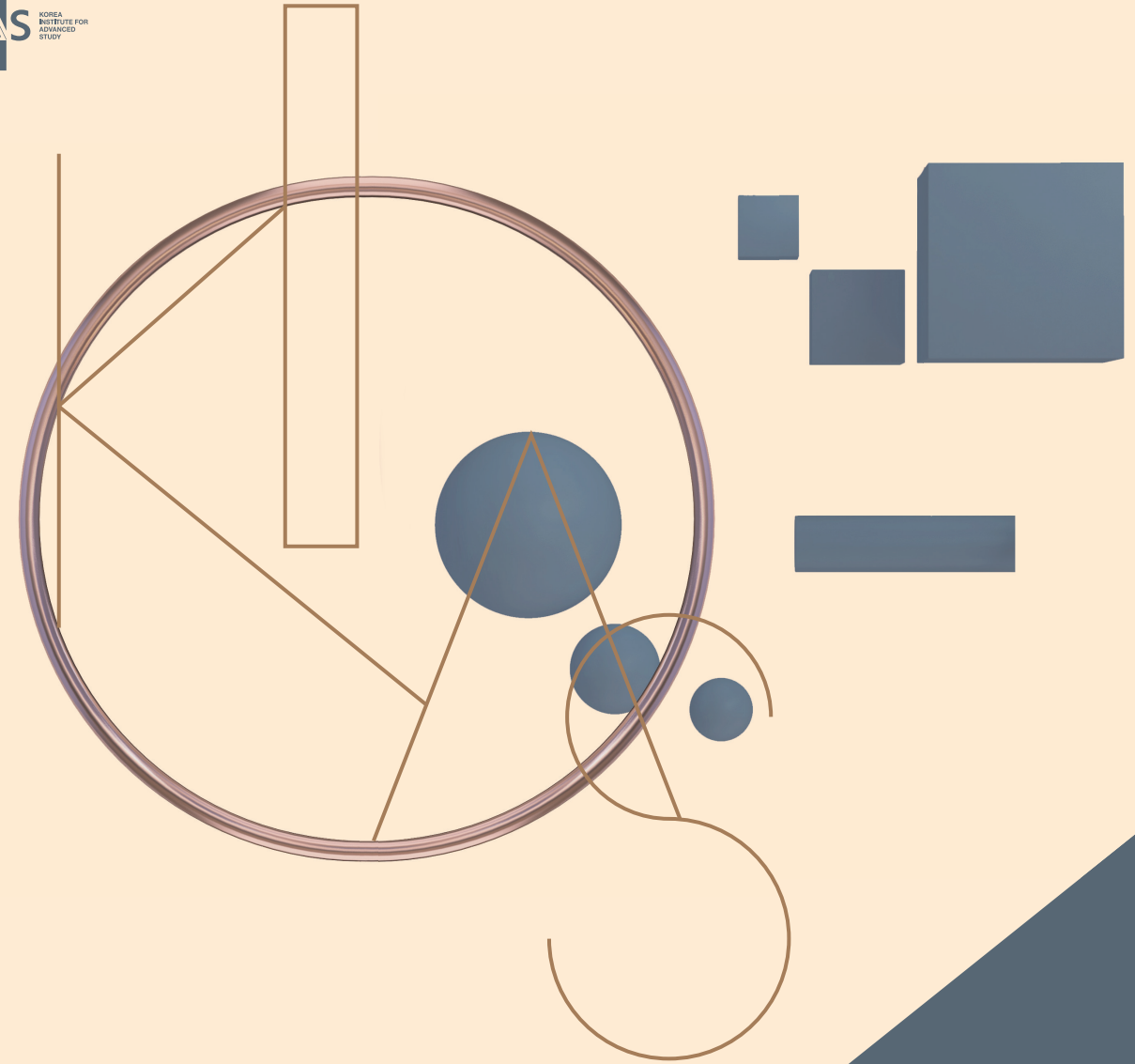


KOREA INSTITUTE FOR ADVANCED STUDY

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KOREA  
INSTITUTE FOR  
ADVANCED  
STUDY

