Our Team

Masataka Fukugita

Research Area: Astrophysics

Principal Investigator

I have worked in astrophysical cosmology, both theoretical and observational, over the last two decades. Around 1987 I began to study the thermal history and consistency tests of the Friedmann model of the Universe. In particular, I was concerned with the cosmological constant Λ, the need of which I realised when I worked on the galaxy number count, which witnessed significant progress with the advent of charge coupled devices. A non-zero Λ was also consistent with the view I obtained from the work to assess the determination of the Hubble constant from nearby galaxies. I raised the issue of the cosmological constant being non-vanishing, but this was an anathema at the time, something that should be avoided at any rate, and I was subsequently strongly criticised by all.

While I tried to assemble observational data, I realised that there was a serious lack of data that could be used for cosmology. Having felt that we could not make progress without more extensive observations, I became engaged in observations. While I was carrying out observational programmes, I was invited by my friends in the US to join a digital sky survey project they conceived (later named the Sloan Digital Sky Survey: SDSS). Having organised a group of Japanese astronomers, and having secured necessary funds, we joined the project in 1992 as its fifth initiating member and worked for this project from the design stage. Since then I have dedicated myself to SDSS for more than a decade. Our contribution has been mostly in instrumentation and preparation for photometry. After completion of the instrument in 1999, I worked mainly on galaxy science and cosmology deduced from the survey. It took 15 years to reach fruition, but the results seem rewarding. The most important results are the verification and advancement of the cosmological model based on the ΛCDM universe, and the data themselves, which can be used for a multitude of precision astrophysical sciences for many years to come.

Along with work for SDSS, I also worked on theories and observations with the Subaru telescope. My most recent work, still under way, is to make an inventory of all energies present in the Universe and study transactions among the entries. This is a synthesis of the data and knowledge obtained over many years, and it shows the accuracy of our knowledge in many different astrophysical processes and observations.

Kunio Inoue

Research Area: Experimental Physics

Principal Investigator

The former Kamiokande was replaced by KamLAND. It holds 1000 tons of liquid scintillator and is especially sensitive to anti-electron-neutrinos. I'm leading the experiment and studying neutrino physics and applied neutrino physics with the detector. KamLAND observes anti-neutrinos from nuclear reactors about 180 km away. It has obtained evidence for reactor neutrino disappearance and explained why detected neutrinos from the Sun are much less than expected. It also observed that neutrinos disappear and reappear repeatedly giving clear evidence of neutrino oscillation. This also provides a precise measurement of the neutrino mass. Thanks to these measurements, information brought by neutrinos from the interior of the obstacle objects can be constructed via a neutrino observation. KamLAND has successfully been applied to measure geologically-produced anti-neutrinos and pioneered a new field, "neutrino geophysics." It is also aiming at observing low energy solar neutrinos.

Michio Jimbo

Research Area: Mathematics

Principal Investigator

In statistical physics and field theory, there are a few models which admit exact solutions, such as the Ising model, one dimensional spin chains or two dimensional conformal field theory. They are known as integrable systems. These systems are special but often have deep mathematical structures, and are useful also as toy models. Another example is the so-called solition equations, systems of differential equations which have abundant exact solutions. They are called classical integrable systems. My research interests are these integrable systems as well as the algebraic structures which lurk behind and control the symmetries of the system, such as infinite dimensional Lie algebras or quantum groups.

My research achievements include: ①correlation functions of the two dimensional Ising model and monodromy preserving deformation of linear differential equations, ②transformation groups for soliton equations, ③formulation of quantum groups and their application to the Yang-Baxter equation, ④space of states for solvable lattice models and integral representations for correlation functions, ⑤elliptic analog of quantum groups. My current interest is to continue ④, with the aim of giving a purely algebraic description for correlation functions of one dimensional spin chains.

Takaaki Kajita

Research Area: Experimental Physics

Principal Investigator

I have been working on the observation of atmospheric neutrinos and the study of neutrino oscillations. Information to be obtained by neutrino oscillation experiments is believed to be important for a deeper understanding of the laws in nature of both the elementary particles and the Universe. Therefore, I will continue working on neutrino physics.

I will work on the T2K experiment, which is a long baseline experiment between the J-PARC high intensity proton accelerator and the Super-Kamiokande detector. The main objective of this experiment is the search for yet-unobserved muon neutrino to electron-neutrino oscillations. Also, I will continue working on atmospheric neutrinos, which could give us unique information on neutrino oscillations that could not be obtained by accelerator based long-baseline experiments. Finally, I will work on R&D towards a future very large neutrino detector for a large-scale long-baseline neutrino oscillation experiment.

