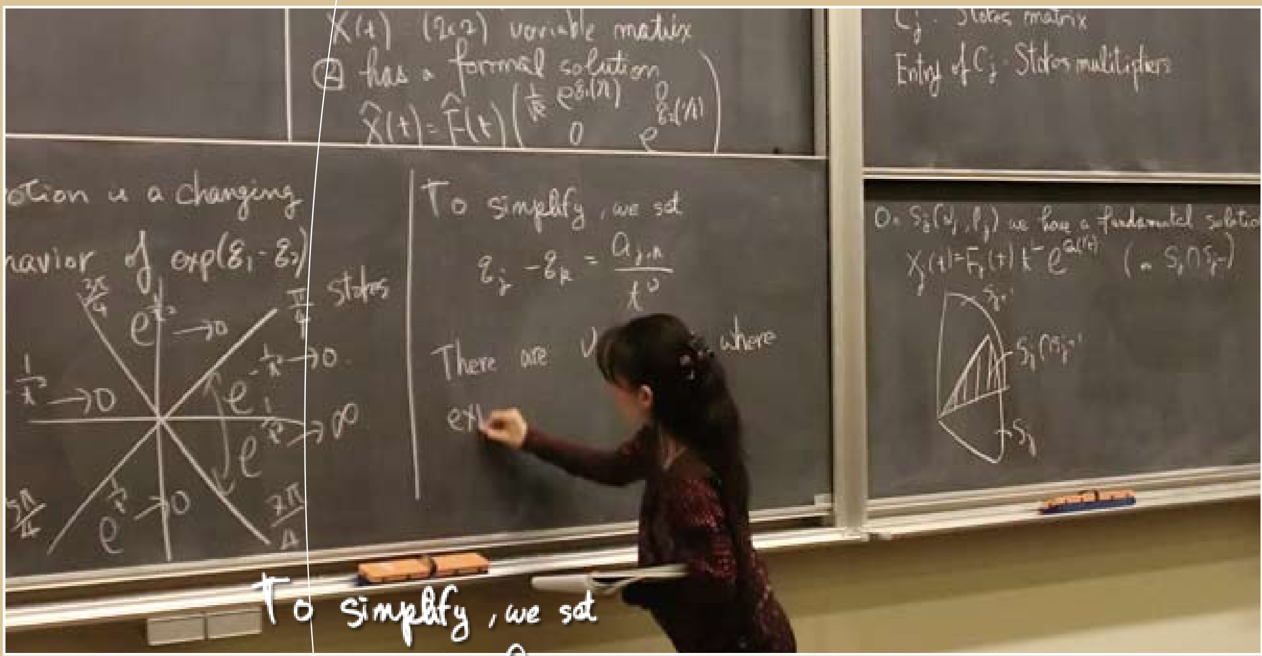
April 2011–March 2012

IPMU

ANNUAL REPORT 2011



To simplify, we set

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There are ν where

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World Premier International Research Center Initiative

THE UNIVERSITY OF TOKYO

TODIAS
東京大学国際高等研究所
TODAI INSTITUTES FOR ADVANCED STUDY

IPMU INSTITUTE FOR THE PHYSICS AND MATHEMATICS OF THE UNIVERSE

IPMU

Institute for the Physics and Mathematics of the Universe
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Design: aha co., ltd.
http://www.a-ha.co.jp/

History (April 2011–March 2012)

April
- The Physical Society of Japan Publication Award to Shigeki Sugimoto
- Construction of IPMU Annex building completed

May
- Architectural Institute of Japan Award to Hidetoshi Ohno, professor at Todai Graduate School of Frontier Science and the designer of IPMU Building
- Focus Week "Astrophysics of dark matter"

June
- New Principal Investigator in mathematics Toshiyuki Kobayashi (Todai Graduate School of Mathematical Sciences)
- SuMIRe Collaboration Meeting for PrimeFocusSpectrograph

July
- Completion of laser-guide star adaptive optics for Subaru Telescope
- External Advisory Committee meeting

August
- Annual site visit of the WPI working group members
- Press release "Cosmic dust at stellar explosions—Discovery of massive dust in SN 1987A"

September
- IPMU-YITP School and Workshop "Monte Carlo tools for LHC"
- The Mathematical Society of Japan Geometry Prize to Kyoji Saito
- The Mathematical Society of Japan Takebe Prize to Tomoyuki Abe

October
- IPMU celebrates the 4th anniversary
- Press release "Galaxy interactions accelerate the growth of supermassive black holes"
- Workshop "Curves and categories in geometry and physics"

November
- Press release "Computer simulation reveals the first stars in the universe weighed about 40 times the Sun"

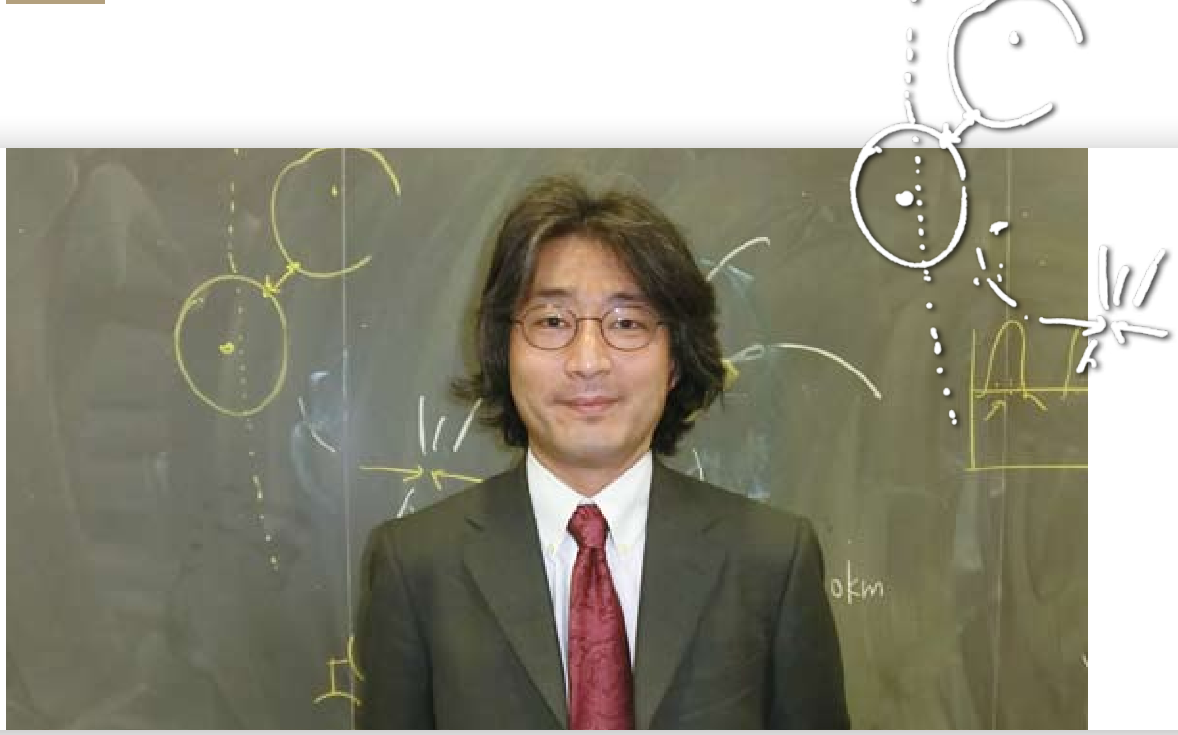
December
- IPMU receives "Superior" grade at the WPI interim review

January
- The 2nd PrimeFocusSpectrograph Collaboration meeting
- The 6th Asian Winter School "Strings, particles and cosmology"
- Press release "Independent study confirms the 2010 discovery of flat dark matter distribution and improves the precision"
- Young Scientist Award in theoretical particle physics to Masahiro Ibe
- IPMU Workshop "Testing gravity with astrophysical and cosmological observations"
- Press release "Missing dark matter located—Inter-galactic space is filled with dark matter"
- Agreement signed between NAOJ and IPMU on PrimeFocusSpectrograph

February
- Mini workshop "Physics at SuperKEKB"
- Todai announcement of IPMU becoming Kavli IPMU
- IPMU Conference "Growing black holes in COSMOS"
- Inoue Science Prize for Young Scientist to Masaomi Tanaka
- Sloan Research Fellowship to Brice Menard

March
- IPMU Workshop "Particle physics of the dark universe"
- Yoji Totsuka Memorial Prize to Masataka Fukugita and Tsutomu Yanagida
- IAU Symposium 279 "Death of massive stars: Supernovae and gamma-ray bursts"
- The Japan Academy Award to Takaaki Kajita
- SuMIRe/PFS conceptual design review and technical group meetings

1 Mission



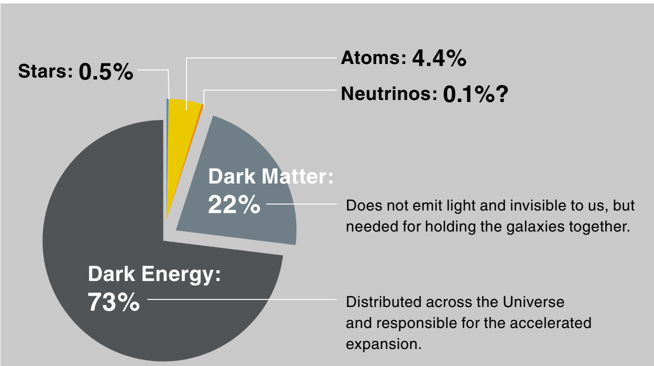
Director Hitoshi Murayama

Initial four and half years have passed since we started a mission to establish an entirely new institute and address fundamental questions of the universe. As far back as the history goes, human beings have always pondered about the origin of the universe, how it is structured, how it works, and where it is going. Our mission is to address these most ancient and fundamental questions that were once studied only by pure thought by using modern technology and development of theoretical framework.

Startup stage of the new institute is well over. We are in a creative mode and moving on with the mission, mostly sticking to the original plan but with some modifications in accordance with recent progresses that has been taking place in these research areas with rapidly increasing speed. Here let us restate our mission.

We Face Big Challenges

For centuries, humans had believed that the entire universe is made of the same material we are made of, namely atoms. In the past decade, this belief was completely overturned. The atoms make up less than 5% of the universe. The dark matter comprises the rest of the matter, about 22% of the universe, yet we do not know what it is. The remainder of about 73%is dark energy which we know even less. It is thought to be responsible for the accelerated expansion of the universe, and its discovery had led to the 2012 Nobel Prize in Physics.



Composition of the universe

In addition to these findings that there are unknown components in the universe, there are also mysteries about the components that should exist yet we don't find. Anti-matter can be created in the laboratory and was surely created in Big Bang. Yet we do not see it in the universe.

Furthermore, we know the universe is superconducting and makes certain kinds of forces short-ranged within a billionth of a nanometer while keeping electromagnetism and gravity long-ranged. The energy density of the superconductor should contribute about 10^{62}% to that of the universe, which must be cancelled by yet another component at an incredible accuracy. It is natural to suspect some underlying reason which we do not know yet rather than accepting it as a lucky coincidence.

Why Physics and Mathematics?

The reason for the combination of physics and mathematics is quite obvious. Throughout the history of physics, it was an invention of new mathematics that offered helping hand whenever a paradigm shift was inevitable in physics. It has been the case, and will be for the foreseeable future. Physics, being the most quantitative among sciences, relies heavily on the most advanced types of mathematics.

The big challenges we face today cry out for a new paradigm of the universe, and hence new physics and new mathematics.

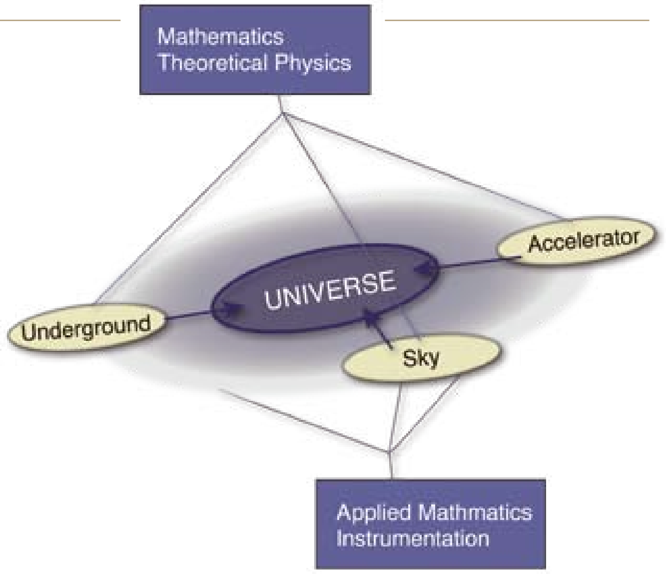
Three Experimental Approaches

Prof. Koshiba who won 2002 Nobel Prize in physics for detecting neutrinos from the supernova 1987A with the Kamiokande detector demonstrated that neutrinos can be used to study the universe in a way not imagined before. Furthermore the Super-Kamiokande and KamLAND experiments had discovered that ghostly neutrinos have tiny but finite masses at the level predicted by the unified theories at 13 orders of magnitude beyond the reach of the current accelerator experiments. Thus, the neutrino masses are giving us a precious glimpse of physics at the ultra-high energy and very early universe. It is perhaps ironic that the best way to study the universe is to go underground. Underground experiments are also likely avenues to discover the dark matter of the universe.

Looking up at the sky is undoubtedly a very essential experimental approach for exploring the universe. Both in ground-based and space-based observations, we have made great strides in recent years. It is the sky observation that determined the breakdown of the composition of the universe. Large-scale galaxy surveys further revolutionize our understanding of the universe. The scope of the galaxy survey using the Subaru telescope is greatly expanded due to the 2009 approval of the SuMIRe project. It combines the originally envisioned imaging survey with a newly proposed spectroscopic survey.

The most direct assault on the mysteries of the universe comes from the brute-force method that tries to recreate the Big Bang in the laboratory, namely particle accelerators. The world highest energy LHC accelerator is capable of mimicking the Big Bang in a "Little Bang" that brings us direct and critical information on the condition at the birth of the universe. The other type of accelerators operates at lower energies of particular interest but with an enormous beam intensity. High precision measurements at newly proposed SuperKEKB can be sensitive to the presence of new particles and new interactions beyond the Standard Model. Any new finding at these accelerators and figuring out their roles in the universe should be one of the most far-reaching consequence of our mission.

The T2K experiment that detects the neutrinos from the J-PARC accelerator at the Super-Kamiokande is a mixture of accelerator-based and underground-based approaches. It is a novel way to attack the mystery why we exist in the universe at all, namely the preponderance of matter over anti-matter.



Common Threads

The multi-prong experimental assault on these three fronts, namely underground, sky, and accelerator, must be tied with common threads of theoretical physics, mathematics, instrumentation and applied mathematics.

Theoretical physics develops the unified description of the universe based on the available data, and allows us to guide the future plans for next-generation experiments. Theoretical framework that is capable of tackling the challenging mystery at the birth of the universe almost certainly needs new types of highly sophisticated pure mathematics.

Applied mathematics and statistics provide novel approach to deal with huge data set provided from advanced experiments. The upcoming data from galaxy surveys, accelerator and underground are measured in Petabytes (billion Megabytes) and pose an incredible challenge in extracting critical scientific information out of them.

Importance of instrumentation as the common threads is obvious. They make difference whether we can reach a breakthrough in the observations. We can benefit great deal from a well coordinated approach in the instrumentation of the three fronts.

Necessary Ingredients

We conduct three major underground experiments. ZEN at KamLAND looks for a possible conversion of anti-matter (anti-neutrino) to matter (neutrino) in a very rare process called neutrinoless double beta decay. EGADS at Super-Kamiokande tries to enhance the sensitivity of detecting (anti-)neutrinos from the distant supernovae. XMASS aims to directly detect dark matter particles that are thought to pervade our Milky Way galaxy.

We take two complementary approaches in observational astronomy. Wide-scale surveys with ongoing Sloan Digital Sky Survey III, with the just-starting HyperSprimeCam, and with the future PrimeFocusSpectrograph, investigate dark matter and dark energy by studying the expansion history of the universe. On the other hand, dedicated studies of particular type of astronomical objects such as supernovae and clusters are not only of their own interests but prove crucial for detailed understanding and interpretation of the wide-scale survey results.

Results from observational astronomy have to be interpreted in the context of theoretical framework. This framework includes computational approaches in cosmology for studying the evolution of the structure in the universe. Similarly, theoretical approaches in particle physics are taken to understand the data from accelerator experiments and high-energy cosmic rays.

We try to decipher the basic laws of the universe from the observations and phenomenological analyses. Being guided mostly by quantum field theory and string theory, we aim to develop new theories that can describe the entire range of physics, including the beginning of the universe, unification of quantum mechanics and gravity, black holes, dark matter and dark energy.

Mathematicians at IPMU work closely with physicists. This is particularly true with the string theorists. They discuss together the subjects such as mirror symmetry and Calabi-Yaumanifolds, derived category, D-branes, integrable systems.

Our research program covers a wide range of subjects. They are all critical ingredients for addressing the fundamental questions of the universe.

Contents

2 Introduction

The most exciting moment for us in JFY 2011 came on December 14 with an MEXT announcement of an interim evaluation result in which we were given the highest grade "S" (Superior). This evaluation by MEXT was a part of review processes for the first four years since the launch of the initially selected five WPI research centers. The report made the following comment on IPMU.

Interim evaluation: S

We all highly evaluate IPMU's past four years of activities and scientific achievements. During a short period, IPMU has established itself as a world-renown institute from scratch. IPMU has demonstrated outstanding progress toward achieving the goals of the WPI program in all areas—quality of science, globalization, interdisciplinary approach, and organizational reform. The leadership of Professor Murayama is highly appreciated.

Press Conference for Kavli IPMU (February 8, 2012)

Director Hitoshi Murayama was very excited to hear the result. He shared the good news with all staff members, saying "I'm so happy to receive the highest grade after the rigorous review process from the summer to the fall this year. It is a very ambitious goal for young WPI centers to attain a high visibility in the world comparable to world-leading research centers with long traditions. We have focused intensively on building an attractive and exciting research institute that pays a lot of attention to accommodate researchers comfortably, especially those from other countries. This strategy seemed to have paid off handsomely. This would not have been possible without a strong support from the University, competent administrative staff, and from the public at large. We have been ramping up several big projects that are coming to the phase of producing data and science. The next five years are when we have to work hard to truly shine."

The interim report, however, did not end with the only good news. It imposed three actions which should be taken for further strengthening its research program, namely, i) Todai should secure a certain number of tenure positions for IPMU, ii) IPMU should make foreign joint appointments at the faculty levels for enhancing personal exchanges, and iii) IPMU should strengthen the research area of data mining and informatics for forthcoming cosmology observations. Murayama continues to push hard for the items ii) and iii), and to negotiate with Todai President's office for the item i).

While preparing for the interim evaluation was a big burden, it was a good opportunity for us to reexamine the research strategy and make necessary adjustments in accordance with rapidly progressing activities worldwide during the past four years. For accelerator-based research, our original strategy was to participate at LHC in both experiment and phenomenological analyses. However, it is difficult for us to make an impact on the experimental effort given its advanced stage. So our involvement is limited to phenomenology using the released data. Instead, we plan to join Belle II experiment at SuperKEKB for the study of super symmetry and other new physics possibilities. IPMU will participate in both detector construction and physics analyses. The scope of galaxy survey using the Subaru telescope is greatly expanded compared with the originally projected plan after an approval of the SuMIRe (Subaru Measurement of Images and Redshifts) project. It combines the originally envisioned imaging survey using HyperSprimeCam (HSC) with new spectroscopic survey using PrimeFocusSpectrograph (PFS). IPMU leads the formation of the PFS international collaboration and construction of the new spectrograph. Scientific achievements of the past four and half years are summarized in the chapter of Research Highlight.

Another big event of JFY 2011 was an announcement of February 8, 2012 from the University of Tokyo on the establishment of endowment by the Kavli Foundation for IPMU, hence the name of the Institute will be changed to "Kavli IMPU" (Kavli Institute for the Physics and Mathematics of the Universe) starting April1, 2012. At the press conference, the Todai president Junichi Hamada thanked Fred Kavli, the founder of the foundation, who joined via TV connection, for his generous donation. "This donation has provided the occasion to reexamine and reform our systems for managing donated funds," he said. The Kavli Foundation, based in Southern California, sponsors research in astrophysics, nanoscience, neuroscience and theoretical physics at institutes across the globe including China, England, Netherlands, Norway and the United States. The Kavli IPMU will be its 16th institute, its sixth in astrophysics and third in theoretical physics, and the first to be established in Japan.

Including principal investigators, faculty members, postdoctoral fellows, affiliate members, long-term visitors and students, IPMU has now grown to an international research center for 219 core researchers. Their activities are supported by 38 administrative and research support staff. Besides the core researchers, we routinely receive many short-term visitors. We have published 252 papers in JFY 2011. Their quality is competitive with other top-level places based on citation counts.

Number of Core Researchers (March 2012)

	Number	Foreign
Principal Investigators	19	4
Professors (not including 4 PIs)	6	1
Associate Professors	10	2
Assistant Professors	9	3
Postdoctoral Fellows	45	34
Affiliate Members	89	34
Long-term Visitors	13	13
Students	28	0
Total	219	91

Research Activities in JFY 2011

Conferences	12
Seminars	196
Visitors (foreign)	630 (392)
Preprints	216
Publications	252

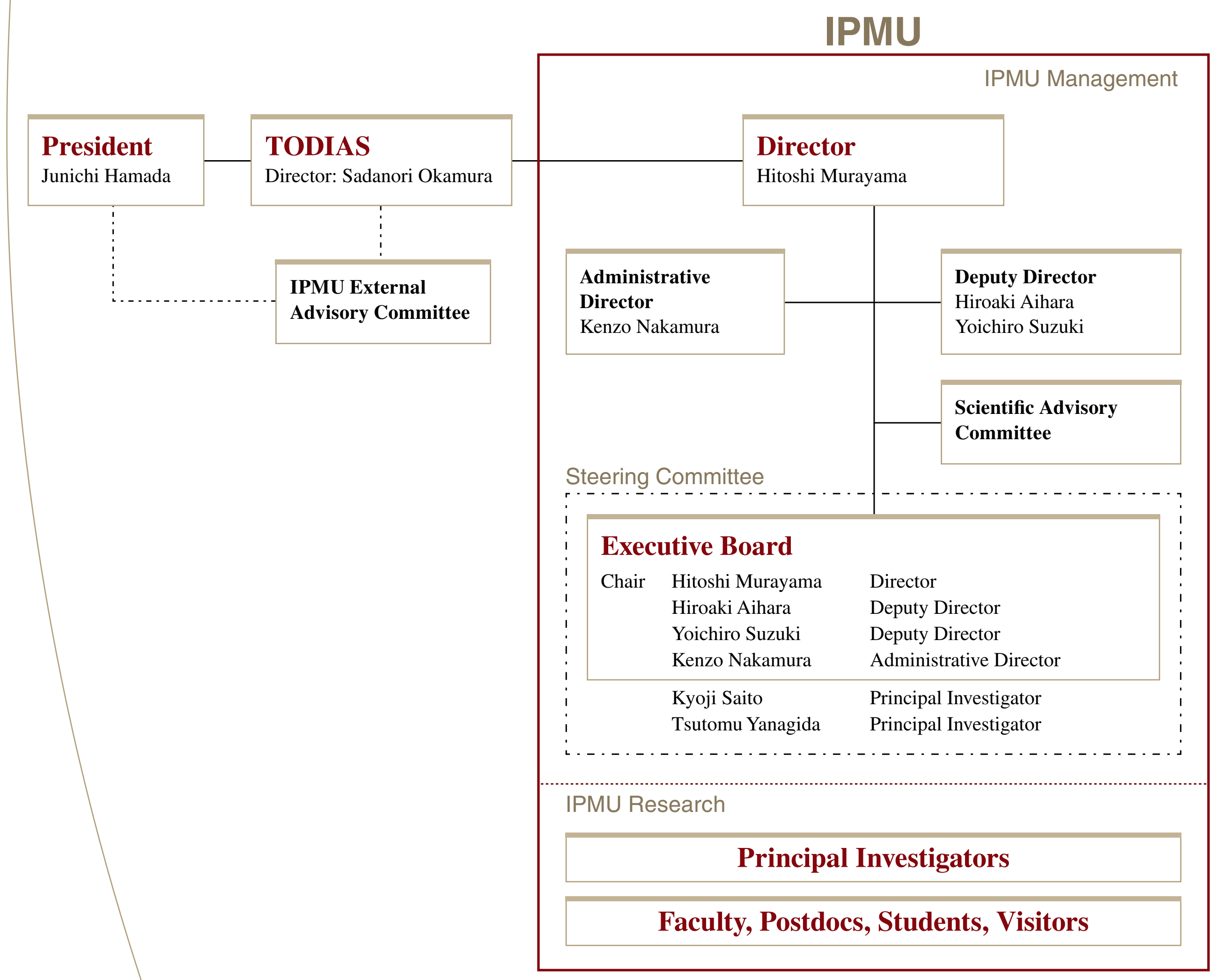
Introduction

3 Organization

IPMU has a rather unique organization. While research is conducted in a flat-structure manner with loosely defined grouping, the decision making is done in a top-down scheme under the Director's strong leadership. This scheme minimizes the administrative load for the researchers. It is also intended to maximally extract young researcher's creative and challenging minds as well as to encourage daily cross-disciplinary interactions.

The IPMU Director is appointed by the Todai President and reports directly to his office. The Director proposes to hire the Principal Investigators to the President. For other hiring of research staff and administrative staff, he has a complete authority. He is also solely responsible for making all other decisions. He is assisted by two Deputy Directors and the Administrative Director. They hold the Executive Board (EB) regularly to ensure smooth operation of the Institute. The EB has direct access to the Office of the President for consultations on both scientific and administrative matters.

With the establishment of Todai Institutes for Advanced Study (TODIAS), the Director is obliged to report the appointments of new Principal Investigators and faculty members to the TODIAS Director. Also, to clear the university formality in faculty hiring, the IPMU decisions have to be endorsed by the IPMU Steering Committee consisting of the EB members plus two faculty members.



The Principal Investigators are the world's leading scientists in their fields. They have a large autonomy in the research they conduct. They can make proposals to the Director to hire research staff at IPMU for their purposes.

The Scientific Advisory Committee (SAC) gives advice to the Director on hiring scientific staff and setting scientific strategies. The members, consisting of two Deputy Directors and five Principal Investigators, are appointed by the Director.

The External Advisory Committee (EAC), appointed by the Todai President, reviews annually the scientific achievement and activities of the Institute and advises the President on scientific priorities and the research activities to keep the Institute stay on the course of their objectives.

The Scientific Advisory Committee Members (March 2012)

Hiroaki Aihara	U of Tokyo Physics Dept	high energy physics
Yoichiro Suzuki	U of Tokyo, ICRR	astroparticle physics
Toshitake Kohno	U of Tokyo Mathematics Dept	mathematics
Hirosi Ooguri	Caltech	particle theory
Kyoji Saito	IPMU	mathematics
David Spergel	Princeton U	astrophysics
Tsutomu Yanagida	IPMU	particle theory

The External Advisory Committee Members (March 2012)

John Ellis	CERN	particle theory
Makoto Gonokami	U of Tokyo	quantum optics
Young-Kee Kim	Fermilab/U of Chicago	high energy physics
Sadayoshi Kojima	Tokyo Tech	mathematics
David Morrison	UC Santa Barbara	mathematics and physics
Roberto Peccei	UCLA; Chair	particle theory
Steven Kahn	SLAC/Stanford U	astrophysics

The main laboratory building on Kashiwa Campus provides a basis for our researchers. Even most of experimentalists who are involved in Kamioka experiments and telescopes spend a good fraction of their time in Kashiwa for analyzing data, sharing seminars and discussing with theorists. The IPMU Kamioka Branch is a basis for IPMU staff who are working at the Kamioka experiments. The IPMU Berkeley Satellite, besides being a place for research, serves as a contact place to the US scientific community. We also have a close collaborative relation with several institutions in both Japan and abroad as well as other departments within the University of Tokyo.

Host Institute (Univ. of Tokyo)

- Department of Mathematics
- Institute for Cosmic Ray Research (Kashiwa, Kamioka)
- Department of Physics
- Department of Astronomy

IPMU

Kashiwa Campus

Kamioka Branch

Berkeley Satellite

Collaborating Institutions (international)

- Department of Astrophysical Sciences, Princeton University, USA
- Institut des Hautes Etudes Scientifiques (IHES), France

Collaborating Institutions (domestic)

- National Astronomical Observatory in Japan
- Department of Physics, Kyoto University
- High Energy Accelerator Research Organization (KEK)
- Yukawa Institute for Theoretical Physics, Kyoto University
- Research Center of Neutrino Science, Tohoku University

IPMU holds close relations with similar research institutions in the world for encouraging exchanges in research and training of young staff. We have signed either agreements or memorandum of understanding with those institutions.