SCHOOL OF  
MATHEMATICS

SCHOOL OF  
PHYSICS

SCHOOL OF  
COMPUTATIONAL SCIENCES

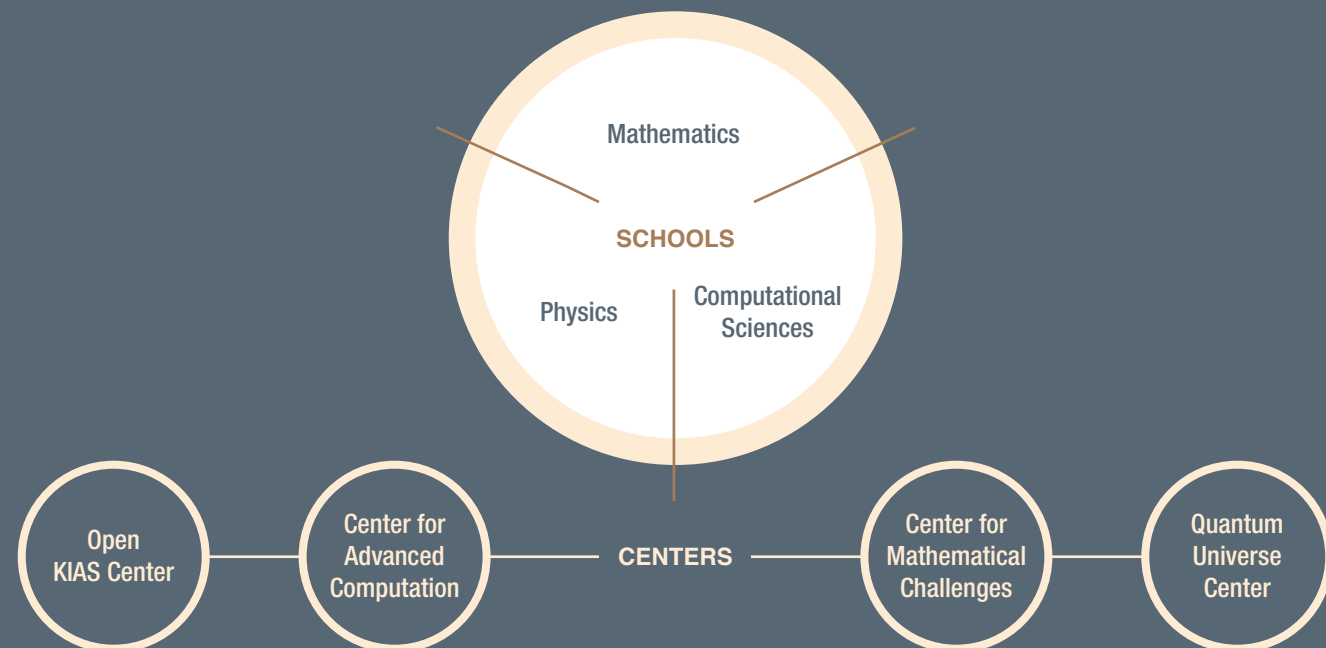
## Imagine the Impossible

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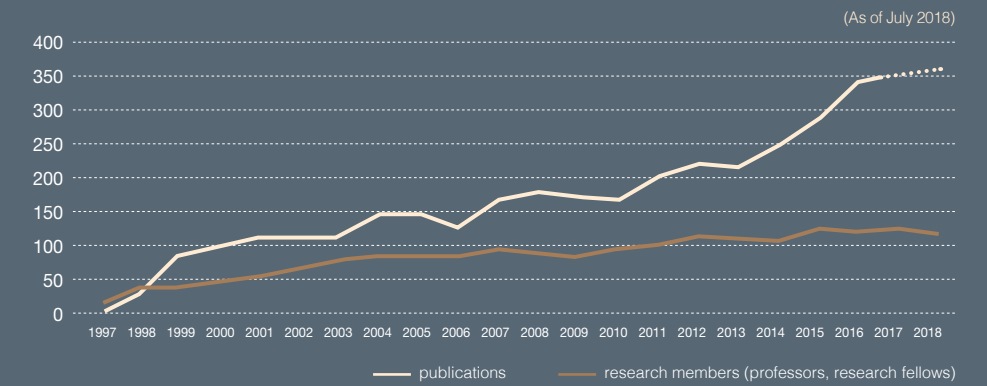


## Schools & Centers



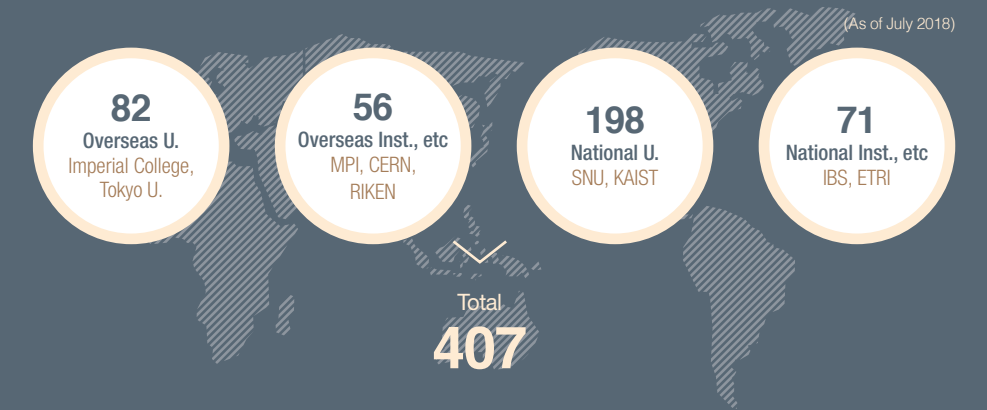
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## Alumni

KIAS alumni are leading successful careers at renowned universities and research institutes across the globe. These include Imperial College, Tokyo University, MPI, CERN, and RIKEN, as well as prominent organizations in Korea, such as Seoul National University, KAIST, IBS, and ETRI.



## Notable Awards

- |   |  |   |   |   |
|---|--|---|---|---|
| <b>Alfred Sloan Fellow</b><br>Kim, Jeong Han (1997)   | <b>FILA Basic Science Award</b><br>Kim, Inkang (2016)                | <b>Killam Research Fellowships</b><br>Kim, Yong Baek (2018)                               | <b>Nobel Prize</b><br>Kosterlitz, John M. (2016)  | <b>Wolfson Merit Award</b><br>Kim, Myungshik (2015)   |
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## Professors

### Mathematics

<b>Distinguished Professor</b>	Zelmanov, Efim I.	Algebra, Group Theory
<b>Professors</b>	Choe, Jaigyoung	Differential Geometry
	Choi, Youn-Seo	Analytic Number Theory
	Hwang, Jun-Muk	Complex Geometry
	Kang, Nam-Gyu	Analysis, Probability
	Keum, JongHae	Algebraic Geometry
	Kim, Bumsig	Algebraic and Symplectic Geometry
	Kim, Inkang	Hyperbolic Geometry
	Park, Jinsung	Global Analysis