Stavros Katsanevas

Research Area: Experimental Physics

Principal Investigator

My research interests include supersymmetry, neutrino physics, astroparticle physics, novel photodetectors and distributed systems of smart sensors.

My major achievements in the last 10-15 years are:

1. Authorship of the main supersymmetry generator of the LEP experiments: SUSYGEN and supersymmetry phenomenological papers
2. Co-authorship of the design of the neutrino beam from CERN to Gran Sasso
3. Design and realisation of a new hybrid photodetector of high sensitivity, high spatial and time resolution
4. Design of a very large distributed system for “intelligent” sensors for the neutrino experiment OPERA

Since several years my science policy efforts are concentrated on the coordination of the European programs in astroparticle physics (network ASPERA) and my scientific efforts on the R&D in view of very large megaton-type detector for proton decay and neutrino physics and astrophysics.

Toshitake Kohno

Research Area: Mathematics

Principal Investigator

I am working in the area of geometry and topology in mathematics. My interests cover 3-dimensional manifolds, braid groups, knot theory, and the geometry of configuration spaces and moduli spaces. The fundamental group reflects the geometric structure of the space. A starting point of my research is to understand this non-commutative group in a geometric manner by means of differential forms on the space.

In attempting to construct representations of braid groups based on iterated integral of logarithmic forms, I found a relation between the monodromy of the KZ equation in conformal field theory and quantum groups. My recent research achievements include integral representation of the space of conformal blocks by multi-variable hypergeometric functions, geometry of infinite dimensional spaces such as the space of knots and the loop spaces of configuration spaces and the algebraic structure of their homology. In particular, the latter is closely related to string theory.

Masayuki Nakahata

Research Area: Experimental Physics

Principal Investigator

My research interests are neutrino particle physics, neutrino astronomy, the search for the character of dark matter, and the experimental verification of the Grand Unified Theory (GUT). The observation of atmospheric, solar and accelerator neutrinos at Super-Kamiokande (SK) demonstrated that neutrinos have masses and change their species while traveling in space. I will perform a precise measurement of solar neutrinos, and investigate neutrino masses and mixings. If a supernova happens to appear in our galaxy, SK is able to detect about 10,000 neutrino events, and it would reveal the detailed mechanism of the supernova explosion. And if the supernova neutrinos accumulated from the beginning of the universe (called supernova relic neutrinos) are observed, they should tell us about the history of star formation in the universe. It is well known that dark matter accounts for 20% of the energy of the universe, but the character of dark matter is not known yet. I want to unravel its character by a low background underground experiment. I would also like to find experimental evidence of GUT through proton decay.

Mihoko Nojiri

Research Area: Theoretical Physics

Principal Investigator

We now have evidence that most of the matter in our universe is unknown particles about which we understand very little. These particles must have been created in the early universe through high energy collisions of the standard model particles. Starting from 2008, the Large Hadron Collider (LHC) at CERN will reproduce such high energy collisions so that we have a chance to see the evidence of dark matter (DM) production in our universe.

My current research focuses on the discovery and reconstruction of DM at LHC. The direct production of such particles is very difficult to see, but in many models DM is produced with a set of new particles and production of DM can be observed as the missing energy. We may even be able to learn deeper reasons why these particles are needed by understanding such events carefully.

Half of my research activity involves collaboration with other experimentalists. The LHC is a big project which needs the coherent work of theorists and experimentalists, and I hope IPMU can play a key role in increasing communication between the two.

Ken'ichi Nomoto

Research Area: Astronomy

Principal Investigator

I am working on Supernovae, which are the stellar explosions at the end of their lives. These are the key events in the evolution of stars, formation of neutron stars and black holes, and origin of heavy elements. Supernovae occur under extreme conditions, whose studies could lead to finding a new physics.

My current focuses are: ①Type Ia Supernova Cosmology: These supernovae have revealed the presence of cosmic acceleration and Dark Energy. Clarifying the progenitors and explosion mechanism of these supernovae can contribute to precision cosmology. ②Evolution and Explosion of First Stars and Cosmic Chemical Evolution: Nucleosynthesis of stars with initially no heavy elements is compared with the chemical abundances of old stars. ③Gamma-Ray Bursts and Hypernovae: Studied are the production mechanisms of huge explosion energy from black holes and neutron stars. Studies of nucleosynthesis in Hypernovae would clarify the important contribution of hypernovae in the origin of elements.