Foreign institutions having exchange program with IPMU

University of California Berkeley, Physics Department
University of Chicago, Department of Astronomy and Astrophysics
Institute for Advanced Study, School of Natural Sciences
Johns Hopkins University, Department of Physics and Astronomy
New Mexico State University, Astronomy Department
Princeton University, Department of Astrophysical Sciences
University of Washington, Astronomy Department
Washington State University, Department of Mathematics
Stanford University, Kavli Institute for Particle Astrophysics and Cosmology (KIPAC)
Technical University of Munich, Physics Department
Ludwig Maximilian University of Munich, Physics Department
Max Planck Institute, Astronomy and Astrophysics
Max Planck Institute, Extra-terrestrial Physics
Max Planck Institute, Physics Department
European Southern Observatory (ESO)
National Taiwan University, Research Center for Cosmology and Particle Astrophysics

4 Staff

IPMU research staff at the 4th anniversary celebration

Director

Hitoshi Murayama, particle theory, cosmology

Deputy Directors

Hiroaki Aihara, high energy physics, astrophysics
Yoichiro Suzuki, astroparticle physics, neutrino physics

Principal Investigators

Hiroaki Aihara (Tokyo Phys), high energy physics, astrophysics
Alexey Bondal (IPMU & Steklov Inst), mathematics
Masataka Fukugita (Tokyo ICRR), astrophysics
Kunio Inoue (Tohoku), neutrino physics
Takaaki Kajita (Tokyo ICRR), neutrino physics
Stavros Katsanevas (Paris 7), astroparticle physics
Toshiyuki Kobayashi (Tokyo Math), mathematics
Toshitake Kohno (Tokyo Math), mathematics
Hitoshi Murayama (IPMU & UC Berkeley), particle theory, cosmology
Masayuki Nakahata (Tokyo ICRR), astroparticle physics
Mihoko Nojiri (KEK), particle theory
Ken'ichi Nomoto (IPMU), astronomy
Hirosi Ooguri (Caltech), mathematics, string theory
Kyoji Saito (IPMU), mathematics
Henry Sobel (UC Irvine), astroparticle physics
David Spergel (Princeton), astrophysics
Naoshi Sugiyama (Nagoya), cosmology
Yoichiro Suzuki (Tokyo ICRR), astroparticle physics
Tsutomu Yanagida (IPMU), particle theory

Faculty Members

Tomoyuki Abe, mathematics
Alexey Bondal (Joint Appointment with Steklov Inst), mathematics
Kevin Bundy, astronomy
Simeon Hellerman, string theory
Kentaro Hori, string theory
Hiroshi Karoji, astronomy
Satoshi Kondo, mathematics
Keiichi Maeda, astronomy
Kai Martens, astropharticle physics
Shigeki Matsumoto, cosmology
Todor Milanov, mathematics
Shinji Mukohyama, cosmology
Hitoshi Murayama, particle theory, cosmology
Ken'ichi Nomoto, astronomy
Masamune Oguri, cosmology
Kyoji Saito, mathematics
John Silverman, astronomy
Hajime Sugai, astronomy
Shigeki Sugimoto, string theory
Yuji Tachikawa, string theory
Masahiro Takada, cosmology
Tadashi Takayanagi, string theory
Naoyuki Tamura, astronomy
Yukinobu Toda, mathematics
Akihiro Tsuchiya, mathematics
Mark Vagins, astroparticle physics
Taizan Watari, string theory
Tsutomu Yanagida, particle theory
Naoki Yasuda, astronomy
Naoki Yoshida, astrophysics

Postdoctoral Fellows

Cosimo Bambi (till August 2011), cosmology
Melina Bersten, astronomy
Jyotirmoy Bhattacharya, string theory
Biplob Bhattacherjee, particle theory
Scott Carnahan, mathematics
Chuan-Ren Chen (till August 2011), particle theory
Won Sang Cho (till August 2011), particle theory
Rafael Da Silva De Souza (till August 2011), cosmology
Yu-Chieh Chung, string theory
Richard Eager, string theory
Jason Evans, particle theory
Brian Feldstein, particle theory
Gaston Folatelli, astrophysics
Sergey Galkin, mathematics
Alexander Getmanenko, mathematics
Ahmet Emir Gumrukcuoglu, cosmology
Minxin Huang, string theory
Emille Ishida (till August 2011), cosmology
Johanna Knapp, string theory
Alexandre Kozlov, neutrino physics
Tsz Yan Lam, astrophysics
Alexie Leauthaud, astronomy
Changzheng Li, mathematics
Chunshan Lin, cosmology
Wei Li (till August 2011), string theory
Jing Liu, astroparticle physics
Sourav Mandal, particle theory
Yu Nakayama, string theory
Takahiro Nishimichi, astrophysics
Atsushi Nishizawa, astronomy
Takaya Nozawa, astronomy
Noriaki Ogawa, particle theory
Yutaka Ookouchi, particle theory
Domenico Orlando (till September 2011), string theory
Michael Pichot (till June 2011), mathematics
Susanne Reffert (till September 2011), string theory
Robert Quimby, astronomy
Tomoki Saito, astronomy
Kenneth Shackleton (till October 2011), mathematics
Cornelius Schmidt-Colinet, string theory
Johannes Schmude, string theory
Christian Schnell, mathematics
Malte Schramm, astronomy
Ikko Shimizu, astrophysics
Jing Shu (till August 2011), particle theory
Charles Steinhardt, astronomy
Matthew Sudano, particle theory
Masaomi Tanaka (till November 2011), astronomy
Masayuki Tanaka, astronomy
Jiayu Tang (till June 2011), cosmology
Valentin Tonita, mathematics
Shunsuke Tsuchioka, mathematics
Mircea Voineagu, mathematics
Kai Wang (till May 2011), particle theory
Marcus Werner, mathematical physics
Simon Wood, mathematics

Graduate Students

Gen Chiaki, astrophysics
Tomohiro Fujita, particle theory
Keisuke Harigaya, particle theory
Koji Ichikawa, mathematics
Ayuki Kamada, particle theory
Yasuomi Kamiya, astronomy
Takuma Kurokawa, astrophysics
Takashi Matsuda, mathematics
Sogo Mineo, high energy physics
Hironao Miyatake, high energy physics
Takashi Moriya, astronomy
Kimihiko Nakajima, astronomy
Ryoichi Nishio, particle theory
Kohei Nishiyama, particle theory
Hidemasa Oda, mathematics
Tomoki Ohtsuki, mathematics
Ryosuke Sato, particle theory
Masato Shirasaki, astrophysics
Kohsaku Tobioka, particle theory
Tomonori Ugajin, particle theory
Kouta Usui, particle theory
Wen Yin, particle theory
Kazuya Yonekura, particle theory

Affiliate Members

Kou Abe (Tokyo ICRR), astroparticle physics
Mina Aganagic (UC Berkeley), string theory
Raphael Bousso (UC Berkeley), cosmology
Patrick Decowski (NIKHEF), high energy physics
Mamoru Doi (Tokyo Astron), astronomy
Yuri Efremenko (Tennessee), neutrino physics
Tohru Eguchi (Kyoto YITP), field theory
Motoi Endo (Tokyo Phys), string theory
Sanshiro Enomoto (Washington), neutrino physics
Masami Ouchi (Tokyo ICRR), astronomy
Andrea Ferrara (S.N.S. Pisa), astronomy
Stuart Freedman (LBNL), neutrino physics
Brian Fujikawa (LBNL), neutrino physics
Masaki Fukushima (Tokyo ICRR), astroparticle physics
Kaoru Hagiwara (KEK), particle theory
Lawrence Hall (UC Berkeley), particle theory
Koichi Hamaguchi (Tokyo Phys), particle theory
Tetsuo Hatsuda (Tokyo Phys), particle theory
Yoshinari Hayato (Tokyo ICRR), neutrino physics
Masashi Hazumi (KEK), astrophysics
Karsten Heeger (Wisconsin), neutrino physics
Katsuki Hiraide (Tokyo ICRR), astroparticle physics
Raphael Hirschi (Keele), astronomy
Junji Hisano (Tokyo ICRR), particle theory
Petr Horava (UC Berkeley), string theory
Glen Horton-Smith (Kansas), neutrino physics
Shinobu Hosono (Tokyo Math), mathematical physics
Masahiro Ibe (Tokyo ICRR), particle theory
Ken'ichi Izawa (Kyoto YITP), particle theory
Hiroshi Kaji (Tokyo ICRR), high energy physics
Jun Kameda (Tokyo ICRR), neutrino physics
Masaki Kashiwara (Kyoto RIMS), mathematics
Akishi Kato (Tokyo Math), mathematical physics
Yasuyuki Kawahigashi (Tokyo Math), mathematics
Seiji Kawamura (Tokyo ICRR), astroparticle physics
Masahiro Kawasaki (Tokyo ICRR), cosmology
Edward Kearns (Boston), neutrino physics
Sergey Ketov (Tokyo Met U), cosmology
Chiaki Kobayashi (Australia), astronomy
Kazuyoshi Kobayashi (Tokyo ICRR), astroparticle physics
Masayuki Koga (Tohoku), neutrino physics
Eiichiro Komatsu (Texas), cosmology
Yusuke Koshio (Tokyo ICRR), neutrino physics
Takahiro Kubota (Osaka), string theory
Alexander Kusenko (UCLA), particle theory, astrophysics
Andrew Liang (Tokyo ICRR), neutrino physics
Marco Limongi (INAF Rome), astronomy
Brice Menard (Johns Hopkins), cosmology
Makoto Miura (Tokyo ICRR), high energy physics
Shigetaka Moriyama (Tokyo ICRR), neutrino physics
Takeo Moroi (Tokyo Phys), particle theory
Kengo Nakamura (Tohoku), neutrino physics
Tsuyoshi Nakaya (Kyoto), high energy physics
Shoei Nakayama (Tokyo ICRR), neutrino physics
Kazunori Nakayama (Tokyo Phys), particle theory
Yasunori Nomura (UC Berkeley), particle theory
Hiroshi Ogawa (Tokyo ICRR), astroparticle physics
Kimihiro Okumura (Tokyo ICRR), neutrino physics
Christian Ott (Caltech), astrophysics
Masami Ouchi (Tokyo ICRR), astronomy
Serguey Petcov (SISSA), particle theory
Andreas Piepke (Alabama), neutrino physics
Yoshihisa Saito (Tokyo Math), mathematics
Hidetaka Sakai (Tokyo Math), mathematics
Katsuhiko Sato (NINS), cosmology
Kate Scholberg (Duke), neutrino physics
Hiroyuki Sekiya (Tokyo ICRR), neutrino physics
Masato Shiozawa (Tokyo ICRR), neutrino physics
Fedor Smirnov (Paris 6), mathematics
Michael Smy (UC Irvine), neutrino physics
James Stone (Boston), high energy physics
Fuminobu Takahashi (Tohoku), particle theory
Ryutaro Takahashi (Tokyo ICRR), astroparticle physics
Atsushi Takahashi (Osaka), mathematics
Atsushi Takeda (Tokyo ICRR), astroparticle physics
Yasuo Takeuchi (Tokyo ICRR), neutrino physics
Atsushi Taruya (Tokyo RESCEU), astrophysics
Nozomu Tominaga (Konan), astrophysics
Edwin Turner (Princeton), astrophysics
Misha Verbitsky (HSE Natl Res U), mathematics
Alexander Voronov (Minnesota), mathematics
Christopher Walter (Duke), neutrino physics
Kazuhiro Yamamoto (Tokyo ICRR), gravity
Masaki Yamashita (Tokyo ICRR), high energy physics
Jun'ichi Yokoyama (Tokyo RESCEU), astrophysics
Masashi Yokoyama (Tokyo Phys), high energy physics
Ken-ichi Yoshikawa (Tokyo Math), mathematics

Long-term Visitors (more than 1 month, * affiliate member)

Steven Bickerton (Princeton), astrophysics
Debajyoti Choudhury (Delhi), astrophysics
Alexander Dolgov (Ferrara), particle theory
Stuart Freedman* (LBNL), neutrino physics
Brian Fujikawa* (LBNL), neutrino physics
Chang Kee Jung (SUNY Stony Brook), neutrino physics
Eiichiro Komatsu* (Texas), cosmology
Alexander Kusenko* (UCLA), particle theory
Tristan Laine Smith (UC Berkeley), cosmology
Hung-Hsu Ling (ASIAA), astronomy
Brice Menard* (CITA), cosmology
Tatsuma Nishioka (Princeton), string theory
Serguey Petcov* (SISSA), particle theory
Raphael Ponge (Tokyo Math), mathematics
Alexey Rosly (ITEP), mathematics
Yefeng Shen (Michigan), particle theory
Elena Sorokina (Sternberg Astro Inst), astronomy
Tröster Tilman (ETH Zurich), gravity
Edwin Turner* (Princeton), astrophysics
Marcos Valdes (SNS Pisa), astrophysics
Misha Verbitsky* (HSE Natl Res U), mathematics
Alexander Voronov* (Minnesota), mathematics

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5 Research Program

5.1 Alternative Gravity Theories

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Einstein's theory of relativity unifies a 3-dimensional space and a 1-dimensional time as a spacetime and describes gravity as a fabric of curved spacetime. This picture has been very successful in explaining and predicting many gravitational phenomena. Experimentally, however, we do not know how gravity behaves at distances shorter than 0.01 mm. At shorter distances, gravity may behave completely differently from what we expect. For example there may be hidden dimensions at short distances. In fact, many theories, including superstring theories and M-theory, require the existence of such extra dimensions. Extra dimensions may exist everywhere in our universe, but they are somehow hidden from us. One possibility recently investigated very actively is called the brane-world scenario. In this scenario our universe is supposed to be a 3-dimensional surface, called brane, floating in higher-dimensional space. Although we cannot see extra-dimensions directly, we may hope to detect some indirect evidence of extra-dimensions in high-energy experiments or cosmological observations.

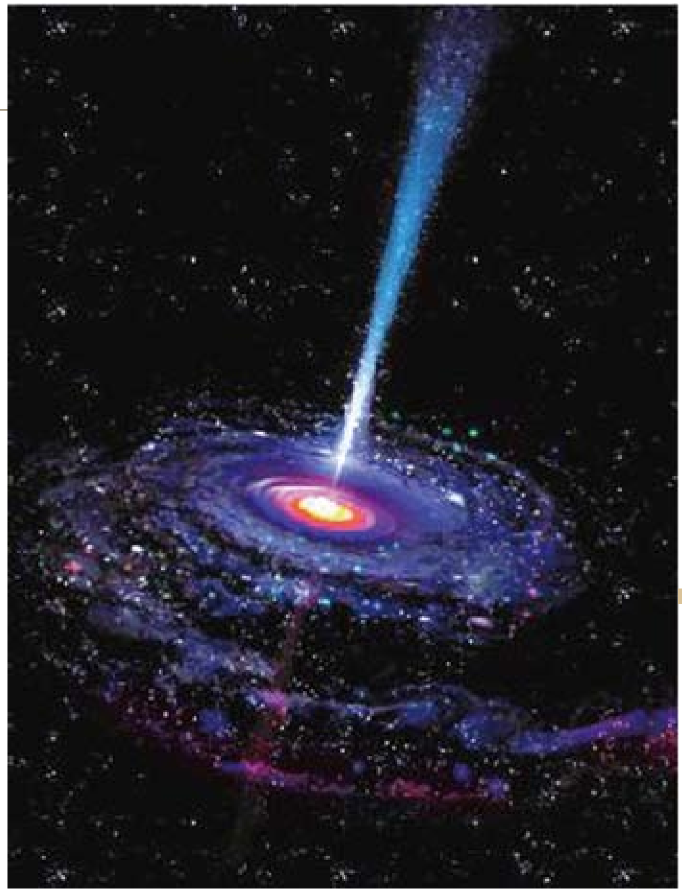
$$K_{ij} = -\mathcal{G}_{ijkl}\frac{1}{\sqrt{g}}\frac{\delta S_{\rm cl}}{\delta g_{kl}} + \eta^{\alpha\beta}E_{\alpha\beta}{}^{ij}$$

$$\mathcal{G}^{ijkl} = \frac{1}{2}\left(g^{ik}g^{jl} + g^{il}g^{jk}\right) - \lambda\, g^{ij}g^{kl}$$

Gravity at very long distances (for example, billions of light-years) may also be as weird as at short distances. Precision observational data recently revealed that the expansion of our universe is accelerating. If Einstein's theory is correct, this requires that more than 70% of our universe is filled with invisible, negative pressure, energy. This energy is named dark energy, but we do not know what it really is. This situation reminds us of a story in the 19th century: when the perihelion shift of Mercury was discovered, some people hypothesized the existence of an invisible planet called Vulcan, a so-to-speak dark planet, to explain the anomalous behavior of Mercury. However, as we all know, the dark planet was not real and the correct explanation was to change gravity, from Newton's theory to Einstein's. With this in mind, we wonder if we can change Einstein's theory at long distances to address the mystery of dark energy.

5.2 Astroparticle Physics

Patrick Decowski
Emir Gumrukcuoglu
Brian Feldstein
Andrea Ferrara
Karsten Heeger
Junji Hisano
Ayuki Kamada
Masahiro Kawasaki
John Kehayias
Alexander Kozlov
Alexander Kusenko
Keiichi Maeda
Sourav Mandal
Kai Martens
Shigeki Matsumoto
Shinji Mukohyama
Yasunori Nomura
Christian Otto
Henry Sobel
Charles Steinhardt
James Stone
Yoichiro Suzuki
Masahiro Takada
Mark Vagins
Tsutomu Yanagida



Artist's conception of a supermassive black hole in the center of an active galaxy
Credits: NASA

High-energy phenomena naturally occurring in the universe provide a wealth of data and new valuable insights into particle physics and cosmology. IPMU researchers use the universe as a laboratory for testing new theories of dark matter and new physics beyond the Standard Model, and for understanding the basic properties of the universe. In the past year, several exciting developments in particle astrophysics were initiated by IPMU members.

Dark Matter

Its existence is supported by a substantial body of astrophysical evidence, but the identity of the dark matter particle (or particles) remains a mystery. Since one does not know the interactions of dark matter particles, besides their gravitational interactions, one must pursue a broad range of possibilities.

One necessary condition is that the dark matter particles must be stable on cosmological time scales. Stability is often associated with asymmetry. So, one may approach the question of dark matter identity by asking what symmetries might guarantee the stability of dark matter. A very powerful symmetry is the conservation of $(B-L)$, the difference between the baryon and lepton numbers. Ibe, Matsumoto, and Yanagida have pointed out that, if dark matter takes advantage of this formidable symmetry, then the dark matter particle must have a well defined mass, independent of the details of new physics. The researchers provided two very appealing examples, one of which can explain an unusual signal recently reported by one of the experiments.

Matsumoto and collaborators explored another possible connection between a symmetry and dark matter. Weakly interacting massive particle (WIMP) is one of the most popular dark-matter candidates, which emerges in many models of new physics at the TeV scale. Matsumoto and collaborators have pointed out that, if the WIMP is a vector particle associated with some gauge symmetry broken at the TeV scale, then the Higgs mass is often predicted to be 120–125 GeV range, consistent with Large Hadron Collider results.

Another well-motivated dark matter candidate is a very light scalar particle, called axion. Kawasaki and collaborators have described the production of these particles from the collapse of domain walls, which could have formed in the early universe because of topological properties of the underlying field theory. This production channel can generate a substantial quantity of relic axions, which has implications for axion properties and for understanding of dark matter.

An aesthetically appealing possibility is that both dark matter and ordinary matter might have emerged from the same process in the early universe. It is remarkable that the amounts of these two components are not very different: they are within one order of magnitude of each other, which would have to be regarded as fortuitous if they arise from unrelated processes. Kawasaki and collaborators have proposed a scenario in which axino dark matter arises from decays of supersymmetric Q-balls. In a separate paper, Kasuya and Kawasaki studied gravitino dark matter produced in Q-ball decays.

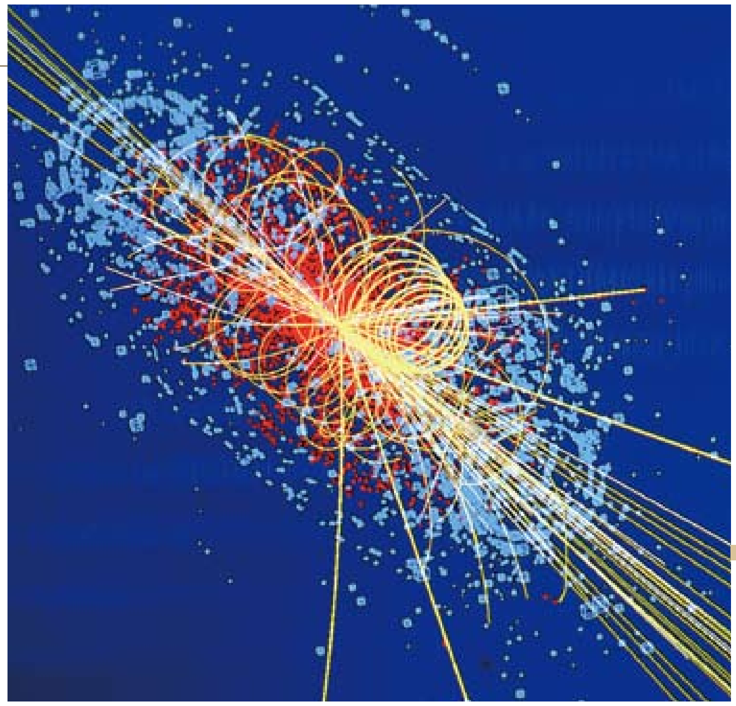
Dark matter may also be related to neutrinos. Neutrino masses are most elegantly explained by the famous seesaw mechanism, which employs right-handed counterparts of the usual left-handed neutrinos. If one of the right-handed neutrinos has a small Majorana mass, which is natural in the split seesaw and in some other models, then the resulting low-mass sterile neutrino can play the role of dark matter. Kusenko and Loewenstein have continued the search for dark matter in the form of sterile neutrinos using dedicated observations on X-ray telescopes. They have published new limits based on observations of dwarf spheroidal galaxies.

Supermassive Black Holes Then and Now

Supermassive black holes exist in the centers of galaxies, including Milky Way, but there is no compelling theory of their formation. Evolution of massive stars can produce black holes with masses of the order of a few solar masses, but the origin of million-solar-mass black holes remains a mystery. Furthermore, observations of quasars imply that such objects have already existed at some very high red shifts, suggesting the possibility of their primordial origin. Observational evidence points to a population of black holes with a narrow mass distribution around 10^5solar masses at early times, from which the observed distribution of masses could emerge via mergers and accretion. Kawasaki, Kusenko, and Yanagida have described a plausible scenario for the primordial origin of supermassive black holes. Cosmological inflation occurs when the energy density is dominated by a scalar field, slowly moving in a relatively flat potential. Theories beyond the standard model predict a plethora of such scalar fields, and the inflaton can follow a non-trivial path in the labyrinth of flat directions. Therefore, a two-stage or multi-stage inflation can be a generic feature of supersymmetry and string theory. When the inflaton switches between these directions, the spectrum of density perturbations can acquire a feature that can give rise to primordial black holes. The latest event of this kind could have produced a narrow spectrum of black holes with the requisite characteristic mass of 10^5 solar masses, thus explaining the origin of supermassive black holes.

The largest supermassive black holes, with masses of hundred million solar masses and beyond, are the most powerful sources of radiation in the universe. These giant black holes absorb gas and stellar matter in the centers of active galaxies, spewing very high energy gamma rays and cosmic rays, which are accelerated in their powerful jets. TeV gamma rays cannot travel large distances because they lose energy in interactions with starlight and infrared light re-emitted by dust. Yet, some very energetic gamma rays have been observed from some very distant objects. This created a puzzle. Lorentz invariance violation, as well as the existence of axion-like particles mixed with the photon, have been considered as possible explanations. However, Kusenko and collaborators showed that the observed spectra, as well as their relatively mild dependence on the red shift, can be explained by the secondary gamma-rays, which did not originate at the source, but were produced in the cosmic ray interactions along the line of sight. This interpretation paves the way for measuring magnetic fields deep in the voids between galaxies, where the primordial seed fields may have existed from the time of Big Bang. Furthermore, one can measure correctly the extragalactic background light, which reveals the history of star formation in the universe.

5.3 Collider Phenomenology



Biplob Bhattacherjee
Brian Feldstein
Minxing Huang
Masahiro Ibe
John Kehayias
Alexander Kusenko
Sourav Mandal
Shigeki Matsumoto
Mihoko Nojiri
Serguey Petcov
Matthew Sudano
Kohsaku Tobioka

Collider phenomenology is now one of the most important research programs in particle physics because the CERN Large Hadron Collider (LHC) experiment has been running since autumn 2009. In fact, the LHC experiment has been providing many precious data on the studies of the standard model (SM) and physics beyond the SM, and those are being used to test various models of particle physics. The members of IPMU collider phenomenology group have therefore great opportunities in exploring these physics, and pursue a broad range of research.

The LHC experiment enables us to systematically investigate the electroweak symmetry breaking, to study quantum chromodynamics (QCD), and to probe new physics beyond the SM. Among several researches of collider phenomenology, the most of the members in the group are studying physics beyond the SM such as

- Low energy supersymmetry,
- Composite Higgs (Little Higgs, etc.),
- Extra-dimensions at low energy-scale,
- Other unexpected exotics.

The LHC experiment is currently suggesting the existence of the higgs boson at about 125GeV, while no new physics signals are discovered yet. These results are (and will be) used to have a deep understanding of physics beyond the SM at the TeV energy-scale.

It is also worth emphasizing that the study of the collider phenomenology at the IPMU has several advantages, because the study is directly and indirectly influenced by other research programs. Connections between the study of collider phenomenology and those of model buildings of particle physics, dark matter searches, and cosmology are particularly of importance. As already mentioned in this report of other research-programs, IPMU has many active researchers working on these topics. It is thus possible for the members of the group to efficiently perform their studies.

In addition to collider phenomenology at the LHC experiment, some of the members are also studying those at other collider experiments which are planned in near future. They are especially interested in the studies of physics beyond the SM at High Luminosity-LHC (HL-LHC) experiment and future linear collider experiments such as the International Linear Collider (ILC) and Compact Linear Collider (CLIC).

5.4 Cosmology and Statistics

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Tsz Yan Lam
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Atsushi Nishizawa
Yasunori Nomura
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Masato Shirasaki
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Edwin Turner
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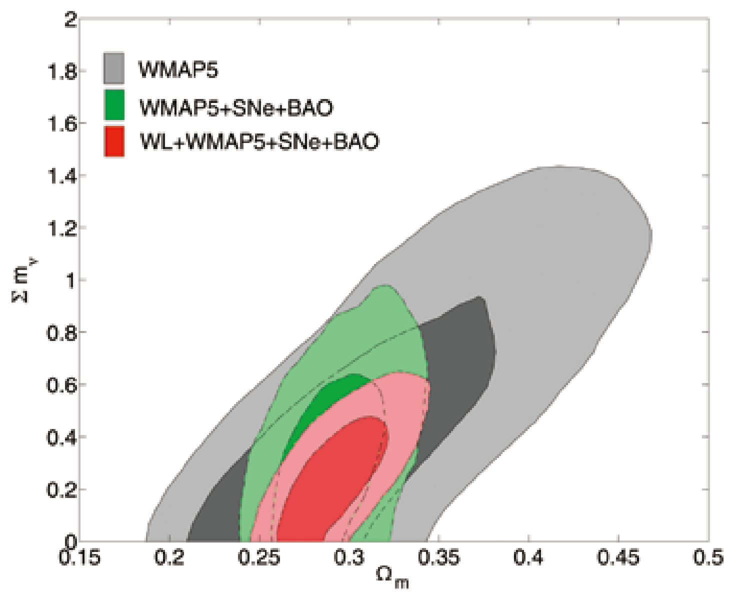
Naoki Yoshida

The size of data set in cosmological observations is huge. For example, the Sloan Digital Sky Survey-III (SDSS-III) creates a color image of more than a trillion pixels. That is so big and detailed that one would need 500,000 high-definition TVs to view it at its full resolution. This trend will continue at even faster rates as larger telescopes become available in near future. For handling these massive data set and extracting maximum amount of information, we must keep developing more and more sophisticated statistical methods. Relevant issues that are actively pursued are selecting models, methods of estimating parameters, Bayes' theorem and other statistical techniques.



In the study of gravitational lensing which is actively carried out at IPMU, as an example, we try to extract tiny distortion of the observed image of a galaxy from its true shape. We do so by modeling the galaxy shape in a mathematically rigorous manner and convolving the sampling effects and noise in the observation. This type of data analysis requires close collaboration between cosmologists and statisticians.

5.5 Dark Matter Experiment

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Alexander Kozlov
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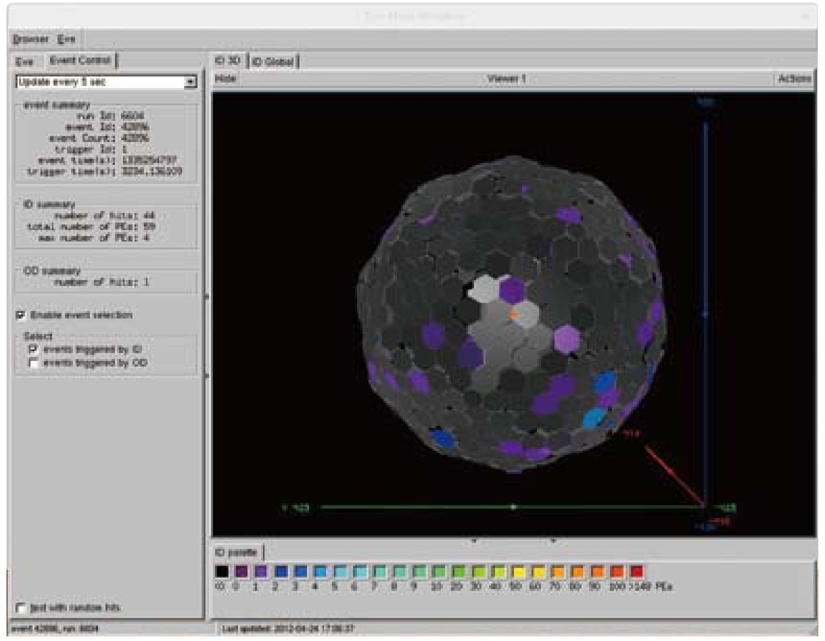
Masayuki Nakahata
Anreas Piepke
Yoichiro Suzuki
Yasuo Takeuchi

A 23% of all there is in the Universe is what we call Dark Matter. Dark because unlike normal matter (4% of all there is) it does not interact with light. So we cannot see it with our telescopes, although we can clearly see its imprint on the distribution and movement of the visible stars and galaxies through gravitational forces among them. But while in this way we can even map its distribution throughout the accessible history of our universe, we have no clear hints yet as to its true nature.



One possibility is that Dark Matter takes part in the weak interaction of particle physics. As this particular possibility is very attractive also from the point of view of particle theory, it has given rise to a variety of dedicated experiments around the world. WIMP has become the shorthand for this type of Dark Matter: Weakly Interacting Massive Particle.

IPMU is involved in this effort through the XMASS experiment at its Kamioka branch. In the XMASS detector one metric ton of xenon is kept as a liquid at -100 Celsius. The dense liquid provides both a large target mass at its center as well as shielding against radioactive backgrounds. Fast neutrons from the surrounding rock are moderated and remaining muons tagged in an 800 ton active water shield in which the detector is immersed.

Since the detector was first filled in late 2010 operational parameters were optimized in various commissioning runs. With this program concluding and a new Flash-ADC based data taking system being commissioned in spring 2012 the experiment is expected to start taking high quality physics data in 2012. Soon thereafter we expect to become the world's most sensitive detector for WIMPs. With data from our commissioning phase we may already being commissioned in spring 2012, the experiment starts taking high quality physics data in 2012.

