Conference "D-modules and Hodge Theory"

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From 23rd to 27th of January 2017, a conference entitled "D-modules and Hodge Theory" was held at the Kavli IPMU. There were 15 invited speakers, including three who gave two lectures.

Hodge theory, a main theme of the conference, sits at the intersection of various fields: algebraic, analytic, and arithmetic geometry. The story starts when W.B.D. Hodge discovered a marvelous decomposition of singular cohomologies of Kähler varieties by means of harmonic forms. Even though the proof is completely analytic, this decomposition can be interpreted in terms of algebraic geometry, and the existence of such decomposition is regarded as a unique feature of algebraic (or Kähler) geometry. Some decades after Hodge's discovery, A. Weil conjectured a surprising conjecture for varieties over finite fields. J.P. Serre pointed out that complex analogue of his conjecture could be solved by using Hodge theory. Since then, Hodge theory has been a source of inspiration for those studying cohomology theory over finite fields. On the other hand, inspired by works on the Weil conjecture, P. Deligne found a new way to understand Hodge decomposition from a more philosophical point of view: invention of Hodge structure. Following this philosophy as well as Grothendieck's "yoga of 6 functors," M. Saito established the theory of Hodge modules by using ideas from D-module theory. The next step was seeking for analogous structure for "irregular connection" generalizing Saito's theory. The program was initiated C. Sabbah after C. Simpson's work on twister Hodge structure, and recently completed by T. Mochizuki. One of the main aims of the conference was to understand this theory and relevant topics.

Mochizuki gave two lectures on his works. In the first lecture, he explained some basic facts on this theory, and in the second lecture, he gave some applications. His theory enabled him to explain some facts appearing in mirror symmetry in a more natural way, which is expected to lead to more applications. K.S. Kedlaya gave two lectures on the resolution of turning points, which was shown independently by Mochizuki. Kedlaya's method uses ideas from p-adic analysis. The most interesting aspect of his proof is that, by combining differential equation theory for Berkovich spaces and valuation theoretic point of view, he can explain the blow-up locus in a coherent manner. A. D'Agnolo gave lectures on irregular Riemann-Hilbert correspondence that he established in the work with M. Kashiwara. This result enables us to understand Stokes phenomenon in a higher dimensional situation. In the heart of the proof, they used resolution of turning points.

The conference was very successful with a lot of attendance from many universities and with various backgrounds.

Conference: MEXT Scientific Research on Innovative Area "Why Does the Universe Accelerate? – Exhaustive Study and Challenges for the Future –"

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There are observational evidences for two periods of accelerated cosmic expansion: at the very beginning, known as inflation, and the present. Since gravity, according to Newton as well as Einstein, is known as an attractive force, gravity can only "pull" the expansion to slow it down. Hence cosmic acceleration is the biggest mystery in cosmology. What is "pushing" the Universe to speed it up? We often invoke "inflation" and "Einstein's cosmological constant" as its theory, but they have many unnatural features and are far from satisfying explanations. The purpose of this research area is to understand the origin of the accelerated cosmic expansion, as well as its interplay with dark matter which competes with the acceleration to build galaxies and clusters of galaxies. To address this problem, we launched the research program "Why Does the Universe Accelerate? – Exhaustive Study and Challenges for the Future –" (PI: Hitoshi Murayama), based on the MEXT Scientific Research on Innovative Area (FY2015 – 2019). We propose to conduct the research program based on a comprehensive approach; Theory units ranging from cosmic acceleration due to inflation (A01: Misao Sasaki, Kyoto Univ.), to decelerated expansion phase due to

dark matter (A02: Fuminobu Takahashi, Tohoku Univ.), and late-time cosmic acceleration due to dark energy (A03: Naoshi Sugiyama, Nagoya Univ./Kavli IPMU): Observational units based on the CMB experiments (B01: Masashi Hazumi, KEK/Kavli IPMU), galaxy imaging survey (B02: Satoshi Miyazaki, NAOJ), galaxy redshift survey (B03: Masahiro Takada, Kavli IPMU), and the Thirty-Meter Telescope (B04: Tomonori Usuda, NAOJ): and then Ultimate units developing tools of combining different cosmological datasets to fully extract cosmological information (D01: Eiichiro Komatsu, MPA/Kavli IPMU) and seeking ultimate theory of cosmic acceleration from super-string theory with top-down perspective (C01: Hirosi Ooguri, Caltech/Kavli IPMU). This is a 5-year research program (FY2015-FY2019).

