko Honda (University of Southern California)
16:00 – 18:00, June 11, 2013

Review of Hodge theory III
Dong Uk Lee (IBS-CGP)
16:45 – 18:45, June 10, 2013

Introduction to knot contact homology
Youngjin Bae (IBS-CGP)
16:00 – 18:00, June 5, 2013

Left- and right-handed fibered Dehn twists
Otto van Koert (Seoul National University)
16:00 - 18:00, June 4, 2013

Review of Hodge theory II
Dong Uk Lee (IBS-CGP)
16:45 – 18:45, June 3, 2013

Behavior of Hamiltonian systems under morphisms of phase spaces
Sangwook Lee (IBS-CGP)
16:00 – 18:00, May 29, 2013

Review of Hodge theory I
Dong Uk Lee (IBS-CGP)
16:45 – 18:45, May 27, 2013

Quantum mechanics and geometry on Siegel-Jacobi spaces
Stefan Berceanu (Horia Hulubei National Institute of Physics and Nuclear Engineering)
16:45 – 17:45, May 20, 2013

The globalization of Korean mathematics and the role of the IBS Center for Geometry and Physics (한국 수학의 국제화와 IBS 기하학수리물리 연구단의 역할)
Hyungju Park (National Institute for Mathematical Sciences, POSTECH)
17:00 – 18:00, May 23, 2013

Equivariant Fukaya category
Cheol-Hyun Cho (Seoul National University)
16:00 – 18:00, May 17, 2013

Period integrals of smooth projective hypersurfaces and homotopy theory II
Jeehoon Park (POSTECH)
16:45 – 18:45, May 13, 2013

Instability of Hamiltonian dynamical system
Ji Li (Nanjing University)
15:00 – 16:00, April 25, 2013

Seiberg-Witten equation with special metrics
Inyoung Kim (Stony Brook University)
14:00 – 15:00, April 25, 2013

Period integrals of smooth projective hypersurfaces and homotopy theory
Jeehoon Park (POSTECH)
16:45 – 18:45, April 22, 2013

Moduli stabilization in string compactifications
Lilia Anguelova (Perimeter Institute)
16:00 – 17:00, April 19, 2013

Lectures on algebraic principles of quantum field theory V. Representing quantum deformation functor (continued)
Jae-Suk Park (IBS-CGP, POSTECH)
16:45 – 18:45, April 15, 2013

Model categories
Calin Iuliu Lazaroiu (IBS-CGP)
16:45 – 18:45, April 8, 2013

Lectures on algebraic principles of quantum field theory IV. Representing quantum deformation functor
Jae-Suk Park (IBS-CGP, POSTECH)
16:45 – 18:45, April 1, 2013

Hidden aspects of quantization and geometry
Elena Mirela Babalic (Horia Hulubei National Institute of Physics and Nuclear Engineering)
15:00 – 16:00, March 27, 2013

Singularity of hyper-elliptic curve
Jihye Seo (McGill University, Centre de Recherches Mathématiques)
14:00 – 15:00, March 27, 2013

Lectures on algebraic principles of quantum field theory III. Quantum deformation functor
Jae-Suk Park (IBS-CGP, POSTECH)
16:30 – 18:30, March 25, 2013

Lectures on algebraic principles of quantum field theory II. Homotopy algebra
Jae-Suk Park (IBS-CGP, POSTECH)
16:30 – 18:30, March 18, 2013

Lectures on algebraic principles of quantum field theory I. Classical theory
Jae-Suk Park (IBS-CGP, POSTECH)
16:30 – 18:30, March 11, 2013

Floer-Gromov theory and field theory I, II
Yakov Savelyev (Université de Montréal)
16:00 – 18:00, February 27, 2013

I. Introduction to homological mirror symmetry, semi-orthgonal decompositions, and birational geometry
II. Variation of geometric invariant theory quotients and derived categories
David Favero (Universität Wien)
16:00 – 18:00, January 9, 2013

I. Thin instantons in G2 manifolds and Seiberg-Witten invariants
II. Thick-thin decomposition of Floer trajectories and adiabatic gluing
Ke Zhu (Harvard University)
16:00 – 18:00, January 8, 2013

Euler-Maclaurin formula and a cocycle given by Todd series
Byungheup Jun (Korea Institute for Advanced Study)
17:00 – 18:00, December 21, 2012

Hodge theory and number theory II
Dong Uk Lee (Korea Advanced Institute of Science and Technology)
16:00 – 18:00, December 18, 2012

Hodge theory and number theory I
Dong Uk Lee (Korea Advanced Institute of Science and Technology)
16:00 – 18:00, December 17, 2012

Periods of certain representations of Lie algebras IV
Jeehoon Park (POSTECH)
20:00 – 22:00, November 15, 2012

Theoretical physics meets pure mathematics
Seungjoon Hyun (Yonsei University),
Sangmin Lee (Seoul National University),
Jeehoon Park (POSTECH),
John Terilla (City University of New York),
Jae-Suk Park (IBS-CGP, POSTECH)
16:15 – 17:15, November 9, 2012

A beginner's guide to physics and mathematics of scattering amplitudes
Sangmin Lee (Seoul National University)
15:15 – 16:15, November 9, 2012

