Our Team

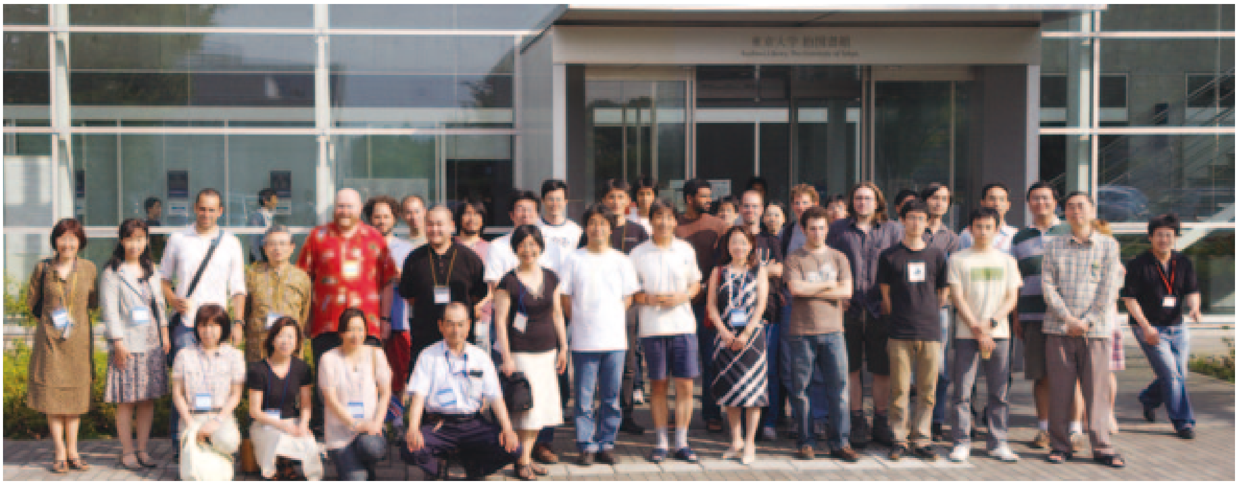
Alexey Bondal

Research Area: Mathematics

Principal Investigator

Some non-mathematicians tend to view mathematics merely as a collection of technical tools to use whenever these tools are applicable to their work. Some mathematicians have a similar point of view regarding homological algebra and algebraic geometry, one of the most technical areas of mathematics. This restrictive approach often fails for both mathematics and these particular areas of it. As experience shows, one has to use the very ideology of the theory and not just concrete results in order to get real insight when applying homological algebra and algebraic geometry to his/her research.

Nowadays, these areas, which are my primary subjects of research, have an enormous influence on various areas in mathematics, mathematical physics, and string theory. I have developed an approach to noncommutative geometry by means of derived categories, an advanced technique in homological algebra. Derived categories, which first emerged as a very abstract mathematical tool, are now considered to be the most powerful method for describing D-branes of topological field theories in physics. In addition to applications, one has to continually develop the basics of homological algebra and its applications to algebraic geometry, in order to mathematically understand various proposals by physicists aimed at describing the structural evidence of our world. Among my results is the discovery of homological relation between geometry of some algebraic varieties and representation theory, reconstruction of algebraic varieties from their derived categories, a homological interpretation of the Minimal Model Program in birational geometry, introduction of Serre functor and invariants of derived categories based on it, construction of enhancements of triangulated categories, the discovery of the action of the braid group on the set of exceptional collections - particular kind of bases in triangulated categories.



A get-together of IPMU volunteers with IPMU scientists and administrative staff

Paul H. Frampton

Research Area: Theoretical Physics

IPMU Professor

My research interests in theoretical physics include particle phenomenology, theoretical cosmology and string theory. I have worked mostly in particle theory model building beyond the standard model with predictions of new particles such as the axigluon in the chiral color model and the bilepton in the 331 model. Both are examples of additional gauge bosons.