### Physics

<b>Distinguished Professor</b>	Mukhanov, Viatcheslav	Theoretical physics, Cosmology
	Smirnov, Alexei	Neutrino Physics, Astrophysics
<b>Professor Emeritus</b>	Kim, Chung Wook	Neutrino Physics, Cosmology
<b>Professors</b>	Chun, Eung Jin	Particle Physics
	Kim, Yong Baek	Condensed Matter Physics
	Ko, Pyungwon	Theoretical High Energy Physics
	Lee, Kimyeong	Theoretical Physics
	Lee, Sungjay	High Energy Physics
	Park, Changbom	Astrophysics, Cosmology
	Park, Hyunggyu	Statistical Physics
	Park, Kwon	Condensed Matter Physics
	Yi, Piljin	String Theory

### Computational Sciences

<b>Distinguished Professor</b>	Kosterlitz, John M.	Statistical Physics
<b>Professor Emeritus</b>	Kim, Dae Mann	Micro-and Nano-electronic Devices
<b>Professors</b>	Hyeon, Changbong	Theoretical and Computational Biophysics
	Kim, Jaewan	Quantum Computation and Information
	Kim, Jeong Han	Combinatorics, Extremal Graph Theory, Random Structure
	Kim, Myungshik	Quantum Information
	Lee, Jooyoung	Protein Folding, Bioinformatics, Global Optimization
	Son, Young-Woo	Theoretical and Computational Materials Science

## KIAS Scholars

### Mathematics

	Catanese, Fabrizio	Algebraic Geometry
	Ciocan-Fontanine, I.	Algebraic Geometry, Topology
	Favero, David	Algebraic Geometry
	Huh, June	Algebraic Geometry, Singularity Theory
	Jang, Juhi	Analysis and PDEs
	Kim, Henry	Number Theory
	Lee, Kyungyong	Algebraic Geometry, Algebraic Combinatorics, Cluster Algebras
	Mukai, Shigeru	Algebraic Geometry
	Oguiso, Keiji	Geometry
	Oh, Hee	Lie Groups, Number Theory, Ergodic Theory
	Shin, Sug Woo	Number Theory
	Sibony, Nessim	Complex Analysis
	Zhang, Genkai	Lie Groups, Representation Theory, Harmonic Analysis

### Physics

	Gauntlett, Jerome	Theoretical Physics
	Ibarra, Alejandro	Particle Physics
	Minasian, Ruben	String Theory
	Parke, Stephen	Neutrino Phenomenology
	Pichon, Christophe	Astrophysics
	Tong, David	String Theory

### Computational Sciences

	Gross, Steven Paul	Experimental and Computational Biophysics, Primarily Involving Molecular Motors
	Hwang, Wonmuk	Molecular Biomechanics
	Im, Wonpil	Biophysics
	Kuwajima, Kunihiro	Protein Folding
	Liwo, Jozef Adam	Computational Study of Biomolecules
	Pincus, Philip Alan	Theoretical Problems in Soft Condensed-Matter Physics
	Thirumalai, Devarajan	Theoretical and Computational Biophysics and Bioinformatics

## SCHOOL OF MATHEMATICS

The School of Mathematics supports scholarship in a broad range of mathematical sciences including both pure and applied mathematics such as algebraic geometry, number theory, differential geometry, low-dimensional topology, harmonic analysis, global analysis, mirror symmetry, and partial differential equations. The fundamental objective of the School is to create new mathematical knowledge and nurture young mathematicians by engaging rising talents in the full spectrum of mathematical sciences.

### ALGEBRAIC GEOMETRY

Algebraic Geometry, which originated from the study of solutions to polynomial equations, has been a central area in modern mathematics, with close ties and intensive interactions with many areas of mathematics and theoretical physics. The research group at KIAS has taken a leading role in the development of algebraic geometry in Korea. Three faculty members at the School of Mathematics have been invited to speak in the section of Algebraic and Complex Geometry in ICM's. Research topics of the group include algebraic surfaces, Fano varieties, and mirror symmetry.

### ANALYSIS · PROBABILITY

Analysis and probability theory uses methods from complex-real-harmonic analysis to study random phenomena such as random lattice models, stochastic differential equations, and random matrix theory. Research topics of this group include the probabilistic and complex analytic implementation of the conformal field theory and its applications to Schramm-Loewner evolution (SLE), fine structures of SLE curves, universality problems for the distribution of eigenvalues of random normal matrices, Ward's identities for Boltzmann-Gibbs ensembles and their application to conformal field theory.

### ANALYTIC NUMBER THEORY

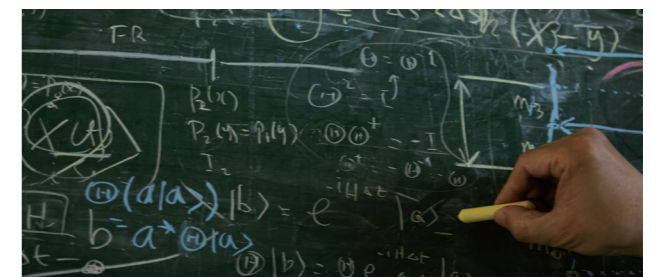
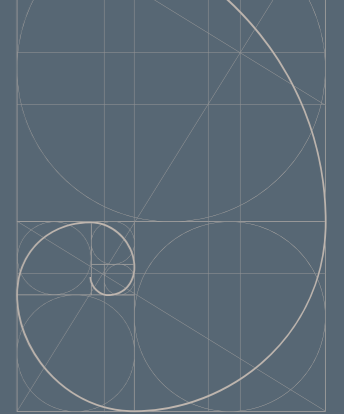
Known as the "Queen of Mathematics", number theory is an abstruse specialty concerned with the properties of whole numbers. Analytic number theory is a branch of number theory dealing with problems of number theory treated by methods of analysis. Analytic number theory has influenced various mathematical subjects, including harmonic analysis, ergodic theory and dynamics, additive and multiplicative combinatorics, and theoretical computer science. There are many important results and problems in analytic number theory. Among them are the prime number theorem, the Riemann hypothesis and Waring's problem.

