Annual Report 2024

Korea Institute for Advanced Study

Imagine the Impossible

School of Mathematics

School of Physics

School of Computational Sciences

Korea
Institute for
Advanced
Study

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KIAS

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Korea Institute for Advanced Study

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Sincerely,

Tae Won Noh
President, Korea Institute for Advanced Study (KIAS)

Tae Won Noh

Imagine the Impossible

Report from the President

The year 2024 marked another meaningful chapter in the ongoing journey of the Korea Institute for Advanced Study (KIAS) toward excellence in basic science. As an institution dedicated to advancing the frontiers of theoretical research, KIAS has continued to cultivate innovation, foster collaboration, and make impactful contributions to the global scientific community. It is my privilege to share this year's key achievements, which reflect our unwavering commitment to scientific discovery and the nurturing of future leaders.

Strengthening Research Excellence

This year, we welcomed two distinguished scholars to our faculty: Professor La Joonhyun in the School of Mathematics and Professor Lee Seung Joon in the School of Physics. Their appointments not only strengthen our academic capacity but also align with our strategic vision of attracting top global talent to maintain KIAS's standing as a world-class research institute.

In addition, KIAS researchers have continued to push the boundaries of knowledge in mathematics, physics, and computational sciences. Their work has earned prestigious awards and international recognition, illustrating their global impact and leadership in their respective domains.

Global Collaboration and Academic Exchange

KIAS remains committed to fostering international collaboration and serving as a hub for scientific exchange. In 2024 alone, we hosted numerous academic events, including seminars and conferences that brought together leading scientists from around the world. These gatherings not only facilitated the sharing of ideas but also strengthened KIAS's position as a global leader in theoretical research.

We also welcomed a significant number of visiting scientists, who found at KIAS a fertile environment for collaborative and independent inquiry. Their presence reflects KIAS's increasing recognition as a destination for cutting-edge research in theoretical science.

Nurturing Future Leaders

Our dedication to cultivating young researchers remains unwavering. In 2024, KIAS supported a robust cohort of research fellows who contributed to innovative projects while benefiting from the mentorship of our esteemed faculty. Since its inception in 1997, KIAS has nurtured over 500 researchers who have gone on to assume influential roles in academia and industry worldwide. This legacy demonstrates our role in guiding the next generation of scientific leaders.

Looking Ahead

As we move forward, KIAS is poised to build upon its successes by continuing to invest in talent acquisition, fostering interdisciplinary collaboration, and enhancing our global outreach. Our long-term vision includes expanding research infrastructure and creating an even more dynamic environment where creativity thrives.

In closing, I extend my deepest gratitude to our faculty, staff, research fellows, visiting scientists, and collaborators for their dedication and contributions throughout 2024. Together, we reaffirm our commitment to advancing fundamental science for the betterment of society.

History

1995

Mar.
Feasibility study on the establishment of KIAS

Dec.
Formation of KIAS Establishment Committee

1996

Aug.
Appointment of Prof. Efim I.Zelmanov of University of California at San Diego (1994 Fields Medalist) as Distinguished Professor of the School of Mathematics

Nov.
School of Mathematics and School of Physics were established.

Official scientific operation began with research staff of 1 Distinguished Professor, 2 Professors, and 3 Research Fellows.

1997

Dec.
Appointment of Prof. Chung Wook Kim of Johns Hopkins University as the 1st President

1998

Oct.
Publication of the 1st issue of the KIAS Newsletter

Dec.
Introduction of 'Associate Member Program'

1999

Aug.
Appointment of Prof. Leonard Susskind of Stanford University (1998 Sakurai Prize Awardee) as Distinguished Professor of the School of Physics

2000

Aug.
Stephen Hawking's visit to KIAS

Sep.
School of Computational Sciences was established.