Hirosi Ooguri

Research Area: Theoretical Physics

Principal Investigator

In the past few hundred years, scientists have searched for fundamental laws of nature by exploring phenomena at shorter and shorter distances. Surprisingly, there are reasons to think that the hierarchical structure of nature will terminate at 10^{-35} meter, the so-called Planck length. 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. I am trying to develop theoretical tools to apply superstring theory to questions relevant to high energy physics, astrophysics, and cosmology.

Kyoji Saito

Research Area: Mathematics

Principal Investigator

To understand the arc length 2π of a unit circle is one of the most ancient mathematical subject. Since the unit circle C is given by the quadratic equation $x^2+y^2=1$, using the complex variable $z=x+iy$, one has $\oint_c dz/z=2\sqrt{-1}\pi$. This integral is called a period integral, since the inverse function of the indefinite integral $\int dz/z$ is the exponential function with period $2\sqrt{-1}\pi$. This period integral can be described by the Lie algebra of type A_1. Period integrals over complex curves defined by cubic or quartic equations are called elliptic integrals, whose inversion functions are the elliptic functions. These elliptic integrals can be described by the Lie algebras of type A_2, B_2 and G_2 of rank 2. In this way, several interesting mathematical structures are crossing in the study of period integrals. In order to construct a higher dimensional generalization of the elliptic integrals, called the integral of primitive forms, categorically, I introduced certain infinite dimensional Lie algebras associated with infinite root systems. The flat structure (or, Frobenius manifold structure) and the flat coordinates, which appeared as a by-product of this study, is nowadays one of the standard languages used to describe mirror symmetry. It is an important thema to determine the automorphic forms obtained by inverting the period integral maps.

Katsuhiko Sato

Research Area: Astrophysics

Principal Investigator

I am working on particle astrophysics and cosmology, in particular gravitational collapse of stellar cores, supernova neutrinos and inflationary models in the early universe. Currently I am working on ①Propagation of UHCRs (Ultra High Energy Cosmic Rays) in intergalactic space and their observational anisotropies, ②Magnet-rotational collapse of stellar cores as the model of supernovae and the engine of gamma ray burst sources, ③Emission of gravitational radiation and neutrinos from collapsing stellar cores, ④Phase transition of ultra high density matter, in particular nuclear pasta structure in neutron stars and supernova cores, ⑤Big Bang Nucleosynthesis in an inhomogeneous universe, and so on. My research achievements include: ①proposal of the neutrino trapping theory that neutrinos are confined and Fermi degenerate in supernova cores, ②proposal of the accelerating expansion model in the Early Universe (Inflationary Universe Model), and solving the monopole overproduction problem by Inflation (with M. Einhorn), ③proposal of multi-production of universes during Inflation (with M. Sasaki, H. Kodama and K. Maeda), and ④pioneering works on astrophysical and cosmological constraints on the mass and lifetime of Weakly Interacting Particles such as neutrinos and axions (with M. Kobayashi and H. Sato).

David Spergel

Research Area: Astrophysics

Principal Investigator

I am a theoretical astrophysicist. My interests range from the search for planets around nearby stars to the shape of the universe.

Over the last few years, the WMAP Satellite has been the main focus of my research. WMAP was successfully launched on June 30, 2001. The results from WMAP are described in a series of papers. The WMAP 2003 paper is currently the 4th most cited paper in the entire SPIRES catalog . My next major CMB project is the Atacama Cosmology Telescope (ACT) and supporting observations through the Southern Cosmology Surveys, an international collaboration.

I am part of a group of scientists and engineers at Princeton University who are developing new technologies that should hopefully enable the direct imaging of earth-like planets.

I am part of the new Princeton Center for Theoretical Physics . In 2008/9, we are having a focused program on “Big Bang and Beyond.” I am also part of the new Institute for the Physics and Mathematics of the Universe (IPMU) .