5.6 Detector Developments

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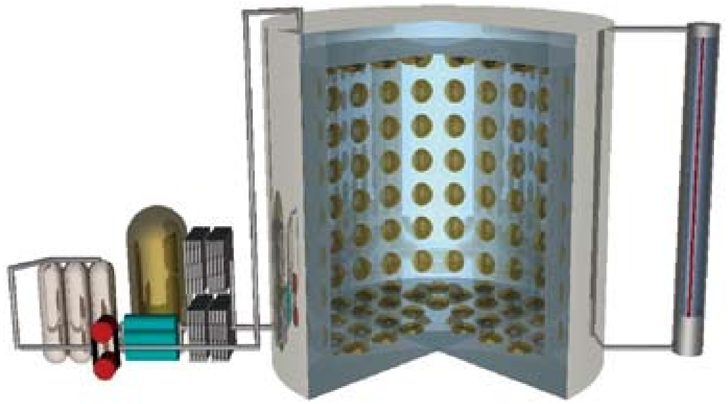
Karsten Heeger
Glenn Horton-Smith
Ken-iti Izawa
Jing Liu
Alexander Kozlov
Kai Martens
Andreas Piepke
Ryutaro Takahashi
Yasuo Takeuchi
Mark Vagins

Experimental physics and observational astronomy rely on cutting-edge technologies to build detectors that push the frontier of knowledge with the data they deliver. Data is the life blood of science, as the scientific method demands that every insight be tested against the hard evidence of experimental data. The art of experimentation is to provide both reliable and pertinent data to test the theories that the disciplined use of knowledge and imagination conjure from the massive body of scientific data already accumulated.

Active detector development provides the means to extend the reach of current and future experiments, and very possibly new technology that may well find its way back into your living room or workshop. It is a vital ingredient in ourquest to understand the Universe. The projects below are as diverse as the problems encountered and the individuals working on them.



EGADS Project (Evaluating Gadolinium's Action on Detector Systems), which is now under construction in the Kamioka mine, will be used to establish the viability of gadolinium enhanced water Cherenkov detector for detecting supernova relic neutrinos.

5.7 Inflation and Early Universe

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Emir Gumrukcuoglu
Masahiro Ibe
Masahiro Kawasaki
John Kehayias
Alexander Kusenko
Chunshan Lin
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Yasunori Nomura
Charles Steinhardt
Masahiro Takada
Taizan Watari
Tsutomu Yanagida
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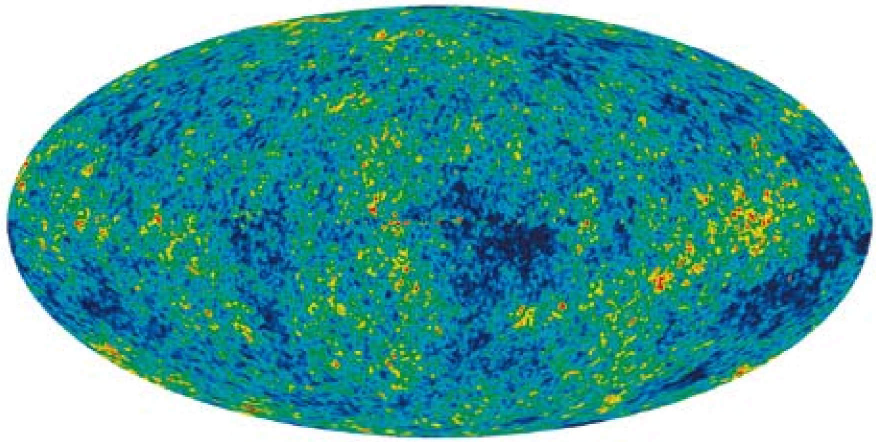
The Universe is expanding; the further away a galaxy is, the faster it is moving, which is known as the Hubble's law. This observational fact implies that, if we go back in time, the Universe was small, dense and extremely hot. The evolution of the early universe is described by the Friedmann-Lemaitre-Robertson-Walker (FLRW) universe, a homogeneous and isotropic solution of the Einstein equations of the general relativity, and the standard big bang theory is based on the FLRW universe. The Hubble's law, the big bang nucleosynthesis (BBN), the comic microwave background (CMB) radiation provide key support or the standard big bang theory. Those three observations still remain important probes of the early Universe.

Despite its great success the big bang theory is plagued with serious theoretical issues such as the horizon problem, the flatness problem, and the monopole problem. Those problems are beautifully solved by the introducing an inflationary expansion at the very early stage of the Universe. What is more important about inflation is that quantum fluctuations of a scalar field driving the inflation (called an inflaton) generate tiny density perturbations, which can account for the seed of the structures such as galaxies and clusters of the galaxies seen in the current Universe. The properties of the density perturbations depend on the inflation models, which can be probed by studying tiny inhomogeneities in the CMB temperature anisotropy.



Credit: NASA/WMAP Science Team

The recent progress in observational techniques has enabled us to study the evolution of the early universe with unprecedented precision, and our understanding of the Universe has significantly increased. Nevertheless it is not fully known how the inflation occurred, how the universe was reheated after inflation, how the dark matter as well as the baryon asymmetry were created, whether there is large non-Gaussianity in the density perturbations or not, and so on. We would like to tackle those questions in order to reveal how the universe evolved from the inflationary epoch into what it looks like at present.

Research Program

5.8 Mathematics

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Alexey Bondal
Scott Carnahan
Richard Eager
Sergey Galkin
Kentaro Hori
Alexander Getmanenko
Yasuyuki Kawahigashi
Toshiyuki Kobayashi
Toshitake Kohno
Satoshi Kondo
Siu Cheong Lau
Changzheng Li
Todor Milanov
Hirosi Ooguri
Kyoji Saito
Christian Schnell
Yuji Tachikawa
Akihiro Tsuchiya
Yukinobu Toda
Valentin Tonita
Kouta Usui
Misha Verbitsky
Marcus Werner
Simon Wood

One can say that the history of mathematics is more or less equivalent to the history of mankind attacking problems in reason or knowledge. Mathematics abstracts the truth behind generalities. It began as a useful tool in everyday physics in the sense that we count numbers, we measure length and volume. Then as seen in Euclidean geometry of Euclid or in the problem of determining the existence or non-existence of roots in algebraic equations, the practical side became lost and mathematics becomes pure pursuit of knowledge of human kind. Diophantine equations, Fermat's lifework, do not affect our life at all whether they had integral solutions or not.

In the 17th century, Newton found differential and integral calculus, giving a language and method to describe the law of dynamics in nature, so then mathematics encountered physics. This is a good example of mathematics providing the scientific community, and sometimes society in general, with a common language and method to describe phenomena in their study. This in turn helps to establish mathematician's original concepts. Particularly in recent years the interaction between mathematics and physics has been in full flow.

This interaction is more important than ever, and mathematics of the 20th century developed through an enormous influence from physics. Gauge theory, quantum field theory, general relativity, and superstring theory in physics have provided major impetus in the field of mathematics such as algebraic geometry, differential geometry, topology, representation theory, algebraic analysis and number theory.

Although the influence is great, mathematicians have been and will be working on those problems in mathematics which arose and to be solved purely within mathematics. A prominent recent example is the resolution of Fermat's last theorem. Notably, there exist examples where those tools developed purely mathematically have interesting applications in physics.

IPMU is a very exceptional research environment for mathematicians, in that there always are physicists nearby. The mathematicians at IPMU are to develop both physics and mathematics through much discussions with the physicists. However, the emphasis is on that the true interest of mathematics is in mathematics, so the researchers undertake their research with their top priority in the field of mathematics.

Geometry:
Geometry is a collection of branches of mathematics, which studies mathematically defined geometric objects. For instance, geometric objects include topological spaces, differentiable manifolds, Riemannian manifolds, symplectic manifolds, complex manifolds and algebraic varieties. These are not only geometric figures but also have important mathematical structures, which make the theories behind them very rich. Also the geometry plays an important role in describing our universe, and has contributed much to physics. For instance, Riemannian geometry is necessary in developing Einstein's theory of general relativity. On the other hand, by the influence of string theory, it has been found recently that there are deep connections among these geometric theories. The most significant example is the mirror symmetry, which predicts a duality between symplectic manifolds and algebraic varieties. These have been developed as different mathematical fields, but are now expected to be equivalent by the duality between the two different types of string theories. The mirror symmetry is one of the themes of the study of geometry at IPMU.

In the theory of mirror symmetry, a Calabi-Yau 3-fold plays an important role. It is an algebraic manifold of complex dimension three (real dimension six), with a Ricci flat metric. In string theory, our universe is considered to be 10 dimensional, and a Calabi-Yau 3-fold appears as an extra six dimensional space. The mirror symmetry predicts an equivalence between period integrals on a Calabi-Yau 3-fold and a curve counting theory (Gromov-Witten theory) on its mirror manifold. In IPMU, there are specialists in each side, and the mirror symmetry is studied vigorously. K. Saito has studied the theory of periods for a long time, and found the notion of Frobenius structures on the deformation spaces of the singularities. This Frobenius structure is now an essential tool in describing the mirror symmetry. T. Milanov is an expert in Gromov-Witten theory, and studies the Frobenius structures determined by Gromov-Witten invariants.

Another way to describe the mirror symmetry is to use the homological algebra. This was proposed by Kontsevich in 1994, and it is formulated as an equivalence between the derived category of coherent sheaves on a Calabi-Yau 3-fold and the derived Fukaya category on its mirror manifold. A. Bondal is a leading expert in derived categories of coherent sheaves, and invented the notions of exceptional collections, enhancement of the derived category. These notions are now essential in the study of derived categories. Y. Toda studies stability conditions on derived categories, and Donaldson-Thomas type invariants counting stable objects in the derived categories. This corresponds to "BPS state counting" in string theory, and an interesting research subject also in string theory.

The study of the geometry in IPMU does not restrict to the mirror symmetry, and the geometry is studied from various viewpoint. T. Kobayashi studies the action of discrete groups on non-Riemannian homogeneous spaces, and develops an original theory from a new geometric viewpoint. He discovered that local rigidity may fail even in higher dimensions for indefinite-Riemannian symmetric spaces, and is challenging to develop spectral theory in connection with their deformation theory. Also T. Kohno studies quantum invariants on low dimensional manifolds, which are related to integrable systems and the conformal field theory. He revealed a quantum group symmetry for homological representations of braid groups and described the image of quantum representations of mapping class groups. In this way, there are various studies of the geometry at IPMU, and we aim to have a further breakthrough by combining these studies.

Algebra:
Algebra was originally the field of mathematics that studied numbers and equations. In fact, in the Middle Ages, a central problem in algebra was solving algebraic equations of higher degrees. In the 19th century, Évariste Galois discovered a symmetry hidden in such equations, which led to the invention of the notion of a group. After this discovery, the focus of the field of algebra shifted to understanding deep hidden structures.

Homological algebra is one such example. Homological algebra stems from geometry and was originally a way to count the number of holes of, say, doughnuts. Once geometric notions are abstracted to homological algebra, many new invariants which do not necessarily have an obvious geometric interpretation appear naturally. Derived categories are one such example. Derived categories were originally invented as a tool for efficiently computing (co) homologies, but today they are considered interesting in their own right. Mathematicians at the IPMU are pursuing a number of interests in the field of derived categories. For example, one question of interest is how much information on a given variety the derived category of coherent sheaves over that variety possesses. This question is currently—with the relation to mirror symmetry in mind being actively studied by A. Bondal and Y. Toda, as was written in Geometry section above. We are also trying to construct additional frameworks, such as differential graded algebra for example, to encode more information on a variety by enhancing the structures on its derived category or its abstraction, the triangulated category.

Another field of interest is groups or group actions. Groups were originally a language for describing symmetries behind solutions of equations, but nowadays, they are an indispensable tool not only in mathematics but also in many areas of physics such as crystallography or gauge theory. Often, groups are studied through their representation theory. K. Saito considers sets of vanishing cycles coming from geometry as a generalization of root systems, and applies the corresponding theory of infinite dimensional Lie algebras and its representations to geometry. In T. Kobayashi's new theory of global analysis for minimal representation and visible action on complex varieties, which are his recent themes, group appear as "leit motiv", and the theory is expanded in a way special cases are connected to infinite dimensional representation theory. A. Tsuchiya studies the algebraic structures of logarithmic conformal field theory such as the representation theory of the chiral algebra and conformal blocks. T. Kohno studies monodromy representations of braid groups appearing in conformal field theory from the point of view of hypergeometric integrals.

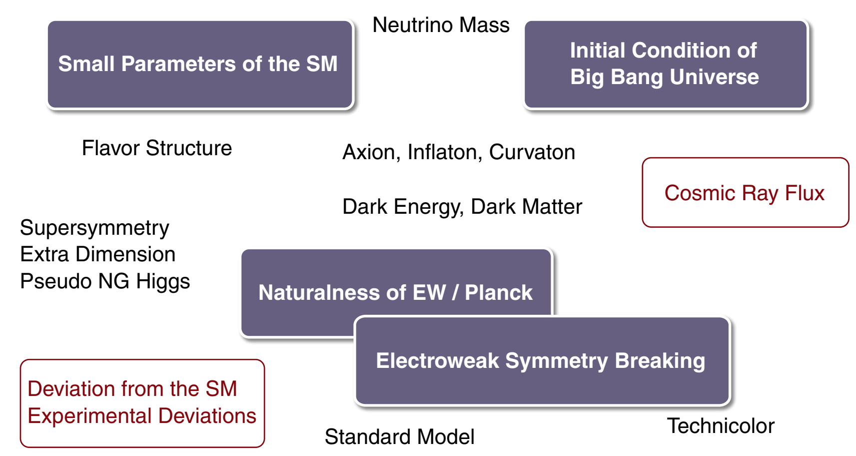
Some researchers at the IPMU also study equations, one of the original goals of algebra. One of the ultimate goals of modern arithmetic is a framework called the Langlands program, which predicts that two seemingly completely different looking sets of representations coming from arithmetic coincide in a natural sense. This vast conjecture includes even Fermat's last theorem as a very small part. It is therefore not surprising that this program is thought to be very difficult to realize, however a number of simpler variants exist. S. Kondo and T. Abe are working on the local Langlands program and the Langlands program for function fields for example. Yet another variant of the Langlands program, for which a connection to S-duality in physics has been observed, is the geometric Langlands program. The Langlands program and its variants have therefore become very active and important modern topics of research.

As one can see, we study many branches of algebra here at the IPMU. Algebra may not necessarily directly deal with understanding the universe and moreover most of the algebraists at the IPMU are interested in mathematics in and of itself, not in its application to other fields. However, when the efforts of practitioners of different disciplines align, the benefit to all fields involved is huge. Our daily efforts in understanding the structures ubiquitous to mathematics feed directly into efforts directed at understanding the most fundamental phenomena of nature. We therefore await the next great breakthrough rivaling Galois' discovery of groups.

5.9 Models beyond the Standard Model

Biplob Bhattacherjee	Ayuki Kamada	Serguey Petcov
Brian Feldstein	John Kehayias	Charles Steinhardt
Emir Gumrukcuoglu	Alexander Kusenko	Matthew Sudano
Junji Hisano	Sourav Mandal	Kohsaku Tobioka
Masahiro Ibe	Shigeki Matsumoto	Taizan Watari
Koji Ichikawa	Shinji Mukohyama	Yin Wen
Ken-iti Izawa	Yasunori Nomura	Tsutomu Yanagida

Up to now, we have seen that a quantum field theory with quarks, leptons and vector bosons for three different forces describes reasonably well all the experimental data available so far. Among the vector bosons, however, those corresponding to the weak force (which is responsible for the β-decay of nucleons) are known to have masses. There are three such vector bosons, and they are called W^+, W^- and Z bosons, or weak bosons, as a whole. From the consistency of quantum field theories, it is known that something must be behind the nonzero masses of these vector bosons. It has not been confirmed experimentally yet how these masses are generated.



What is called the Standard Model provides a simple theoretical idea how the weak bosons acquire masses. According to the Standard Model, the masses originate from condensation of quanta of a new scalar boson, called Higgs boson. The Higgs boson is the last missing piece of the Standard Model, and will be discovered in experiments in near future, if the weak bosons have masses through the mechanism predicted by the Standard Model. Is that the end of the story? Maybe ..., but maybe not. Let us think about the following questions.

- The Higgs boson is the only scalar field in the Standard Model; all other dynamical degrees of freedom in the Standard Model are either fermions or vector fields. Why does the Standard Model have one scalar field, and just one? Why does its condensation develop?

- The Newton constant $G_N \simeq 6.7\times10^{-11}\mathrm{m^3kg/s^2}$ corresponds to an energy scale $1/\sqrt{G_N\hbar/c^3} \sim 10^{19}$ GeV. Why is there a huge hierarchy of order 10^{17} between this energy scale and the weak boson masses of order 10^2 GeV, and how can the weak boson masses remain so small under quantum corrections?

In order to solve these questions theoretically, various models beyond the Standard Model have been constructed so far, and we still continue to do so in quest of a better solution to these problems. Once we have concrete models, we can examine whether such models are really consistent with all the available experimental data, predict what kind of signals can be expected in future experiments, and even propose experiments to confirm such models.

The origin of the masses of the weak bosons is not the only puzzle of the Standard Model. It is known that huge fraction of the universe consists of dark matter and dark energy. It is very unlikely that dark matter is actually the ordinary matter particles in the Standard Model. This is where we find another motivation to extend the Standard Model. Our universe may have become so large because of an inflationary process in the early universe, and quantum fluctuations of a scalar field may become the fluctuations of density in the early universe, which eventually become galaxies and clusters of galaxies. So, here is another motivation to introduce a new degree of freedom and extend the Standard Model. Such cosmological issues as inflation, primordial density perturbations and dark matter motivate extensions of the Standard Model, and models in quantum field theories are *the* appropriate framework in order to work on these issues.

Recent reports of excess in high-energy cosmic ray fluxes, deviation from the Standard-Model prediction of the anomalous magnetic moment of muon, and some other reports of deviations from the Standard Model predictions may also be indications of some physics beyond the Standard Model. We therefore seek for theoretical models that account for these phenomena.

We also address the following problems. The Standard Model is described by a quantum field theory with about 30 parameters, and the values of these parameters can be determined only by measuring them experimentally. Would it be possible to determine them theoretically, by considering theoretical frameworks that contain the Standard Model?

The thermal history of early universe is described very well by the Standard Model at least back to the era with the temperature of order MeV, but it is only with several input parameter values of initial condition of the universe. Those initial condition parameters include baryon asymmetry, normalization of density contrast and the amount of dark energy. How are these initial condition parameters set? Once again, it is impossible to think about such problems without a model that extends the Standard Model.

For non-experts

After k_B, c and $\hbar$ are set to unity, [length] = [energy]$^{-1}$ is the only dimension left in physics. The fundamental law of physics in nature has been probed down to the length scale of order 10^{-3} fm = 10^{-8} $\AA$, which is equivalent to the energy scale of order 10^2 GeV = 10^{11} eV. Nothing is known for sure yet, however, what is happening at even shorter distance scales.

5.10 Neutrino Physics

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Sanshiro Enomoto
Brian Feldstein
Karsten Heeger
Junji Hisano
Glenn Horton-Smith
Takaaki Kajita
Alexander Kozlov
Alexander Kusenko
Jing Liu
Sourav Mandal
Kai Martens
Shinji Mukohyama
Masayuki Nakahata
Tsuyoshi Nakaya
Christian Otto
Serguey Petcov
Anreas Piepke
Kate Scholberg
Henry Sobel
James Stone
Masahiro Takada
Yasuo Takeuchi
Mark Vagins
Christopher Walter
Tsutomu Yanagida

What are the building blocks of nature? Most people have heard of electrons, which are indeed (as far as we can tell) fundamental particles, as well as protons and neutrons, which are themselves composite objects composed of much smaller fundamental particles called quarks. But there are much more unusual fundamental particles, too, and perhaps the most mysterious of these are the neutrinos.

The Standard Model of particle physics contains three generations of fundamental particles. In each of these generations, or families, there are two quarks and two much less massive particles called leptons. In the first family one such lepton is the electron, which carries an electric charge, and the other first-generation lepton is called the electron neutrino, which is electrically neutral. The second generation contains two more types of quarks, a charged lepton called the muon, and the muon neutrino, while the third family contains a final pair of quarks, a charged lepton called the tau, and a tau neutrino.

The three types of neutrinos, the electron neutrino, the muon neutrino, and the tau neutrino, are exceedingly challenging to study, because they hardly interact with matter at all. That means neutrino detectors need to be very big, very sensitive, or both. At IPMU we have teams of researchers working on some of the best and most famous neutrino detectors in the world.

The Super-Kamiokande [Super-K] detector is a 50,000 ton tank of water buried deep under the Japanese Alps. By studying neutrinos generated by cosmic ray interactions in the Earth's atmosphere, in 1998 Super-K made the stunning discovery that different types of neutrinos can spontaneously transform from one type to another, a process known as neutrino oscillation. This also implied that at least two of the three neutrinos have a small, but non-zero mass, something not predicted by the Standard Model. This was the first time since its inception that the Standard Model needed to be revised based on solid experimental data. In 2001 Super-K made a crucial contribution to the solution of the solar neutrino problem by indicating that solar neutrinos produced by the Boron-8 reaction in the Sun could change their flavor while in flight, and uniquely selected the large mixing angle solution to the problem. IPMU members are now working on GADZOOKS!, an initiative to enrich the ultrapure water inside Super-Kamiokande with the element gadolinium. This will greatly reduce backgrounds and, among many other physics benefits, should allow the first-ever detection of a constant stream of neutrinos from distant supernovas.

The KamLAND neutrino detector is located in the same ancient zinc mine as Super-Kamiokande, but instead of water it is filled with 1,000 tons of liquid scintillator. This makes it very sensitive, especially to low energy neutrinos from nuclear reactors and those generated by radioactive decays within the Earth itself. In 2002 KamLAND was the first experiment to observe disappearance of reactor neutrinos, which matched other experiments' solar neutrino data in spectacular fashion. After lowering the energy threshold at which their data could be analyzed, in 2005 KamLAND was the first experiment to detect geoneutrinos, ushering in an entirely new way to study the Earth's interior. Also in 2005, KamLAND saw evidence of spectral distortions in the reactor neutrino signal; clear proof of neutrino oscillations. IPMU members are currently working on modifying KamLAND to detect very low energy solar neutrinos produced by the Beryllium-7 reaction in the Sun, as well as transforming the KamLAND detector into a huge neutrinoless double beta decay experiment via the addition of Xenon-136 to the detector volume.

As we continue to understand the mysterious neutrinos, as well as the varied processes which produce them within the Earth, upon the Earth, above the Earth, within the Sun, and inside exploding stars, IPMU researchers are using these tiniest of particles to probe the most inaccessible places and farthest reaches of the universe itself.

5.11 Observational Cosmology

Kevin Bundy
Andrea Ferrar
Gaston Folatelli
Tsz Yan Lam
Alexie Leauthaud
Keiichi Maeda
Brice Menard
Sogo Mineo
Hironao Miyatake
Shinji Mukohyama
Kimihiko Nakajima
Takahiro Nishimichi
Atsushi Nishizawa
Ken'ichi Nomoto
Takaya Nozawa
Masamune Oguri
Masami Ouchi
Robert Quimby
Tomoki Saito
Masato Shirasaki
Malte Schramm
John Silverman
Charles Steinhardt
Hajime Sugai
Masahiro Takada
Masayuki Tanaka
Atsushi Taruya
Edwin Turner
Naoki Yoshida

Understanding the nature and origin of large-scale structure in the Universe is one of most compelling issues in observational cosmology. The currently most conventional scenario is given by the cold dark matter (CDM) dominated model, where gravitational instability mainly driven by spatial inhomogeneities of CDM distribution amplifies the seed density perturbations to form the present-day hierarchical structures. Therefore revealing distribution and amount of CDM is crucial to understanding the formation of large-scale structure. In addition the presence of dark energy drives the accelerating cosmic expansion, and therefore affects the growth of structure formation. The dark matter distribution and the nature of dark energy can be explored from massive galaxy surveys.

We have been actively working both on the measurements using currently available telescope facilities and on the planning of future instruments. The two powerful investigative tools are the gravitational lensing effect and the baryon acoustic oscillation.

Gravitational lensing effect:
The path of light ray emitted by a distant galaxy is bent by gravitational force of intervening large-scale structure during the propagation, causing the image to be distorted—the so-called weak lensing shear. Conversely, measuring the coherent shear signals between galaxy images allows us to reconstruct the distribution of invisible dark matter. Moreover, since the weak lensing shear deals with the light propagation on cosmological distance scales, the lensing strengths depend on the cosmic expansion history that is sensitive to the nature of dark energy. Thus weak lensing based observables offer a powerful way for studying the nature of invisible components, dark matter and dark energy. We are carrying out observational and theoretical studies of weak lensing phenomena using our own Subaru data sets as well as simulations of large-scale structure.

Baryon acoustic oscillation:
To measure properties of dark energy, one needs to measure the expansion history of the Universe precisely. Because light travels at a finite speed, one can measure the expansion rate of the past by looking far. Comparing the expansion rate at varying distances would reveal the expansion history. The expansion itself is relatively easy to measure. The light emitted by a distant galaxy is stretched by the expansion of space and becomes redder, which can be measured by any decent spectrograph.

To measure the expansion history, however, we also need to know how far back in time the light was emitted from the galaxy, or equivalently, how far away it is. Measuring precise distances in cosmological scales is very challenging. Clustering of baryonic matter at a certain characteristic scale that is imprinted by baryon acoustic oscillation (BAO), or propagation of acoustic waves, in the early universe serves as a "standard ruler" for cosmological observations. This technique requires to study millions of galaxies in a wide field of view, and map the spatial distribution of luminous galaxies to detect the characteristic scale.

Hyper Suprime Camera (HSC):
The HSC, currently under construction, is the project to replace the prime focus camera of Subaru Telescope (8.2 meter optical-infrared telescope at the summit of 4,200 m-Mauna Kea, Hawaii) with a new camera that has wider field-of-view than the current one by a factor of 10. Fully utilizing the unique capabilities of HSC, its survey speed and excellent image quality, we are planning and designing a massive galaxy survey that covers an area of a few thousand square degrees and reaches to the depth to probe the Universe up to red shifts of a few. In fact these data sets will provide us ideal data sets for exploring the nature of dark matter and dark energy via measurements of cosmological observables available from the data, weak lensing and galaxy clustering statistics. We, IPMU members, are actively involved in this HSC project, and working on the designing and planning of HSC galaxy survey and development of data analysis pipeline.

Sloan Digital Sky Survey III:
In January 2011, the SDSS-III collaboration released the largest digital color image of the sky ever made. The image has been put together over the last decade from millions of 2.8-megapixelimages taken at the 2.5-meter telescope at the Apache Point Observatory in New Mexico, thus creating a color image of more than a trillion pixels. This new SDSS-III data release, along with the previous SDSS-I and SDSS-II data releases that it builds upon, gives astronomers the most comprehensive view of the night sky ever made. SDSS data have already been used to discover nearly half a billion astronomical objects, including asteroids, stars, galaxies and distant quasars.

IPMU has been a part of the SDSS-III and involved in the study of these rich images. But our focus has been to conduct a new survey to a deeper universe with the improved spectrograph. This survey, the Baryon Oscillation Spectroscopic Survey (BOSS), maps the spatial distribution of luminous galaxies and quasars to detect the characteristic scale imprinted by baryon acoustic oscillations in the early universe. Using the acoustic scale as a standard ruler, we can infer the angular diameter distance to the galaxy red shift. The BOSS has started to take data in 2009 and will continue until 2014. Its goal is to precisely measure how Dark Energy has changed over the recent history of the Universe.

PrimeFocusSpectrograph (PFS):
The PFS project that mounts a next generation spectrograph on the Subaru telescope and is planned to start data taking later this decade was overwhelmingly endorsed at the Subaru Users meeting of January 2011. Using a wide angle view of Subaru telescope and the PFS, we can study several thousand galaxies at the same time and use the baryon acoustic oscillation technique.

In addition to BAO, there are a number of other measurements to constrain the properties of dark energy using this instrument. Furthermore, this type of spectrograph with a large field of view and a massive multi-object capability will be unique among the largest telescopes in the world, allowing for unprecedented studies of formation and evolution of galaxies, as well as the assembly history of our own Milky Way Galaxy.

The strength of this project comes from exploiting the data using HyperSuprimeCam (HSC), a 3-tonne digital camera with 900 million pixels, slated for the first light in 2012. The combination of imaging using HSC and spectroscopy using PFS on Subaru is dubbed SuMIRe, Subaru Measurement of Images and Red shifts. The SuMIRe project is expected to repeat and exceed the tremendous success of Sloan Digital Sky Survey (SDSS), but with a much deeper view of the Universe back to the era that formed early stars and supermassive blackholes.

5.12 Proton Decay

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Alexander Kozlov
Yasunori Nomura
Kate Scholberg
Henry Sobel
James Stone
Yoichiro Suzuki
Yasuo Takeuchi
Mark Vagins
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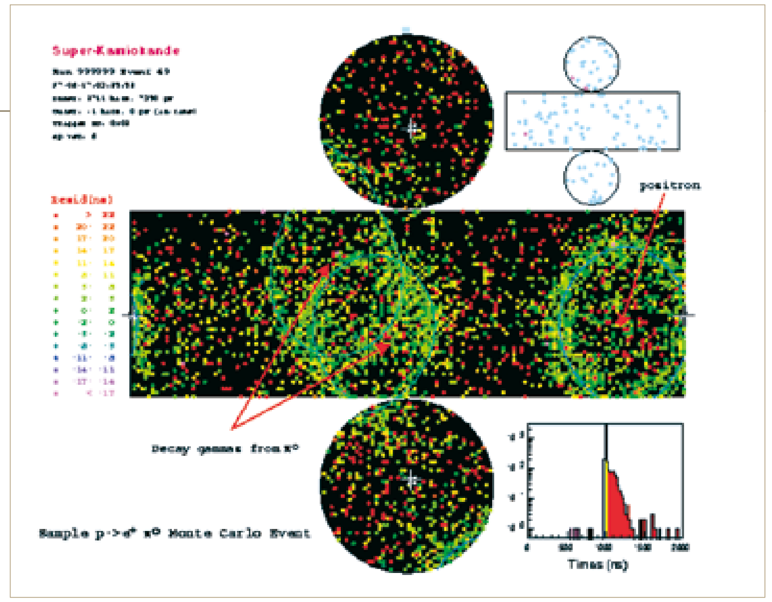


The stability of the proton represents one of the greatest theoretical and experimental challenges in particle physics today. In most grand unified theories, particularly those with a TeV intermediate mass scale, the proton "wants" to decay. Experimentally, however, the proton seems determined to outlive us all. Beginning with the first large-scale searches in the 1980's, one promising theory after another has floundered on the shoals of nucleon decay. To date, no hint of a nucleon decay signal has emerged.