2001

Jul.
Re-appointment of Prof. Chung Wook Kim as the 2nd President

2004

Jul.
Appointment of Prof. Mahn Won Kim of KAIST as the 3rd President

2006

Jan.
International Review of the School of Mathematics by an external review committee of experts

May.
Introduction of the 'KIAS Scholar Program'

2007

Oct.
The 10th Founding Anniversary of KIAS

Nov.
International Review of the School of Physics by an external review committee of experts

2009

Jan.
Introduction of 'Open KIAS Program (OKC)'

Nov.
International Review of the School of Computational Sciences by an external review committee of experts

KIAS honored as the 'Research Excellence Institution' by the Ministry of Science and Technology in recognition of its exemplary achievements 'Associate Member Program' in scientific research.

2010

Jul.
Appointment of Prof. Doochul Kim of Seoul National University as the 5th President

Dec.
Introduction of 'Center for Advanced Computation (CAC)'

2011

Sep.
Asian Institutes for Advanced Study Forum was held

Oct.
KIAS held its 1st KIAS Advisory Board Meeting

2012

Aug.
Inauguration Conference of Transdisciplinary Research Program

2013

Jan.
Introduction of 'Center for Mathematical Challenges (CMC)'

Sep.
Appointment of Prof. JongHae Keum of KIAS as the 6th President

Oct.
KIAS held its 2nd KIAS Advisory Board Meeting

2014

Jan.
Introduction of 'Quantum Universe Center [QUC]'

2015

May.
Appointment of Prof. Ashoke Sen of State University of New York at Stony Brook (2012 Fundamental Physics Prize Winner) as Distinguished Professor of the School of Physics

2016

May.
Appointment of Prof. John Michael Kosterlitz of the Brown University (2016 Novel Laureate in Physics) as Distinguished Professor of the School of Computational Sciences

Sep.
KIAS held its 3rd KIAS Advisory Board Meeting

Oct.
The 20th Founding Anniversary of KIAS

Nov.
Appointment of Prof. Yong-Hee Lee of KAIST as the 7th President

2017

Nov.
Appointment of Prof. Alexei Smirnov of MPIK Heidelberg and ICTP (2016 The Albert Einstein Medal) as Distinguished Professor of the School of Physics

2018

Jan.
Publication of KIAS web magazine 'HORIZON'

Sep.
International Review of the School of Mathematics and the School of Physics by an external review committee of experts

Oct.
Appointment of Prof. Viatcheslav Mukhanov of Ludwig Maximilian University of Munich (2015 Max Planck Medal) as Distinguished Professor of the School of Physics

2019

Sep.
International Review of the School of Computational Sciences by an external review committee of experts

2020

Jan.
Appointment of Prof. Jaigyoung Choe of KIAS as the 8th President

2021

Jan.
IntroducIntroduction of 'Center for AI and Natural Sciences (CAINS)'

Publication of the KIAS Expositions

The Quadran - scentennial KIAS Lectures

2022

Jun.
Publication of the KIAS Springer Series

Jul.
Distinguished Professor June E Huh, School of Mathematics, won the 2022 Fields Medal

2023

Jul.
Introduction of June E Huh Center for Mathematical Challenges (HCMC), the expansion of the former CMC

2024

Jun.
Appointment of Prof. Tae Won Noh of Seoul National University as the 9th President