### GLOBAL ANALYSIS · DIFFERENTIAL GEOMETRY

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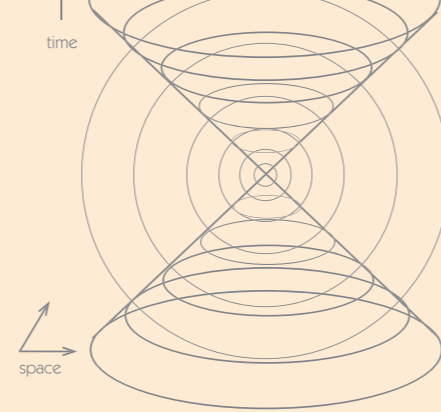
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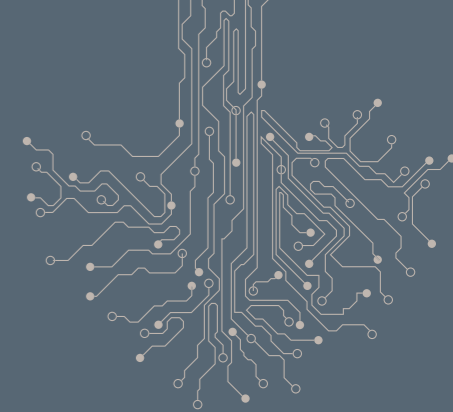
## SCHOOL OF PHYSICS

KIAS aspires to serve as a basin of fundamental knowledge that will play a pivotal role in the advancement of human civilization. With this aim in mind, the School of Physics conducts research in broad areas of theoretical physics: string theory, field theory, particle physics, statistical physics, condensed matter physics, astrophysics and cosmology.



## SCHOOL OF COMPUTATIONAL SCIENCES

The School of Computational Sciences supports research in a broad range of fields for which computational methods are appropriate or even necessary: quantum information science, combinatorics, discrete mathematics, bioinformatics, and the theoretical and computational aspects of physics, biophysics, and material science. The School is uniquely positioned to promote interdisciplinary research and the cross-pollination of ideas that occurs when the boundaries between conventional disciplines are blurred.



### ASTROPHYSICS

The KIAS Astrophysics Group is working on many topics of astrophysics, particularly in the areas of extragalactic astronomy and cosmology. Since the 2000's cosmology has changed radically and became a truly quantitative science requiring precision measurements and predictions. A goal of modern cosmology is to construct a physical universe model most consistent with astronomical observations. There have been continuous efforts towards this aim by observing the properties and the distribution of galaxies, large-scale structures, and cosmic microwave background radiation to constrain cosmological parameters within one percent uncertainty through joint analyses of various observational data. The KIAS astrophysics group has been contributing to this wonderful job.

### CONDENSED MATTER PHYSICS

Condensed matter physics is the branch of physics dealing with the physical properties of systems containing a vast number of strongly interacting, constituent particles. The term, condensed matter physics, was coined to encompass various systems, including solids, liquids, plasma, and even biological systems. This diversity makes condensed matter physics one of the most active fields in contemporary physics. Active research topics include superconductivity, the quantum Hall effect, the topological phases of matter, quantum phase transitions, artificial nanostructures, and quantum materials in general.

### PARTICLE PHYSICS

The ultimate goal of particle physics is to identify the basic building blocks of Mother Nature and their interactions, and study their roles in the evolution of the Universe. The current paradigm of particle physics is the Standard Model (SM) proposed by Weinberg and Salam. However, this paradigm should be extended (beyond the SM) in order to accommodate massive neutrinos, nonbaryonic dark matter, matter-antimatter asymmetry and inflation, to name a few. KIAS particle physics group members have been working on neutrino physics, dark matter (axion, sterile neutrino or weakly interacting massive particle), some extensions of the SM (supersymmetry, extra dimensions, etc.), and applications of various effective field theories to specific phenomenology.

### STATISTICAL PHYSICS

Statistical physics attempts to describe the macro and mesoscopic nature of systems in a coherent and systematic theory. Its scope ranges from small systems of just a few nanometers in size to macro-systems. In particular, living matters and their orchestrated social behavior are one of the hot foci of recent research. The most interesting feature of many-body physics is 'emergent' behavior. As a typical example, a collection of H<sub>2</sub>O molecules responds like a liquid (water) and a solid (ice) depending on the external environments, displaying emergent properties such as fluidity, elasticity, and so on. While equilibrium emergent phenomena are rather well understood, non-equilibrium ones ubiquitous in nature, including life itself, lack basic understanding and call for further research.