In spite of this, the study of nucleon decay provides one of the few approaches to the problem of confronting grand unified theories with experimental data, and any progress toward this goal has unique value for the future development of physics. This program has already been a success. The simplest unification model, minimal SU(5), has been ruled out by the experimental results. Every subsequent grand unification theory will remain only a mathematical construct if further experimental information is not available.

The search for nucleon decay requires massive detectors. A search with a sensitivity of 10^{33} years, for example, requires a detector with approximately 10^{33} nucleons. Since there are 6×10^{29} nucleons per ton of material, this implies detectors of multi-kiloton scale.

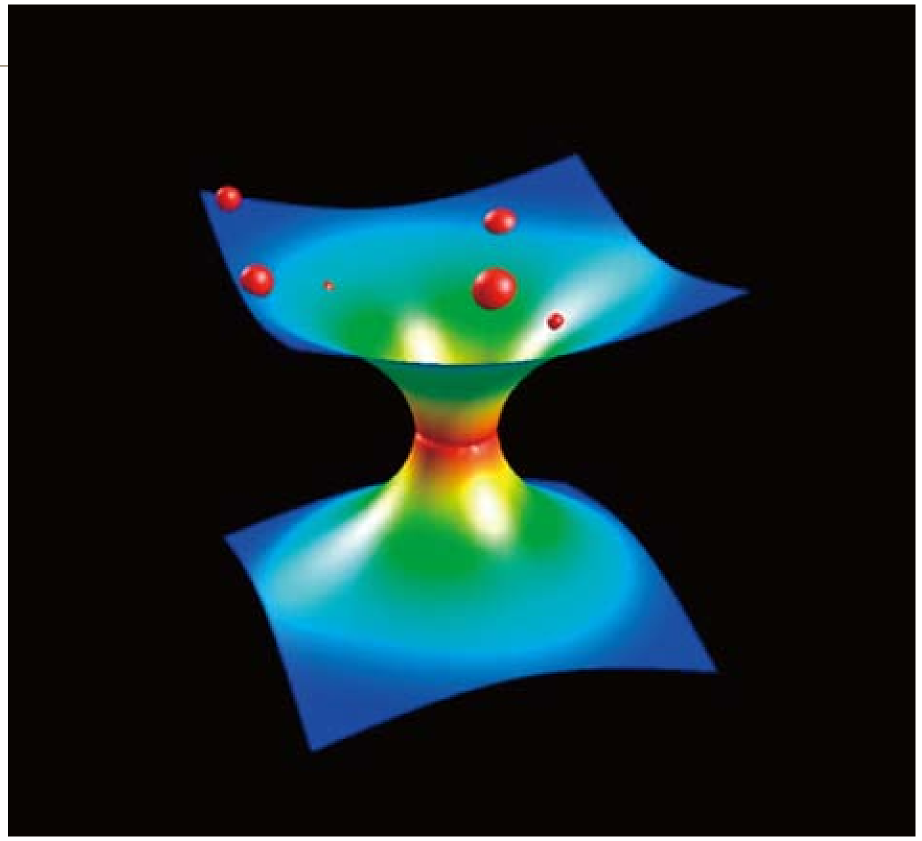
The "classical" proton decay mode, $p \to e^+\pi^0$, can be efficiently detected with low background. At present, the best limit on this mode ($\tau/\beta > 1.21 \times 10^{34}$ yr, 90% CL) comes from a 206 kton-yr exposure of Super-Kamiokande. The detection efficiency of 45% is dominated by final-state π^0 absorption or charge-exchange in the nucleus, and the expected background is 2 events/Mton-yr.

Supersymmetric theories favor the mode $p \to \nu K^+$, which is experimentally more difficult due to the unobservable neutrino. The present limit from Super-Kamiokande is the resultof combining several channels, the most sensitive of which is $K^+ \to \mu^+ \nu$ accompanied by a de-excitation signature from the remnant ^{15}N nucleus. Monte Carlo studies suggest that this mode should remain background free for the foreseeable future. The present combined limit is $\tau/\beta > 3.3 \times 10^{33}$ yr (90% CL).

Recent theoretical work suggests that if supersymmetric SO(10) provides the framework for grand-unification, the proton lifetime (into the favored νK^+ decay mode) must lie within about one order of magnitude of present limits. Similarly, SO(10) theories suggest τ/β (e π^0) $\approx 10^{35}$years—about a factor of ten beyond the present limit. Thus, continued progress in the search for nucleon decay inevitably requires larger detectors.

Moreover, the enormous mass and exposure required to improve significantly on existing limits (and the unknowable prospects for positive detection) underline the importance of any future experiment's ability to address other important physics questions while waiting for the proton to decay. Proton decay experiments have made fundamental contributions to neutrino physics and particle astrophysics in the past, and any future experiment must be prepared to do the same.

5.13 String Theory



Jyotirmoy Bhattacharya
Yu-Chieh Chung
Richard Eager
Mitsutoshi Fujita
Sergey Galkin
Simeon Hellerman
Kentaro Hori
Minxin Huang
John Kehayias
Johanna Knapp
Todor Milanov
Shinji Mukohyama
Hirosi Ooguri
Cornelius Schmidt-Colinet
Johannes Schmude
Matthew Sudano
Shigeki Sugimoto
Yuji Tachikawa
Tadashi Takayanagi
Taizan Watari

In the past few hundred years, scientists have searched for fundamental laws of nature by exploring phenomena at shorter and shorter distances. Does this progression continue indefinitely? Surprisingly, there are reasons to think that the hierarchical structure of nature will terminate at 10^{-35} meter, the so-called Planck length. Let us perform a thought-experiment to explain why this might be the case. Physicists build particle colliders to probe short distances. The more energy we use to collide particles, the shorter distances we can explore. This has been the case so far. One may then ask: can we build a collider with energy so high that it can probe distances shorter than the Planck length? The answer is no. When we collide particles with such high energy, a black hole will form and its event horizon will conceal the entire interaction area. Stated in another way, the measurement at this energy would perturb the geometry so much that the fabric of space and time would be torn apart. This would prevent physicists from ever seeing what is happening at distances shorter than the Planck length. This is a new kind of uncertainty principle. The Planck length is truly fundamental since it is the distance where the hierarchical structure of nature will terminate.

Space and time do not exist beyond the Planck scale, and they should emerge from a more fundamental structure. Superstring theory is a leading candidate for a mathematical framework to describe physics at the Planck scale since it contains all the ingredients necessary to unify general relativity and quantum mechanics and to deduce the Standard Model of particle physics. Superstring theory has helped us solve various mysteries of quantum gravity such as the information paradox of black holes posed by Stephen Hawking. The theory has given us insights into early universe cosmology and models beyond the Standard Model of particle physics. It provides powerful tools to study many difficult problems in theoretical physics—often involving strongly interacting systems—such as QCD (theory of quark interactions), quantum liquid and quantum phase transitions. It has also inspired many important developments in mathematics. All of these aspects of string theory are vigorously investigated at IPMU.

5.14 Structure Formation

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Andrea Ferrara
Ayuki Kamada
Tsz Yan Lam
Masami Ouchi
Tomoki Saito
Ikko Shimizu
Masato Shirasaki
Alexie Leauthaud
Brice Menard
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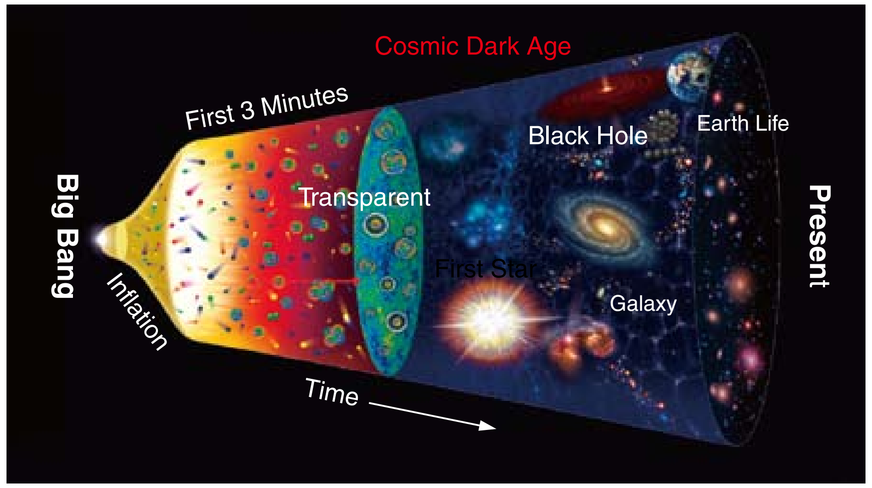
Yu Nakayama
Malte Schramm
John Silverman
Charles Steinhardt
Masahiro Takada
Masayuki Tanaka
Takahiro Nishimichi
Atsushi Nishizawa
Ken'ichi Nomoto
Masamune Oguri
Atsushi Taruya
Edwin Turner
Naoki Yoshida

There are rich structures in the present-day universe, such as stars, galaxies, and large-scale structure. We study how these objects are formed using large computer simulations and sophisticated theoretical models.

The standard Big Bang model posits that the universe was nearly homogeneous and very hot when it was born. Tiny "ripples" in the distribution of matter were generated through a rapid expansion phase called inflation in the very early universe. These primeval density fluctuations grew by the action of gravity, eventually forming luminous objects such as galaxies.



Adapted from "Physics of the history of the universe" by Yasuo Fukui *et al.*

The energy content of the universe and basic statistic that describe the condition of the early universe have been determined with great accuracy from recent observations of cosmic microwave background radiation, large-scale galaxy distribution and distant supernovae. Cosmology is now at a stage where theory can make solid predictions, whereas a broad class of observations can be directly used to verify them. Planned large astronomical surveys such as Sloan Digital Sky Survey III and Subaru HyperSprime Cam Survey will provide rich information on the nature of dark matter and dark energy. Accurate theoretical predictions are needed to make the full use of the observational data.

Our primary interests are in primordial star formation in the early universe, the formation and evolution of galaxies, and the formation of large-scale structure. Results from these studies will be used for making good plans and proposals for Subaru-HSC/PFS dark energy survey.

5.15 Supernova

Credit: Subaru telescope

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Andrea Ferrara
Gaston Folatelli
Raphael Hirschi
Alexander Kusenko
Marcos Limongi
Keiichi Maeda
Kai Martens
Takashi Moriya
Ken’ichi Nomoto
Takaya Nozawa
Christian Ott
Robert Quimby
Kate Scholberg
Henry Sobel
James Stone
Yasuo Takeuchi
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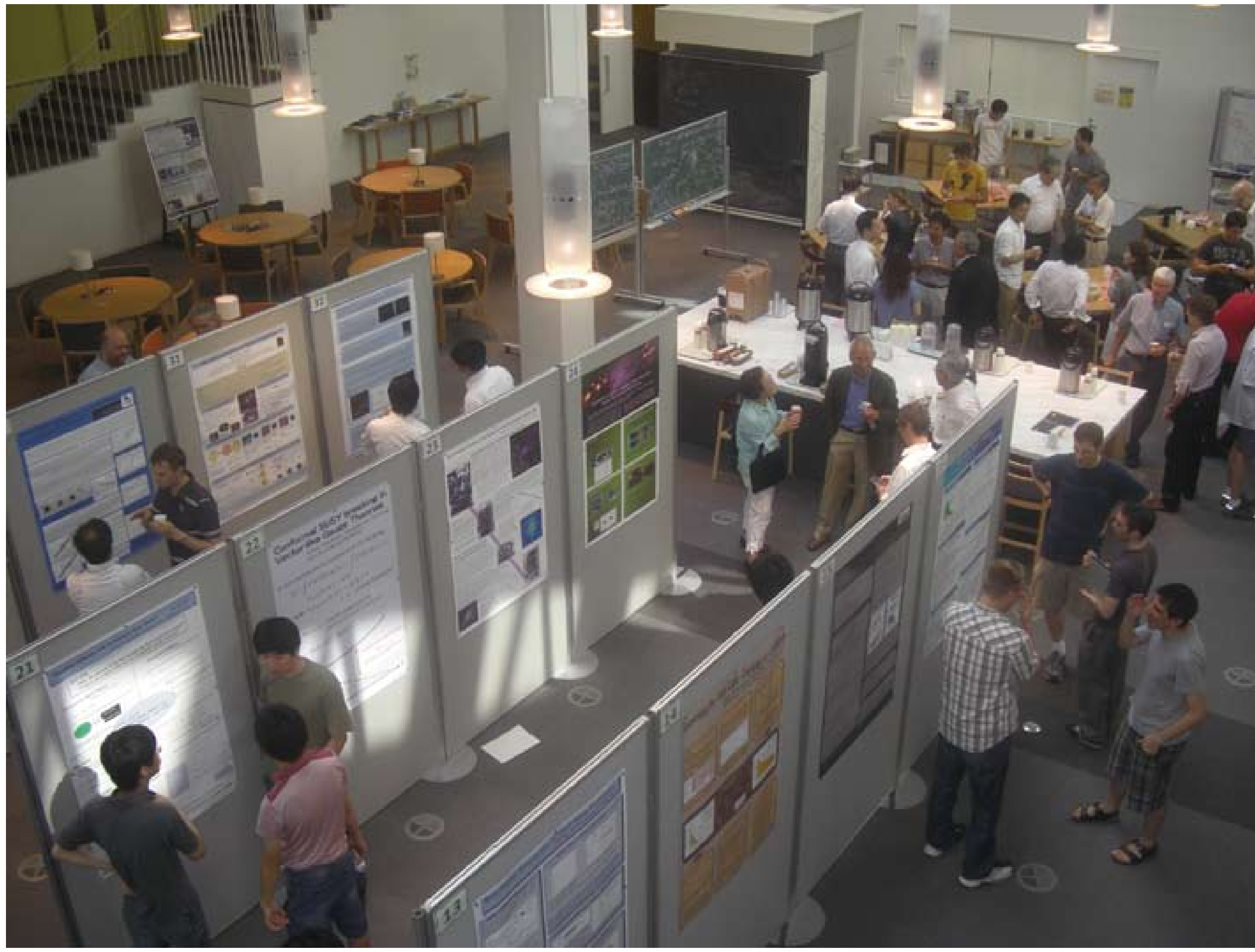
Supernovae are explosions of stars at the end of their lives. Core-collapse supernovae (Type II, Ib, and Ic) are the outcome of the gravitational collapse of massive stars (i.e., more than ten times as massive as the Sun), followed by formation of a neutron star or a black hole, announced by a huge amount of neutrinos. Thermonuclear supernovae (Type Ia) are explosions driven by nuclear reactions within a white-dwarf star.

Supernovae provide natural laboratories for a range of physical processes, such as neutrino physics, some of which cannot be addressed by experiments on the Earth. Furthermore, they are the main contributors of heavy elements in the Universe; without them, baryons in the Universe would be only hydrogen, helium and some minor elements, although in reality the Universe is filled with about a hundred different sorts of elements. Their energy produced at the explosions is huge, and supernova explosions could play important roles even in formation and evolution of galaxies. Finally, importance of understanding their natures is highlighted by their use as cosmological distance indicators, leading to the discovery of the Dark Energy.

Our understanding of the above issues is still far from satisfying, with various issues still under investigation. At IPMU, we cover most of the topics related to supernovae both in theory and observation/experiment; evolution of stars toward supernovae, theory of explosions, attempt to detect these neutrinos at Kamioka, nucleosynthesis of elements up to iron and beyond, formation of dust grains, theory of optical emission from supernovae and evaluation of their use as cosmological distance indicators, and observations using the Subaru telescope including future large survey planning with the HSC. By unifying these attempts, we aim to comprehensively understand supernovae and their influences on the evolution of the Universe.



6 Research Highlight: First Four and Half Years

The IPMU aims to address the deepest and biggest questions about the nature of the Universe: How it started, what it is made of, what its fate is, what laws govern it, and why we exist in it. In order to address such questions, we need a team that has varied approaches yet working cohesively together. The team has to range from experimentalists and observers who take the real data about the nature of the Universe, theoretical physicists and astrophysicists who interpret the data and make new predictions, those who build foundational theories that inspire mathematics, and mathematicians who provide new frameworks for use in theoretical physics. Since the launch of the IPMU, we have been assembling such a coherent team with some significant fruits already produced by this stage. Given the progress in mounting the next-generation experiments and devising observational strategies, we anticipate even greater output in the next few years.

To describe the progress and results to date, we use the categories based on traditional disciplines below. But we try to emphasize the cross-connections among them to demonstrate the emerging fusion among disciplines. Note that the selection of results described here is meant to be examples, not exhaustive. Names of co-authors outside IPMU are not mentioned due to space limitation.

6.1 Experimental Physics

Experimental physics is the primary way to directly obtaining information about the nature of the Universe. IPMU has been participating in two major experiments, the Super-Kamiokande and KamLAND experiments in the Kamioka observatory. Solar neutrino results were reported from both phases SK-II (*Phys. Rev.* **D 78**, 032002 (2008)) and SK-III (*Phys. Rev.* **D 83**, 052010 (2011)) and confirmed the global picture of the solar neutrino physics in statistically and systematically independent fashion. The SK-II result was particularly difficult because of the high energy threshold. KamLAND clearly showed that neutrinos oscillate at more than 5 sigma confidence level (*Phys. Rev. Lett.* **100**, 221803 (2008)), and provided the most accurate measurement of θ_{12}, hinting at non-zero θ_{13} which would be important for the future of the field (*Phys. Rev.* **D 83**, 052002 (2011)). These experiments have been at mature stages and the IPMU has been contributing to the ongoing operations.

We are making progress in three major new initiatives, ZEN, EGADS, and XMASS. While no concrete results had been obtained yet by long-term efforts to start new experiments, substantial progress has been made on all three of them.

6.1.1 ZEN

The ZEN project is being put together to look for a possible conversion of anti-matter (anti-neutrino) to matter (neutrino) in a very rare process called neutrinoless double beta decay.

It was motivated by the celebrated results from the Super-Kamiokande experiment that discovered the extremely small but finite mass of neutrinos in 1998, followed by the resolution of the decades-long solar neutrino problem by the KamLAND experiment in 2002. These results showed that, in addition to the right-handed anti-neutrinos discovered back in 1950s, there must also be electrically neutral left-handed ones. The question is whether such left-handed ones are identical to left-handed neutrinos which are also known to exist, or a completely new variety of elementary particle not discovered to date. If the former case is true, called Majorana neutrinos, there is no fundamental distinction between matter and anti-matter. Then the neutrinos could have played a critical role in reshuffling the amount of matter and anti-matter in the early universe, creating a small excess matter at the level of one part in a billion, leading to the atomic matter in the Universe today after the rest of matter and anti-matter had annihilated into photons. This theory is called leptogenesis, pointed out by PI Tsutomu Yanagida that Majorana neutrinos naturally arise with tiny masses in grand unified theories, and later together with another PI Masataka Fukugita that neutrinos could indeed explain the origin of atomic matter. If leptogenesis is true, neutrinos and anti-neutrinos can transform to each other, addressing the question why we exist in the Universe.

The concept for the ZEN project was developed by Alexandre Kozlov in 2007. It utilizes the existing KamLAND detector, which has 1kt of liquid scintillator with radio contaminants below $3.5\times10^{-18}g/g$ for uranium and $5.2\times10^{-17}g/g$ for thorium. Using this ultra-clean environment and decent energy resolution, ZEN looks for the neutrinoless double beta decay: a neutron inside a large nucleus decays into a proton, electron, and anti-neutrino, where the anti-neutrino transforms to a neutrino, and is re-absorbed by another neutron in the same nucleus, thereby emitting two electrons but no neutrinos in the nuclear transition. He pointed out that a large amount of gaseous xenon can be dissolved into the liquid scintillator, allowing for the search for this rare process which may occur only once in 10^{26} years. IPMU appointed Kozlov in 2008 as a distinguished (long-term) postdoc, and he has been leading the effort to convert the KamLAND experiment into the new phase. The lead institution for the KamLAND experiment, Research Center for Neutrino Science, is lead by the PI Kunio Inoue who acquired necessary funding for the first stage of the ZEN project in 2009. The data taking has start in 2011 and results were reported from the first batch of data: precise measurement of ordinary double beta decay half-life and a limit on the neutrinoless double beta decay, and setting the most stringent limit on the Majoron coupling to the neutrino. Even though there are many on-going experiments looking for a similar process around the world, ZEN is expected to overtake them quickly and produce the world's best result in the 2012–2013 time-frame. It has sensitivity to the effective neutrino mass of 50 meV, eventually improving to the 20 meV with a future upgrade.

6.1.2 EGADS

Most of the chemical elements we see around us had been forged deep inside stars by nuclear fusion process, then were subsequently blown off into the space by supernova explosions. Our Sun is believed to be a third-generation star that was composed of such elements produced by the earlier generation of stars. Therefore, the history when and how many supernova explosions occurred is directly tied to the chemical evolution of the Universe, hence the question why we exist. The PI Ken Nomoto has been one of the leading experts in the theory of supernova explosions while he pointed out that we have not obtained the detailed quantitative understanding of chemical abundance of the Universe.

While ZEN addresses the question why there is atomic matter at all, EGADS tries to address the question of chemical evolution by observing supernovae at billions of light years away using neutrinos. The Kamiokande experiment observed about ten (anti-) neutrinos from the SN1987A in the Large Magellanic Cloud and confirmed the basic understanding of core collapse supernova, leading to the Nobel prize to Masatoshi Koshiba. The current Super-Kamiokande will be able to detect thousands of neutrinos if another supernova explosion occurs in our Milky Way galaxy. However, study of chemical evolution requires observation of supernova neutrinos from cosmological distances (billions of light years), and the current detector does not have adequate sensitivity.

Mark Vagins, together with a theorist John Beacom in 2004, proposed to dump chemical compound of gadolinium into the ultra-pure water in the Super-Kamiokande detector to enhance the sensitivity of detecting (anti-)neutrinos from the distant supernovae. This is well known in the community as the "GADZOOKS!" proposal. The IPMU appointed Vagins in 2008 as a Professor to kick-start this effort. Such a study will provide complementary information to the direct observation of supernova using large telescopes, which is the research led by Assistant Professor Keiichi Maeda discussed below. Our PI Masayuki Nakahata and Vagins obtained funding of 133 million yen from JSPS in 2009 to study the experimental feasibility of this proposal. With this funding, they constructed a new water tank inside the Kamioka mine to study the impact of gadolinium on the transparency and stability of water, which started in 2011. The Super-Kamokande collaboration will judge whether to dump gadolinium compound based on the results from this R&D in the next few years.

6.1.3 XMASS

Beyond the origin of atomic matter studied by ZEN and its chemical composition by EGADS, they do not address more than 80% of matter in the Universe called dark matter. Currently there is very little empirical information about its nature except for its gravitational influence on motion of stars, galaxies, and light.

XMASS was conceived by our PI Yoichiro Suzuki in 2000, and funding was acquired in 2007. Even though there was already an ongoing effort at the Institute for Cosmic Ray Research, IPMU naturally joined the effort to build the detector and analyze the data. We appointed Associate Professor Kai Martens in 2008 with expertise in reducing the radon background in the liquid xenon, as well as a very able postdoc Jing Liu.

The first generation of the experiment has one kiloton of liquid xenon surrounded by a hexagonal array of photomultiplier tubes, which is further suspended inside a 5-kt water tank to shield external neutron background. The tubes are specially fabricated to satisfy the stringent cleanliness requirements. The sphere had been assembled in October 2010, and the commissioning started in November. The external background is suppressed by the water shield with veto counter as well as the fiducial volume cut using the reconstructed vertex positions. The physics run started in 2011 and the first result becomes available in 2012. Being the largest dedicated dark matter detector in the world, it should provide competitive sensitivity to other competing experiments even with a tight fiducial volume cut down to approximately 100 tons.

6.2 Observational Astronomy

The most direct way to study the Universe is by observing it with telescopes. There are two complementary approaches, one is to perform a dedicated study of a particular type of astronomical objects, while the other is to conduct a wide survey of the sky. They are not mutually exclusive and often a large survey does provide a crucial catalog of a particular type of objects. Yet we discuss each approach separately for simplicity.

6.2.1 Wide-scale Surveys

To study the overall trend of the Universe, in particular its expansion history driven by dark matter and dark energy, we try to avoid distraction by properties of individual objects marred by their own peculiarities. Rather, we should try to observe a similar type of objects as a probe over a wide range of areas and depths to conduct a kind of "cosmic census" with as unbiased sampling as possible in order to unveil the nature of the Universe itself. Of special interest is the nature of dark energy, which is responsible for the accelerated expansion of the Universe, yet its nature is unknown. By accurately measuring the expansion history, we hope to determine the nature of dark energy behind it, and extrapolate the history into the future to address the question what the fate of the Universe is. Moreover, the dark energy poses a serious challenge to particle physicists because the estimated size of the vacuum energy is 10^{120} too large. To overcome this challenge, many theoretical possibilities had been proposed to explain the accelerated expansion, including "alternative gravity" theories different from that by Einstein.

Sloan Digital Sky Survey III

Immediately after the launch, IPMU joined the largest scale survey project called Sloan Digital Sky Survey, which was slated to start in 2009 on a 2.5-m telescope on Apache Point, New Mexico, USA. The current phase combines the imaging and spectroscopic survey over a large area of 10,000 square degrees.

The IPMU contributed CCDs, the critical element of the imaging survey which is now completed. The resulting publication called Data Release 8 (H. Aihara et al., *Astroph. J.Suppl.*, **193**, 29 (2011)) is the largest image of the Universe obtained in astronomy to date with more than a trillion pixels.

The collaboration is now in the mode of spectroscopic survey to precisely determine the motion of galaxies along the line of sight using the red shift of spectral lines. The completed imaging survey will allow us to identify a particular type of galaxy called Luminous Red Galaxy that serves as an unbiased sample. The combination of imaging and spectroscopic survey allows us to observe the characteristic distance scale in the distribution of galaxies called the baryon acoustic oscillation (BAO) which results from the sound waves in the hot plasma of atomic nuclei (baryons), electrons, and photons when the Universe was as hot as 3,500 degrees. The distance of BAO acoustic peaks can be precisely calculated based on the current data so that it provides a standard ruler to measure distances over the cosmological scales accurately. Since the distance is synonymous to time, and the red shift is nothing but the expansion of space, we will obtain far more precise data of the expansion history from $z \approx 0.6$ and on than currently available. Seven faculty members and many postdocs are involved in SDSS-III at the IPMU.

HyperSuprimeCam

The next major survey project is an imaging survey using the 8.2-m Subaru telescope on Mauna Kea owned by National Astronomical Observatory of Japan (NAOJ). The new digital camera called HyperSuprimeCam (HSC) is being built with approximately 0.9-billion pixels weighing 3 tons together with the sophisticated and precise corrector lens system. Thanks to the much bigger mirror, the survey will probe much deeper into the younger Universe to extend the measurement of the expansion history back to earlier times, and determine the nature of the dark energy with the best accuracy anticipated in the next five years in a head-to-head competition with the US project Dark Energy Survey (DES).

The project was already underway before the IPMU started based on the collaboration of NAOJ, the University of Tokyo, KEK, Princeton University, and ASIAA (Taiwan). The primary measurement technique is based on the weak gravitational lensing that maps out the distribution of (invisible) dark matter by the shear of images of distant galaxies. The growth of the dark matter structure is determined by the expansion history, which depends on the nature of dark energy.

Immediately after the launch, the IPMU quickly created a hub of activities for the HSC hosting regular meetings and assembling a team for analyzing the data, building upon the experience with SDSS-III. We put together the core team for this project, by appointing Associate Professor Masahiro Takada with an expertise in analyzing the weak lensing data, Associate Professor Naoki Yoshida who can create mock catalog using computer simulations, and Professor Naoki Yasuda with expertise on data handling. Further addition of Assistant Professors John Silverman, Masamune Oguri, and Kevin Bundy expands the scientific scope of the imaging survey into super-massive black holes and galaxy evolution. In addition, the project turned out to be impossible without the financial contributions from the IPMU which amount to approximately a half of the project cost. The major portion comes from the 3.4 billion yen award from the FIRST (Funding Program for World-Leading Innovative R&D on Science and Technology) program to Director Hitoshi Murayama starting in 2010.

We are making steady progress for this major survey. The camera is being readied for the first light in the fall this year. The first data challenge took place in 2010. The actual survey is expected to start in the year 2012.

PrimeFocusSpectrograph and SuMIRe

It is clear from the experience with SDSS-III that we obtain drastically enhanced information by following up an imaging survey with a spectroscopic survey. Currently no major spectroscopic survey is planned beyond SDSS-III in the world. Murayama's FIRST award is precisely the combination of the HSC imaging survey and the new spectroscopic survey on the same Subaru telescope to cover about the same comoving volume as the SDSS-III extending into much younger Universe. The combination is dubbed SuMIRe (Subaru Measurement of Images and Redshifts). Even though Murayama was trained as a theoretical particle physicist, he now leads an international collaboration of astronomers and instrumentalists to build the next generation multi-object spectrograph with a robotic fiber positioner that can simultaneously take spectra of thousands of galaxies at the same time, an example among many cross-disciplinary developments at the IPMU.

Even though the award of 3.4 billion yen is not sufficient for SuMIRe, international partners pledged to contribute resources to build the proposed multi-object spectrograph. Caltech and NASA Jet Propulsion Laboratory will contribute the robotic fiber positioner with 10 micron accuracy, Princeton and Laboratoire d'Astrophysique Marseilles will build spectrograph covering 380 to 1300 nm, allowing for a continuous red shift survey of galaxies from nearby to $z \approx 6$ using OII and Lyman alpha lines. The formation of collaboration is well underway and the conceptual design will be fixed by this September.

6.2.2 Dedicated Studies

Even though the large-scale surveys are the key to the most cosmological studies, dedicated studies of particular type of astronomical objects prove crucial for detailed understanding and interpretation of survey results. Such studies are already well underway at the IPMU and many results had been obtained, providing important input on systematic errors for the SDSS-III, HSC, and PFS surveys.

Supernovae

The initial discovery of accelerating expansion and hence dark energy was based on the observation of Type-Ia supernovae billions of light years away. Type-Ia supernovae are exploding stars that become brighter than their host galaxies, and are clearly visible even at such distances. PI Ken Nomoto pioneered theoretical investigations of the nature of such explosions, concluding that they are the binary system of a white dwarf and an accompanying star, where the accretion of gas from the star onto the white dwarf exceeds the Chandrasekhar limit against the instability to form a black hole. Because the Chandrasekhar limit does not depend on the precise nature of the object or the environment, Type-Ia supernova exhibit a remarkable universality that their luminosities are more or less the same dubbed "standard candles," at least for those observed nearby. However, it remained an important question if those far away are indeed the same, which was the basic assumption behind the claimed discovery of dark energy. If there is a systematic variation among the supernovae, it would cast doubt on the discovery of dark energy.