Derived deformation theory and homotopy probability
John Terilla (City University of New York)
15:30 – 16:30, November 7, 2012

Periods of certain representations of Lie algebras III
Jeehoon Park (POSTECH)
17:00 – 19:00, October 31, 2012

Simulacra and simulation on the quantum world II
Jae-Suk Park (IBS-CGP, POSTECH)
20:00 – 22:00, October 25, 2012

How to find counterfeit coins? An algorithmic version
Jeong Han Kim (Yonsei University)
11:00 – 12:00, October 19, 2012

Periods of certain representations of Lie algebras II
Jeehoon Park (POSTECH)
20:00 – 22:00, October 11, 2012

Periods of certain representations of Lie algebras I
Jeehoon Park (POSTECH)
20:00 – 22:00, September 20, 2012

Between strings, categories and topology
Calin Lazaroiu (Horia Hulubei National Institute of Physics and Nuclear Engineering)
20:00 – 22:00, September 17, 2012

Simulacra and simulation on the quantum world I
Jae-Suk Park (IBS-CGP, POSTECH)
20:00 – 22:00, September 13, 2012

Visitor Programs and Visitors

Mixing interesting people working on interesting problems in one place has the potential to reveal commonalities, promote collaboration, and help those people advance in understanding. To this end, the center hosts a constantly changing group of visiting scholars, whose activity is thought of as a central part of the center's mission. Many visitors are selected by the director and group leaders collectively based on research themes of the center. Research fellows play a valuable role by suggesting thematically appropriate visitors to the director and group leaders.

The center has also established an alternative visiting program via the website. Mathematicians and physicists with research interests in line with CGP members are invited to apply for periods in residence at the center. In order to support the creation of new collaborative research, the center also offers full support for small groups of researchers (two to four) from different institutions to work in close physical proximity for intensive periods. One researcher may be a CGP member, but this is not necessary.

List of All Visitors

Cheol-Hyun Cho (Seoul National University)
December 20 – December 22, 2013

Seungjoon Hyun (Yonsei University)
December 20 – December 22, 2013

Hansol Hong (Seoul National University)
December 20 – December 21, 2013

Stefan Adrian Carstea (Horia Hulubei National Institute of Physics and Nuclear Engineering)
December 13 – December 20, 2013

Joonyeong Won (Korea Institute for Advanced Study)
December 17 – December 18, 2013

Wenfeng Jiang (Nanjing University)
November 17 – December 15, 2013

Kento Fujita (Research Institute for Mathematical Sciences)
December 12 – December 14, 2013

Jinhyun Park (Korea Advanced Institute of Science and Technology)
December 2 – December 3, 2013

Dmitry Kaledin (Independent University of Moscow, Steklov Mathematical Institute)
October 20 – November 30, 2013

Chin–Yu Hsiao (Institute of Mathematics, Academia Sinica)
November 22 – November 26, 2013

Daniel Krefl (Seoul National University)
November 21 – November 23, 2013

Jaeho Shin (Korea Institute for Advanced Study)
November 21 – November 22, 2013

Sijong Kwak (Korea Advanced Institute of Science and Technology)
November 8, 2013

Yongnam Lee (Korea Advanced Institute of Science and Technology)
November 8, 2013

Dohyeong Kim (POSTECH)
November 4, 2013

Seonhwa Kim (Seoul National University)
October 30 – November 1, 2013

Junmyeong Jang (University of Ulsan)
October 31, 2013

Dohyeong Kim (POSTECH)
October 28, 2013

Dohyeong Kim (POSTECH)
October 21, 2013

Hông Vân Lê (Institute of Mathematics of ASCR)
October 3 – October 17, 2013

Kiryong Chung (Korea Institute for Advanced Study)
October 10 – October 11, 2013

Jinwon Choi (Korea Institute for Advanced Study)
October 10 – October 11, 2013

Thomas Kragh (Uppsala University)
September 28 – October 5, 2013

Zhixian Zhu (Korea Institute for Advanced Study)
September 27 – September 28, 2013

Darko Milinkovic (University of Belgrade)
September 14 – September 28, 2013

Hyowon Park (Korea Advanced Institute of Science and Technology)
September 23 – September 28, 2013

Kazushi Ueda (Korea Institute for Advanced Study, Osaka University)
August 25 – August 29, 2013

Vasile Brinzanescu (Simion Stoilow Mathematics Institute of the Romanian Academy)
August 15 – August 25, 2013

Radu Purice (Simion Stoilow Mathematics Institute of the Romanian Academy)
August 15 – August 25, 2013

Cheol-Hyun Cho (Seoul National University)
August 16 – August 23, 2013

Jongil Park (Seoul National University)
August 15 – August 17, 2013

Nils Carquville (Simons Center for Geometry and Physics)
July 19 – July 28, 2013

Alexander Givental (UC Berkeley)
June 16 – July 15, 2013

Wolfgang Lerche (CERN, University of Heidelberg)
June 30 – July 5, 2013

Gabriel C. Drummond-Cole (Northwestern University)
June 19 – June 26, 2013

John Terilla (City University of New York)
June 19 – June 26, 2013

Jean-Pierre Bourguignon (IHÉS)
June 20 – June 23, 2013

Joseph Hirsh (City University of New York)
June 19 – June 22, 2013

June Huh (University of Michigan)
June 19 – June 23, 2013

Sung-Jin Oh (Princeton University)
June 19 – June 22, 2013

Kenji Fukaya (Kyoto University, Simons Center for Geometry and Physics)
June 20 – June 22, 2013