### STRING THEORY

String theory aims to be an all-encompassing theory of the Universe in a single quantum mechanical framework, where matter consists not of point-particles but rather of tiny loops of string at the fundamental level. From this novel idea, the laws of physics that include Einstein's theory of general relativity, the Standard Model of particle physics appear in a surprising but unified fashion. String theory thus offers a theoretical framework to explore a number of fundamental issues of quantum gravity, such as the microscopic origin of black hole entropy and the information paradox. String theory also provides new and very deep insights into the non-perturbative aspects of quantum gauge theories. The most startling among these ideas, known as AdS/CFT correspondence, has been applied in areas ranging from nuclear physics to condensed matter physics, and has provided both qualitative and quantitative methods to study strongly coupled phenomena.



### EXTREMAL COMBINATORICS

Extremal combinatorics generally asks how large or small a family of objects that satisfy certain properties is. It includes (but is not limited to) extremal set theory, extremal number theory, and extremal graph theory. Example questions include: What is the largest possible families of subsets of  $n$ -element sets none of which contain any other sets in the family? What is infimum of the density of sets of integers that contain no arithmetic progression of length  $k$ ? What is the minimum integer  $n$  for which every red-blue coloring of the edges of a complete  $n$ -vertex graph induces either a red complete graph of order  $s$  or a blue complete graph of order  $t$ ? These questions are problems in the areas of extremal set theory, extremal number theory and extremal graph theory.

### PROTEIN FOLDING · BIOINFORMATICS · GLOBAL OPTIMIZATION

The protein folding problem is one of the most fundamental issues in science and technology. We approach the problem in terms of solving a global optimization problem of a complex energy function which governs the microscopic interactions between atoms. When successfully executed, highly accurate atomic models of protein structures can be obtained. This allows researchers to determine otherwise-hard-to-obtain protein structures with insufficient experimental data. This kind of approach is now being extended to other problems, such as materials design and machine learning.

### QUANTUM INFORMATION SCIENCE

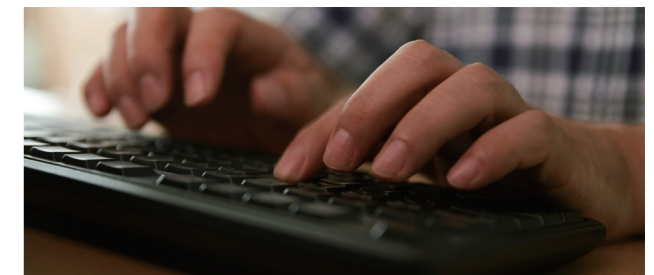
Quantum physics has successfully explained the principles of the microscopic world. It has also provided the working principles for various types of hardware for digital information processing and communications, such as semiconductor devices and lasers, even when the operating system and software are unrelated to quantum physics. Now the quantum information processing, including quantum computation and communication, must harness quantum principles not only for hardware, but also for operating systems and software. We are studying fundamental aspects of quantum information science including quantum entanglement and its applications.

### THEORETICAL AND COMPUTATIONAL BIOPHYSICS

Biological systems are maintained through numerous interactions spanning broad spectra of time and length scales. The emergence of life from individual physicochemical processes of cellular constituents is an outstanding question in biophysics. The research interests of the group lie in the dynamics of DNA, RNA, and proteins at the single molecule level, as well as in the interactions among these molecules in giant macromolecular complexes such as chromosomes. Further studies toward understanding biological phenomena at the systems level are a long term research plan of the group.

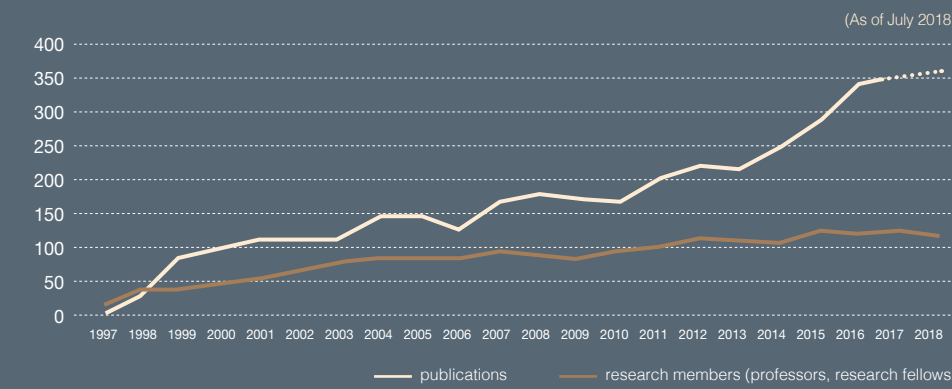
### THEORETICAL AND COMPUTATIONAL MATERIALS SCIENCE

A primary goal of the research of the theoretical and computational materials science group in KIAS is to understand and predict material properties at the most fundamental level using atomistic first-principles, or ab initio, quantum-mechanical calculations. A variety of computational approaches are used that require only atomic numbers and positions as input. Calculation results from such first principle methods have agreed with experiments excellently, except in the case of certain materials showing strong electron correlations. The research of KIAS focuses on various electronic, phononic, magnetic, mechanical and topological properties of low dimensional materials, the mutual interactions of these materials, and the spectroscopic consequences.



