Our Team

Shigeki Sugimoto

Research Area: Theoretical Physics

IPMU Professor

"What is the world made of?" One of the main goals of elementary particle physics is to answer this question. Nowadays people believe that all the matter we see around us is made of quarks and leptons, which are interacting via four fundamental forces (gravity, electromagnetic, strong and weak forces). Recently, we encountered a clue to a new possibility which looks completely different from this traditional view of world.

According to the standard theory of elementary particles, baryons are made of three quarks, mesons are made of a quark-antiquark pair, and the strong interaction among them is described by QCD. However, we found some evidence that string theory in a certain curved background may also describe the same physics. In this description, mesons appear as strings and baryons are a kind of soliton called D-branes. We analyzed properties of hadrons based on string theory and found that various physical quantities roughly agree well with the experimental values. Although there are still a lot of things to clarify, we think this is a very interesting possibility and expect fruitful developments in the future.

Mark Vagins

Research Area: Experimental Physics

IPMU Professor

Having spent fourteen years working on neutrino experiments in Japan — and the last decade as the American convener of Super-Kamiokande's solar and supernova neutrino group — I am honored and excited to join IPMU as its first full-time foreign professor.

My research is focused on developing new methods of observing neutrinos, both through the enhancement of existing detectors like Super-Kamiokande (Super-K) and via the design and construction of future facilities. One of my main goals is to measure, for the first time, the diffuse supernova neutrino background (DSNB), often called the "relic" supernova neutrinos.

Supernova explosions have been going on since the start of star formation, and the neutrinos from all of these historical supernovas now fill space. Measuring this DSNB will tell us much about the evolution of the universe, the average rate of star formation, and even the lifetime of the neutrino.

Adding water-soluble gadolinium to Super-K should allow us to detect these relic neutrinos without having to build an all-new experiment. Enhancing Super-K in this manner will also make possible other new physics, including high-statistics reactor antineutrino oscillation studies. My work at the Institute will be focused on making these new measurements a reality.

Shinji Mukohyama

Research Area: Cosmology

IPMU Associate Professor

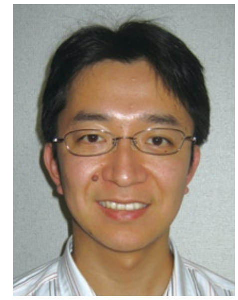
Modern cosmology has been developed and refined based on precision observational data. It is fair to say that many of the parameters describing our universe have been determined, or at least are in the process of being determined, with good precision. However, the physics behind the values of these parameters is still covered by a veil of mystery. For example, we do not know what dark energy and dark matter really are, although our universe is thought to be filled mostly with them. Also, what made our universe so big? This question can be addressed by cosmic inflation, but again we do not know the physical origin of the vacuum energy driving inflation. Three big mysteries, dark energy, dark matter and inflation, are standing in the way of cosmology which boasts precision observational data.

I have been working on research subjects such as brane world cosmology, string cosmology, Higgs phase of gravity and horizon thermodynamics in order to tackle the mysteries of the universe. I will continue this challenging task by using every possible means such as general relativity, particle physics and superstring theory.

Masahiro Takada

Research Area: Astronomy

IPMU Associate Professor



My research interest lies in the field of observational cosmology, especially aimed at understanding how hierarchical structures of the Universe have been formed. The standard scenario predicts that cosmic structures are formed as a result of amplification of primordial seed fluctuations due to gravitational instability mainly driven by dark matter. In addition, another mysterious component (to cause the present-day cosmic acceleration), dark energy affects structure formation through the effect on cosmic expansion. Finally, the Big Bang relic neutrinos' finite masses imprint characteristic features onto large-scale structures. Therefore, a detailed study of the properties and time evolution of structure formation processes using cosmological observations allows us to explore the nature of dark matter, dark energy and neutrinos. This is the final goal of my research.

What I have worked on so far includes: ① developing a method based on cosmological gravitational lensing to probe dark energy, ② reconstructing dark matter distribution in a galaxy cluster based on a lensing analysis of the Subaru data, and ③ developing a model to describe the effect of finite-mass neutrinos on structure formation.

Keiichi Maeda

Research Area: Astronomy

IPMU Assistant Professor

Supernovae are the explosions that announce the death of stars. I investigate the physical processes involved under these extreme conditions, and evaluate the use of these explosions as probes of the cosmology and the evolution of the Universe. So far, I have worked primarily on supernova explosions of massive stars: nucleosynthesis and radiation processes to simulate their appearance, and observations mainly using the Subaru telescope. My research activities revealed that the explosion geometry is far from spherical, and that this is an intrinsic ingredient of the supernova explosion. Also, the deviation seems to be larger in more energetic explosions which are linked to high energy transients called gamma-ray bursts. Currently, my research is mainly on Type Ⅰa supernovae, which are the thermonuclear explosions of white dwarfs. The aim is to clarify the still-unknown progenitors and explosion mechanisms, to provide a solid basis for using these luminous objects in cosmological study, and then to come up with new ideas with which to explore the evolution of the Universe.

Fuminobu Takahashi

Research Area: Theoretical Physics

IPMU Assistant Professor

My main interest lies in understanding why our universe looks the way it does today. Particle cosmology plays an important role in shedding light on the evolution of the universe as well as on the underlying fundamental theory.

In the early universe, interesting phenomena — completely different from those we see in everyday life — may have occurred. For instance, recent observations strongly suggest that there was an inflationary epoch during which the universe expanded at terrific speed. On the other hand, it is not fully known how the universe was heated or how the matter that constitutes our bodies was created after inflation.