Bumsig Kim (Korea Institute for Advanced Study)
June 19 – June 22, 2013

Ko Honda (University of Southern California)
June 9 – June 23, 2013

Gang Tian (Peking University, Princeton)
June 19 – June 21, 2013

Stefan Berceanu (Horia Hulubei National Institute of Physics and Nuclear Engineering)
May 17 – May 24, 2013

Hyungju Park (POSTECH)
May 23, 2013

Cheol-Hyun Cho (Seoul National University)
May 15 – May 18, 2013

Ji Li (Nanjing University)
April 24 – April 29, 2013

Inyoung Kim (Stony Brook University)
April 23 – April 26, 2013

Lilia Anguelova (Perimeter Institute)
April 17 – April 22, 2013

Jihye Seo (Centre de Recherches Mathématiques, McGill University)
March 22 – April 10, 2013

Elena Mirela Babalic (Horia Hulubei National Institute of Physics and Nuclear Engineering)
March 25 – April 7, 2013

Sangmin Lee (Seoul National University)
April 5 – April 6, 2013

Junyoung Won (Korea Institute for Advanced Study)
March 21 – March 22, 2013

Yakov Savelyev (Université de Montréal)
February 26 – February 28, 2013

Byunghee An (Korea Institute for Advanced Study)
January 22 – January 26, 2013

Ke Zhu (Harvard University)
January 5 – January 11, 2013

David Favero (Universität Wien)
January 8 – January 10, 2013

Sangwook Lee (Seoul National University)
December 26, 2012

Donghoon Park (Korea Advanced Institute of Science and Technology)
December 6 – December 24, 2013

Kyurak Cheong (Korea Institute for Advanced Study)
December 5 – December 24, 2012

Byungheup Jun (Korea Institute for Advanced Study)
December 5 – December 24, 2012

Dong Uk Lee (Korea Advanced Institute of Science and Technology)
December 16 – December 22, 2012

Jeong Han Kim (Yonsei University)
December 6 – December 8, 2012

Calin Iuliu Lazaroiu (Horia Hulubei National Institute of Physics and Nuclear Engineering)
November 25 – December 1, 2012

Jeehoon Park (POSTECH)
September 20 – November 15, 2012

John Terilla (City University of New York)
November 6 – November 12, 2012

Sangmin Lee (Seoul National University)
November 9 – November 10, 2012

Seungjoon Hyun (Yonsei University)
November 9 – November 10, 2012

Jeong Han Kim (Yonsei University)
October 18 – October 20, 2012

Calin Iuliu Lazaroiu (Horia Hulubei National Institute of Physics and Nuclear Engineering)
September 11 – September 18, 2012

Joseph Hirsh (City University of New York)
July 29 – August 8, 2012

Gabriel C. Drummond-Cole (Northwestern University)
July 29 – August 8, 2012

Outreach

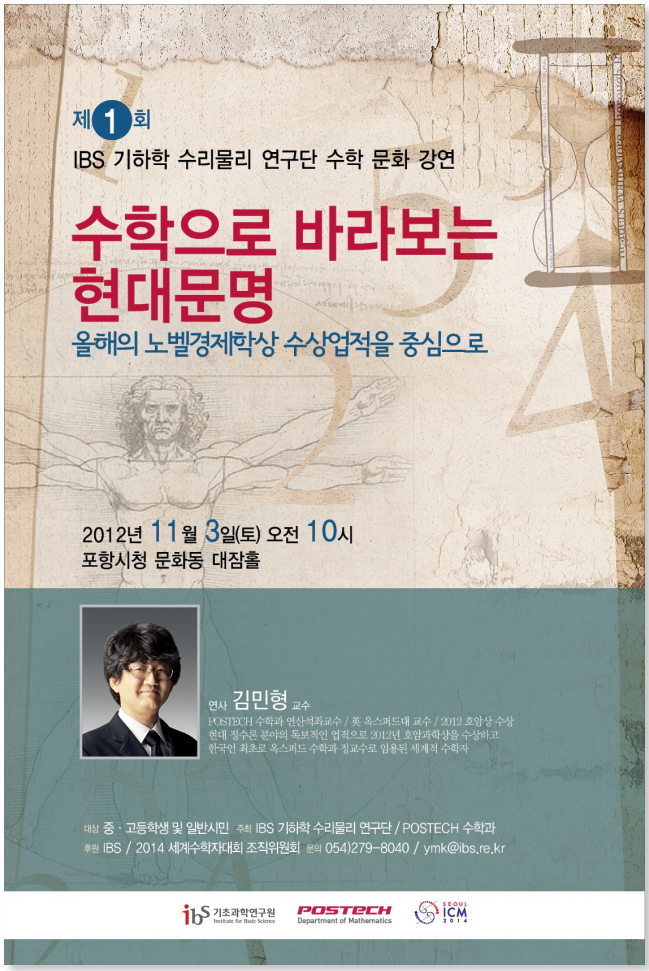
Public outreach is an important mission of the IBS Center for Geometry and Physics. The center has organized several public events with the collaboration of the City of Pohang, where the center is located, and the Korean Mathematical Society. The events were popular and well attended by numerous middle and high school students as well as adults.