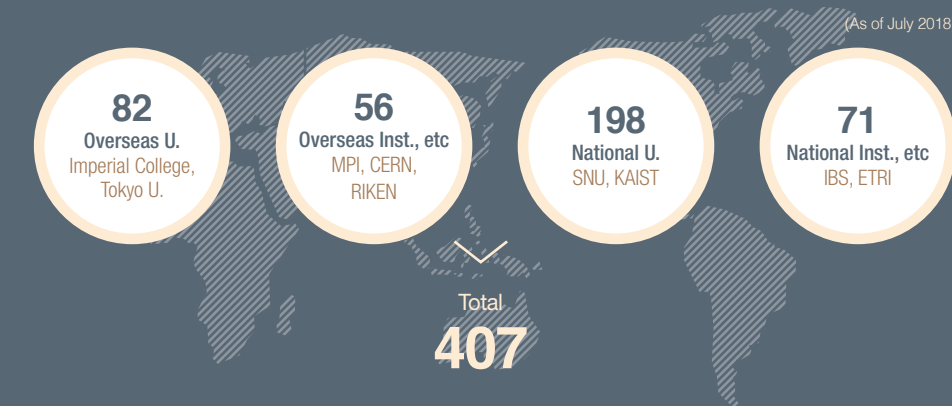
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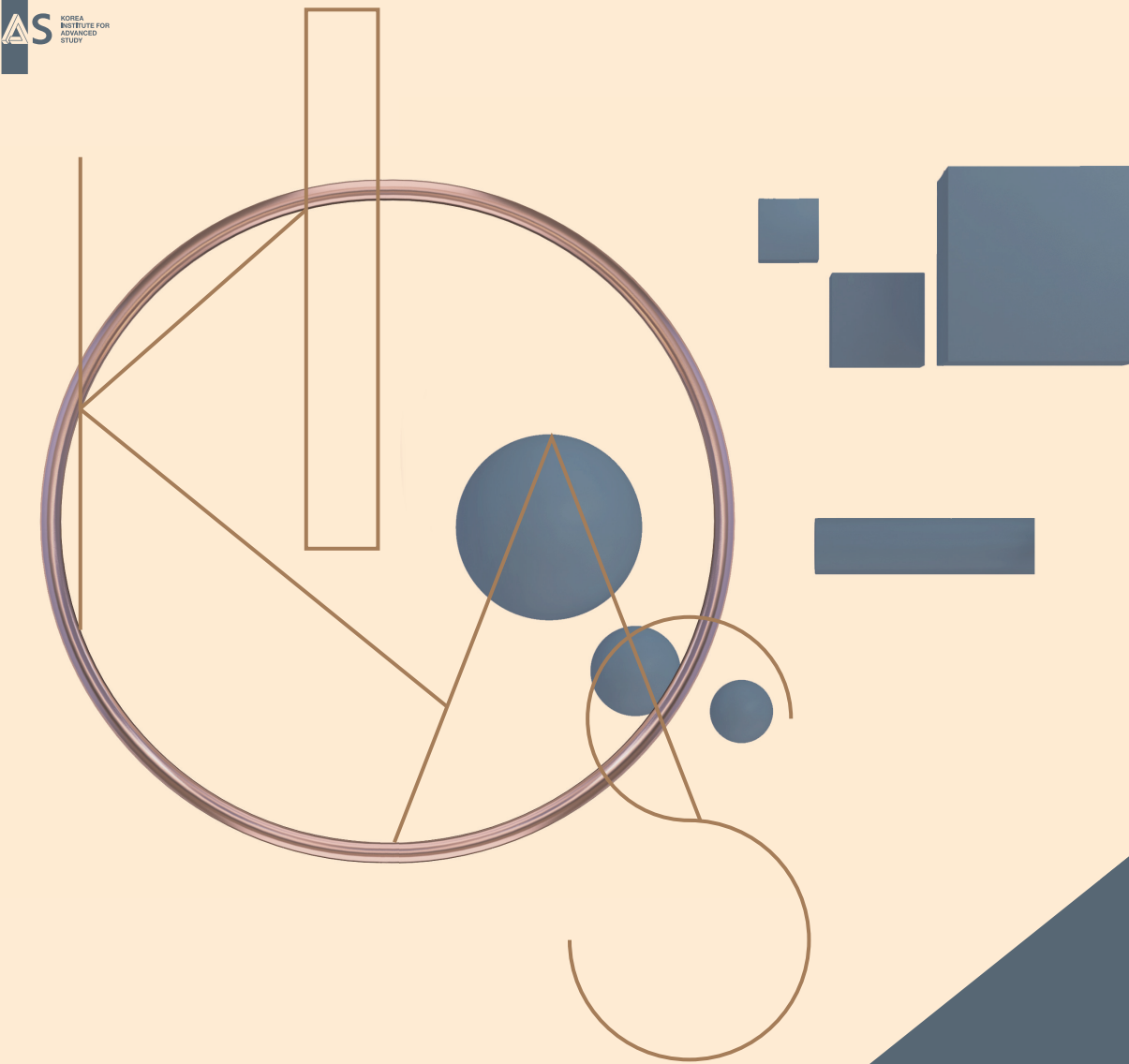