Recently I have shown that an inflaton, the potential energy of which drives inflation, generically decays into standard-model particles as well as a superpartner of the graviton. I hope that this discovery will become an important guide to unravel the thermal history of the universe as well as the new physics beyond the standard model.

Yukinobu Toda

Research Area: Mathematics

IPMU Assistant Professor

Algebraic varieties are geometric objects defined by zero locus of polynomials, and their properties have been studied for a long time in the form of such familiar shapes as parabolas and circles. On the other hand, a special class of algebraic varieties called Calabi-Yau manifolds is playing an important role in modern superstring theory, in which an interesting conjecture called mirror symmetry has been proposed. This conjecture claims that there should exist a symmetry between two different mathematical objects (algebraic varieties and symplectic manifolds), and now this conjecture is described by an abstract notion of triangulated categories. Triangulated categories corresponding to algebraic varieties are derived categories of coherent sheaves, and I have been studying derived categories.

My recent works are descriptions of the spaces of stability conditions on certain derived categories, and constructions of the moduli spaces of (semi) stable objects on them. Here the notion of stability conditions is considered to give a mathematical framework of BPS-branes in superstring theory, and we can observe several interesting symmetries other than mirror symmetry by studying derived categories and stability conditions on them. I believe that we can understand such symmetries uniformly, by establishing a new geometry based on derived categories, and developing the theory of stability conditions.

Alexandre Kozlov

Research Area: Experimental Physics

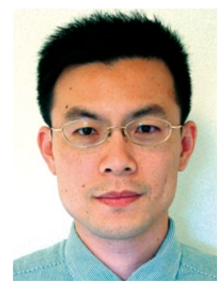
Distinguished Postdoc

Large detectors located in well-shielded deep underground facilities provide various unique opportunities to search for rare processes originating from dark matter interactions, nucleon decay, double beta decays, etc. I participate in the KamLAND collaboration which built the world's largest liquid scintillator detector with the primary goal of studying neutrino oscillations. In addition, KamLAND may also provide a very clean environment where searches for new physics can be initiated. In the future the KamLAND detector will be used to search for neutrinoless double beta decays by introducing Xenon-136 gas into the sensitive detector volume. If discovered, neutrinoless double beta decay would help to answer questions about both the absolute scale and the origin of neutrino mass.

Chuan-Ren Chen

Research Area: Theoretical Physics

Postdoc



In the near future, the Large Hadron Collider (LHC) will provide us some hints about physics beyond the Standard Model. My current research focuses mainly on exploring the collider phenomenology of new physics and on studying how to distinguish different models at the LHC. In addition to the LHC, cosmology measurements recently have given us direct evidence for new physics, such as dark matter and baryon asymmetry. Therefore, I am also very interested in examining the interplay between LHC phenomenology and cosmology.

Shushi Harashita

Research Area: Mathematics

Postdoc

I am a mathematician. My research interests are in the area of number theory and algebraic geometry. I have studied the structure of the moduli space of polarized abelian varieties in positive characteristic. The moduli space has two main stratifications: Newton Polygon and Ekedahl-Oort. I am now interested in the structure of each stratification and in the intersections of NP-strata and EO-strata. I believe that this research will result in some good contributions to number theory and algebraic geometry (and to physics in the future).

Sugumi Kanno

Postdoc

Research Area: Cosmology

String theory is a promising candidate for the final fundamental theory of physics. Inflation is a phenomenologically very successful idea. Now, a new field of research called string cosmology is beginning to describe inflation geometrically. There exist three main approaches toward a realistic model of the early universe; the string theorist's approach, the general relativist's approach and the cosmologist's approach. My approach is interdisciplinary in the sense that I try to combine advantages of each approach.

Issha Kayo

Postdoc

Research Area: Astronomy

The main topic of my research is to extract cosmological information from the large-scale structure of the Universe, particularly using the actual data taken by the Sloan Digital Sky Survey and virtual data generated by N-body simulations. I am also interested in the gravitational lensing phenomenon caused by the gravity of galaxies or the large-scale structure, and hunting gravitationally lensed quasars from the summit of Mauna Kea, Hawaii.

Satoshi Kondo

Postdoc

Research Area: Mathematics

I am interested in number theory, particularly Grothendieck's theory of motives and Beilinson's conjectures. During my Ph.D. work at the University of Tokyo under Kazuya Kato, I worked on Drinfeld modular analogue of Beilinson's result on modular curves. In a joint work with Seidai Yasuda we generalized it to higher dimensions, and applied it to the computation of lower K-groups of elliptic curves over a function field of a curve over a finite field.

Yuji Sano

Research Area: Mathematics

Postdoc

My research interest is the existence problem of the canonical Kahler metrics such as Kahler-Einstein metrics. Nowadays it is conjectured that the condition for their existence would be described in terms of stability of manifolds in the sense of Geometric Invariant Theory. I think that an interesting point of this conjecture is that it connects two aspects; differential geometry and algebraic geometry. I expect that this problem could give us a new view of geometry.

Yasuhiro Shimizu

Research Area: Theoretical Physics

Postdoc

My research interest is physics beyond the standard model of particle physics. Experiment at the LHC will hopefully uncover the mechanism of electroweak symmetry breaking and/or physics beyond the standard model. Among various models beyond the standard model, I have studied supersymmetric models, in which the lightest supersymmetric particle may be the dark matter of our universe.

Shinya Wanajo

Research Area: Astronomy

Postdoc

My research interests include the origin of the elements and some related topics such as the mechanism of supernova explosions and cosmic chemical evolution. In particular, I am interested in the r-process, which is responsible for the production of a half of the elements heavier than iron such as silver, gold, platinum, and uranium. I have been studying nucleosynthesis in supernovae as well as Galactic chemical evolution to identify the astrophysical origin of the r-process species.