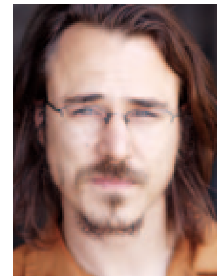
While awaiting the LHC at CERN I have become active in cosmology questions. Cyclic cosmology based on dark energy can avoid the initial singularity associated with the big bang. I have identified all dark matter as intermediate-mass black holes which is fully consistent with all observations. Both of these projects rely on consideration of the entropy of the universe.

I have been fascinated by string theory ever since its earliest days. I was a postdoc of the Japanese theorist Nambu when he invented it!

Alex Bene

Research Area: Mathematics

Postdoc

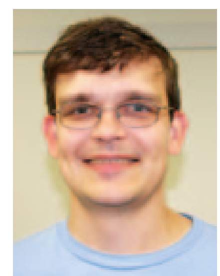


In my research, I study Riemann surfaces, their moduli spaces, and their mapping class groups. The main tool I employ is a type of Feynman diagrams called a fatgraph which essentially gives a combinatorial representative of such surfaces. With this combinatorial perspective, one can use QFT techniques to study the cohomological aspects of moduli of Riemann surfaces and mapping class groups. More recently, I have used this combinatorial approach to study representations of mapping class groups, the classical Johnson homomorphisms, and finite type invariants of 3-manifolds. This last topic is interesting as it has a different QFT interpretations, and many of these finite type invariants also can be described in terms of similar Feynman diagrams.

Alexander Getmanenko

Research Area: Theoretical Physics

Postdoc

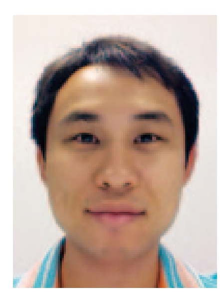


My research is on the Schrödinger equation in the complex domain, semiclassical approximation, and “resurgent analysis” linking perturbative and non-perturbative asymptotics. Among other quantum tunneling problems treated by these techniques, I study the Witten Laplacian whose eigenfunctions are expected to contain information about pseudoholomorphic discs in the symplectic formulation of the string theory. I am excited to come to Japan with its tradition of complex-analytic methods for differential equations.

Minxin Huang

Research Area: Theoretical Physics

Postdoc



My research explores various aspects of the AdS/CFT correspondence, including giant gravitons and pp-waves. I also study topological string theory. Topological string theory counts the number of holomorphic curves in Calabi-Yau space, a problem of great interest in the mathematics of algebraic geometry. Finally, I am interested in the applications of string theory to cosmology and particle physics. Some of my recent works with collaborators study the non-Gaussian feature in the anisotropy of the Cosmic Microwave Background (CMB) in various inflationary models inspired by string theory constructions.

Daniel Krefl

Research Area: Theoretical Physics

Postdoc

Lately, my work has been mainly concerned with extending the topological string machinery to orientifolds, that is, a combined gauging of world-sheet parity and a target-space involution. Besides the physical importance of orientifolds in superstring theories, this also leads to some new mathematics. This is because, roughly speaking, the free-energy of the orientifolded topological string is the generating function of maps from the world-sheet to target-space, where the world-sheet may now possess boundaries and cross-caps, thus, giving a physical count of some new invariants of the target-space.

Yogesh Kumar Srivastava

Research Area: Theoretical Physics

Postdoc

Black Holes provide an intriguing arena in which to explore the challenges posed by the interplay of general relativity and quantum mechanics. String Theory has successfully explained Bekenstein-Hawking entropy in terms of statistical degeneracy associated with different brane configurations. Initial comparisons were made using only the Einstein-Hilbert action (i.e., neglecting higher derivative and quantum corrections in the string effective action) on the macroscopic side and considering large charge limit on the microscopic side. Recently, I have been interested in extending the agreement to include the corrections. I am also working on constructing actual microstates for string theoretic black holes.

Matthew Carl Sudano

Research Area: Theoretical Physics

Postdoc

Despite the phenomenal success of modern particle physics, we know that our understanding is incomplete, and there is reason to believe that we may soon have hard evidence of new physics! I have been studying supersymmetry, a form of new physics that may alleviate some of the unattractive features of the standard model. In particular, I have worked on both the high-energy problem of realizing calculable dynamical supersymmetry breaking and the low-energy problem of generalizing the parameterization of its effects.