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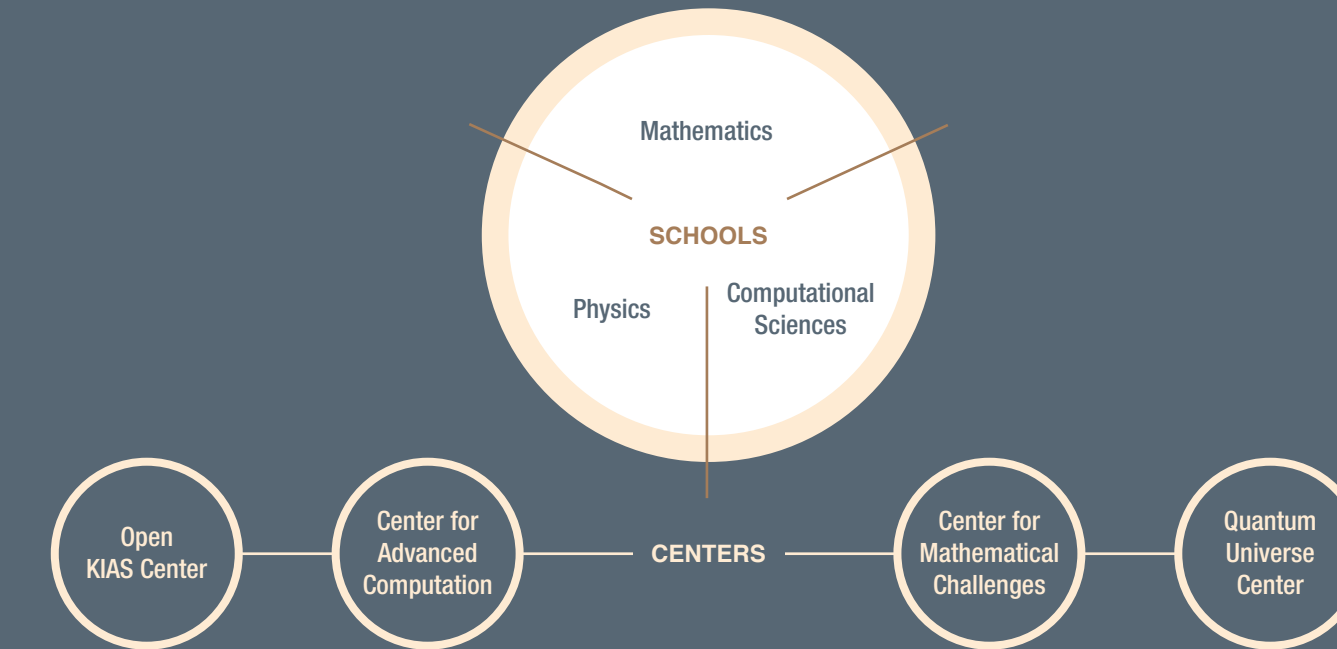
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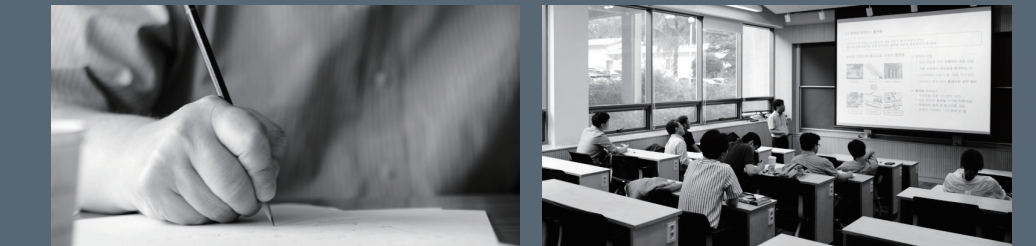
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## Professors

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	Choe, Jaigyoung	Differential Geometry
	Choi, Youn-Seo	Analytic Number Theory
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<b>Professors</b>	Kang, Nam-Gyu	Analysis, Probability
	Keum, JongHae	Algebraic Geometry
	Kim, Bumsig	Algebraic and Symplectic Geometry
	Kim, InKang	Hyperbolic Geometry
	Park, Jinsung	Global Analysis

### Physics

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	Smirnov, Alexei	Neutrino Physics, Astrophysics
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	Ko, Pyungwon	Theoretical High Energy Physics
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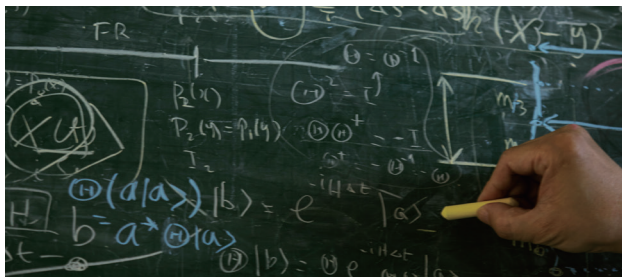
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Hyperbolic geometry, which was explored by Bolyai and Lobachevsky complementary to Euclidean geometry in the 19th century, was popularized by W. Thurston when he applied it to 3-dimensional geometry and topology for his geometrization program. It has been used in the theory of special relativity, particularly in Minkowski spacetime and gyrovector space, and has influenced geometric group theory, low dimensional topology and various branches of mathematics. A KIAS faculty member is leading the research in this area in Korea. Research topics in the group include 3-4 dimensional geometry and topology, symmetric spaces, geometric structures, and the study of rigidity and flexibility of lattices in semisimple Lie groups.

## SCHOOL OF PHYSICS

KIAS aspires to serve as a basin of fundamental knowledge that will play a pivotal role in the advancement of human civilization. With this aim in mind, the School of Physics conducts research in broad areas of theoretical physics: string theory, field theory, particle physics, statistical physics, condensed matter physics, astrophysics and cosmology.