We appointed Assistant Professor Keiichi Maeda to look into the possibility of such a systematic variation among the supernovae, because he had proposed new ways to calibrate the individuality among supernovae in a series of theoretical investigations. He then turned into observing supernovae himself, an example of cross-disciplinary developments at the IPMU. He quickly showed that supernova explosions are not spherical, by observing the supernovae intentionally 100 days after the initial dramatic phase when they became "boring." This way, the "dust has cleared" and he could observe the core of the explosion, which exhibited the bipolar spectrum of the oxygen lines. The bipolar spectrum implies that the Doppler shifts due to the expanding core shows two prominent velocities along the line of sight, demonstrating the aspheric explosions (*Science*, **319**, 1220 (2008)). However, this observation was about a different type of supernova explosions called core-collapse, targeted by the EGADS discussed earlier.

Maeda then extended the study to Type-Ia, the critical ones for the dark energy. There indeed has been a concern that the evolution of spectra from Type-Ia supernovae appears to show individuality, casting doubt on the purported standard candle. In his publication (*Nature*, **466**, 82 (2010)), he had demonstrated using the new observations that the apparent individuality is due to the viewing angle of aspheric explosions. This work settles one of the major concerns about the Type-Ia supernovae as the standard candle.

At the same time, obtaining more samples of Type-Ia supernovae for close examinations would be extremely useful. PI Ken Nomoto managed to re-observe the supernova reported by Tycho Brahe back in 1572, thanks to a dust cloud that reflects light and produced an "echo." Using the modern telescope, he showed that it was a Type-Ia supernova (*Nature*, **456**, 617 (2008)).

To continue calibration of the Type-Ia supernovae, we appoint a distinguished postdoc Robert Quimby this fall who had discovered a new and the brightest type of supernovae, and get involved in the Palomar Transient Factory II to assemble the largest sample of supernovae ever.

Clusters

Clusters of galaxies have high concentrations of dark matter which had been shown conclusively by the strong gravitational lensing, where a distant galaxy which happens to be exactly behind the cluster is seen as a "giant arc." However, modern statistical analysis allows for a systematic study of shear of images even when the gravitational lensing effect is not as dramatic. This study requires an excellent imaging, possible only with some of the newest and best telescopes, and careful analyses of systematics. Furthermore, this weak lensing effect constitutes the basis of the HSC survey to map out dark matter distribution and the nature of dark energy behind it. Understanding systematic errors would be the key question for the HSC survey.

Associate Professor Masahiro Takada was trained as a theoretical astrophysicist, but now is moving into mapping the dark matter distributions from observations of a large number of galaxy clusters even when the gravitational lensing effect is only as small as 10%. Using his expertise, he demonstrated that the distribution of dark matter in 25 clusters is not spherical with a high statistical significance (*MNRAS*, **405**, 2215 (2010)), consistent with expectation by computer simulations like those by Naoki Yoshida discussed below. By using an improved theoretical prediction and observation, he also placed a theoretically robust limit on the mass of neutrinos (*Phys. Rev.* **D** 79, 023520 (2009).

Distinguished Postdoc Masayuki Tanaka discovered the most distant spectroscopically confirmed X-ray cluster in the Subaru/XMM-Newton deep field (*Astrophys. J. Lett.* **716**, L152 (2010)). It exemplifies kinds of observations we can perform more routinely with the Hyper-SuprimeCam in the future that allows us to search systematically for distant clusters, which will test theoretically predicted formation of structure using numerical simulations by Yoshida and others.

6.3 Theoretical Astrophysics and Phenomenological Particle Physics

Results from the large-scale surveys, dedicated observations, and big experiments have to be interpreted in the context of theoretical frameworks. At the same time, theory makes quantitative predictions and provides service to make the analyses of the data possible. Having both types of researchers under the same roof (and sometimes in the same bodies!) makes this cross-fertilization an important aspect of the IPMU research program.

6.3.1 Computational Astrophysics and Cosmology

Computational cosmology studies the evolution of the structure in the Universe from the initial condition observed in the cosmic microwave background, the ancient light from the Universe only 380,000 years old. So-called "N-body simulations" that studies the structure in the dark matter distribution are well established, thanks to their non-interacting nature that makes the simulation relatively easy. However, inclusion of atomic matter proves highly non-trivial as they interact via the electromagnetic as well as gravitational forces, complicating the simulation. In addition, study of the observed structure requires a huge dynamic range from the billions of light years (size of the observable Universe) down to a few light minutes (distance between the Sun and the Earth).

Associate Professor Naoki Yoshida pioneered numerical simulation to study the interaction of atomic matter over the required huge dynamic range. In his publication (*Nature*, **459**, 49 (2009)), he outlines the evolution from the so-called dark ages to the formation of first stars and galaxies. In another publication together with the PI Ken Nomoto, they proposed a new theory of forming super-massive black holes in early galaxies by accretion of gas and dark matter (*JCAP*, **8**, 024 (2009)). His simulations are roughly five years ahead of the competition. The work by Yoshida together with a particle physics postdoc Cosimo Bambi and others showed an obstacle of accretion to super-spinning black holes (*Phys. Rev.* **D 80**, 104023 (2009)).

In addition to theoretically understanding the observed structure, his work provides the mock catalog of stars and galaxies that can be compared to the forthcoming large-scale surveys to understand the systematic errors. For example, PI Naoshi Sugiyama, together with Yoshida, Takada, and IPMU postdocs, published a detailed examination of the non-Gaussian errors which turned out to be a non-issue despite claims otherwise in the literature (*Astrophys. J.*, **701**, 945(2009)).

6.3.2 Large-scale Structure

The evolution of structure can be worked out theoretically using the linear approximations, namely to the first order in its inhomogeneity. However, the observed structure shows non linear effects that are crucial in comparison between the observations and theory. Obtaining accurate theoretical predictions in the non-linear regime is becoming a focus of attention in the recent research world wide.

For instance, the constraint on the neutrino mass from the large-scale structure of the Universe is an interesting area of research at the intersection of particle physics and astronomy. However, obtaining accurate theoretical predictions has been the major obstacle. Takada, a theoretical astrophysicist, developed an improved theory at higher orders in inhomogeneities in the presence

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of massive neutrinos, as demonstrated by the Super-Kamiokande and KamLAND experiments and predicted by PI Yanagida, to attain a robust theoretical predictions and published in a physics journal (*Phys. Rev. Lett.*, **100**, 191301 (2008), *Phys. Rev.* **D 80**, 083528 (2009)), another example of cross-fertilization.

In addition, Takada and others showed that the combination of imaging and spectroscopic surveys would be sensitive to alternative theories of gravity at cosmological distances (*Phys. Rev.* **D 81**, 023503 (2010)). This direction of research appears to fuse the research on fundamental theories and astronomical observations.

6.3.3 Collider Phenomenology

Collider experiments provide unique opportunities to probe the conditions of the early Universe beyond what can ever be studied optically, namely the surface of last scattering where atoms are ionized due to high temperatures and the mean free path of photons is microscopic. Similarly to the observational astronomy, data from the collider experiments such as Tevatron and the LHC are vast and complicated, and require detailed theoretical studies that allow for extracting crucial information. Of particular interest is the production of dark matter particles that escape detection, and their existence and properties need to be inferred from other particles produced at the same time. Such an analysis requires clever ideas as well as detailed and accurate theoretical predictions. On the other hand, as the data inspire new models, it is critical to work out the consequences of new models to the collider signal. This is the two-way bridge that would be indispensable when new physics is discovered. Sometimes direct collaboration between theorists and experimentalists proves useful.

For example, measuring masses of new particles that decay into an invisible particle in a cascade is a well-known difficult problem. A kinematic variable called $mT2$ had been proposed as a means to address this problem. However, the initial state radiation, which becomes increasingly harder as the particle mass increases, complicates the definition of $mT2$. We added a new PI Mihoko Nojiri right after the launch, and she proposed a new strategy based on $mT2min$ to solve this complication (*Phys. Rev. Lett.*, **103**, 151802 (2009)). An even more difficult problem is to measure spins of new particles. PI Hitoshi Murayama proposed a novel technique using interference among the helicity states that are free from model assumptions (*Phys. Rev.* **D 78**, 014028 (2008)).

On the other hand, Nojiri picked up a novel model proposed by IPMU postdocs Park and Shu inspired by the cosmic-ray data and developed its detailed phenomenology of its collider signals for the first time (*JHEP*, **9**, 078 (2009)). Murayama proposed a different model motivated by the unexpected large forward-backward asymmetry in the top-quark pair production at Tevatron and worked out its collider consequences (*Phys. Rev.* **D 81**, 015004 (2010)). PI Tsutomu Yanagida collaborated with an experimentalist for a detailed study of how to test the anomaly mediated supersymmetry breaking mechanism (proposed by Murayama and others) at the LHC (*Phys. Lett.* **B 664**, 185 (2008)).

6.3.4 Cosmic-ray phenomenology

IPMU is addressing the nature of dark matter with the underground experiment XMASS, astronomical observations, theoretical models, and collider data. In addition, cosmic rays may contain products of dark matter annihilations in the Milky Way halo. In fact, some of the recent data from PAMELA (positrons), ATIC, and FERMI (electrons and positrons) showed excess beyond past expectations, while their interpretation is not clear yet.

Assistant Professor Fuminobu Takahashi had proposed a novel possibility to explain the older cosmic-ray data from dark-matter decays while avoiding excessive production of antiprotons before the recent data by assigning lepton numbers (similar to electrons) to the dark matter particles (*JCAP,* **02**, 004 (2009)). The model became one of the targets of more recent experiments. PI Tsutomu Yanagida proposed dark-matter decays instead of annihilations that avoid many of other existing constraints within the lifetime range motivated by grand-unified models (*Phys. Lett.* **B 673,** 247 (2009)). Their joint work was the first paper to propose a hidden gauge boson (*Phys. Lett.* **B 673**, 255 (2009)). Postdocs Jing Shu and Seongchan Park worked by themselves and proposed a new kind of extra-dimensional model to explain the data (*Phys. Rev.* **D 79**, 091702 (2009)).

Note that many models proposed in the literature that enhance the dark matter annihilation in the halo relies on the Sommerfeld enhancement effect which had been proposed by PI Nojiri and Associate Professor Shigeki Matsumoto back in 2003. In addition, PI Yanagida and Murayama pointed out a different mechanism to enhance the annihilation in the halo dubbed Breit-Wigner enhancement (*Phys. Rev.* **D 79**, 095009 (2009)), which may be relevant in the future even when the current interpretation of data will not turn out to be correct.

6.4 Fundamental Theory

Based on the experiments and observations, and using the bridge between data and theory, IPMU aims at deciphering the basic laws of the Universe. Using quantum field theory and string theory, new theories are being developed. In addition, many of them turn out to be useful for applications to other branches of science.

6.4.1 Model Building

Motivated by observed data and inspired by the proposed fundamental theories such as string theory, “model building” serves as the link to build the fundamental theory. For instance, the observed masses of three generations of quark and lepton are different by order(s) of magnitudes among generations and the standard theory offers no explanations. F-theory, a version of string theory compactified on elliptic Calabi-Yau four-folds, was proposed as a natural way to explain this pattern. However, complications in understanding these manifolds make the link technically challenging. Associate Professors Taizan Watari (physicist) and Yukinobu Toda (mathematician) tackled these complications with a careful analysis of sheaves and showed that the original model proposed by Cumrun Vafa and others actually did not work as hoped(*Nucl. Phys.* **B 806**, 224 (2009)). Watari further published a series of papers studying how new models can be constructed to achieve the original aim.

Explicit models often receive severe constraints from many apparently disconnected experimental data sets. PI Tsutomu Yanagida has been working on models of the mechanism of gauge-mediated supersymmetry breaking. In a series of papers, he managed to demonstrate that it is possible to satisfy all constraints from the large-scale structure of the Universe, dark matter searches, collider searches, stability against quantum tunneling.

6.4.2 Fundamental Laws and Alternative Gravity Theories

To construct fundamental laws to describe the Universe, in particular the black holes or the Big Bang itself, it is crucial to incorporate microscopic physics (quantum mechanics) and macroscopic physics (general relativity) into a single framework. This effort has been hampered by uncontrollable infinities in theoretical calculations. Currently the string theory presents the best hope in this direction. However, the string theory still lacks a precise definition while it is very rich in its structure, and hence working out explicit consequences of the theory is very challenging.

There has been a long-standing problem in the quantum aspects of black holes. As Stephen Hawking pointed out, black holes actually have entropy. However entropy in thermodynamics arises from microscopic degrees of freedom in statistical mechanics, and how to count the microscopic degrees of freedom has been the challenge. PI Hirosi Ooguri tackled this problem using the topological string theory and a recent mathematical works by Okounkov and others on the wall crossing in the Donaldson-Thomas theory, and generalized the consistent counting by the previous works to arbitrary non-compact toric Calabi-Yau manifolds (*Comm. Math. Phys.*, **292**, 179 (2009)). The counting was found equivalent to the ways atoms can be removed from melting crystals. He further showed how the smooth classical description arises from this picture (*Phys. Rev. Lett.*, **102**, 161601 (2009)). Ooguri also has a series of papers to address the mechanism of supersymmetry breaking from the string-theory perspective, connecting to the model-building activity in view of the experimental and observational constraints.

Recently, Petr Hořava proposed a novel way to unify quantum mechanics and gravity keeping the divergences in calculations under control (renormalizable). Whether the proposal correctly reproduces Einstein's general relativity is still not clear. Associate Professor Shinji Mukohyama quickly took up this proposal and studied its relevance to cosmology. He pointed out it naturally produces the scale-invariant cosmological perturbation needed to explain the observed structure of the Universe without resorting to the accelerated expansion of space called inflation (*JCAP,* **6**, 001 (2009)). It provided a strong motivation to study this Hořava-Lifshitz model further worldwide. In addition, postdocs Domenico Orlando and Susanne Reffert (*Class. Quant. Grav.*, **26**, 155021 (2009)) showed that the Hořava-Lifshitz model is indeed likely to be renormalizable by relating its divergence structure to that of the topologically massive gravity. This paper was cited as 2010 Highlights of Classical Quantum Gravity Journal.

6.4.3 Applications to Other Areas

String theory has such a rich structure that makes it possible to accommodate a wide range of physical systems. In recent years, it became a very active subject to use the string theory as a framework rather than the fundamental theory of gravity.

Professor Shigeki Sugimoto is well-known for the Sakai-Sugimoto model to describe theory of strong interactions using the string theory, as exemplified by his Kimura Prize in Theoretical Physics, Yukawa-Tomonaga Prize, and Outstanding Paper Prizes from Japanese Physical Society twice. Using his model, he carried out the detailed investigations of the properties of baryons (proton, neutron, etc) including their magnetic moments and form factors, and showed that the predictions are quite consistent with the data beyond the anticipated level of accuracies (*Prog. Theor. Phys.*, **120**, 1093 (2008)).

Associate Professor Tadashi Takayangi has produced a series of papers discussing the application of string theory to condensed matter physics. In particular, topological insulators are arguably the hottest subject in condensed matter physics in recent years. Takayanagi demonstrated that the string theory is useful in classifying different types of topological insulators (*Phys. Lett.* **B 693**, 175 (2010); *Phys. Rev.* **D 82**, 086014 (2010)). He has also pointed out the relationship between the evolution of the black hole entropy and the entanglement entropy in condensed matter systems with a Todai graduate student (*JHEP*, **1011**, 054 (2010)).

6.5 Mathematics

Research in mathematics strongly influences research in theoretical physics as it enables attack on problems not conceivable before. At the same time, needs and progress in theoretical physics inspire new directions in mathematics research. The IPMU intends to develop this type of cross-fertilization not possible with the traditional departmental structure in the University. In addition to the original group of PIs, we have appointed a new PI Alexey Bondal who is half-time at the IPMU, Associate Professor Yukinobu Toda, and Assistant Professors Satoshi Kondo, Todor Milanov.

Furthermore, some of our physicists have strong background in mathematics. We appointed Professor Kentaro Hori away from Toronto University, where he held a half-time position each in Physics and Mathematics departments. PI Ooguri, a physicist, won the inaugural award of the Leonard Eisenbud Prize from American Mathematical Society, and holds a position both in the Physics and Mathematics Departments at Caltech. Many of our members publish in the journals at the interface between physics and mathematics, such as *Advances in Theoretical and Mathematical Physics, Communications in Mathematical Physics, Communications in Number Theory and Physics.* Despite very different style in publications, there are even articles coauthored by physicists and mathematicians as mentioned above.

One particular interest among mathematicians is the mirror symmetry between complex analytic and symplectic manifolds, which was originally suggested by the string theorists studying the compactification of string theory on Calabi-Yau 3-folds. Further developed by Kontsevich, Fukaya and others into the homological mirror symmetry conjecture, this is an active area of research closely related to the string theory. The latest appointment, Assistant Professor Todor Milanov works on a unique approach to the mirror symmetry by constructing generating function for the Gromov-Witten invariant for mirror-symmetric pairs using the integral systems (KdV hierarchy). PI Alexey Bondal pioneered derived category of coherent sheaves, which has become the basis for understanding properties of D-branes in string theory. Our members attack various hard mathematical problems such as Beilinson conjecture, Generalized Moonshine Conjecture, Strominger-Yau-Zaslow conjecture. We added new PIs Kyoji Saito and Alexey Bondal since the launch because of their strong track record for laying foundations for the branches of mathematics that became crucial tools for physics research later.

As mentioned already above, Toda has helped Watari to work out consequences on the quark and lepton masses of a model based on the F-theory formulation of the string theory. He has been working on the derived category of the sheaves, relevant to the dynamics of D-branes in the string theory as well as structure of Calabi-Yau manifolds on which string theory is compactified. He introduced new enumerate invariants of curves on Calabi-Yau 3-folds which generalized counting invariants of stable pairs introduced by Pandharipande and Thomas (*Duke Math. Journ.*, **149**, 157-208 (2009)). He then investigated the space of certain weak stability conditions on the triangulated category of D0-D2-D6 bound states on a smooth projective Calabi-Yau 3-fold, and constructed the DT type invariants counting semi-stable objects in his triangulated category, which are new curve counting invariants on a Calabi-Yau 3-fold (*Journ. Amer. Math. Soc.*, **23**, 1119-1157 (2010)). Both works have close relationship to the wall-crossing phenomena, and were inspired partially by the joint workshop on wall crossing between physicists and mathematicians at the IPMU.

Since the Fields-Medal paper by the physicist Witten, which related topological field theories to the theory of knots and braids, this also has been a common area of interest between physicists and mathematicians. PI Toshitake Kohno showed that the bar complex of the configuration space of ordered distinct points in the complex plane is acyclic (*Topology and its Applications*, **157**, 2-9 (2010)). The 0-dimensional cohomology of this bar complex is identified with the space of finite type invariants for braids. He constructed a universal holonomy homomorphism from the braid group to the space of horizontal chord diagrams over Q, which provides finite type invariants for braids with values in Q.

PI Hirosi Ooguri discovered that the elliptic genus of the K3 surface has a natural decomposition in terms of dimensions of irreducible representations of the largest Mathieu group M24 (*Exper. Math.* **20**, 91 (2011)). This observation has inspired mathematicians worldwide to understand the origin of this mysterious connection. In his other work (*Comm. Number Theory Physics*, **2**, 743-801 (2008)), he obtained constraints on the spectrum of primary fields in 2D conformal field theories from the moduliary of the elliptic genus. Modular forms lie at the intersection of quantum field theory in physics and many areas of mathematics including arithmetic geometry.

Assistant Professor Satoshi Kondo works on arithmetic geometry. In his publication (*Journal of Pure and Applied Algebra*, **215**, 511-522 (2011)), he showed that the product structures of motivic cohomology groups and of higher Chow groups are compatible under the comparison isomorphism of Voevodsky, extending the result of Weibel, where he used the comparison isomorphism which assumed that the base field admits resolution of singularities. The mod n motivic cohomology groups and product structures in motivic homotopy theory are defined, and it is shown that the product structures are compatible under the comparison isomorphisms. In a series of papers yet to be published, he has shown how to generalize a theorem of Beilinson on K2 of a modular curve to the situation of Drinfel'd modular curves, and the existence of a formula that should be regarded as the first evidence, in higher dimensions, toward the correct statement of Beilinson's conjectures for function fields. We will appoint Assistant Professor Tomoyuki Abe who works also on the arithmetic geometry but from the algebraic point of view.

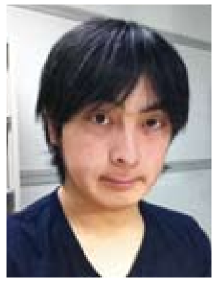
PI Kyoji Saito is interested in the global transcendental nature of functions and numbers, which appear in connection with several moduli problems in mathematics. In one approach he developed the theory of period integrals of primitive forms, which had big impact on the string theory research and became one of the basic tools called the Frobenius manifold structure. The other approach he takes is by statistical mechanical limit procedure, connected to thermal and statistical physics. In his recent work (*Publ. RIMS*, **46**, 37-113 (2010)), he developed a general frame work on the space $\Omega(\Gamma, G)$ of thermo-dynamical limit functions (free energy) associated to the Cayley graph of any cancellative monoid Γ. They are, at present, abstractly defined in certain Hopf algebra as accumulating points of finite free energy, is hardly calculable. But, in certain good cases he showed that some traces of such limit F-functions can be expressed as a residue of certain meromorphic functions.

7 Awards

The 16th JPS Award for Academic Papers on Physics was awarded to Shigeki Sugimoto jointly with Hiroyuki Hata, Tadakatsu Sakai and Shinichiro Yamato. This award is given to the authors of important papers published in JPSJ and Progress of Theoretical Physic within the past 5 years. Their paper “Baryons from Instantons in Holographic QCD” (Prog. Theor. Phys., 117 1157 (2007)) calculated the baryon spectrum by applying gauge/string duality to QCD.

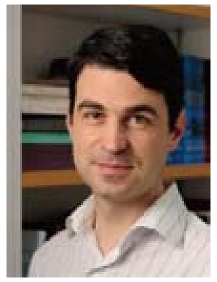
The Mathematical Society of Japan Geometry Prize was awarded to Kyoji Saito for his contribution in geometry of period integrals. He has modernized the theory of elliptic integrals and period integrals developed by Euler, Abel, Jacobi and others in the 18th to 19th centuries. This work has great influence not only on various fields of mathematics, but also on the developments in the frontier of today’s theoretical physics.

Tomoyuki Abe was awarded the 2011 Takebe Prize of the Mathematical Society of Japan for his work on the theory of arithmetic D -modules and its application to arithmetic geometry. On varieties over field of characteristic p, the theory of l -adic ($l \neq$ p) cohomology is well established. Since around the 60s, a “good” theory of p -adic cohomology has been searched and a candidate has been the theory of arithmetic D -modules initiated by Berthelot. But it is yet to be constructed. Abe contributed to its foundation as well as application to a ramification theory.



Masahiro Ibe won the Young Scientist Award in theoretical particle physics jointly with Ryuichiro Kitano of Tohoku University for their paper “Sweet Spot Supersymmetry” that appeared in Journal of High Energy Physics in 2007. They have proposed a scenario for explaining the symmetry breaking mechanism of the supersymmetry theory in which the gravity-mediation and gauge-mediation
work together in such a way that constraints of cosmological phenomenology are naturally satisfied.

Masaomi Tanaka won the Inoue Research Award for Young Scientists for his work on three dimensional properties of supernova explosions. Based on detailed simulations and polarimetric observations using Subaru telescope, he showed that supernovae are not spherically symmetric, but actually have three-dimensional structures. He moved to NAOJ in December 2011.



Brice Menard won the 2012 Sloan Research Fellowship. This fellowship seeks to stimulate fundamental research by early-career scientists and scholars of outstanding promise. He has been working on cosmology, galaxy formation, and gravitational lensing analysis of large imaging and spectroscopic surveys.

Masataka Fukugita (left) and Tsutomu Yanagida (right) jointly received the Yoji Totsuka Memorial Prize for their important contribution in the study of baryon number asymmetry. The model they proposed, widely known as Leptogenesis, explains the present-day matter-dominated universe as a consequence of CP violation among heavy right-handed neutrinos during the period when the universe underwent electroweak phase transition. The concept of heavy right-handed neutrinos, known as “See-saw mechanism” was introduced in 1970s by Yanagida for explaining the extreme smallness of neutrino masses. The Leptogenesis, although not experimentally verified yet, is one of the most elegant approaches for explaining the baryon number asymmetry, and has been giving great impact to particle physics as well as to cosmology.

Takaaki Kajita was awarded the Japan Academy Award for discovering the neutrino oscillation in the atmospheric neutrinos. Kajita and his collaborators, working first at Kamiokande and later at Super-Kamiokande, established a method to distinguish muon-type and electron-type in the atmospheric neutrinos, leading to an observation of deficit in the muon-type neutrinos from expectation. Based on subsequent detailed study, they discovered that the reason of the deficit was due to the oscillation of muon-type to electron-type during flight.

8 Seminars

JFY2011

Norimi Yokozaki (U Tokyo)
Soft Leptogenesis and Gravitino Dark Matter in Gauge Mediation
Apr 06, 2011

Masayuki Tanaka (IPMU)
A new method to identify AGNs and the nature of low-luminosity AGNs
Apr 07, 2011

Kazuo Hosomichi (YITP)
SUSY Gauge Theories on Squashed Three-Spheres
Apr 12, 2011

Keiichi Maeda (IPMU)
Asymmetry in Type Ia Supernovae: An Origin of Their Observational Diversities?
Apr 14, 2011

Mitsutoshi Fujita (IPMU)
Geometric entropy and confinement / deconfinement transition in d = 4 QCD like theories
Apr 19, 2011

Yoshitaka Hatta (Tsukuba U)
Jets at weak and strong coupling
Apr 20, 2011

Masahiro Futaki (U Tokyo)
On the construction of the virtual fundamental class
Apr 20, 2011

Takashi Moriya (IPMU)
Supernova Explosions in Dense Circumstellar Medium
Apr 21, 2011

Kazunobu Maruyoshi (SISSA)
Quantized integrable systems, matrix models and AGT correspondence
Apr 26, 2011

Koichi Hamaguchi (IPMU)
The Unification of Forces
Apr 27, 2011

Masahiro Takada (IPMU)
Information content in cosmological observables
Apr 28, 2011

Massimo Bianchi (U Rome)
Small Black-Holes and Higher Spin States in Heterotic String
May 17, 2011

Takahiro Tanaka (YITP)
Natural selection of inflationary vacuum required by infra-red regularity and gauge invariance
May 18, 2011

Yasunobu Uchiyama (SLAC/Stanford U)
The Supernova Origin of Galactic Cosmic Rays
May 18, 2011

Kentaroh Yoshida (Kyoto U)
Yangian symmetry in deformed WZNW models on squashed spheres
May 24, 2011

Junichi Tanaka (U Tokyo)
Recent results from ATLAS at the LHC
May 25, 2011

Adam Amara (ETH-Zurich)
Gravitational Lenses of the Dark Universe
May 26, 2011

Masahito Yamazaki (Princeton U)
6 = 3 + 3
May 31, 2011

Jacob Bourjaily (Princeton U)
Quantum Field Theory and the Analytic S Matrix, Redux
Jun 01, 2011

Jan de Boer (U Amsterdam)
Some recent results on microstate geometries
Jun 01, 2011

John Silverman (IPMU)
(Astro)-supercolliders: growing black holes in galaxy mergers
Jun 02, 2011

Alexander Vikman (CERN)
Cosmology, Scalar Fields and Hydrodynamics
Jun 03, 2011

Murray Brightman (MPE)
An X-ray - infrared study of AGN unification and selection
Jun 07, 2011

David Spergel (Princeton U & IPMU)
Cosmology Results from the Atacama Cosmology Telescope
Jun 08, 2011

Yu Nakayama (Caltech)
Refined topological string for Omega background
Jun 14, 2011

Mihoko Nojiri (KEK & IPMU)
Challenges in Fukushima and Japan
Jun 15, 2011

Marco Valdes (U Pisa)
The high-z interplay between annihilating DM and the IGM
Jun 16, 2011

Martin Schnabl (Inst Phys Prague)
Multiple brane solutions in Open String Field Theory
Jun 20, 2011

Yoshio Sano (National Inst Informatics)
Thermo-dynamical limit function's seminar
Jun 20, 2011

Tomoyuki Abe (IPMU)
Product formula for p-adic epsilon factors
Jun 21, 2011

Masahito Ueda (U Tokyo)
Maxwell's Demon: Introduction to Information Thermodynamics
Jun 22, 2011

Masamune Oguri (IPMU)
Dark matter distribution in clusters from strong + weak lensing
Jun 23, 2011

Shunsuke Tsuchioka (IPMU)
Recent advances in modular representation theory of the symmetric groups
Jun 28, 2011

Jiro Soda (Kyoto U)
Statistical Symmetry Breaking in the CMB
Jun 29, 2011

Morimitsu Tanimoto (Niigata U)
Impact of Large θ_{13} on Flavor Physics
Jun 30, 2011

Yoichi Kazama (U Tokyo)
Green-Schwarz superstring with conformal symmetry
Jul 05, 2011

Anzhong Wang (Baylor U)
Anisotropic scalings and a theory of quantum gravity
Jul 06, 2011

Takamitsu Tanaka (Columbia U/MPI Astrophys)
Modeling the Electromagnetic Signature of Merging Supermassive Black Holes
Jul 07, 2011

Kimitake Hayasaki (Kyoto U)
A Road to Supermassive Black Hole Merger
Jul 07, 2011

Yosuke Imamura (Titech)
Exact results in 3d gauge theories andM-theory
Jul 12, 2011

Eiichiro Komatsu (U Texas)
Cosmic Near Infrared Background
Jul 14, 2011

Christian Schnell (IPMU)
Some results from Hodge theory
Jul 19, 2011

Clifford Cheung (UC Berkeley)
Signs of a Hidden Sector from Supersymmetry(s)
Jul 20, 2011

Masami Ouchi (ICRR)
Probing the Epoch of Reionization
Jul 21, 2011

David Morrison (UCSB)
Mirror symmetry and non-complete intersection Calabi-Yau manifolds
Jul 25, 2011

Maximo Pernas (KIT)
Ultra High Energy Cosmic Rays: latest results from the Pierre Auger Observatory
Jul 26, 2011