The following are the schedules and abstracts of the public lectures the center hosted:

Harmony in Mathematics, *Hong–Jong Kim (Seoul National University)*

BEXCO, Busan, 16:00 – 16:50, June 30, 2013

Art and mathematics are very old close friends. Ancient Greek mathematicians explained how harmonious sounds are made. Renaissance artists discovered how to translate scenes in space onto a canvas. Through mathematics, one can learn the most important tools to become a bigger person: deduction and intuition. In everyday life, we see, hear, and feel the harmony.



Mathematics of Planet Earth, *Christiane Rousseau (University of Montreal)*

BEXCO, Busan, 19:00 – 19:50, July 1, 2013

Earth is a complex planet inside the solar system, with dynamic movements in the mantle, an atmosphere, and oceans. It supports life and is organized by humans. More recently the future of life is threatened by climate change and overexploitation of resources. Mathematics provides tools to discover the history of the Earth, explore its interior, study its climate, and understand its ecosystems. The lecture will highlight with examples the role of mathematics in discovering and understanding our planet and the challenges in helping protect it.

A Look at Modern Civilization through Mathematics, *Minhyong Kim (POSTECH, University of Oxford)*

Pohang City Hall, 10:00 – 11:00, November 3, 2012

Research Report

Symplectic Topology, Hamiltonian Dynamics and Mirror Symmetry

Mathematics of Quantum Field Theory

Arithmetic, Birational and Complex Geometry of Fano Varieties

Symplectic Topology, Hamiltonian Dynamics and Mirror Symmetry

Group Leader: Yong-Geun Oh

Research Highlights

Piecewise smooth Hamiltonian geometry and C^0-symplectic topology

Since the advent of Hamiltonian mechanics at the end of the 19th century, Hamiltonian dynamics has been an area of fundamental research both in physics and in mathematics. In the last two decades of development in symplectic topology, the interplay between Hamiltonian dynamics and (pseudo)holomorphic curves has revealed many genuinely symplectic phenomena. Recent progress in symplectic topology reveals that the symplectic aspect of dynamical systems in two dimensions carries the potential for deeper understanding of (area-preserving) dynamical systems in two dimensions. One prominent open question in the area is Mather's question on the simpleness of the area-preserving homeomorphism group of the sphere S^2 or the disk D^2.

Yong-Geun Oh's effort toward answering Mather's question reveals some unforseen aspects of Hamiltonian dynamics, symplectic topology, and the piecewise smooth category of symplectic topology. It appears that for the study of the C^0-relationship between the three major players of Hamiltonian dynamics, the Hamiltonian function, the action integral, and spectral invariants, the optimal category of symplectic topology is the piecewise smooth one. Director Oh hopes that this research will not only enhance our understanding of C^0-sympletic topology but help to resolve Mather's simpleness question, which would open up a new area of research concerning the interaction between C^0-symplectic topology and dynamical systems in a much more interactive way.

In relation to this research, CGP will hold a conference "*C^0-symplectic topology and dynamical systems*" as one of the conferences in the inaugural Thematic Program of *"Symplectic topology and mirror symmetry."* The conference will gather experts in the area and provide a place for discussion and interaction between scholars from Korea and abroad.

Geometry and analysis of contact-instantons

Yong-Geun Oh works collaboratively with the CGP research fellow **Rui Wang**, who was one of his doctoral graduate students at the University of Wisconsin-Madison, on a new elliptic system of the first-order nonlinear partial differential equation associated to a contact manifold. The moduli space of such elliptic system is expected to be used to study the topology and geometry of contact manifolds. In the last couple of years, Yong-Geun Oh and Rui Wang established the foundation of the framework of what they call contact-instantons by establishing a priori $W^{k,p}$-estimates and exponential decay properties, which are important ingredients to set up Fredholm theory for the moduli space.

In other work, Oh provided other essential analytical ingredients: the definition of off-shell energy, the ε-regularity theorem and bubbling arguments. He also laid the foundation for compactifying the moduli space of smooth contact-instantons. He hopes that this research will provide a new, more transparent, definition of contact homology type invariants as pure contact invariants, without using symplectization. Oh will also apply this new analytical machinery to the study of contact topology and contact Hamiltonian dynamics.

The study of pseudo-Anosov braids and the mapping class group.

The conjugacy problem is one of the fundamental problems on group theory and related to knot theory because any conjugate braids give the same knot or link via closure. Furthermore, the security of so-called braid cryptosystems, which have been suggested and investigated by many cryptographers and mathematicians, relies on the difficulty of the conjugacy problem for the braid group. This means that an efficient algorithm for solving the conjugacy problem in the braid group would fundamentally undermine such cryptosystems. There is a theoretical but not practical solution by generating a finite invariant set with unknown growth. However, because of experimental results, it was conjectured that this invariant set has polynomial growth with respect to the number of strands for the generic case. **Byung Hee An** together with Ki Hyoung Ko (Korea Advanced Institute of Science and Technology) disproved this conjecture by generating infinitely many such families whose invariant sets grow exponentially.

