Extremely Big Eyes on the Early Universe at Kavli IPMU

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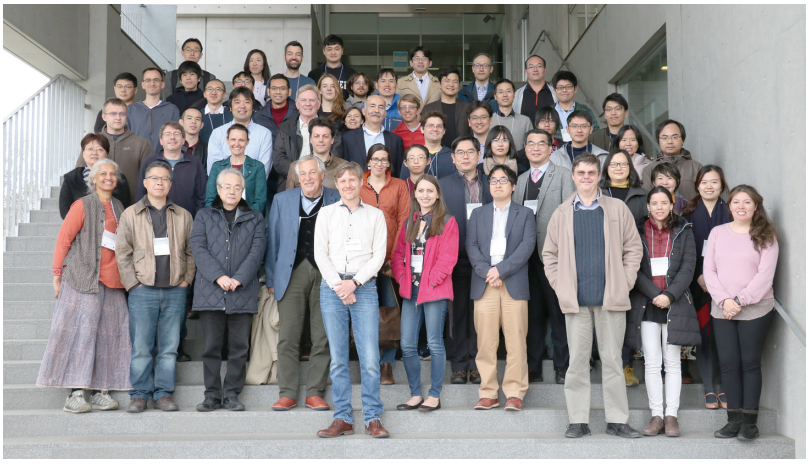
With the advent of giant telescopes 20 - 40m in diameter, the next decade will see a transformational phase for ground-based optical/near-infrared astronomy. The construction of three such telescopes has already started or will soon start: the Thirty Meter Telescope (TMT), the Extremely Large Telescope (ELT), and the Giant Magellan Telescope (GMT), with the Japanese astronomical community being a prominent member of the TMT. To promote alertness on the opportunities they offer for our understanding of the distant Universe, a three-part conference series started with the kickoff meeting at UCLA this past January, followed by the second conference at Kavli-IPMU (March 25 - 29) while the third conference will be held in Rome this September.

The workshop was attended by over 70 participants from the Asia/Pacific region, US and Europe. The status and capabilities of each telescope were reported, making clear that, while the ELTs will come after several years of JWST (James Webb Space Telescope) operation, still they will outperform it in various ways. First, being diffraction limited thanks to advanced adaptive optics, they will have 3 to 6 times better spatial resolution, or just 20 - 40 parsecs at redshift = 7. The ELTs will also offer higher spectral resolution, access to shorter wavelengths, higher spectroscopic multiplex and a much longer lifetime.

These unparalleled capacities will allow giant leaps forward in our understanding of first galaxies and cosmic reionization, of the coevolution of galaxies and their central supermassive black holes, of the baryon cycle in and out galaxies feeding star formation and spreading metals out of them, and of physical processes responsible for halting star formation in galaxies. The current state of the art was illustrated in over 50 presentations, also emphasizing that galaxies must be seen in the context of their large scale environment. In this respect, the large surveys being conducted with Subaru's Hyper-Suprime Cam and in the near future with the Prime-Focus Spectrograph are paving the way for the ELTs. We also heard from theoreticians constructing ever larger and more detailed simulations of galaxies and their need for observational constraints from the next generation of giant telescopes.



Several important issues emerged and were discussed at the conference. How to optimize the three telescopes ensuring they together cover the broadest possible range of capabilities, hence allowing the largest variety of science programs? Indeed, it will not be possible for each individual telescope to support all the instruments that would exploit its large aperture. Therefore, some complementary capability between the three telescopes will be highly beneficial, leaving then to the ingenuity of the science teams to take advantage of them. Thus the ultimate aim of the workshop was to look forward from the current research and prepare for the exciting future opportunities offered to optical and near-infrared astronomy.

Representation Theory, Gauge Theory and Integrable Systems

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From Feb. 4 to Feb. 8, 2019, Kavli IPMU hosted a workshop on "Representation theory, gauge theory and integrable systems" organized by Hiraku Nakajima (Kavli IPMU), Francesco Sala (Kavli IPMU), Yuji Tachikawa (Kavli IPMU), and Yutaka Yoshida (Kavli IPMU). It was supported in part by JSPS Grant Number 16H06335 and by financial support from MEXT.