Yuichiro Nakai (YITP)
Inflation in Gauge Mediation and Gravitino Dark Matter
Jul 27, 2011

Jean Coupon (Tohoku U)
New insights on galaxy evolution since z ~ 1.2 from the CFHT Legacy Survey
Jul 28, 2011

Tatsuma Nishioka (Princeton U)
A Chiral Magnetic Effect from AdS/CFT with Flavor
Aug 02, 2011

Siu Cheong Lau (IPMU)
SYZ mirror symmetry for toric Calabi-Yau manifolds
Aug 05, 2011

Taizan Watari (IPMU)
F-theory and elliptic fibrations; physics intro & casual discussion of math aspects
Aug 09, 2011

Jock McOrist (U Cambridge)
Linear Sigma Models and Heterotic Vacua
Aug 15, 2011

Suet-Ying Mak (U Southern Cal)
Constraints on modified gravity from future surveys
Aug 16, 2011

Kathryn Zurek (U Michigan)
Asymmetric Dark Matter
Aug 23, 2011

Seong-Chan Park (Chonnam National U)
Super-Planckian scattering at the LHC
Aug 24, 2011

Thomas Greif (MPI Astrophys)
The formation of the first stars and galaxies
Aug 25, 2011

Kenichi Konishi (Pisa U)
The monopole-vortex complex: dual gauge symmetry from flavor
Aug 26, 2011

Jaewon Song (Caltech)
ABCD of 4d/2d correspondence
Aug 30, 2011

Raphael Ponge (SNU)
Noncommutative Geometry and the Hirzebruch-Riemann-Roch Formula
Aug 31, 2011

Olivier Dore (NASA JPL)
Planck Early Measurements of the Cosmic Infrared Background Anisotropies
Sep 01, 2011

Noppadol Mekareeya (Imperial Coll London)
Universalities of Theories with Tri-vertices
Sep 06, 2011

Tzu-Ching Chang (ASIAA)
21-cm Cosmology
Sep 08, 2011

Priyotosh Bandyopadhyay (KIAS)
Aspects of Higgs searches in CP-violating MSSM at the Large Hadron Collider
Sep 14, 2011

Jason Rhodes (NASA JPL)
WFIRST and Euclid
Sep 15, 2011

Rob Myers (Perimeter Inst)
Holographic Entanglement Entropy
Sep 27, 2011

Rob Myers (Perimeter Inst)
Holographic C-theorems
Sep 27, 2011

Sudeep Das (BCCP/UC Berkeley/LBL)
A New View of the CMB from the ATACAMA Cosmology Telescope
Sep 28, 2011

Tristan Smith (UC Berkeley)
Looking for cracks in the standard cosmological model: neutrinos and non-Gaussianity
Sep 29, 2011

Richard Ellis (Caltech)
Did galaxies reionize the Universe: progress and challenges
Oct 03, 2011

Takeshi Morita (U Crete)
Gregory-Laflamme as the confinement / deconfinement transition in holographic QCD
Oct 04, 2011

Richard Ellis (Caltech)
Cosmic Dawn: The Quest for the First Stars and Galaxies
Oct 05, 2011

Biplob Bhattacherjee (IPMU)
Jet substructure and new physics searches at the LHC
Oct 06, 2011

Richard Ellis (Caltech)
Observational probes of dark energy: the role of HSC and PFS
Oct 06, 2011

Shin'ichiro Ando (U Amsterdam)
Gamma-ray probes of dark matter annihilation
Oct 11, 2011

Bunyo Hatsukade (Kyoto U)
Millimeter Survey of Distant Dusty Starburst Galaxies
Oct 13, 2011

Peter Behroozi (Stanford U)
Constraining the Complete Star Formation History of Observable Galaxies from z = 0 to z = 8
Oct 13, 2011

Naoki Yoshida (IPMU)
Elements of Gravitational Lensing: Introduction to weak lensing
Oct 13, 2011

Norihiro Iizuka (CERN)
On the Taxonomy of Holographic Fermi/Non-Fermi Liquids
Oct 14, 2011

Amanda E. Bauer (Australian Astron Obs)
Linking Star Formation Histories with Galaxy Assembly
Oct 20, 2011

Masahiro Komatsu (Nagoya U)
Measurement of the neutrino velocity with the OPERA detector in the CNGS beam
Oct 20, 2011

Marcus Werner (IPMU)
Introduction to Gravitational Lensing II: Strong lensing, quasi-Newtonian formalism, the lensing map
Oct 20, 2011

Kaoru Ono (Hokkaido U)
Lagrangian Floer theory on compact toric manifolds (Part 1)
Oct 24, 2011

Kaoru Ono (Hokkaido U)
Lagrangian Floer theory on compact toric manifolds (Part 2)
Oct 24, 2011

Peng Zhao (DAMTP)
Electromagnetic duality from integrable spin chain
Oct 25, 2011

Chunshan Lin (IPMU)
A Matter Bounce By Means of Ghost Condensation
Oct 27, 2011

Noriyuki Abe (Hokkaido U)
On a classification of irreducible modulo p representations of a split p-adic group
Oct 27, 2011

Johannes Andersen and Birgitta Nordstrom (Niels Bohr Inst)
The Origin of the Elements in the Universe
Oct 28, 2011

Scott Tremaine (IAS Princeton)
Supermassive Black Holes and Galaxies
Nov 02, 2011

Scott Tremaine (IAS Princeton)
Seminar on Supermassive Black Holes
Nov 04, 2011

Alan McConnachie (NRC Herzberg Inst)
Towards the Next Generation of the CFHT: a dedicated, 10m, wide-field, highly-multiplexed spectroscopic facility for Mauna Kea
Nov 07, 2011

Scott Tremaine (IAS Princeton)
Two lectures on the extrasolar planet: observational and theoretical (1)
Nov 07, 2011

Aleksandr Ivanovich Efimov (Steklov Math Inst)
On Donaldson-Thomas theory for quivers with potentials (Part I)
Nov 07, 2011

Scott Tremaine (IAS Princeton)
Two lectures on the extrasolar planet: observational and theoretical (2)
Nov 07, 2011

Aleksandr Ivanovich Efimov (Steklov Math Inst)
On Donaldson-Thomas theory for quivers with potentials (Part II)
Nov 07, 2011

Ivan Cheltsov (U Edinburgh)
What are higher-dimensional analogues of D_n, E_6, E_7 and E_8 singularities?
Nov 08, 2011

Scott Tremaine (IAS Princeton)
Stellar dynamics lecture - 1: Kozai-Lidov resonance
Nov 08, 2011

Valeri Frolov (U Alberta)
Spinoptics in a stationary spacetime
Nov 08, 2011

Constantin Shramov (Steklov Math Inst & HSE)
On tetragonal construction of R. Donagi
Nov 08, 2011

Scott Tremaine (IAS Princeton)
Stellar dynamics lecture - 2: integration algorisms
Nov 09, 2011

Marcus Werner (IPMU)
Gravitational Lensing III
Nov 10, 2011

Jean-Philippe Uzan (Inst Astrophys Paris)
Testing the equivalence principle: the link between constants, gravitation and cosmology
Nov 10, 2011

Fedor Smirnov (U Paris 6)
Fermionic structure in lattice, conformal and massive integrable field theory
Nov 14, 2011

Timothy Logvinenko (U Warwick)
Derived Reid's recipe for threefold singularities (Part I)
Nov 14, 2011

Timothy Logvinenko (U Warwick)
Derived Reid's recipe for threefold singularities (Part II)
Nov 15, 2011

Richard Hill (U Chicago)
Universal behavior in the scattering of heavy, weakly interacting dark matter on nuclear targets
Nov 15, 2011

Fedor Smirnov (U Paris 6)
Hidden fermionic structure of the XXZ model
Nov 15, 2011

Changzheng Li (IPMU)
Quantum cohomology of flag varieties
Nov 16, 2011

Jun Zhang (U Texas)
Conquering Systematic Errors in Weak Lensing Measurements
Nov 16, 2011

Jens Chluba (U Toronto)
Signals from the cosmological recombination era and spectral distortions of the CMB
Nov 17, 2011

Tadashi Takayanagi (IPMU)
Introduction to AdS/CFT Correspondence
Nov 17, 2011

Dmitri Panov (King's College London)
Hyperbolic geometry and symplectic Calabi-Yau varieties
Nov 18, 2011

Yanki Lekili (U Cambridge)
Fukaya category of the punctured torus
Nov 19, 2011

Siu-Cheong Lau (IPMU)
Enuemerative meaning of mirror maps for toric Calabi-Yau manifolds
Nov 21, 2011

Akira Shudo (Tokyo Met U)
The Stokes geometry of a quantum nonintegrable map
Nov 22, 2011

Sharon Rapoport (Mt. Stromlo Obs)
Gravitational Lensing as the Source of Enhanced Strong MgII Absorption Towards Gamma-Ray Bursts
Nov 24, 2011

John Kehayias (IPMU)
Discrete R-Symmetries and Generalized Gaugino Condensation (and Three Generations)
Nov 24, 2011

Francesco Miniati (ETH)
Generation of Magnetic Field in Cosmic Structure
Nov 24, 2011

Marcus Werner (IPMU)
Introduction to Gravitational Lensing IV: Schwarzschild lens and the singular isothermal sphere, image magnification, critical set
Nov 24, 2011

Jim Gunn (Princeton U)
Lectures on photometry and detectors (Part 1)
Nov 28, 2011

Jim Gunn (Princeton U)
Lectures on photometry and detectors (Part 2)
Nov 28, 2011

Shinji Hirano (Nagoya U)
Summing up All Genus Free Energy of ABJM Matrix Model
Nov 29, 2011

Alexei Smirnov (ICTP Trieste)
Challenges of neutrino oscillation physics
Nov 30, 2011

Omar Benvenuto (U Nacional de La Plata)
Signals of Quark-Gluon Plasma Formation in Astrophysical Environments
Dec 01, 2011

Jim Gunn (Princeton)
Lectures on photometry and detectors (Continued)
Dec 01, 2011

Andrei Pajitnov (U Nantes)
The Novikov homology and complex hyperplane arrangements
Dec 01, 2011

Jim Gunn (Princeton U)
Lectures on optics and the atmosphere (Part 1)
Dec 05, 2011

Jim Gunn (Princeton U)
Lectures on optics and the atmosphere (Part 2)
Dec 05, 2011

Yasuaki Hikida (Keio U)
Higher spin AdS_3 supergravity and its dual CFT
Dec 06, 2011

Fanky Wong (U Hong Kong)
Gravitational lensing in a dark matter free braneworld model
Dec 06, 2011

Naoyuki Tamura (NAOJ)
Subaru fiber multi-object spectroscopy: current & future instruments for large census in astronomy
Dec 07, 2011

Jim Gunn (Princeton U)
Studying the Evolution of Galaxies with the Subaru Telescope
Dec 07, 2011

Chris Hirata (Caltech)
Understanding the cosmic recombination epoch
Dec 08, 2011

Masaki Shigemori (KMI Nagoya U)
Exotic branes, double bubbles, and superstrata
Dec 12, 2011

Jim Gunn (Princeton U)
Lectures on image processing, spectroscopy and spectrophotometry (Part 1)
Dec 12, 2011

Jim Gunn (Princeton U)
Lectures on image processing, spectroscopy and spectrophotometry (Part 2)
Dec 12, 2011

Kiyoshi Takeuchi (U Tsukuba)
Confluent A-hypergeometric functionsand rapid decay homology cycles
Dec 13, 2011

Toshiyuki Kobayashi (U Tokyo)
Global Geometry and Analysis on Locally Homogeneous Spaces
Dec 14, 2011

Adam Falkowski (LPT Orsay)
Spinning the Top
Dec 15, 2011

Marja Hanussek (U Bonn)
Probing neutrino masses in the baryon triality cMSSM at $\sqrt{s} = 7$ TeV
Dec 15, 2011

Thomas Flacke (U Michigan & Wurzburg U)
Precision constraints on UED models and implications for the LHC
Dec 16, 2011

Izuru Mori (Shizuoka U)
McKay Type Correspondence for Quantum Projective Spaces (Part 1)
Dec 19, 2011

Izuru Mori (Shizuoka U)
McKay Type Correspondence for Quantum Projective Spaces (Part 2)
Dec 19, 2011

Marcus Werner (IPMU)
Magnification invariants and Lefschetz fixed point theory: Caustics and their classification, global and universal magnification invariants
Dec 19, 2012

Daniel Brattan (Durham U)
Fluid gravity at finite r
Dec 20, 2011

Satoshi Shirai (UC Berkeley)
Model Discrimination at the LHC
Dec 22, 2011

Akihiro Tsuchiya (IPMU)
Lefschetz fixed point theory: Real Lefschetz fixed point formula and intersection theory
Dec 24, 2011

Yasunori Nomura (UC Berkeley)
Quantum Mechanics, Gravity, and the Multiverse
Jan 04, 2012

Hiroyuki Kawamura (KEK)
Parton distribution functions and CDF dijet anomaly
Jan 18, 2012

Marcus Werner (IPMU)
Gravitational Lensing VI : "Magnification invariants and Lefschetz fixed point theory"
Jan 19, 2012

Reina Reyes (Chicago KICP)
Observational constraints on disk galaxy formation from Tully-Fisher relation and weak gravitational lensing
Jan 19, 2012

Misha Verbitsky (IPMU)
Trisymplectic manifolds
Jan 19, 2012

Albrecht Klemm (U Bonn)
Refined holomorphic anomaly equations
Jan 20, 2012

Misha Verbitsky (HSE, National Res U)
Twistor correspondence for hyperkaehler manifolds and the space of instantons
Jan 23, 2012

Shankadeep Chakrabortty (IOP Bhubaneswar)
Dissipative force on an external quark in heavy quark cloud
Jan 24, 2012

Misha Verbitsky (HSE, National Res U)
Trihyperkaehler reduction
Jan 24, 2012

Yingjie Peng (ETH Zurich)
A Global Model for Galaxy Evolution: Simplicity and its Consequences
Jan 25, 2012

Amir Aazami (Duke U)
Gravitational lensing VII : "Magnification invariants and orbifolds"
Jan 26, 2012

Aleksey Cherman (DAMTP Cambridge)
Long-distance properties of baryons in the Sakai-Sugimoto model
Jan 30, 2012

Ben Davison (U Oxford)
Motivic Donaldson Thomas invariants and the Kontsevich Soibelman integration map (Part I)
Jan 30, 2012

Ben Davison (U Oxford)
Motivic Donaldson Thomas invariants and the Kontsevich Soibelman integration map (Part II)
Jan 30, 2012

Philip Argyres (U Cincinnati)
Instantons on $R^3 \times S^1$ and a semi-classical realization of IR renormalons
Jan 31, 2012

Akihiro Tsuchiya (IPMU)
Tensor structure on module category of W_p Vertex Operator Algebras
Jan 31, 2012

Thomas Sotiriou (SISSA)
Black holes in Einstein-aether and Horava-Lifshitz gravity
Feb 01, 2012

Risa Wechsler (KIPAC/Stanford U)
The Galaxy-Dark Matter Connection across Mass and Time
Feb 02, 2012

Ken Intriligator (UCSD)
SCFTs, OPEs, and susy breaking mediation
Feb 03, 2012

Wu-yen Chuang (NTU)
BPS State Wallcrossing and ADHM Sheaf Theory (Part I)
Feb 06, 2012

Wu-yen Chuang (NTU)
BPS State Wallcrossing and ADHM Sheaf Theory (Part II)
Feb 06, 2012

Yuri Prokhorov (Moscow State U)
Subgroups of Cremona groups I
Feb 08, 2012

Mathias Garny (DESY)
Towards a quantum treatment of leptogenesis
Feb 08, 2012

Sergei Blinnikov (ITEP)
Supernova shocks in circumstellar medium: from puzzles to cosmological tools
Feb 08, 2012

Yuri Prokhorov (Moscow State U)
Subgroups of Cremona groups II
Feb 09, 2012

Elena Sorokina (Sternberg Astron Inst)
SN explosions inside extended non-hydrogen circumstellar shells
Feb 09, 2012

Alexander Dolgov (U Ferrara)
Electric and magnetic screening in plasma with charged Bose-Einstein condensate
Feb 09, 2012

Raphael Flauger (IAS/NYU)
Axion Monodromy Inflation and Related Phenomenology
Feb 15, 2012

Tomer Tal (Yale U)
Evolution of the most massive galaxies: a statistical study of SDSS LRGs
Feb 16, 2012

Jeremiah Heller (Bergische U Wuppertal)
Atiyah-Hirzebruch spectral sequences for real varieties
Feb 17, 2012

Yukari Ito (Nagoya U)
McKay correspondence via G-Hilbert schemes
Feb 20, 2012

David Curtin (SUNY Stony Brook)
Spontaneous R-symmetry breaking with Multiple Pseudomoduli
Feb 22, 2012

Alexander Getmanenko (IPMU)
Asymptotic analysis of the function Ei(x)
Feb 23, 2012

Mitsutoshi Fujita (U Washington)
SL(2,R) duality on AdS/BCFT
Feb 24, 2012

Takeo Higuchi (KEK)
The Upcoming Grand Challenge by the Super B-Factory Experiment
Feb 27, 2012

Evgeny Shinder (MPIM)
Mahler measures and pencils of Calabi-Yau varieties
Feb 28, 2012

Alexander A. Voronov (U Minnesota)
Derived fusion tensor product
Mar 01, 2012

Tony Pantev (U Pennsylvania)
Mirror symmetry and mixed Hodge structures
Mar 05, 2012

Pyungwon Ko (KIAS)
A Resolution of the Flavor Problem of Two Higgs Doublet Models with $U(1)_H$ Higgs flavor Symmetry
Mar 07, 2012

Giovanni Morando (U Padova/RIMS)
The Riemann-Hilbert correspondences and sheaves on subanalytic sites
Mar 07, 2012

Shinji Mukohyama (IPMU)
Introduction to Inflationary Universe
Mar 07, 2012

Giorgos Leloudas (U Copenhagen)
Hydrogen-deficient explosions and their environments
Mar 08, 2012

Masashi Hamanaka (Nagoya U)
Soliton Theories and Quasideterminants
Mar 08, 2012

Chan-Y. Park (Caltech)
Ramification Points of Seiberg-Witten Curves
Mar 13, 2012

Christian Schnell (IPMU)
Holonomic D-modules on abelian varieties
Mar 15, 2012

Yefeng Shen (U Michigan)
Landau-Ginzburg/Calabi-Yau correspondence of all genera for elliptic orbifold P^1
Mar 19, 2012

Gleb Arutyunov (U Utrecht)
Towards q-deformations of the Mirror
Mar 21, 2012

Kohei Kamada (DESY)
Spontaneous Cogenesis from the MSSM Flat Direction as the Origin of Matter and Dark Matter
Mar 21, 2012

Joseph Anderson (U Chile)
Core-collapse supernovae as tracers of massive star formation within nearby galaxies
Mar 22, 2012

Noppadol Mekareeya (MPI Munich)
Integer Partitions, 3d Mirror Symmetry and 3d Gauge Theories
Mar 27, 2012

Asantha Cooray (UC Irvine)
Cosmology at Sub-mm Wavelengths: From Herschel to CCAT and Beyond
Mar 27, 2012

Takashi Oka (U Tokyo)
Strong field QFT in condensed matter photoinduced topological phase transition and manybody Schwinger mechanism
Mar 28, 2012

Mircea Voineagu (IPMU)
Filtrations of the singular homology of real varieties
Mar 29, 2012

Alexandre Kozlov (IPMU)
Search for new physics using underground detectors
Mar 30, 2012

9 Conferences

JFY2011

May 30–June 2
Focus Week “Astrophysics of Dark Matter”

July 29
Town Meeting on Future Program on High-Energy Physics in Japan

September 5–10
The 2011 IPMU-YITP School and Workshop on Monte Carlo Tools for LHC

October 31–November 4
Workshop “Curves and Categories in Geometry and Physics”

January 10–20, 2012
The 6th Asian Winter School “Strings, Particles and Cosmology”

January 23–February 3, 2012
Workshop “Testing Gravity with Astrophysical and Cosmological Observations”

February 1, 2012
Mini Workshop “Physics at SuperKEKB”

February 13–22, 2012
Workshop “Growing Black Holes in COSMOS”

February 13–17, 2012
Workshop “Extended Root Systems and Fundamental Groups”

March 2, 2012
Workshop “Particle Physics of the Dark Universe”

March 12–16, 2012
IAU Symposium 279 “Death of Massive Stars: Supernovae and Gamma Ray Bursts”

10 Conference Talks
(including seminars given outside IPMU)

JFY2011

Seminar at IHEP
(2011.04, IHEP China)
Wei Li
Understanding Flat Space holography via Entanglement

Seminar at ITP
(2011.04, ITP China)
Wei Li
Holography and Entanglement of Flat Space

Seminar at Tsinghua Univ
(2011.04, Tsinghua Univ, China)
Wei Li
Holography and Entanglement of Flat Space

Joint Seminar on Number Theory of Laboratoire J.-V. Poncelet and IITP RAS
(2011.04.04, Independent Univ Moscow)
Sergey Galkin
Kummer and Niemeier (Fano and Mathieu - II)

Seminar at Perimeter Inst
(2011.04.05, Ontario, Canada)
Tadashi Takayanagi
Holographic Entanglement Entropy and Its Applications

Seminar at CCPP
(2011.04.12, New York Univ, New York)
Cosimo Bambi
Testing the Kerr black hole hypothesis

Seminar at Sofia Univ
(2011.04.13, Sofia, Bulgaria)
Todor Milanov
The primitive forms of K. Saito

Seminar at Tsukuba Univ
(2011.04.13, Tsukuba)
Alexander Getmanenko
Resurgent analysis of the Witten Laplacian in one dimension

Max-Planck Inst fuer astrophysics seminar
(2011.04.14, Garching, Germany)
Naoki Yoshida
The Collisionless Boltzmann Equation

Seminar at the Univ Mississippi
(2011.04.14, Oxford, Mississippi)
Cosimo Bambi
Testing the Kerr black hole hypothesis

Marx Review, LBNE Science Subcommittee
(2011.04.15, SLAC)
Mark Vagins
Gadolinium, EGADS, and LBNE

Seminar at Zhejiang Univ
(2011.04.15, Hangzhou, China)
Kai Wang
A revisit to top quark forward-backward asymmetries

ITA Univ Heidelberg colloquium
(2011.04.18, Heidelberg)
Naoki Yoshida
Simulating structure formation in the early universe

Seminar at Penn State
(2011.04.18, State College, Pennsylvania)
Cosimo Bambi
Testing the Kerr black hole hypothesis

Seminar at HKU
(2011.04.19, Hong Kong)
Emille E. O. Ishida
Cosmic Explosions: the role of SN in Cosmology

Physics Seminar
(2011.04.19, Hong Kong Univ)
Rafael de Souza
Cosmic Explosions-GRBs

Ludwig-Maximilian-Univ Colloquium
(2011.04.20, Munchen)
Masahiro Takada
Subaru weak lensing study of X-ray luminous clusters

Seminar at Excellence of Cluster
(2011.04.21, Garching, Germany)
Masahiro Takada
Cosmological constraints on neutrino masses

Seminar at CfA
(2011.04.22, Harvard-Smithsonian Center for Astro-physics, Cambridge, Massachusetts)
Cosimo Bambi
Testing the Kerr black hole hypothesis

From Black Holes to Hydrodynamics
(2011.04.27, Univ Victoria, Canada)
Shinji Mukohyama
Dynamical black hole as a holographic dual of Bjorken Flow

American Physical Society Meeting
(2011.04.30, Anaheim, California)
Hirosi Ooguri
Spatially Modulated Phases

Seminar at Univ Washington
(2011.05.03, Seattle)
Mitsutoshi Fujita
Geometric entropy and confinement / deconfinement transition

Seminar at Univ Vienna
(2011.05.04, Vienna)
Sergey Galkin
Fano and Mathieu, Kummer and Niemeier

Seminar at INR Moscow
(2011.05.05, Moscow)
Shinji Mukohyama
Cosmological implications of Horava-Lifshitz gravity

Colloquium at Univ Chicago
(2011.05.06, Chicago)
Toshiyuki Kobayashi
Global Geometry and Analysis on Locally Symmetric Spaces-Beyond the Riemannian Case

Seminar at Texas Cosmology Center
(2011.05.06, Univ Texas Austin)
Tsz Yan Lam
Velocity Probe on Cosmology

Seminar at Univ Vienna
(2011.05.06, Vienna)
Sergey Galkin
Mutations of potentials and shards of the mirror

Number Theory and Physics at the Crossroads (11w5001)
(2011.05.08 - 2011.05.13, Banff, Canada)
Sergey Galkin
Fano and Mathieu

PHENO 2011 symposium
(2011.05.09 - 11, Univ Wisconsin, Madison)
Won Sang Cho
Mass Measurement in Boosted Decay Systems at Hadron Colliders

Colloquium at Univ Tokyo
(2011.05.10, Tokyo)
Masayuki Tanaka
A new method to identify AGNs and the nature of low-luminosity AGNs

Seminar at Max Planck Inst for Astrophysics
(2011.05.10, Garching, Germany)
Emille E. O. Ishida
PCA in Cosmology

Seminar at Cosmology Group of Berkeley
(2011.05.10, Berkeley)
Masahiro Takada
Subaru weak lensing study of X-ray luminous clusters

Colloquium at Kyoto Univ
(2011.05.13, Kyoto)
Masayuki Tanaka
A new method to identify AGNs and the nature of low-luminosity AGNs

Cosmological Non-Gaussianity: Observations Confront Theory Workshop
(2011.05.13 - 15, MCTP, Ann Arbor, Michigan)
Tsz Yan Lam
Peculiar Velocity and primordial non-Gaussianity

The 20th General Meeting of the ILC Physics Working Group
(2011.05.14, KEK)
Shigeki Matsumoto
Studying Very Light Gravitino at the ILC

NSF/CBMS conference on Deformation Theory of Algebras and Modules
(2011.05.16 - 20, NCSU, Raleigh, North Carolina)
Alexander A. Voronov
Quantum Deformation Theory

Three String Generations
(2011.05.16 - 20, IHES, Paris)
Hirosi Ooguri
Comments on Worldsheet Formulation of the Omega Background

Special day on Lie groups
(2011.05.17, Utrecht Univ, the Netherland)
Toshiyuki Kobayashi
Restrictions of Verma Modules to Symmetric Pairs and Some Applications to Differential Geometry

Seminar at Cosmology Group of Berkeley
(2011.05.17, Berkeley)
Tsz Yan Lam
Velocity Probe on Cosmology

NERQUAM Meeting
(2011.05.19, Yale Univ)
Charles Steinhardt
Broad [OIII] Emission in SDSS Quasars

Seminar at Caltech
(2011.05.20, Pasadena)
Tsz Yan Lam
Velocity Probe on Cosmology

Symplectic geometry and related topics
(2011.05.23 - 27, Chengdu, China)
Todor Milanov
Landau-Ginzburg/Calabi-Yau correspondence for simple elliptic singularities

Frascati Workchop 2011: Multifrequency Behaviour of High Energy Cosmic Sources
(2011.05.23 - 28, Vulcano, Italy)
Keiichi Maeda
Core-Collapse Supernova Diversities: From the Weakest to Most Powerful Explosions
Keiichi Maeda
Type Ia Supernova Explosion Mechanism and Implication for Cosmology

Seminar at YITP
(2011.05.25, Kyoto)
Masaomi Tanaka
3D Explosion Geometry of Core-Collapse Supernovae

FTPI Seminar
(2011.05.26, Univ Minnesota)
Emir Gumrukcuoglu
Cosmology in the " UV" limit of Horava-Lifshitz gravity

Essential Dimension and Birational Geometry
(2011.05.27 - 28, Univ Edinburgh)
Sergey Galkin
Cremona and Mathieu

ALMA high-z workshop
(2011.05.31, NAOJ, Mitaka, Japan)
Tomoki Saito
Constraining the dust contents of extended-Lya-selected objects at $z > 3$

Excellence Cluster Universe Colloquium
(2011.05.31, Garching, Gernamy)
Rafael S. de Souza
Constraints on Population III.1 and III.2 Gamma-Ray Burst Rate

Seminar at Tsinghua Univ
(2011.06.02, Beijing)
Todor Milanov
W-constraints for simple singularities

Seminar at Nagoya Univ
(2011.06.02, Nagoya)
Masahiro Takada
Stacked weak lensing and its cosmological applications

RIMS Algebraic Geometry Seminar
(2011.06.02, Kyoto)
Sergey Galkin
Mirrors for Mori and Mukai

Kyoto Univ Algebraic Geometry Seminar
(2011.06.03, Kyoto)
Sergey Galkin
New ways to count up to 15

Stellar and Intermediate Mass Black Holes: Gravitational Physics and Radiation Sources Across the Universe
(2011.06.05 - 26, Aspen, Colorado)
Cosimo Bambi
Testing the Kerr black hole paradigm with electromagnetic radiation

Eleventh Workshop on Non-Perturbative Quantum Chromodynamics
(2011.06.06 - 10, Paris)
Shigeki Sugimoto
QCD and String Theory

KIAS Summer School on Mirror Symmetry: Mirror Constructions for Fano Varieties
(2011.06.06 - 11, Anmyundo, Korea)
Sergey Galkin
Five lectures on Fano Mirrors (Mirror Constructions for Fano Varieties)

Seminar at ICG
(2011.06.07, Univ Portsmouth, UK)
Shinji Mukohyama
Cosmological implications of Horava-Lifshitz gravity

MPE seminar
(2011.06.07, Garching, Germany)
Rafael S. de Souza and Emille E. O. Ishida
Probing cosmic star formation up to z = 9.4 with GRBs

Seminar at Univ Tokyo Komaba
(2011.06.09, Tokyo)
Domenico Orlando
The Gauge-Bethe correspondence: Dualities and Branes

Workshop on the Arithmetic of Function Fields
(2011.06.13 - 17, Imperial College London, UK)
Satoshi Kondo
On the values of Drinfeld modular Beilinson-Kato type elements at supersingular points

Seminar at Univ Heidelberg
(2011.06.15, Heidelberg)
Johanna Knapp
Calabi-Yaus, F-theory, Toric Geometry and beyond

Seminaire de Geometrie Arithmetique Paris-Tokyo
(2011.06.15, Univ Tokyo and IHES)
Tomoyuki Abe
Product formula for p-adic epsilon factors

Seminaire de topologie
(2011.06.17, Institut Fourier, Grenoble)
Toshitake Kohno
La theorie de Morse-Novikov pour arrangements d'hyperplans