Another fundamental problem is about automorphism groups. The braid groups on a manifold are subgroups of the mapping class groups. N. Ivanov proved that in many cases the automorphism groups for subgroups (in particular for braid groups) of mapping class groups become the whole mapping class groups. Some cases were missing from this proof. **Byung Hee An** determined the automorphism groups for braid groups for all missing cases.

Publications

- Published Papers

1. **Yong-Geun Oh**; Kenji Fukaya; Hiroshi Ohta; Kaoru Ono
   Lagrangian Floer theory over integers: spherically positive symplectic manifolds
   Pure Appl. Math. Q., **9** (2013), No. 2, 189 – 289.

2. **Yong-Geun Oh**; Kenji Fukaya; Hiroshi Ohta; Kaoru Ono
   Displacement of polydisks and Lagrangian Floer theory
   J. Symplectic Geom., **11** (2013), No. 2, 231 – 268.

3. **Byung Hee An**; Ki Hyoung Ko
   A family of pseudo-Anosov braids with large conjugacy invariant sets
   J. Knot Theory Ramifications, **22** (2013), No. 6.

- Accepted Papers

1. **Youngjin Bae**
   The growth sequence of symplectomorphisms on symplectically hyperbolic manifolds
   to appear in Israel J. Math.

2. **Yong-Geun Oh**; Kenji Fukaya; Hiroshi Ohta; Kaoru Ono
   Anti-symplectic involution and Floer cohomology
   to appear in Geom. Topol.

- Preprints

1. **Yong-Guen Oh**; **Rui Wang**
   Analysis of contact instantons II: exponential convergence for the Morse-Bott case
   arXiv:1311.6196

2. **Yong-Geun Oh**; Kenji Fukaya; Hiroshi Ohta; Kaoru Ono
   Lagrangian Floer theory and mirror symmetry on compact toric manifolds

3. **Juhyun Lee**
   Tight contact structure on $\Sigma_g \times I$

4. **Yong-Geun Oh**
   Localization of Floer homology of engulfable topological Hamiltonian loop
   arXiv:1111.5996

5. **Yong-Geun Oh**; **Rui Wang**
Canonical connection and contact Cauchy-Riemann maps on contact manifolds I
arXiv:1212.5186

6. **Yong-Geun Oh**; **Rui Wang**
Canonical connection on contact manifolds
arXiv:1212.4817

7. **Yong-Geun Oh**; Kenji Fukaya; Hiroshi Ohta; Kaoru Ono
Technical details on Kuranishi structure and virtual fundamental chain
arXiv:1209.4410

8. **Yong-Geun Oh**; Hông Vân Lê
Deformations of coisotropic submanifolds in locally conformal symplectic manifolds
arXiv:1208.3590

9. **Yong-Geun Oh**
Geometry of generating functions and Lagrangian spectral invariants
arXiv:1206.4788

Invited Talks

- Plenary talks at conferences

1. Yong-Geun Oh, *Hamilton-Jacobi equation and continuous Hamiltonian dynamics*
2013 KMS Annual Meeting, October 26 – 27, 2013
Korean Mathematical Society, Seoul, Korea.

- Invited talks at conferences

1. Yong-Geun Oh, *Analysis of contact Cauchy-Riemann maps and canonical connection on contact manifolds*
Tokyo-Seoul Conference on Differential Geometry, November 30 – December 1, 2013
University of Tokyo, Tokyo, Japan.

2. Yong-Geun Oh, *Lagrangian intersections, symplectic quasistates and open-closed Floer theory*
Korea Institute for Advanced Study Center for Mathematical Challenges Inaugural Conference, November 18 – 19, 2013
Korea Institute for Advanced Study, Seoul, Korea.

3. Youngjin Bae, *Dynamics on virtually contact structures*
East Asian Symplectic Conference 2013, September 18 – 21, 2013
Kagoshima University, Kagoshima, Japan.

4. Rui Wang, *The analysis of pseudo-holomorphic curves in contact manifolds*
East Asian Symplectic Conference 2013, September 18 – 21, 2013
Kagoshima University, Kagoshima, Japan.

5. Yong-Geun Oh, *Geometry of generating functions and Lagrangian spectral invariants*
Symposium in Honor of Alan Weinstein, July 18 – 20, 2013
Institute Henri Poincaré, Paris, France.

6. Yong-Geun Oh, *Geometry of generating functions and piecewise smooth Hamiltonian geometry*
The 1st GAIA-Institut Fourier Joint Conference on Geometry, July 11 – 16, 2013
POSTECH, Pohang, Korea.

7. Juhyun Lee, *On the number of isotopies of contact structures on thickened hyperbolic surfaces*
The Asian Mathematical Conference 2013, June 30 – July 4, 2013
SEAMS, Busan, Korea.