Henry W. Sobel

Research Area: Experimental Physics

Principal Investigator

My physics interests are focused primarily on tests of conservation laws and studies of fundamental interactions between particles. Historically I have focused on studies of the neutrino and the search for nucleon decay. I also have a significant interest in astrophysics and cosmic rays. My current research consists of the continuation of the Super-Kamiokande experiment and preparation for the long baseline neutrino oscillation experiment, T2K. The multi-detector experiment T2K currently under construction is likely to be the first neutrino oscillation experiment to discover a non-zero θ_{13} via appearance of electron neutrinos. It is optimized to detect electron neutrino interactions at the precise energy of maximum muon neutrino disappearance. This experiment will test what seems to be the only small angle in the neutrino mixing matrix. In addition, this experiment will precisely measure muon neutrino disappearance and may find the first evidence that the large θ_{23} mixing is not fully maximal. A possible second phase of the experiment, with upgraded beam and far detector, may be able to discover leptonic CP violation. In the first phase of this experiment, due to begin in 2009, Super-Kamiokande will be the far detector target. The newly rebuilt SK must be calibrated and understood before the beam begins. In addition, I am involved in the planning for a new deep underground laboratory in the U.S. called DUSEL, for "Deep Underground Science and Engineering Laboratory." My primary interest in this laboratory is the possibility of constructing a next generation nucleon decay detector.

Naoshi Sugiyama

Research Area: Astrophysics

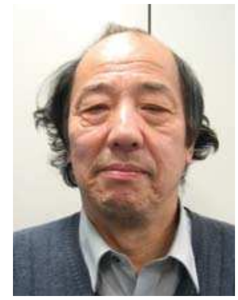
Principal Investigator

I am working mostly on theoretical observational cosmology, in particular the structure formation of the universe. My main interest is temperature anisotropies of cosmic microwave background radiation (CMB). I am currently working on: reionization of the universe due to early star and galaxy formation, fluctuations of 21cm and evolution of primordial magnetic fields and their observational implications, observational clues about dark energy and dark matter, high energy astrophysics and so on. My research accomplishments include: building a Boltzmann code in the gauge invariant formalism to calculate density and temperature power spectra, proposing a useful fitting formula for the cold dark matter power spectrum, comprehensive study of detailed physical processes on generation of CMB temperature fluctuations (with Wayne Hu), pointing out the possibility of measuring the space curvature of the universe by CMB fluctuations (with Marc Kamionkowski and David Spergel), and developing a realistic galaxy formation scenario based on semi-analytic galaxy formation (with Andrew Benson, Adi Nusser and Cedric Lacey).

Akihiro Tsuchiya

Research Area: Mathematics

Principal Investigator



I started my mathematical research in the latter half of the 1960s in the field of differential topology. The research of differential topology was in the final phase of the development. I succeeded to determine completely the characteristic classes of spherical fiber spaces, which was a main problem in this field. In the latter half of the 1980s I began to study the mathematical foundations of conformal field theory. Conformal field theory is a two dimensional quantum field theory that describes the critical phenomena in two dimensional statistical physics. It was found by three Russian physicists in the beginning of 1980s, and the close relationship with string theory in elementary particle physics was clarified afterwards. I developed conformal field theory by using methods and techniques of modern mathematics such as representation theory of infinite dimensional algebra, the theory of D-modules and the theory of moduli spaces in algebraic geometry. Through these results I gave new insights and directions to modern mathematics.

Tsutomu Yanagida

Research Area: Theoretical Physics

Principal Investigator

The Standard Model is extremely successful for describing the present-day physics of the elementary particles. However, there are several puzzles to be solved. I am very much interested recently in the puzzle of the Higgs particle, which is one of the crucial ingredients in the Standard Model. The Standard Model predicts the mass of the Higgs particle at about 100 GeV. However, bosons like the Higgs particle acquire huge masses from quantum corrections, in principle. It is, therefore, quite natural to consider that the Higgs particle receives a huge mass of the order of 10^{18} GeV on the the Planck scale. One may assume that the Higgs particle obtains a mass of about 100 GeV because of a miracle cancellation between a tree-level mass and the quantum corrections. But, that seems very unnatural and I do not believe it is the case. The above problem can be easily solved if there is supersymmetry, that is, an exchanging symmetry between a boson and a fermion. If the symmetry is exact, masses of a boson and of a fermion are the same for each other. On the other hand we know that fermions do not receive large mass corrections from the quantum effects and hence masses of bosons are stable against the quantum corrections. Therefore, we may naturally explain the 100 GeV mass for the Higgs particle if the supersymmetry-breaking scale is about 1 TeV. We applied the above idea to the Standard Model and found an upper bound of the Higgs mass as <130 GeV. I expect that this prediction will not only be confirmed at the coming LHC experiment but also that various particles predicted in the supersymmetric Standard Model will be discovered at the LHC.