Seminar at ASIAA
(2011.06.17, ASIAA, Taiwan)
Hajime Sugai
Subaru's Future - Prime Focus Spectrograph in SuMIRe Project -

Seminar at Utrecht Univ
(2011.06.17, Utrecht, the Netherlands)
Johanna Knapp
Calabi-Yaus, F-theory, Toric Geometry and beyond

Representation Theory XII
(2011.06.19 - 26, Dubrovnik, Croatia)
Toshiyuki Kobayashi
Restrictions of Verma Modules to Symmetric Pairs and Some Applications to Differential Geometry

IX. International Workshop: Lie Theory and Its Applications in Physics
(2011.06.20 - 26, Varna, Bulgaria)
Toshiyuki Kobayashi
Analysis on Minimal Representations

Supernovae and their Host Galaxies
(2011.06.20 - 24, Australian National Maritime Museum, Sydney)
Masaomi Tanaka
Spectropolarimetry of Type Ib/c Supernovae
Keiichi Maeda
Asymmetric SN Ia Explosions and Their Observational Diversities

Seminar at Tohoku univ
(2011.06.20, Sendai) Masayuki Tanaka
A new method to identify AGNs and the nature of low-luminosity AGNs

Supernovae and Their Host Galaxies
(2011.06.20 - 24, Australian National Maritime Museum, Sydney)
Keiichi Maeda
Asymmetric SN Ia Explosions and Their Observational Diversities

35th Johns Hopkins Workshop on AdS/CFT and its Applications
(2011.06.22 - 24, Budapest)
Shigeki Sugimoto
Holographic Description of Hadrons from String Theory

Strings 2011
(2011.06.27 - 07.01, Uppsala, Sweden)
Tadashi Takayanagi
Holographic Entanglement Entropy and its New Developments

Strings and Cats Meeting in Vienna
(2011.06.29 - 07.01, Vienna)
Sergey Galkin
Mirror's symmetry
Sergey Galkin
The ubiquity of reflexivity
Johanna Knapp
Calabi-Yau Manifolds and Dualities from the Gauged Linear Sigma Model

Seminar at IoA, Univ Tokyo
(2011.06.30, Tokyo)
Masayuki Tanaka
A new method to identify AGNs and the nature of low-luminosity AGNs

Seminar at RESCEU, Univ Tokyo
(2011.07.04, Tokyo)
Emir Gumrukcuoglu
Primordial anisotropy as a source of statistical isotropy breaking

Intensive lecture course at Univ Tokyo
(2011.07.07 - 14, Tokyo)
Masahiro Takada
Lecture series "Weak gravitational lensing"

Gravity, Lorentz Violation & Superluminality
(2011.07.11 - 15, INR, Moscow)
Shinji Mukohyama
Cosmology and black hole with ghost condensate

Homological Mirror Symmetry and Category Theory
(2011.07.11 - 15, Split, Croatia)
Sergey Galkin
Non-commutative mirror symmetry

Kiso Observatory Schmidt Symposium 2011
(2011.07.13 - 14, Kiso, Japan)
Masaomi Tanaka
Supernova Survey with KWFC

Intensive Lectures at Hokkaido Univ
(2011.07.13 - 15, Sapporo, Japan)
Tadashi Takayanagi
String Theory

Seminar Sophus Lie
(2011.07.15 - 16, Erlangen, Germany)
Toshiyuki Kobayashi
Multiplicities of Irreducible Representations

Seminar at Perimeter Inst
(2011.07.21, Waterloo, Canada)
Cosimo Bambi
Testing the nature of black hole candidates

Seminaire de topologie
(2011.07.23, Univ de Nantes, France)
Toshitake Kohno
Groupe de monodromie de la theorie des champs conformes

2011 Summer School & Workshop: Weak and Strong Gravitational Lensing
(2011.07.23 - 08.03, NAOC, Beijing)
Masahiro Takada
Lecture 1: WL Systematics
Lecture 2: WL Higher-Order Statistics
Lecture 3: WL Simulations

Branching problems for unitary representations
(2011.07.25 - 29, Max Planck Inst for Mathematics, Bonn)
Toshiyuki Kobayashi
Branching problems for unitary representations–algebraic aspects
Toshiyuki Kobayashi
Branching problems for unitary representations–analytic aspects

Singularity theory and its applications
(2011.07.25 - 31, USTC, Hefei, China)
Toshtiake Kohno
Monodromy groups of conformal field theory
Christian Schnell
Hodge modules on abelian varieties

INT Summer School on Applications of String Theory
(2011.07.25 - 29, Univ Washington, Seattle)
Shigeki Sugimoto
Holographic Mesons and Baryons

4th international conference in Integrable systems and mathematical physics
(2011.07.25 - 29, Wuhan, China)
Todor Milanov
W-constraints for Frobenius manifolds

Seminar at Univ Tokyo
(2011.07.26, Tokyo)
Hajime Sugai
Challenges with Subaru Telescope

Summer School for Young Astronomers
(2011.08.01 - 04, Aichi, Japan)
Keiichi Maeda
Type Ia Supernovae: Current Status and Future Perspectives

Hyperplane arrangements and applications
(2011.08.08 - 12, PIMS, Univ British Columbia, Vancouver)
Toshitake Kohno
Morse-Novikov theory for hyperplane arrangements

Summer Institute 2011
(2011.08.12 - 18, Fuji-Yoshida, Japan)
Shigeki Matsumoto
Dark matter and Baryon asymmetries from sneutrino condensate

Arithmetic and Geometry of K3 surfaces and Calabi-Yau threefolds
(2011.08.16 - 25, Fields Inst, Toronto)
Christian Schnell
The fundamental group is not a derived invariant

Seminar at MCTP
(2011.08.16, Ann Arbor, Michigan)
Shinji Mukohyama
Cosmological implications of Horava-Lifshitz gravity

15th Lomonosov Conference on Elementary Particle Physics
(2011.08.18 - 24, Moscow State Univ)
Alexandre Kozlov
Towards the KamLAND-Zen experiment

String Phenomenology 2011
(2011.08.22 - 26, Univ Wisconsin, Madison)
Taizan Watari
Studying GPD in Holographic QCD

The Fifth Asia-Pacific Conferences on Few-Body problems in Physics 2011
(2011.08.22 - 26, Sungkyunkwan Univ, Seoul)
Shigeki Sugimoto
Hadrons from string theory

Seminar at Kinki Univ
(2011.08.22, Higashi Osaka, Japan)
Mitsutoshi Fujita
Probing AdS Wormholes by Entanglement Entropy

Sendai Symposium
(2011.08.23, Tohoku Univ, Sendai)
Toshitake Kohno
Lecture 1, Homological representations of braid groups and KZ equations
Lecture 2, Quantum representations of mapping class groups

SUSY 2011
(2011.08.27 - 09.02, Fermilab)
Sourav Mandal
Quarks and Leptons as Nambu-Goldstone Fermions Under E7/SO(10)

Lie Groups: Geometry and Analysis (JSPS/DFG seminar)
(2011.09.05 - 10, Paderborn, Germany)
Toshiyuki Kobayashi
Conformally Equivariant Differential Operators and Branching Problems of Verma Modules

Harmonic Analysis, Deformation Quantization, Noncommutative Geometry
(2011.09.05 - 09, Scalea, Italy)
Toshiyuki Kobayashi
Analysis of Minimal Representations

12th International Conference on Topics in Astroparticle and Underground Physics
(2011.09.05 - 09, Munich)
Jing LIU
The XMASS 800kg experiment
Alexandre Kozlov
Status of the KamLAND-Zen experiment

Derived Categories in Algebraic Geometry
(2011.09.05, Steklov Inst, Moscow)
Alexey Bondal
Orthogonal decompositions of sl(n) and mutually unbiased bases

GOPIRA symposium
(2011.09.06 - 7, Kyoto)
Masamune Oguri
Gravitational lens survey with UH88 observation
Masayuki Tanaka
Queue mode observations at Subaru revisited

Large Aperture Millimeter/Submillimeter Telescopes in the ALMA Era
(2011.09.12 - 13, Osaka Prefecture Univ, Osaka)
Masahiro Takada
Subaru HyperSuprimeCam

Workshop on Variation of Cohomology: D-Modules, Monodromy and Arithmetic
(2011.09.14 - 16, Bayreuth, Gernamy)
Sergey Galkin
Apery class and Gamma-conjectures

JPS meeting
(2011.09.16 - 19, Hirosaki Univ, Aomori, Japan)
Tadashi Takayanagi
String Theory and Condensed Matter Physics
Shigeki Matsumoto
Studying very light gravitino at the ILC

Univ Minnesota Topology seminar
(2011.09.19, Minneapolis)
Alexander A. Voronov
Quantum Master Equation and the topology of moduli spaces

Conference on geometric structures in mathematical physics
(2011.09.19 - 26, Golden Sands, Bulgaria)
Sergey Galkin
Generalized K3 automorphisms

Cosmology with X-ray and Sunyaev-Zeldovich Effect Observations of Galaxy Clusters
(2011.09.19 - 22, Huntsville, Alabama)
Masamune Oguri
Halo Profiles from Lensing Observations of Clusters

KIAS-YITP Joint Workshop "String Theory, Holography, and Beyond"
(2011.09.20 - 24, KIAS, Seoul)
Shigeki Sugimoto
On S-duality in non-supersymmetric gauge theory
Tadashi Takayanagi
Holographic Dual of BCFT

Dark matter and new physics
(2011.09.21 - 11.06, KITPC, Beijing)
Shigeki Matsumoto
Dark matter and Baryon asymmetries from sneutrino condensate

Univ Minnesota Topology seminar
(2011.09.26, Minneapolis)
Alexander A. Voronov
QME and the topology of moduli spaces, II: different approaches to Costello's theorem

LCWS11
(2011.09.26 - 30, Granada, Spain)
Shigeki Matsumoto
Testing Little Higgs Mechanism at Future Colliders

The 21st workshop on General Relativity and Gravitation in Japan (JGRG21)
(2011.09.26 - 29, Tohoku Univ, Sendai)
Emir Gumrukcuoglu
Nonlinear perturbations in the GR limit of Horava-Lifshitz gravity

The mathematical society of Japan autumn meeting
(2011.09.28 - 10.01, Shinshu Univ)
Satoshi Kondo
The Riemann-Roch theorem without denominators in motivic homotopy theory

Analysis on Lie Groups
(2011.09.27, MPI Mathematik, Bonn)
Toshiyuki Kobayashi
On real spherical homogeneous spaces

DESY Theory Workshop: Cosmology meets Particle Physics
(2011.09.27 - 30, Hamburg)
Sergey V. Ketov
Inflation and non-minimal scalar-curvature coupling in gravity and super-gravity

Workshop on Infrared Modifications of Gravity
(2011.09.28, ICTP, Trieste)
Shinji Mukohyama
Cosmology and GR limit of Horava-Lifshitz gravity

Seminar at ATC, NAOJ
(2011.09.29, NAOJ, Mitaka, Japan)
Hajime Sugai
Subaru's Future - Prime Focus Spectrograph -

Geometry seminar
(2011.09.29, Univ Edinburgh)
Sergey Galkin
More symmetries of K3

Colloquium at Inst Theo Phys, Rikkyo Univ
(2011.10.04, Tokyo)
Masahiro Takada
Neutrino mass and cosmology

DAGA
(2011.10.06, Univ Padova, Italy)
Tomoyuki Abe
Nearby cycles and vanishing cycles I
Tomoyuki Abe
Nearby cycles and vanishing cycles II

Pre-Planckian Inflation
(2011.10.08, Univ Minnesota)
Shinji Mukohyama
Cosmological implications of Horava-Lifshitz gravity

Topology Seminar
(2011.10.11, Academy of Mathematics and Systems Science, Chinese Academy of Sciences, Beijing)
Changzheng Li
Quantum Pieri rules for complex Grassmannians

Gravity and Lorentz violations
(2011.10.13, Cambridge, UK)
Shinji Mukohyama
Cosmology and GR limit of projectable Horava-Lifshitz gravity

Seminar at Caltech
(2011.10.14, Pasadena, California)
Tadashi Takayanagi
Holographic dual of BCFT

SPICA workshop
(2011.10.18 - 19, Nagoya Univ)
Masayuki Tanaka
Synergy between SPICA, HSC, and PSF

Seminars on Pure Mathematics
(2011.10.19, Hong Kong Univ Sci and Tech)
Changzheng Li
Classical aspects of quantum cohomology of flag varieties

KITP Program: Holographic Duality and Condensed Matter Physics
(2011.10.19, Santa Barbara)
Tadashi Takayanagi
Recent Updates of Holographic Entanglement Entropy

Integrable systems, random matrices, algebraic geometry and geometric invariants
(2011.10.20 - 21, Kyoto Univ)
Satoshi Kondo
On quasi-generic representations of the general linear group of a non-archimedean local field

International Workshop on Geometry and Mathematical Physics
(2011.10.21 - 22, Chinese Univ Hong Kong)
Changzheng Li
Space of lines in G/B

Seminar at CCNY
(2011.10.21, New York)
Shigeki Sugimoto
Holographic Description of Hadrons from String Theory

Southern California Strings Seminar
(2011.10.21, UCLA, Los Angeles)
Tadashi Takayanagi
Holographic Entanglement Entropy and AdS/BCFT

DENET/IAP Conference: The Accelerating Universe
(2011.10.24 - 26, Inst Astrophys de Paris)
Hajime Sugai
Progress in Prime Focus Spectrograph Project
Masamune Oguri
The acceleration of the universe as measured by strong gravitational lensing
Masahiro Takada
Cosmology with SuMIRe HSC/PFS surveys

Seminar at Simons Center for Geometry and Phyics
(2011.10.25, Stony Brook, New York)
Shigeki Sugimoto
Baryons in holographic QCD with G = SU, SO, SP

NAOJ Theoretical Astrophysics Meeting
(2011.10.26 - 28, Yugawara, Japan)
Keiichi Maeda
Progresses in Radiation Transfer Simulations for Supernovae

Seminar at Brown Univ
(2011.10.27, Providence, Rhode Island)
Shigeki Sugimoto
On S-duality in non-supersymmetric gauge theory

Seminar at Lab Astrophys de Marseille
(2011.10.28, Marseille)
Masamune Oguri
Stacked lensing: current measurements and future prospects

Chern Centennial Conference
(2011.10.30 - 11.05, MSRI, Berkeley)
Toshiyuki Kobayashi
Analysis on pseudo-Riemannian locally symmetric spaces

Curves and categories in geometry and physics
(2011.10.31 - 11.04, IPMU)
Christian Schnell
Hodge modules on abelian varieties

Subaru International Conference on Galactic Archaeology
(2011.11.01 - 04, Shuzenji, Japan)
Keiichi Maeda
Nucleosynthesis in Type Ia Supernovae and Observational Constraints

Seminar at YITP
(2011.11.02, Kyoto)
Tadashi Takayanagi
AdS/BCFT

International Workshop on Neutrino Physics, Dark Matter and Gamma Rays
(2011.11.04 - 06, National Chiao Tung Univ, Taiwan)
Shigeki Matsumoto
The GeV-scale dark matter with B-L asymmetry

Lie Groups, Lie Algebras and their Representations
(2011.11.05 - 06, UC Berkeley)
Toshiyuki Kobayashi
Finite Multiplicity Theorems

The 17th International Symposium on Complex Geometry
(2011.11.09 - 12, Sugadaira, Japan)
Changzheng Li
Classical aspects of quantum cohomolgy of flag varieties

The 11th International Symposium on Origin of Matter and Evolution of Galaxies (OMEG11)
(2011.11.14 - 17, RIKEN, Japan)
Keiichi Maeda
Nucleosynthesis in Type Ia Supernovae Driven by Asymmetric Thermonuclear Ignition

Science with HSC AGN survey
(2011.11.16 - 18, Kyoto Univ)
Masayuki Tanaka
A novel method to identify AGNs
Masayuki Tanaka
HSC photometric redshift
Masamune Oguri
Quasar pairs

IPMU Colloquium
(2011.11.17, IPMU)
Tadashi Takayanagi
Introduction to AdS/CFT Correspondence

2nd Workshop on Quarks and Hadrons under Extreme Conditions
(2011.11.17 - 18, Keio Univ, Tokyo)
Shigeki Sugimoto
On S-duality in Non-supersymmetric Gauge Theory

Black Holes: New Horizons
(2011.11.20 - 25, Banff, Canada)
Shinji Mukohyama
Black Holes and GR limit of Horava-Lifshitz gravity

Tuesday Seminar on Topology
(2011.11.22, Univ Tokyo)
Toshitake Kohno
Quantum and homological representations of braid groups

Algebraic geometry seminar
(2011.11.25, Osaka Univ)
Christian Schnell
Hodge modules on abelian varieties

Gravitation Focus Group Meeting & Workshop on Frontiers of Gravitation and Cosmology
(2011.11.30 - 12.01, National Cheng Kung Univ, Taiwan)
Shinji Mukohyama
Alternative Gravity Theories I: Ghost Condensation
Alternative Gravity Theories II: Nonlinear Massive Gravity
Alternative Gravity Theories III: Horava-Lifshitz Gravity

Particle and Cosmology Group Seminar
(2011.12.01, Tohoku Univ, Sendai)
John Kehayias,
Discreet R-Symmetries and Generalized Gaugino Condensation (and Three Generations)

10th Oka Symposium
(2011.12.03 - 04 Nara Women's Univ, Nara, Japan)
Shigeki Sugimoto
Description of hadrons from string theory

Seminar Algebraische Geometrie
(2011.12.05, Freie Univ Berlin)
Sergey Galkin
Inequalities and their extremes

Seminar at Kyusyu Univ
(2011.12.09, Kyusyu Univ, Fukuoka)
Tadashi Takayanagi
AdS/CFT and Entanglement Entropy

Suributsuri-Busseikiso Seminar
(2011.12.10, Gakusyuin Univ, Tokyo)
Tadashi Takayanagi
Geometric Interpretation of Entanglement Entropy via AdS/CFT

Noncommutative Algebraic Geometry and D-branes
(2011.12.12 - 16, Simons Center, Stony Brook, New York)
Johanna Knapp
Phases of non-abelian gauged linear sigma models

International Workshop: Extra Dimensions in the Era of the LHC
(2011.12.12 - 14, Osaka Univ)
Shigeki Matsumoto
Dark matter candidates in the Era of the LHC

SFB647 Colloquium: Raum Zeit Materie
(2011.12.13, Berlin)
Sergey Galkin
Towards the Unified Symmetry

YITP workshop: Entanglement in many body systems and renormalization group
(2011.12.14 - 16, YITP, Kyoto)
Tadashi Takayanagi
AdS/CFT and Entanglement Entropy

Workshop: Extremal Laurent Polynomials and Fano Varieties
(2011.12.14 - 16, Freie Univ Berlin)
Sergey Galkin
Mirror symmetry between Fano varieties and cluster varieties
Sergey Galkin
An introduction to extremal Laurent polynomials

IPMU Colloquium
(2011.12.14, IPMU)
Toshiyuki Kobayashi
Global Geometry and Analysis on Locally Homogeneous Spaces

Elastic and Diffractive Scattering
(2011.12.16 - 20, Qui Nhon, Vietnam)
Taizan Watari
Studying GPD in Gravity Dual

Particle Cosmology
(2011.12.16 - 18, Nagoya)
Masamune Oguri
Testing Lambda CDM with Cluster Lensing
Masahiro Takada
SuMIRe HSC/PFS Project

Cluster workshop
(2011.12.18 - 19, Hakone, Japan)
Masayuki Tanaka
HSC+PFS+eROSITA
Masamune Oguri
Measuring cluster mass distributions with gravitational lensing

Algebraic geometry conference
(2011.12.19 - 23, Chulalongkorn univ, Bangkok)
Sergey Galkin
Homologically minimal fourfolds

Mathematics Seminar
(2011.12.20, Ajou Univ, Korea)
Changzheng Li
Classical and Quantum Schubert Calculus

Xth International Conference on Gravitation, Astrophysics and Cosmology
(2011.12.21, Qui Nhon, Vietnam)
Shinji Mukohyama
Cosmology and GR limit of Horava-Lifshitz gravity

Supernova Explosions and Numerical Simulations
(2011.12.26 - 28, YITP, Kyoto)
Keiichi Maeda
Radiaton Transfer in Supernovae: Recent Progress

Cohomology of Arithmetic Groups (on the occasion of Prof M.S. Raghunathan turning 70 during the year)
(2011.12.28 - 31, TIFR, Mumbai)
Toshiyuki Kobayashi
Discrete Spectrum for Non-Riemannian Locally Symmetric Spaces

Conformally Equivariant Differential Operators and Branching Problems of Verma Modules. Workshop on Geometric Analysis on Euclidean and Homogeneous Spaces (in honor of Sigurdur Helgason's 85th birthday)
(2012.01.08 - 09, Tufts Univ, Massachusetts)
Toshiyuki Kobayashi
Conformally Equivariant Differential Operators and Branching Problems of Verma Modules

East Asian School of Knots and Links
(2012.01.09 - 12, KAIST, Daejon, Korea)
Toshitake Kohno
Quantum and homological representations of braid groups

Lie Groups: Structure, Actions and Representations (in honor of Prof Joe Wolf's 75th birthday)
(2012.01.11 - 2012.01.14, Ruhrd Univ, Bochum, Germany)
Toshiyuki Kobayashi
Stable Spectrum for non-Riemannian Locally Symmetric Spaces

Seminar at Kyoto univ
(2012.01.11, Kyoto)
Shigeki Matsumoto
Recent Progress on Light Dark Matter Scenario

Seminar at Ochanomizu Univ
(2012.01.12, Tokyo)
Tadashi Takayanagi
AdS/CFT from condensed matter viewpoints

The 4th Series of WPI Joint Seminar in AIMR
(2012.01.20, WPI-AIMR, Tohoku Univ, Sendai)
Tadashi Takayanagi
Condensed Matter as Black Holes in String Theory

Testing Gravity with Astrophysical and Cosmological Observations
(2012.01.23 - 02.03, IPMU)
Emir Gumrukcuoglu
Nonlinear perturbations in the GR limit of HL cosmology

Seminar at Univ Tokyo Komaba
(2012.01.26, Komaba, Tokyo)
Shigeki Matsumoto
Present status of dark matter phenomenology

International School on TQFT, Langlands and Mirror Symmetry
(2012.01.31 - 02.04, Huatulco, Mexico)
Sergey Galkin
Homologically minimal fourfolds

Seminar at IoA, Univ Tokyo
(2012.02.02, Tokyo)
Hajime Sugai
Two Instruments for Subaru Telescope

The CERN Winter School on Supergravity, Strings, and Gauge Theory
(2012.02.06 - 10, CERN)
Tadashi Takayanagi
Entanglement Entropy and AdS/CFT

First LeCosPA Symposium: Towards Ultimate Understanding of the Universe
(2012.02.06 - 09, LeCosPA, NTU, Taiwan)
Emir Gumrukcuoglu
Self-accelerating Universe in Nonlinear Massive Gravity

The 5th GRB Workshop
(2012.02.06 - 08, Tokyo Inst Tech, Tokyo)
Keiichi Maeda
GRB-SN Connection

Seminar at JPL
(2012.02.06, JPL, Pasadena)
Masahiro Takada
SuMIRe HSC/PFS projects

Geometry/Topology Seminar
(2012.02.08, Univ Southern Cal, Los Angeles)
Changzheng Li
Classical aspects of the quantum cohomology of flag varieties

Geometry Seminar
(2012.02.09, UCLA, Los Angeles)
Changzheng Li
Classical aspects of quantum cohomology of flag varieties

Representation theory on p-adic algebraic groups
(2012.02.12 - 17, Yokohama National Univ)
Satoshi Kondo
L-factor and epsilon factor

Growing black holes in COSMOS
(2012.02.13 - 22, IPMU)
Masayuki Tanaka
A new method to identify AGNs and the nature of low-luminosity AGNs

Seminar at Amsterdam Univ
(2012.02.13, Amsterdam)
Tadashi Takayanagi
Holographic Fermi Surfaces and Entanglement Entropy

The 7th Kagoshima Algebra-Analysis-Geometry Seminar
(2012.02.14 - 17, Kagoshima Univ, Kagoshima, Japan)
Christian Schnell
Cohomology of holonomic and constructible complexes on abelian varieties

Seminar at IIA
(2012.02.17, Indian Inst Astrophys, Bangalore, India)
Keiichi Maeda
Studying Nearby Type Ia Supernovae and Future Cosmological Applications

Workshop "Integralble systems, random matrices, algebraic geometry and geometric invariants"
(2012.02.20 - 22, Steklov Inst, Moscow)
Satoshi Kondo
Mirahoric representations and the local L-factor

Algebraic Geometry Seminar
(2012.02.20, Texas A&M Univ, College Station, Texas)
Changzheng Li
Quantum Pieri rules for tautological subbundles over symplectic Grassmannians

Workshop on Particle physics & cosmology in Toyama
(2012.02.20 - 21, Toyama univ, Japan)
Shigeki Matsumoto
The GeV-scale dark matter with B-L asymmetry

ILC detector meeting
(2012.02.24, KEK)
Shigeki Matsumoto
New Physics beyond the SM in light of recent LHC data

Subaru Users Meeting FY2011
(2012.02.28 - 03.01, NAOJ, Mitaka)
Masamune Oguri
Precise measurement of dark matter distribution with strong and weak gravitational lensing
Masahiro Takada
PFS Science WG activities
Masayuki Tanaka
Deep near-IR spectroscopy of high-z groups of galaxies

Asia Pacific School/Workshop on Cosmology and Gravitation
(2012.03.01 - 04, YITP, Kyoto)
A. Emir Gumrukcuoglu
Cosmological perturbations in nonlinear massive gravity

Shinshyu Winter School
(2012.03.02 - 05, Shiga, Nagano, Japan)
Shigeki Matsumoto
Lecture on Dark Matter Phenomenology

KEK Theory Workshop 2012
(2012.03.05 - 07, KEK)
Tadashi Takayanagi
Structure of Spacetime and Quantum Entanglement

Workshop on algebraic geometry and the theory of motives
(2012.03.08 - 09, Tohoku Univ)
Satoshi Kondo
On the rational K2 of Drinfeld modular curves

Branching Laws
(2012.03.11 - 31, Inst Math Sci, Singapore)
Toshiyuki Kobayashi
Finite Multiplicity Theorems and Real Spherical Varieties

IAU symposium 279: Death of Massive Stars
(2012.03.12 - 16, Nikko, Japan)
Keiichi Maeda
Asymmetries in Supernovae

Low Dimensional Topology and Number Theory IV
(2012.03.12 - 15, Kyushu Univ)
Toshitake Kohno
Quantum and homological representations of braid groups

Fables Geometry
(2012.03.19 - 23, Univ Geneva, Switzerland)
Sergey Galkin
Reflecting Fano, 1: work of Fano, Iskovskikh, Mori, Mukai, Shokurov, ...
Reflecting Fano, 2: A-model
Reflecting Fano, 3: mirror symmetry

New Physics beyond the Standard Model
(2012.03.19 - 23, YITP, U. of Kyoto)
Shigeki Matsumoto
Summary on non-SUSY scenarios

Motivic structures on quantum cohomology: progress reports
(2012.03.23 - 28, MPI, Bonn)
Duco van Straten, Hiroshi Iritani, Sergey Galkin
Gamma conjectures and recovering topology, 3: Conjecture O

JPS annual meeting
(2012.03.24, Kwansei Gakuin Univ)
Masahiro Takada
Exploring dark energy with SuMIRe HSC/PFS projects
Shigeki Matsumoto
The GeV-scale dark matter with B-L asymmetry

Algebra seminar
(2012.03.28, Michigan State Univ)
Changzheng Li
Classical aspects of quantum cohomology of flag varieties

Hodge theoretic aspects of mirror symmetry
(2012.03.29 - 31, Johannes-Gutenberg-Univ, Mainz)
Sergey Galkin
Exceptional non-commutative Hodge structures and Diophantine approximations

11 Visitors

(This list includes principal investigators and affiliate staff.)