8. Yong-Geun Oh, *Canonical connection and analysis of contact Cauchy-Riemann equation*
PRIMA 2013: Special Session – Symplectic Geometry and Hamiltonian Dynamics, June 24 – 28, 2013
Shanghai Jiao Tong University, Shanghai, China.

- Invited seminar/colloquium talks

1. Rui Wang, *The analysis of pseudo-holomorphic curves in contact manifolds*
(12/20/2013) Beijing Normal University, Beijing, China.

2. Dongning Wang, *Seidel representation, its generalization and applications*
(09/30/2013) Rutgers University, New Brunswick, USA.

3. Youngjin Bae, *Introduction to knot contact homology*
(08/30/2013) Seoul National University, Seoul, Korea.

4. Youngjin Bae, *Dynamics on virtually contact structures*
(07/24/2013) University of Münster, Münster, Germany.

5. Yong-Geun Oh, *Pseudo-holomorphic curves in symplectic and contact topology*
(04/18/2012) University of Georgia, Athens, USA.

6. Yong-Geun Oh, *Compactification of holomorphic curves with prescribed ramifications*
(04/17/2012) University of Georgia, Athens, USA.

7. Yong-Geun Oh, *Gromov-Witten-Floer theory and Lagrangian intersections*
(10/16/2012) Stony Brook University, USA.

Mathematics of Quantum Field Theory

Group Leader: Jae-Suk Park

Research Highlights

Algebraic quantum field theory via the homotopy category of QFT algebras and its applications

The most fundamental obstacle in understanding quantum field theory mathematically is that the Feynman path integral of field theory is not a mathematically defined integral. That is, the path integral measure does not exist or is ill-defined. **Jae-Suk Park**'s main research objective is to have a mathematical formulation of the theory to answer the above question at both the foundational and computational levels by replacing the mathematically ill-defined Feynman path integrals with a new, rigorously defined, homotopical algebraic version based on the (newly defined) homotopy category **hQFT** of QFT algebras. He has investigated various applications of the program:

- ***Periods of Smooth Projective Hypersufaces.*** The simplest possible classical field theory may be a (0+0)-dimensional theory with a polynomial function $y{\cdot}G(x_0, \cdots, x_n)$, where G is a generic homogeneous polynomial, as the classical action. Applying **Jae-Suk Park**'s algebraic formulation to such a case, **Jae-Suk Park** and **Jeehoon Park** have constructed a quantum field theory whose partition function is the period integral of a smooth hypersurface X_G in P^n. This also provides a new homotopy theoretic framework to understand period integrals. The usual period integral, denoted by $\varkappa_1$ - a certain linear map from the middle dimensional cohomology of X_G to $\mathbb{C}$, can be enhanced into a family of multilinear maps $\varkappa = \varkappa_1, \varkappa_2, \cdots$ which is the composition of two non-trivial L_∞-morphisms such that $\varkappa$ depends only on the L_∞-homotopy types of each factor. They use this hidden L_∞-structure to study certain extended deformations and correlations of period integrals, which leave the realm of infinitesimal variations of Hodge structures of X_G. This new formal deformation theory has directions that do not satisfy Griffiths transversality.

- ***Homotopy probability theory.*** The notions of independence in probability theory and algebraic homotopy theory can be combined and generalized to homotopy probability theory. The idea is that the organizing data of successive deviations from being an algebra morphism will be replaced by a generalized morphism of homotopy probability spaces incorporating the notion of algebra morphisms up to homotopy. The commutative probability world with classical independence corresponds to L_∞-homotopy theory. In noncommutative probability, boolean independence corresponds to A_∞-homotopy theory while for free independence there also seems to be a corresponding but hereto unknown homotopy theory. It can be shown that the very "computability" of the joint distributions (the law) of random variables indicates that the space has a hidden infinite homotopy structure, whose presence may be exploited to determine that distributions up to certain

finite ambiguity. Conversely for algebraic homotopy theory, the law of random variables provides a generating function of invariants of corresponding homotopy types. This theory was originally conceived by **Jae-Suk Park** by replacing the Planck constant with 1 in his algebraic quantum field theory.

Structural studies of string and supergravity compactifications.

The class of string, M-theory and supergravity compactifications with fluxes is insufficiently understood. In particular, there is no known analogue of the relation between supersymmetry and reduced holonomy which proved instrumental in the fluxless case due to the power of Berger's classification of reduced holonomy manifolds. To address this problem, **Calin Lazaroiu** proposed an approach to supersymmetric backgrounds with fluxes which reduces their classification to the study of certain algebro-differential systems formulated in terms of Kähler-Atiyah algebras. This so-called "geometric algebra approach" allowed Lazaroui and his collaborators to give clear and systematic formulations to the problem of supersymmetry in flux compactifications and to obtain general rigorous results regarding the so-called "method of bi-linears". In particular, **Calin Lazaroiu** and his collaborators gave a general and compact formulation of Fierz identities and of differential constraints originating from supersymmetry in arbitrary dimensions and signatures and extracted certain reconstruction theorems from such characterisations. Numerous applications were and are being considered.