We held the conference at the High Energy Accelerator Research Organization (KEK) at around the end of the second year from the launch of this program, March 8 – 10 in 2017,

where almost all members from each research group gathered together. At the conference we had updates from each research group/program and there were a lot of productive, stimulating discussions. We also had contributed talks mainly by young researchers. In addition, we had a special session "Primordial Black Hole" (PBH) on the third day, where we discussed the current observational constraint, a scenario to generate PBHs from an inflationary universe, a scenario to explain dark matter with PBHs, and a connection of PBHs to the gravitational events in the Advanced LIGO experiment that detected gravitational waves from a binary black hole system. We had more than 120 participants, and the conference was greatly successful.

Finally we would like to thank the organizers, Masaya Hasegawa, Haruiki Nishino, Shuichiro Yokoyama, and Teruaki Suyama. We also thank the secretaries of KEK for their dedicated support.

Photo: Courtesy of KEK IPNS.

Workshop "Mathematics and Superstring Theory"

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From March 21 to 23, 2017, the workshop entitled "Mathematics and Superstring theory" was held at the Kavli IPMU. This workshop was organized as a summary of the JSPS program "Advancing Strategic International Networks to Accelate the Circulation of Talented Researchers" adopted as "Unlocking the Mysteries of the Accelerating Universe through Superstring Theory and Astrophysical Observations." The aim of this program is to support young researchers in Japan to go abroad and do joint works with foreign researchers. Several researchers in Japan, including workshop organizers Masahito Yamazaki and Yukinobu Toda, went abroad and had discussions in foreign countries.
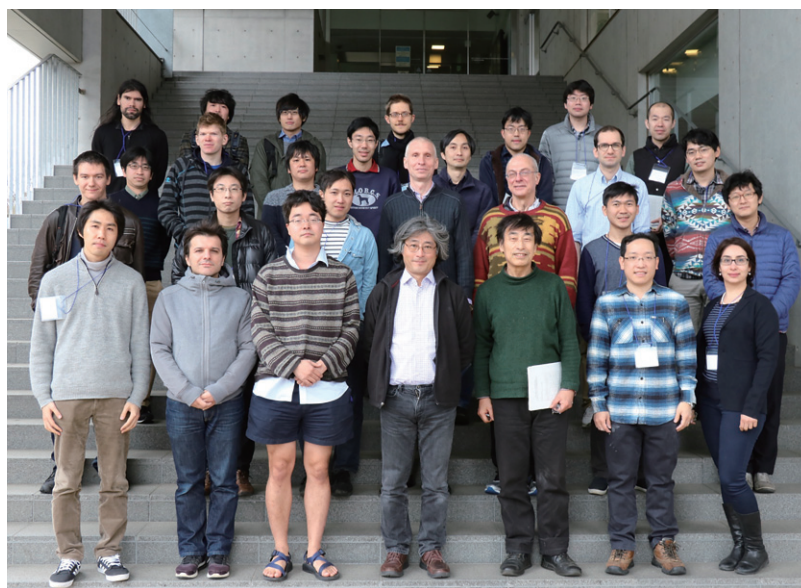
In the workshop, both mathematicians and string theorists came together and had significant discussions. From the mathematics side, there were 7 speakers: Ivan Ip, Zheng Hua, Akishi Ikeda, Atsushi Kanazawa, Georg Oberdieck, Yinbang Lin, and Kyoung-Seog Lee. The contents included various topics: derived algebraic geometry, mirror symmetry, stable pair invariants, derived categories of coherent sheaves, etc. Atsushi Kanazawa talked about Doran-Harder-Thompson conjecture on the construction of mirror Calabi-Yau manifolds by their

degenerations, and showed that their conjecture is true for elliptic curves and some abelian surfaces. Georg Oberdieck talked about his very strong result on the proof of Katz-Klemm-Vafa conjecture on Pandharipande-Thomas stable pair invariants, which count algebraic curves on Calabi-Yau 3-folds, for the products of K3 surfaces and elliptic curves.

From the superstring theory side, there were also 7 speakers: Mauricio Romo, Nezhla Aghaee, Shamil Shakirov, Pietro Longhi, Bruno Le Floch, Dongming Gang, and Taizan Watari. Mauricio Romo talked about sphere correlators for a hybrid model given by some non-affine algebraic

variety equipped with a super-potential. Shamil Shakirov talked about deformations of Chern-Simons topological field theory. It was known that such a deformation exists in the case that boundaries are Riemann surfaces with genus less than or equal to one, but Shakirov explained that it extends to the case that boundaries have genus two. There were also talks on quantization of super Teichmueller spaces, wall-crossing of BPS states, etc., which were also interesting for mathematicians.

During the workshop, both mathematicians and physicists enjoyed many discussions.

Workshop