JFY2011

Serguey Petcov, SISSA (Italy), Particle Theory 03/01-04/18

Ken Mawatari, Tohoku U (Japan) Astrophysics 03/23-04/03

Wataru Kasai, Tohoku U (Japan), Astronomy 03/25-04/20

Eibun Senaha, NCTS (Taiwan), High Energy Physics 03/29-04/04

Raphael Ponge, U Tokyo (Japan), Mathematics 04/01-08/31

Norimi Yokozaki, U Tokyo (Japan), Particle Theory 04/06-04/06

Masahiro Futaki, U Tokyo (Japan), Mathematics 04/06-04/06

Kazuo Hosomichi, Kyoto U (Japan), Particle Theory 04/11-04/13

Keisuke Izumi, U Tokyo (Japan), Cosmology 04/11-04/11, 04/18-04/27

Yoshitaka Hatta, U Tsukuba (Japan), Particle Theory 04/20-04/20

Motoko Kotani, Tohoku U (Japan), Mathematics 04/21-04/22

Tadashi Ishibe, Hiroshima U (Japan), Mathematics 04/23-04/24

Kazunobu Maruyoshi, SISSA (Italy), Particle Theory 04/25-04/28

Tadashi Ishibe, Hiroshima U (Japan), Mathematics 04/30-05/01

Brice Menard, CITA (Canada), Astrophysics 05/05-08/12

Massimo Bianchi, INFN (Italy), String Theory 05/10-05/20

Gustavo Dopke, Heidelberg U (Germany), Astronomy 05/11-05/19

Tadashi Ishibe, Hiroshima U (Japan), Mathematics 05/14-05/15

Sanshiro Enomoto, U Washington (USA), Neutrino Physics 05/16-05/25

Takahiro Tanaka, Kyoto U (Japan), Cosmology 05/17-05/18

Yasunobu Uchiyama, SLAC (USA), Astroparticle Physics 05/18-05/18

Tadashi Ishibe, Hiroshima U (Japan), Mathematics 05/21-05/24

Debajyoti Choudhury, U Delhi (India), Particle Theory 05/21-06/21

Kentaroh Yoshida, Kyoto U (Japan), Particle Theory 05/23-05/27

Io Kawaguchi, Kyoto U (Japan), Particle Theory 05/23-05/27

Adam Amara, ETH Zurich (Switzerland), Cosmology 05/24-05/28

Masao Sako, U Pennsylvania (USA), Cosmology 05/24-05/25

Junichi Tanaka, U Tokyo ICEPP (Japan), High Energy Physics 05/25-05/25

Edwin Turner, Princeton U (USA), Astrophysics 05/26-06/30

Sachiko Tsuruta, Montana State U (USA), Astrophysics 05/27-06/01

Jacob Bourjaily, Princeton U (USA), Particle Theory 05/28-06/05

Alexander Kusenko, UCLA (USA), Particle Theory 05/29-06/04

Graciela Gelmini, UCLA (USA), Astroparticle Physics 05/29-06/02

Kim Griest, UC San Diego (USA), Astroparticle Physics 05/29-06/04

Michael Loewenstein, NASA/GSFC (USA), Astronomy 05/29-06/04

Fuminobu Takahashi, Tohoku U (Japan), Particle Theory 05/29-06/02

Douglas Spolyar, Fermilab (USA), Astroparticle Physics 05/29-06/04

Masahito Yamazaki, Princeton U (USA), String Theory 05/29-06/01

Shiu-Hang (Herman) Lee, Kyoto U (Japan), Astrophysics 05/29-06/04

Marcos Valdes, SNS Pisa (Italy), Astrophysics 05/29-06/30

Jan de Boer, U Amsterdam (Netherlands), String Theory 05/30-06/01

Ian-Woo Kim, U Michigan (USA), Particle Theory 05/30-06/01

Shingo Hirano, U Tokyo (Japan), Astronomy 05/30-06/02

Masahiro Ibe, U Tokyo ICRR (Japan), Particle Theory 05/30-06/02

Motohiko Kusakabe, U Tokyo ICRR (Japan), Particle Theory 05/30-06/02

Ken'ichi Saikawa, U Tokyo ICRR (Japan), Particle Theory 05/30-06/02

Toshifumi Yamada, KEK (Japan), Particle Theory 05/30-06/02

Yasuhiro Yamamoto, KEK (Japan), Particle Theory 05/30-06/02

Masato Yamanaka, KEK (Japan), Particle Theory 05/30-06/02

Sachiko Kuroyanagi, U Tokyo ICRR (Japan), Cosmology 05/30-06/02

Satoshi Shirai, KEK (Japan), Particle Theory 05/30-06/02

Katsushi Arisaka, UCLA (USA), High Energy Physics 05/31-06/01

Takahiro Sumi, Osaka U (Japan), Astroparticle Physics 05/31-06/02

Kazunori Kohri, KEK (Japan), Cosmology 05/31-06/01

Eiichiro Komatsu, U Texas (USA), Cosmology 06/01-07/31

Alexander Vikman, CERN (Switzerland), Cosmology 06/01-06/09

David Spergel, Princeton U (USA), Cosmology 06/04-06/18

Murray Brightman, MPI for Extraterrestrial Phys (Germany), Astrophysics 06/06-06/08

Daisuke Nagai, Yale U (USA), Cosmology 06/07-06/09

Michael Smy, UC Irvine (USA), Neutrino Physics 06/08-06/18

Hiroshi Isono, TIFR (India), String Theory 06/09-06/09

Shogo Masaki, Nagoya U (Japan), Cosmology 06/09-06/10

Sachiko Tsuruta, Montana State U (USA), Astrophysics 06/13-06/22

Yu Nakayama, Caltech (USA), String Theory 06/13-06/20

Brian Fujikawa, LBL (USA), Neutrino Physics 06/16-07/12

Karsten Heeger, U Wisconsin Madison (USA), Neutrino Physics 06/17-06/25

Martin Schnabl, Inst Phys AS CR (Czech), String Theory 06/20-06/20

Yoshio Sano, National Inst Informatics (Japan), Mathematics 06/21-06/21

Masahito Ueda, U Tokyo (Japan), Condensed Matter Phys 06/22-06/22

Stuart Freedman, UC Berkeley (USA), Neutrino Physics 06/24-08/02

Anzhong Wang, Baylor U (USA), Cosmology 06/26-07/24

Jiro Soda, Kyoto U (Japan), Cosmology 06/28-06/29

Morimitsu Tanimoto, Niigata U (Japan), Particle Theory 06/29-06/30

Yusuke Shimizu, Niigata U (Japan), Particle Theory 06/29-06/30

Takamitsu Tanaka, Columbia U (USA), Astrophysics 07/04-07/07

Ta-Shen Tai, RIKEN (Japan), Particle Theory 07/04-07/06

Yoichi Kazama, U Tokyo (Japan), Particle Theory 07/05-07/05

Kimitake Hayasaki, Kyoto U (Japan), Astrophysics 07/07-07/07

Yoichi Ohyama, ASIAA (Taiwan), Astronomy 07/07-07/13

Shiang-Yu Wang, ASIAA (Taiwan), Astronomy 07/10-07/12

Paul Ho, ASIAA (Taiwan), Astronomy 07/10-07/14

Hung-Hsu Ling, ASIAA (Taiwan), Astronomy 07/10-07/14

James Gunn, Princeton U (USA), Astrophysics 07/10-07/13

Wako Aoki, NAOJ (Japan), Astronomy 07/11-07/13

Toshihiro Kawaguchi, U Tsukuba (Japan), Astrophysics 07/11-07/13

Richard Ellis, Caltech (USA), Astronomy 07/11-07/13

Michael Seiffert, NASA JPL/Caltech (USA), Astronomy 07/11-07/13

Olivier Le Fevre, LAM (France), Astronomy 07/11-07/13

Jean-Paul Kneib, OAMP (France), Astronomy 07/11-07/13

Laerte Sodre, U Sao Paulo (Brazil), Astronomy 07/11-07/13

Nobuo Arimoto, NAOJ (Japan), Astronomy 07/11-07/13

Hideki Takami, NAOJ Hawaii (USA), Astronomy 07/11-07/13

Yasushi Suto, U Tokyo ICEPP (Japan), Cosmology 07/11-07/13

Tohru Nagao, Kyoto U (Japan), Astronomy 07/11-07/13

Issha Kayo, Toho U (Japan), Astrophysics 07/11-07/13

Masahiko Kimura, NAOJ Hawaii (USA), Astronomy 07/11-07/13

Kimihiko Nakajima, U Tokyo (Japan), Astronomy 07/11-07/13

Masami Ouchi, U Tokyo ICRR (Japan), Astronomy 07/11-07/13

Naruhisa Takato, NAOJ Hawaii (USA), Astronomy 07/11-07/13

Akitoshi Ueda, NAOJ (Japan), Astronomy 07/11-07/13

Yosuke Imamura, Titech (Japan), String Theory 07/12-07/12

Clifford Cheung, UC Berkeley (USA), Particle Theory 07/16-07/23

Tadashi Ishibe, Hiroshima U (Japan), Mathematics 07/22-07/23

David R. Morrison, UC Santa Barbara (USA), Mathematics 07/24-07/27

John Ellis, CERN (Switzerland), Particle Theory 07/24-07/27

Roberto Peccei, UCLA (USA), Particle Theory 07/25-07/27

Steven Kahn, SLAC (USA), Cosmology 07/25-07/27

Yuichiro Nakai, Kyoto U (Japan), High Energy Physics 07/26-08/16

Makoto Gonokami, U Tokyo QPEC (Japan), Quantum Optics 07/26-07/26

Yoichi Tsuchiya, U Tokyo (Japan), Particle Theory 07/27-08/12

Jean Coupon, Tohoku U (Japan), Astronomy 07/28-07/30

Tatsuma Nishioka, Princeton U (USA), String Theory 07/31-08/21

Misao Sasaki, Kyoto U (Japan), Cosmology 08/01-08/05

Reiko Nakajima, IEU Ewha Womans U (Korea), Astrophysics 08/02-08/26

Hung-Hsu Ling, ASIAA (Taiwan), Astronomy 08/02-09/23

Jock McOrist, U Cambridge (UK), String Theory 08/12-08/16

Seong Chan Park, Chonnam National U (Korea), Particle Theory 08/12-08/26

Christopher Walter, Duke U (USA), Neutrino Physics 08/13-08/26

Ilya Zhdanovskiy, MITP (Russia), Mathematics 08/13-09/01

Suet Ying Mak, U Southern Cal (USA), Cosmology 08/14-08/17

Thomas Greif, MPI Astrophys (Germany), Astrophysics 08/20-09/09

Kathryn Zurek, U Michigan (USA), Particle Theory 08/21-08/24

Kenichi Konishi, U Pisa (Italy), Particle Theory 08/22-09/02

Yasuaki Hikida, Keio U (Japan), String Theory 08/22-09/02

Kate Scholberg, Duke U (USA), Neutrino Physics 08/25-08/31

Jaewon Song, Caltech (USA), String Theory 08/26-09/09

Jason Rhodes, NASA JPL/Caltech (USA), Astrophysics 08/31-09/21

Olivier Dore, NASA JPL/Caltech (USA), Cosmology 08/31-09/24

Hendrik Hoeth, IPPP Durham U (USA), Particle Theory 09/02-09/12

Bryan Webber, U Cambridge (UK), Particle Theory 09/03-09/30

Rikkert Frederix, UZH (Switzerland), Particle Theory 09/03-09/10

Andy Buckley, U Edinburgh (UK), High Energy Physics 09/03-09/10

Shuo Yang, Peking U (China), High Energy Physics 09/03-09/11

Yoichi Ninomiya, U Tokyo ICEPP (Japan), High Energy Physics 09/03-09/11

Pavel Ruzicka, Inst Phys AS CR (Czech), High Energy Physics 09/03-09/12

Gavin Salam, CERN (Switzerland), Particle Theory 09/04-09/07

Torbjoern Sjoestrand, Lund U (Sweden), Particle Theory 09/04-09/10

Claude Duhr, Durham U (UK), Particle Theory 09/04-09/09

Sanshiro Enomoto, U Washington (USA), Neutrino Physics 09/04-09/07

Clara Hernandez, Inst Fisica Teorica UAM/CSIC (Italy), High Energy Physics 09/04-09/11

Satyanarayan Mukhopadhyay, Harish-Chandra Res Inst (India), High Energy Physics 09/04-09/11

Subhadeep Mondal, Indian Assoc Cultivation Science (India), High Energy Physics 09/04-09/10

Takaaki Nomura, NCU (Taiwan), Particle Theory 09/04-09/11

Yi-Fan Lin, NCU (Taiwan), High Energy Physics 09/04-09/09

Raman Khurana, Saha Inst (India), High Energy Physics 09/04-09/11

Bhawna Gomber, Saha Inst (India), High Energy Physics 09/04-09/11

Warintorn Sreethawong, U Oklahoma (USA), Particle Theory 09/04-09/17

Mukesh Kumar, U Delhi (India), Particle Theory 09/04-09/11

Rashidul Islam, U Delhi (India), High Energy Physics 09/04-09/11

Fuminobu Takahashi, Tohoku U (Japan), Particle Theory 09/04-09/11

Kazuya Mochizuki, U Tsukuba (Japan), High Energy Physics 09/04-09/10

Yoshitaro Takaesu, KEK (Japan), Particle Theory 09/04-09/10

Yuto Komori, U Tokyo (Japan), High Energy Physics 09/04-09/10

Masaki Asano, U Tokyo ICRR (Japan), Particle Theory 09/04-09/10

Oliver Hall, IPPP Durham U (USA), High Energy Physics 09/04-09/11

Naotoshi Okamura, U Yamanashi (Japan), High Energy Physics 09/04-09/10

Yao Qin, Peking U (China), High Energy Physics 09/04-09/10

Namseok Yoo, Konkuk U (Korea), High Energy Physics 09/04-09/11

Grisha Kirilin, KEK (Japan), High Energy Physics 09/04-09/10

Linlin Zhang, Peking U (China), High Energy Physics 09/04-09/11

Ken-ichi Okumura, Kyushu U (Japan), Particle Theory 09/04-09/10

Soyoung Shim, Konkuk U (Korea), High Energy Physics 09/04-09/11

Frank Krauss, IPPP Durham U (USA), Particle Theory 09/05-09/10

David Grellscheid, Durham U (UK), Particle Theory 09/05-09/10

Kentaro Mawatari, Vrije Univ Brussels (Belgium), Particle Theory 09/05-09/10

Manami Hashi, U Tokyo (Japan), Particle Theory 09/05-09/08

Junya Nakamura, KEK (Japan), High Energy Physics 09/05-09/10

Noppadol Mekareeya, MPI Phys (Germany), String Theory 09/05-09/09

Shin Nakamura, Kyoto U (Japan), Particle Theory 09/06-09/08

Serguey Petcov, SISSA (Italy), Particle Theory 09/08-09/24

Tristan Smith, UC Berkeley (USA), Cosmology 09/08-2012/02/01

Daxian Su, CERN (Switzerland), High Energy Physics 09/08-09/11

Priyotosh Bandyopadhyay, KIAS (Korea), Particle Theory 09/11-09/17

Marcos Valdes, SNS Pisa (Italy), Astrophysics 09/14-09/23

Tzu Ching Chang, ASIAA (Taiwan), Astronomy 09/20-09/22

Marco Peloso, U Minnesota (USA), Particle Theory 09/21-09/26

Sudeep Das, LBL (USA), Cosmology 09/22-09/30

Michael Strauss, Princeton U (USA), Astronomy 09/24-10/03

Robert Lupton, Princeton U (USA), Cosmology 09/24-10/03

Steven Bickerton, Princeton U (USA), Astronomy 09/26-11/18

Robert Myers, Perimeter Inst (Canada), String Theory 09/27-09/29

Richard Ellis, Caltech (USA), Astronomy 10/02-10/08

Hung-Hsu Ling, ASIAA (Taiwan), Astronomy 10/02-10/18

Chiaki Hikage, Princeton U (USA), Astronomy 10/03-10/07

Alexander Kusenko, UCLA (USA), Particle Theory 10/04-12/01

Takeshi Morita, U Crete (Greece), String Theory 10/04-10/04

Shin'ichiro Ando, U Amsterdam (Netherlands), Cosmology 10/10-10/12

Jean Coupon, Tohoku U (Japan), Astronomy 10/11-10/12

Peter Behroozi, Stanford U (USA), Cosmology 10/12-10/14

Issha Kayo, Toho U (Japan), Astrophysics 10/12-10/12

Norihiro Iizuka, CERN (Switzerland), String Theory 10/13-10/15

Bunyo Hatsukade, Kyoto U (Japan), Astronomy 10/13-10/14

Edwin Turner, Princeton U (USA), Astrophysics 10/14-11/02

Tilman Troster, ETH Zurich (Switzerland), String Theory 10/17-2012/03/24

Amanda Bauer, Australian Astron Obs (Australia), Astronomy 10/20-10/20

Masahiro Komatsu, Nagoya U (Japan), Particle Theory 10/20-10/20

Tadashi Ishibe, Hiroshima U (Japan), Mathematics 10/20-10/22

Patrick Decowski, Nikhef (Netherlands), High Energy Physics 10/24-11/01

Kaoru Ono, Hokkaido U (Japan), Mathematics 10/24-10/24

Peng Zhao, U Cambridge (UK), Particle Theory 10/24-10/30

Noriyuki Abe, Hokkaido U (Japan), Mathematics 10/26-10/28

Johannes Andersen, U Copenhagen (Denmark), Astrophysics 10/27-10/29

Hung-Hsu Ling, ASIAA (Taiwan), Astronomy 10/28-11/14

Anton Mellit, U Cologne (Germany), Mathematics 10/29-11/05

Pawel Kampczyk, ETH Zurich (Switzerland), Cosmology 10/29-11/05

Emanuel Scheidegger, U Freiburg (Germany), Mathematics 10/29-11/06

Vadim Vologodskiy, U Oregon (USA), Mathematics 10/30-11/06

Bumsig Kim, KIAS (Korea), Mathematics 10/30-11/05

Ionut Ciocan-Fontanine, U Minnesota (USA), Mathematics 10/30-11/04

David Favero, U Vienna (Austria), Mathematics 10/30-11/08

Colin Diemer, U Miami (USA), Mathematics 10/30-11/08

Seo Ree Park, Seoul Natl U (Korea), Mathematics 10/30-11/07

Scott Tremaine, Princeton U (USA), Astrophysics 10/31-11/11

Alexander Efimov, Steklov Inst (Russia), Mathematics 10/31-11/14

Gabriel Kerr, U Miami (USA), Mathematics 10/31-11/04

Kana Ando, Chiba U (Japan), Mathematics 10/31-11/04

Hiroshi Iritani, Kyoto U (Japan), Mathematics 11/01-11/04

Helge Ruddat, U Mainz (Germany), Mathematics 11/01-11/05

Alexey Rosly, ITEP (Russia), Mathematics 11/01-11/30

Issha Kayo, Toho U (Japan), Astrophysics 11/01-11/01

Ludmil Katzarkov, U Vienna (Austria), Mathematics 11/02-11/07

Paolo Cascini, Imperial Coll London (UK), Mathematics 11/02-11/06

Devendra Kumar Sahu, IIAP (France), Astronomy 11/03-11/29

Konstantin Shramov, Steklov Inst (Russia), Mathematics 11/05-11/15

Ivan Cheltsov, U Edinburgh (UK), Mathematics 11/05-11/10

Jean-Philippe Uzan, IAP (France), Cosmology 11/07-11/18

Brian Fujikawa, LBL (USA), Neutrino Physics 11/07-11/14

Valeri Frolov, U Alberta (Canada), Cosmology 11/07-11/10

Issha Kayo, Toho U (Japan), Astrophysics 11/08-11/08

Yen-Ting Lin, ASIAA (Taiwan), Astrophysics 11/09-11/11

Tadashi Ishibe, Hiroshima U (Japan), Mathematics 11/11-11/13

Claire Lackner, Princeton U (USA), Astrophysics 11/11-11/18

Fedor Smirnov, LPTHE (France), Mathematics 11/13-11/20

Timothy Logvinenko, U Warwick (UK), Mathematics 11/13-11/17

Richard Hill, U Chicago (USA), Particle Theory 11/13-11/15

Jun Zhang, U Texas (USA), Cosmology 11/13-11/19

Jens Chluba, U Toronto (Canada), Astronomy 11/13-11/22

Michael Smy, UC Irvine (USA), Neutrino Physics 11/14-11/20

Adam Burrows, Princeton U (USA), Astronomy 11/15-11/15

Yongzhong Qian, U Minnesota (USA), Astronomy 11/15-11/15

James Lattimer, SUNY Stony Brook (USA), Astronomy 11/15-11/15

Alexis Finoguenov, MPI Extraterrestrial Phys (Germany), Cosmology 11/16-11/25

Francesco Miniati, ETH Zurich (Switzerland), Astrophysics 11/16-11/24

Christopher Walter, Duke U (USA), Neutrino Physics 11/16-11/20

Dmitri Panov, King's Coll London (UK), Mathematics 11/17-11/30

Shinya Wanajo, Tech U Munich (Germany), Astronomy 11/18-12/02

Stuart Sim, Australian Natl U (Australia), Astronomy 11/19-11/30

Sharon Rapoport, Australian Natl U (Australia), Cosmology 11/19-11/30

Yanki Lekili, Kings Coll Cambridge (UK), Mathematics 11/19-11/19

Hung-Hsu Ling, ASIAA (Taiwan), Astronomy 11/21-11/30

James Gunn, Princeton U (USA), Astrophysics 11/21-12/15

Akira Shudo, Tokyo Met U (Japan), Mathematics 11/22-11/22

Omar Benvenuto, National Univ La Plata (Spain), Astrophysics 11/23-12/11

Masayuki Yamanaka, Hiroshima U (Japan), Astronomy 11/23-11/24

Hiroyuki Hirashita, ASIAA (Taiwan), Astronomy 11/24-11/24

Brice Menard, Johns Hopkins U (USA), Astrophysics 11/28-12/09

Jean Coupon, Tohoku U (Japan), Astronomy 11/28-11/30

Shinji Hirano, Nagoya U (Japan), String Theory 11/29-11/29

Alexei Smirnov, ICTP (Italy), Particle Theory 11/30-11/30

Andrei Pajitnov, U Nantes (France), Mathematics 12/01-12/01

Issha Kayo, Toho U (Japan), Astrophysics /12/02-12/02

Tadashi Ishibe, Hiroshima U (Japan), Mathematics 12/02-12/04

Christopher Michael Hirata, Caltech (USA), Astronomy 12/04-12/09

Fanky Wong, Chinese Univ Hong Kong (Hong Kong), Cosmology 12/04-12/10

Yasuaki Hikida, Keio U (Japan), String Theory 12/06-12/06

Naoyuki Tamura, NAOJ Hawaii (USA), Astronomy 12/07-12/08

Shin Mineshige, Kyoto U (Japan), Astrophysics 12/09-12/09

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Yuri Efremenko, U Tennessee (USA), Neutrino Physics 12/12-12/21

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Kiyoshi Takeuchi, U Tsukuba (Japan), Mathematics 12/13-12/13

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James Gunn, Princeton U (USA), Astrophysics 03/18-03/21

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Hung-Hsu Ling, ASIAA (Taiwan), Astronomy 03/18-03/24

Yoichi Ohyama, ASIAA (Taiwan), Astronomy 03/18-03/23

Robert Lupton, Princeton U (USA), Cosmology 03/18-03/25

Gleb Arutyunov, Utrecht U (Netherlands), String Theory 03/19-03/26

Satoshi Miyazaki, NAOJ (Japan), Astronomy 03/19-03/21

Tomonori Usuda, NAOJ Hawaii (USA), Astronomy 03/19-03/20

Sean Couch, U Chicago (USA), Astrophysics 03/19-03/19

Antonio De Oliveira, LNA (Brazil), Astronomy 03/19-03/21

Tania Pereira Dominici, LNA (Brazil), Astronomy 03/19-03/21

Laerte Sodre, U Sao Paulo (Brazil), Astronomy 03/19-03/21

Markus Friedl, HEPHY (Austria), High Energy Physics 03/19-03/19

Immanuel Gfall, HEPHY (Austria), High Energy Physics 03/19-03/19

Christian Irmler, HEPHY (Austria), High Energy Physics 03/19-03/19

Yoshiyuki Onuki, U Tokyo(Japan), High Energy Physics 03/19-03/19

Manfred Valentan, HEPHY (Austria), High Energy Physics 03/19-03/19

Dongha Kah, Kyungpook National U (Korea), High Energy Physics 03/19-03/19

Toru Tsuboyama, KEK (Japan), High Energy Physics 03/19-03/19

Richard Dekany, Caltech (USA), Astronomy 03/20-03/22

Kohei Kamada, DESY (Germany), Cosmology 03/21-03/23

Daniel Perley, Caltech (USA), Astronomy 03/21-03/22

Atsushi Takahashi, Osaka U (Japan), Mathematical Physics 03/21-03/21

Takashi Oka, U Tokyo (Japan), Condensed Matter Phys 03/28-03/28

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J. of Sing. 2012

14 Outreach and Public Communications

We continue to emphasize public awareness of physics and mathematics of the universe through an organized series of public lectures, collaboration with media on TV shows, “ science schools” for middle and high school students, and other means. Japan has been quite effective in communicating exciting discoveries in science and advances in technology to the public at large, inspiring young minds to enter science and engineering. We certainly follow this good track record and further strengthen the public outreach.

Public Lectures and Science Events

A series of three public lectures were presented at the IPMU Science Cafe which was held at Tamarokuto Museum in Tokyo. Karoji’s lecture of April 23 was followed by “Introduction to Galois theory” by Satoshi Kondo (May 28) and “Creating dark matter on earth” by Shigeki Matsumoto (June 25).

“Subaru telescope and dark energy” by Hiroshi Karoji (April 23)

Professor Jerome Freedman of MIT, who received the 1990 Nobel Physics Prize for his experimental study that had led to the discovery of quarks, gave a public lecture “Exploring the universe at the largest and smallest distances.” It was held on the Hongo Campus. While his distinguished accomplishment was done at then the smallest distances, he explained its fascinating link to the largest distance world, namely the universe. The lecture was conducted with a simultaneous translation by Hiroaki Aihara (October 6).

“Uncovering the nature of quarks” by Taizan Watari during the Campus Day of the Kashiwa Campus (October 22).

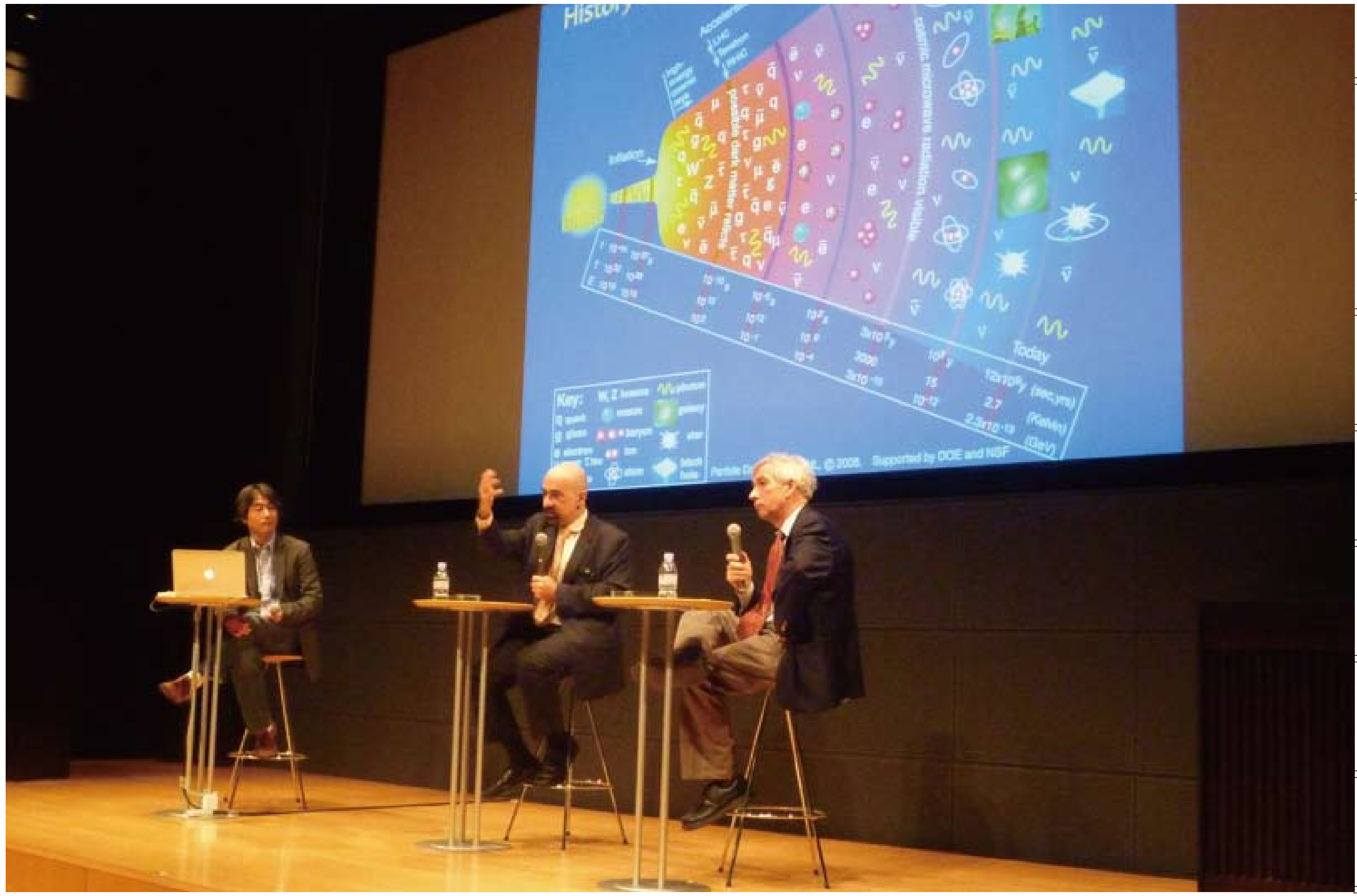
Tadashi Takayanagi chats with the participants after his IPMU-ICRR Joint Public Lecture “Exploring black halls with string theory” that was held on the Hongo Campus (November 12).

Hitoshi Murayama was surrounded by high school students attending the Joint WPI Symposium in Fukuoka (November 12).

“Mystery of accelerating universe” by Takahiro Nishimichi at the Kashiwa Planetarium (November 19).

Hitoshi Murayama greets Motohisa Furukawa, the State Minister in charge of national strategy, economic and fiscal policy during Science and Technology Festa in Kyoto (December 17–18).

IPMU joined the other five WPI institutes in a poster exhibition during The American Association for the Advancement of Science General Meeting in Vancouver, Canada(February 17–19, 2012).



A special event dedicated to the SuMIRe Project “The Universe—its history and fate” took place at the Marunouchi Building Hall in downtown Tokyo during the 2nd PFS collaboration meeting. The PFS stands for PrimeFocusSpectrograph and a part of the SuMIRe Project. Three lectures, “Dark energy and the fate of our universe” by Hitoshi Murayama, “Taking photos of the baby universe—Strange universe filled with dark matter and dark energy” by David Spergel (Princeton and IPMU) and “Cosmic dawn—The quest for the first stars and galaxies” by Richard Ellis (Caltech), were followed by a panel discussion (January 10, 2012).

Reaching Out to Future Scientists

We organized a special program for female students at the junior high school and high school levels. It is an important part of our reaching out to the future scientists. Optionally, the parents were also invited so that they actually could meet our women researchers who could become a role model for their daughters (November 26).

Twenty high school students from all parts of Japan attended three-day science camp "Physics and mathematics for exploring the universe." They learned how to arrive at "shrinking" space-time in special relativity. They "counted infinity" using toy models of fermions and bosons. They also learned how various numbers were discovered while attempting to solve equations (December 26–28).

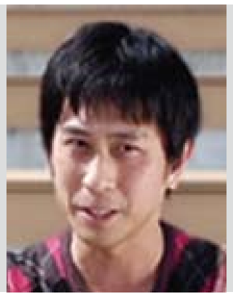
IPMU NEWS

We published four more editions of IPMU NEWS in this period. They cover a wide range of information including conferences and seminars, research highlights and newly arrived members. They also feature interesting topics in other fields of science.

Ask a Scientist

"Ask a Scientist" is a video clip that we release on the website. Scientific terms are explained for general public in just one minute. Six editions were broadcasted during FY2011.

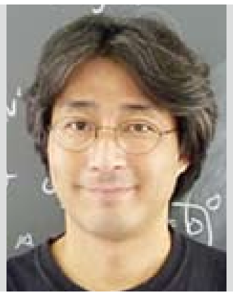
Gravitational Lens Effect
Masahiro Takada



Hubble Sequence
Masayuki Tanaka

Supernova Explosions
Masaomo Tanaka

Group Theory
Tomoyuki Abe



2011 Nobel Physics Prize
Hitoshi Murayama

10–dimensional Space-time
Johanna Knapp

IPMU Community

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