Publications

• Published Papers

1. Elena Mirela Babalic; Ioana-Alexandra Coman; **Calin-Iuliu Lazaroiu**
   A unified approach to Fierz identities
   AIP Conf. Proc. **1564**, 57 (2013).

2. **Calin-Iuliu Lazaroiu**; Elena Mirela Babalic
   Geometric algebra techniques in flux compactifications (II)
   J. High Energy Phys. **2013**, No. 6. 054.

3. E. M. Babalic; I.-A. Coman; C. Condeescu, **Calin-Iuliu Lazaroiu**, A. Micu
   On N = 2 compactifications of M-theory to AdS3 using geometric algebra techniques
   AIP Conf. Proc. **1564**, 63 (2013).

4. **Calin-Iuliu Lazaroiu**; Elena Mirela Babalic; Ioana-Alexandra Coman
   The geometric algebra of Fierz identities in arbitrary dimensions and signatures
   J. High Energy Phys. **2013**, No. 9, 156.

5. **Gabriel C. Drummond-Cole**; **Jae-Suk Park**; John Terilla
   Homotopy Probability Theory I
   J. Homotopy Relat. Struct. On-line DOI 10.1007/s40062-013-0067-y.

- Accepted Papers

1. **Calin-Iuliu Lazaroiu**; Elena Mirela Babalic; Ioana-Alexandra Coman
   The geometric algebra of supersymmetric backgrounds
   to appear in Hirzebruch Memorial Volume, Conf. Proc. for String-Math 2012.

2. **Gabriel C. Drummond-Cole**; **Jae-Suk Park**; John Terilla
   Homotopy Probability Theory II
   to appear in J. Homotopy Relat. Struct.

- Preprints

1. **Calin-Iuliu Lazaroiu**; Elena Mirela Babalic; Ioana-Alexandra Coman
   Geometric algebra techniques in flux compactifications (I)
   arXiv:1212.6766

2. **Jae-Suk Park**; **Jeehoon Park**
   Period Integrals of Smooth Projective Hypersurfaces and Homotopy Lie Algebras
   arXiv:1310.6710

Invited Talks

- Invited talks at conferences

1. Dong Uk Lee, Non-emptiness of Newton stratification of Shimura varieties and the Langlands-Rapoport conjecture
   ASARC Number Theory Workshop, December 16–18, 2013
   Korea Advanced Institute of Science and Technology, Busan, Korea.

- Invited seminar/colloquium talks

1. Dong Uk Lee, *Lectures on Hilbert modular spaces*
   (12/15 – 16/2013) Aoju University, Suwon, Korea.

2. Jae-Suk Park, *What is homotopy correlated space?*
   (10/18/2013) Seoul National University, Seoul, Korea.

3. Calin Lazaroiu, *The geometric algebra of supergravity compactifications*
   (09/20/2013) Simion Stoilow Mathematics Institute of the Romanian Academy, Bucharest, Romania.

4. Calin Lazaroiu, *The geometric algebra of metric cones and supersymmetry*
(09/18/2013) Horia Hulubei National Institute of Physics and Nuclear Engineering, Bucharest, Romania.

5. Jae-Suk Park, *Quantization of Deformation Functor and attached Invariants of Homotopy Types*
(08/23/2013) Stony Brook University, USA.

6. Calin Lazaroiu, *Shades of a Dream: String theory, Mathematics and the Unity of Science*
(05/08/2013) Horia Hulubei National Institute of Physics and Nuclear Engineering, Bucharest, Romania.

7. Calin Lazaroiu, *Shades of a Dream: String theory, Mathematics and the Unity of Science*
(03/29/2013) Ajou University, Suwon, Korea.

8. Jae-Suk Park, *Homotopical Probability Theory*
(11/19/2012) CUNY, New York City, USA.

9. Jae-Suk Park, *Homotopical Probability Theory*
(11/14/2012) University of Pennsylvania, Philadelphia, USA.

Arithmetic, Birational and Complex Geometry of Fano Varieties

Group Leader: Jihun Park

Research Highlights

Birational rigidity of Fano varieties

Mori fibred spaces, alongside minimal models, represent the terminal objects in the minimal model program. If the canonical class is pseudo-effective and its minimal models exist, then they are unique up to flops. However, this is not the case when the canonical class is not pseudo-effective, since Mori fibred spaces are usually not unique terminal objects in the minimal model program. Nevertheless, some Mori fibred spaces behave similarly to minimal models. To distinguish them, one introduces birational rigidity. Fano varieties of Picard rank one with at most terminal Q-factorial singularities are the basic examples of Mori fibred spaces. Birationally rigid Fano varieties behave very much like canonical models. Their birational geometry is very simple. In particular, they are non-rational. The first example of a birationally rigid Fano variety is due to V. Iskovskikh and Yu. Manin. In 1971, they proved that every smooth quartic threefold is birationally rigid. Since then, birational geometers have witnessed great development in the theory of birational rigidity. In late nineties, the 95 families of weighted Fano threefold hypersurfaces were revived and attracted birational geometers to study their properties such as birational rigidity, groups of birational auto-morphisms, elliptic fibration structures, and so forth. In particular, a paper of A. Corti, A. Pukhlikov and M. Reid proved that a general hypersurface in each of the 95 families of weighted Fano threefold hypersurfaces is birationally rigid and conjectured that the same statement holds for every quasi-smooth hypersurface in the families. In 2013, **Jihun Park**, together with I. Cheltsov at the University of Edinburgh, succeeded in confirming the conjecture.