The workshop focuses interfaces among representation theory, gauge theory and integrable systems. There have been numerous connections in recent decades, such as computation of partition functions in gauge theories via representation theory and integrable systems, realization of representations of quantum algebras via moduli spaces in gauge theories, new examples of quantum algebras via gauge theory, and so on. The workshop brought together mathematicians and physicists, including both experts and young people in these related areas from Japan and overseas to discuss new developments and investigate potential directions for future research.

The talks of Nekrasov, Bershtein, and Yamazaki were devoted to relations between 4 or 5 dimensional SUSY (supersymmetric) gauge theories and isomonodromic deformation of differential or difference equations, Painlevé equations. In particular, solutions of Painlevé equations are described by gauge theory partition functions, and bilinear relations, known as Hirota type equations, are derived from properties of SUSY gauge theories.

The talks of Yanagida and Yang were devoted to Hall algebras of categories of coherent sheaves of certain algebraic varieties. Yanagida used coherent sheaves on abelian surfaces and gave a new proof of the bispectral property of Macdonald-Ruijsenaars difference operators as an application. Yang studied the cohomological Hall algebra for coherent sheaves on $\mathbb{C}^3$ supported on the union of coordinate 2-planes, and its relation to Yangian of $\widehat{\mathfrak{gl}}(1)$ and the vertex operator algebra recently introduced by Gaiotto and Rapcak.

Hosseini and Okuda discussed the formula of partition functions, given by the localization technique. Hosseini's talk was devoted to those of 5-dimensional SUSY gauge theories on a toric surface times the circle, and Okuda's talk was for line operators in 4-dimensional SUSY gauge theories. Kanno explained representation theory of quantum toroidal algebra of $\widehat{\mathfrak{gl}}(1)$, in particular, intertwiners between its Fock representations. They are related to the refined topological vertex, the building block of the refined version of the topological string partition functions of toric Calabi-Yau 3-folds.

The talks of Gukov and Pei were about construction of modular tensor categories from a class of 4-dimensional SUSY quantum field theories, and relation between representation theories of vertex operator algebras and geometry of Coulomb branches.

McBreen and Hilburn talked about mysterious relations between Higgs and Coulomb branches of 3-dimensional SUSY gauge theories, called symplectic duality. McBreen proposed a categorical version of the Hikita conjecture, which states an equivalence between the categories associated with Higgs and Coulomb branches. One of the categories is supposed to be the derived category of constructible sheaves on the loop space, whose rigorous foundation is a challenging problem. Hilburn explained the relation between symplectic duality and Langlands duality. Langlands duality also appeared in the talk of Hausel, where he explained examples of branes in moduli spaces of Higgs bundles of a group and its Langlands dual, and their relation under the semiclassical limit of the mirror symmetry.

The talks of Kato and Su were devoted to the relation between equivariant quantum K-theory/cohomology and equivariant K-theory/homology of affine Grassmannians.

Kato introduced the third object, the equivariant K-theory of a semi-infinite flag variety, to connect them vigorously. Su, following the idea of Teleman, defined the action of the latter via shift operators acting on quantum cohomology. Affine Grassmannians are associated with finite dimensional complex reductive groups. There is a growing interest in double affine Grassmannians, which are affine Grassmannians for affine Kac-Moody groups. Muthiah explained an approach to define the analogous double affine flag varieties and their Schubert subvarieties. He discussed Hecke algebras, Bruhat order, etc. in this setting.

Kimura explained a definition of quiver W-algebras associated with a quiver, based on qq-character defined via 4d SUSY quiver gauge theories. The talk of Appel was devoted to an approach to the reflection equation and its solution K-matrices via the category of representations of quantum symmetric pairs, constructed as quantization of small K-matrices.