KIAS 2024

Awards & Honors

Oh, Hee
KIAS Scholar
School of Mathematics

Abel Committee member

American Academy of Arts and Science Member

Kim, Seonwoo
June E Huh Fellow
June E Huh Center for Mathematical Challenges

2024 Outstanding Thesis Award of S-Oil

Choi, Inhyeok
June E Huh Fellow
June E Huh Center for Mathematical Challenges

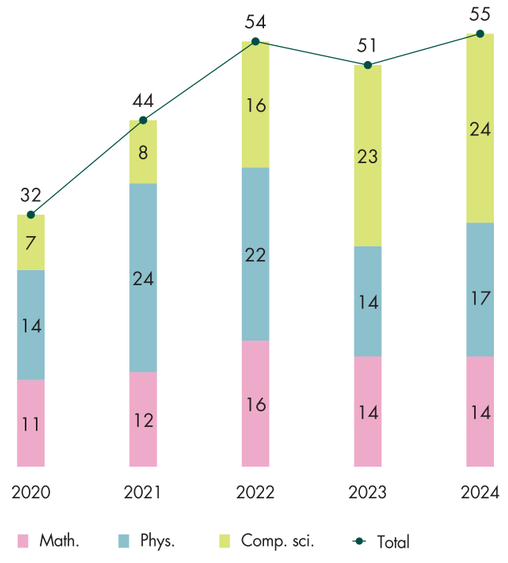
2024 Outstanding Thesis Award of S-Oil

Park, Hyangdong
Research Fellow
School of Mathematics

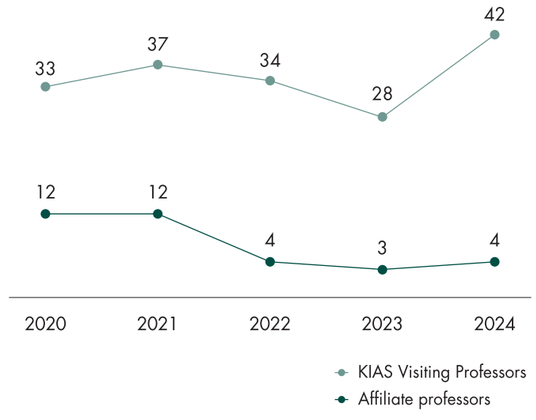
2024 Excellence Award of Korean Federation of Women's Science and Technology Associations