### ASTROPHYSICS

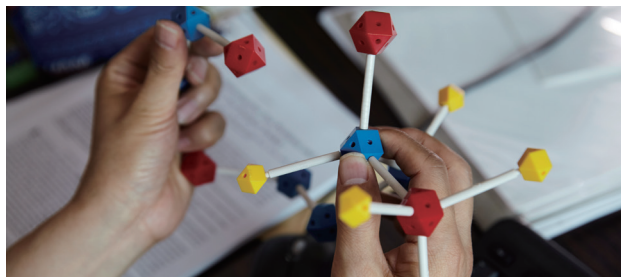
The KIAS Astrophysics Group is working on many topics of astrophysics, particularly in the areas of extragalactic astronomy and cosmology. Since the 2000's cosmology has changed radically and became a truly quantitative science requiring precision measurements and predictions. A goal of modern cosmology is to construct a physical universe model most consistent with astronomical observations. There have been continuous efforts towards this aim by observing the properties and the distribution of galaxies, large-scale structures, and cosmic microwave background radiation to constrain cosmological parameters within one percent uncertainty through joint analyses of various observational data. The KIAS astrophysics group has been contributing to this wonderful job.

### CONDENSED MATTER PHYSICS

Condensed matter physics is the branch of physics dealing with the physical properties of systems containing a vast number of strongly interacting, constituent particles. The term, condensed matter physics, was coined to encompass various systems, including solids, liquids, plasma, and even biological systems. This diversity makes condensed matter physics one of the most active fields in contemporary physics. Active research topics include superconductivity, the quantum Hall effect, the topological phases of matter, quantum phase transitions, artificial nanostructures, and quantum materials in general.

### PARTICLE PHYSICS

The ultimate goal of particle physics is to identify the basic building blocks of Mother Nature and their interactions, and study their roles in the evolution of the Universe. The current paradigm of particle physics is the Standard Model (SM) proposed by Weinberg and Salam. However, this paradigm should be extended (beyond the SM) in order to accommodate massive neutrinos, nonbaryonic dark matter, matter-antimatter asymmetry and inflation, to name a few. KIAS particle physics group members have been working on neutrino physics, dark matter (axion, sterile neutrino or weakly interacting massive particle), some extensions of the SM (supersymmetry, extra dimensions, etc.), and applications of various effective field theories to specific phenomenology.



### STATISTICAL PHYSICS

Statistical physics attempts to describe the macro and mesoscopic nature of systems in a coherent and systematic theory. Its scope ranges from small systems of just a few nanometers in size to macro-systems. In particular, living matters and their orchestrated social behavior are one of the hot foci of recent research. The most interesting feature of many-body physics is 'emergent' behavior. As a typical example, a collection of H2O molecules responds like a liquid (water) and a solid (ice) depending on the external environments, displaying emergent properties such as fluidity, elasticity, and so on. While equilibrium emergent phenomena are rather well understood, non-equilibrium ones ubiquitous in nature, including life itself, lack basic understanding and call for further research.

### STRING THEORY

String theory aims to be an all-encompassing theory of the Universe in a single quantum mechanical framework, where matter consists not of point-particles but rather of tiny loops of string at the fundamental level. From this novel idea, the laws of physics that include Einstein's theory of general relativity, the Standard Model of particle physics appear in a surprising but unified fashion. String theory thus offers a theoretical framework to explore a number of fundamental issues of quantum gravity, such as the microscopic origin of black hole entropy and the information paradox. String theory also provides new and very deep insights into the non-perturbative aspects of quantum gauge theories. The most startling among these ideas, known as AdS/CFT correspondence, has been applied in areas ranging from nuclear physics to condensed matter physics, and has provided both qualitative and quantitative methods to study strongly coupled phenomena.

## SCHOOL OF COMPUTATIONAL SCIENCES

The School of Computational Sciences supports research in a broad range of fields for which computational methods are appropriate or even necessary: quantum information science, combinatorics, discrete mathematics, bioinformatics, and the theoretical and computational aspects of physics, biophysics, and material science. The School is uniquely positioned to promote interdisciplinary research and the cross-pollination of ideas that occurs when the boundaries between conventional disciplines are blurred.

### EXTREMAL COMBINATORICS

Extremal combinatorics generally asks how large or small a family of objects that satisfy certain properties is. It includes (but is not limited to) extremal set theory, extremal number theory, and extremal graph theory. Example questions include: What is the largest possible families of subsets of n-element sets none of which contain any other sets in the family? What is infimum of the density of sets of integers that contain no arithmetic progression of length k? What is the minimum integer n for which every red-blue coloring of the edges of a complete n-vertex graph induces either a red complete graph of order s or a blue complete graph of order t? These questions are problems in the areas of extremal set theory, extremal number theory and extremal graph theory.

### THEORETICAL AND COMPUTATIONAL MATERIALS SCIENCE

A primary goal of the research of the theoretical and computational materials science group in KIAS is to understand and predict material properties at the most fundamental level using atomistic first-principles, or ab initio, quantum-mechanical calculations. A variety of computational approaches are used that require only atomic numbers and positions as input. Calculation results from such first-principle methods have agreed with experiments excellently, except in the case of certain materials showing strong electron correlations. The research of KIAS focuses on various electronic, phononic, magnetic, mechanical and topological properties of low-dimensional materials, the mutual interactions of these materials, and the spectroscopic consequences.

### QUANTUM INFORMATION SCIENCE

Quantum physics has successfully explained the principles of the microscopic world. It has also provided the working principles for various types of hardware for digital information processing and communications, such as semiconductor devices and lasers, even when the operating system and software are unrelated to quantum physics. Now the quantum information processing, including quantum computation and communication, must harness quantum principles not only for hardware, but also for operating systems and software. We are studying fundamental aspects of quantum information science including quantum entanglement and its applications.