It was unfortunate that a few invited speakers canceled their visits at the last moment. But participants told us that it was an exciting and fruitful workshop with many interesting talks on hot topics. Personally, I was very happy to have a discussion on Coulomb branches of gauge theories, and started a collaboration with participants.

Interdisciplinary Approach to Cancer Therapy

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An important movement towards discussion of urgent issues faced by modern cancer research began on the 27th of March. 70 researchers from 8 countries participated in a workshop called the "Interdisciplinary approach of applying cutting-edge technologies at the frontier of cancer research". Its objective was to understand the challenges of eradicating cancer, and to report on the latest developments of cutting-edge technologies used in clinical applications.

Professor Tadayuki Takahashi, a committee organizer and Principle Investigator at Kavli IPMU, opened this inaugural workshop. Addressing an audience consisting of scientists from the field of nuclear medicine, chemistry, physics, engineering, and pharmaceutical sciences, Professor Takahashi asked: "how can we all work together to help physicians establish new treatment for advanced cancers in order to boost cancer survival rates?"

Over the course of 2 days, 16 world-leading interdisciplinary scientists presented their current and future research activities to stimulate new ideas. We heard from eminent medical doctors about current state of affairs in cancer treatment and research. For instance, in Japan over 30% of cancer patients have advanced cancer when diagnosed, and only 14% of stage IV cancer patients will survive after five years using current technologies and treatment.* With the objective of eradicating cancer at the cellular level, Professor Hideyuki Saya from the Division of Gene Regulation at the Institute for Advanced Medical Research at Keio University School of Medicine discussed the need for new methods and technologies which can be used to distinguish between cancer stem cells in order to eliminate both the cancer stem cells themselves and their derivatives.

Particle accelerators play a crucial role in cancer therapy and in the production of radio pharmaceuticals. The Paul Scherrer Institute in Switzerland use proton therapy with remarkable success, treating more than 7,000 patients with a 98% cure rate, while in Japan, RCNP, Osaka Univ. has started Astatine-211 production by cyclotron aiming for new alpha-ray therapy. The development of a new 100-million-dollar radio pharmaceutical facility will be completed by 2023 at TRIUMF in Canada for the purpose of developing advance rare isotope. These movements will inevitably lead to the development of new detection systems.

A recurring theme during the Workshop was highlighting the transferrability of technology and methods developed in high energy physics experiments and in the field of astrophysics to the field of medical imaging. The advancement and present limitations of fast detectors, digital photon counting through to the application of machine learning for signal processing, data analysis and optimized readout algorithms were discussed.

Future development of high energy resolution detectors and reaching beyond the 100 micrometer scale, and visualization of in vivo multiple drug delivery system to boost survival rates is underway at Kavli IPMU. Energy resolution is essential for multi-probe visualization, and particularly for imaging the alpha-emitting cancer therapy isotope Astatine-211 of which there is active collaboration between Kavli IPMU and the National Cancer Center at Kashiwanoha, Japan where experiments for detecting

* T. Matsuda et al., Research Group of Population-Based Cancer Registries of Japan. Population-based survival of cancer patients diagnosed between 1993 and 1999 in Japan: a chronological and international comparative study. *Japanese Journal of Clinical Oncology* 2011; 41: 40-51.

Astatine-211 are currently being performed.

It will likely require new benchmarks of human ingenuity to overcome the unique hurdles facing cancer research. An obvious catalyst for ingenuity is to bring together interdisciplinary researchers from across the World to create new and novel imaging devices to detect the radio pharmaceuticals and just as importantly to also understand what we are seeing.

With that in mind, the organizing committee is pleased to announce that the "INTERdisciplinary Approach to Cancer Treatment (INTERACT)" will be held annually, with the next event being held in France in 2020.

The participants of the inaugural workshop titled "Interdisciplinary approach of applying cutting-edge technologies at the frontier of cancer research" to discuss urgent issues in modern cancer research and to report on the latest developments of cutting-edge technologies used for clinical applications.