Unipotent group actions on affine cones of Fano varieties

In 2003, H. Flenner at Ruhr-Universität Bochum and M. Zaidenberg at the Université de Grenoble proposed the following question:

> *"Does the affine Fermat cubic threefold $x^3 + y^3 + z^3 + w^3 = 0$ in A^4 admit a non-trivial regular G_a-action?"*

This problem stood open for 10 years. The research initiated to understand this simple-looking problem turned out to indicate that the problem was purely geometric and could be considered in a much wider setting. To see the problem from a wider view point, let X be a smooth projective variety with an ample polarization H. The generalized cone over $(X; H)$ is the affine variety defined by

$$\widehat{X} = \mathrm{Spec}\left(\bigoplus_{n} H^0(X; \mathcal{O}_X(nH))\right)$$

The question whether $\widehat{X}$ allows G_a-actions or not includes the original one by H. Flenner and M. Zaidenberg. After the work of the group of T. Kishimoto, Yu. Prokhorov and M. Zaidenberg and the group of Jihun Park, I. Cheltsov and J. Won, this generalized problem attracted many researchers working on birational geometry and affine geometry. In 2013, after some partial results of T. Kishimoto, Yu. Prokhorov and M. Zaidenberg, the collaborative work of **Jihun Park** with I. Cheltsov and J. Won showed that the cones over smooth del Pezzo surfaces of degree 3 do not allow any non-trivial regular G_a-actions. This provided a negative answer to the problem raised by H. Flenner and M. Zaidenberg.

Publications

- Accepted Papers

1. Ivan Cheltsov; **Jihun Park**; Joonyeong Won
   Log canonical thresholds of certain Fano hypersurfaces
   to appear in Math. Z.

2. **In-kyun Kim**; **Jihun Park**
   Log canonical thresholds of complete intersection log del Pezzo surfaces
   to appear in Proc. Edinb. Math. Soc.

3. **Sung Rak Choi**
   On partially ample divisors
   to appear in Math. Nachr.

4. **Sung Rak Choi**
   On partially ample adjoint divisors
   to appear in J. Pure Appl. Algebra.

- Preprints

1. Ivan Cheltsov, **Jihun Park**, Joonyeong Won
   Cylinders in singular del Pezzo surfaces
   arXiv: 1311.5257.

2. Ivan Cheltsov; **Jihun Park**
   Birationally rigid Fano threefold hypersurfaces
   arXiv:1309.0903.

3. Ivan Cheltsov; **Jihun Park**; Joonyeong Won
Affine cones over smooth cubic surfaces
arXiv: 1303.2648.

4. **Sung Rak Choi**
Okounkov bodies of pseudoeffective divisors

Invited Talks

- Invited talks at conferences

1. Youngho Yoon, *Hodge spectrum of hyperplane arrangements*
Symposium in Algebraic Geometry, December 19 – 20, 2013
Korea Institute for Advanced Study, Busan, Korea.

2. Jihun Park, *Non-rationality of the hypersurfaces in the 95 families of Fletcher and Reid*
2013 KMRS Symposium on Algebraic Geometry, November 1 – 2, 2013
Korea Advanced Institute of Science and Technology, Jeonju, Korea.

3. Jihun Park, *Log canonical thresholds and affine cones of del Pezzo surfaces*
Affine Algebraic Geometry Meeting, September 5 – 8, 2013
Kwansei Gakuin University, Osaka, Japan.

4. Sung Rak Choi, *Positivity of divisors I, II*
Algebraic Geometry mini-workshop, July 10 – 12, 2013
Yeungnam University, Gyeunsan, Korea.

5. Jihun Park, *α-functions of smooth del Pezzo surfaces*
PRIMA 2013: Special Session - Geometric Analysis, June 24 – 28, 2013
Shanghai Jiao Tong University, Shanghai, China.

6. Jihun Park, *α-functions of smooth del Pezzo surfaces*
Edge Days: Workshop on algebraic geometry, June 7 – 9, 2013
University of Edinburgh, Edinburgh, UK.

- Invited seminar/colloquium talks

1. Sung Rak Choi, *Geography of log models via base loci*
(11/11/2013) University of Tokyo, Tokyo, Japan.

2. Jihun Park, *Birationally rigid Fano threefold hypersurfaces*
(10/24/2013) University of Edinburgh, Edinburgh, UK.

3. Sung Rak Choi, *Okounkov body of pseudoeffective divisors*
(07/23/2013) Korea Institute for Advanced Study, Seoul, Korea.

4. Jihun Park, *α-functions and affine cones of smooth del Pezzo surfaces*
(07/12/2013) Centro Internazionale per la Ricerca Matematica, Trento, Italy.

5. Jihun Park, *Log canonical threshold and its application*
(04/14/2013) Simion Stoilow Mathematics Institute of the Romanian Academy, Bucharest, Romania.

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