Number of Research Activities

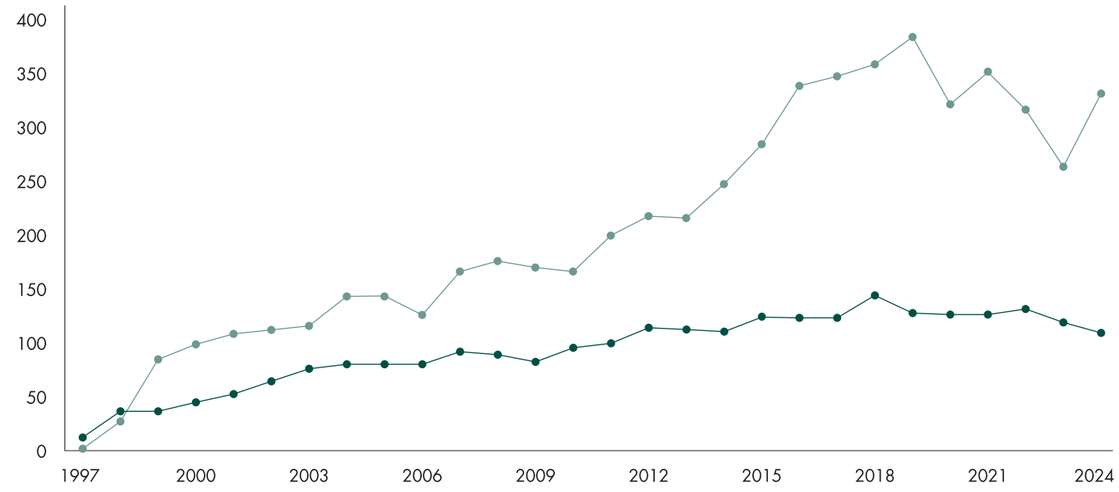
Conferences



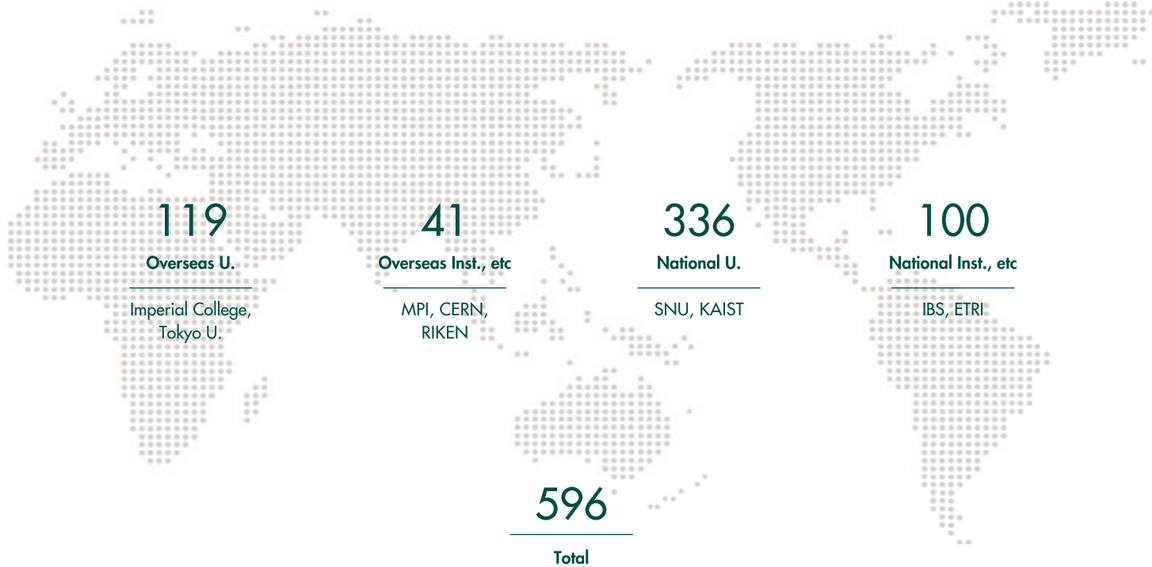
Visiting Faculty



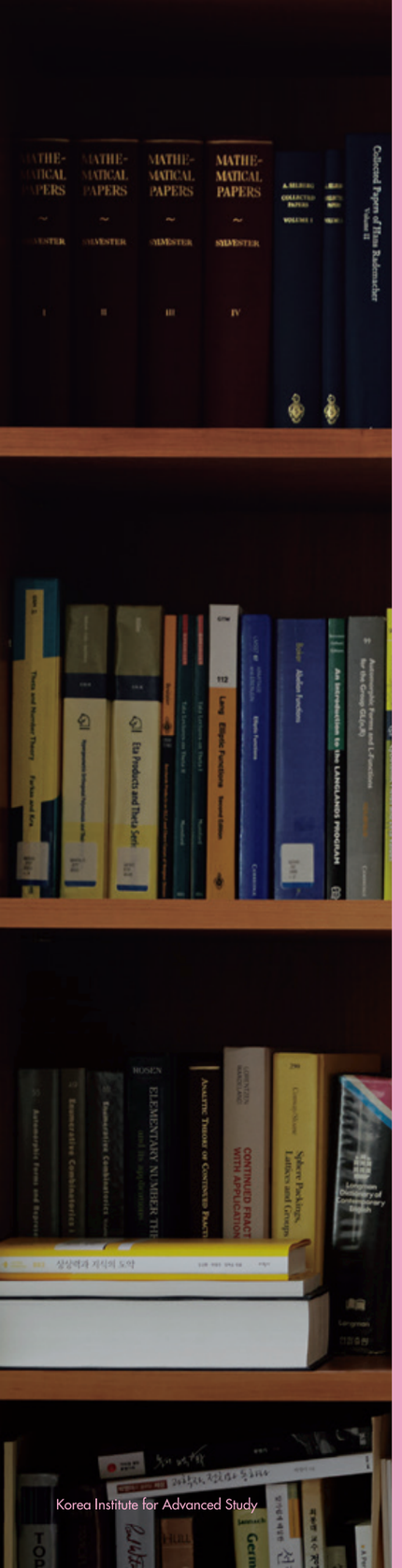
KIAS at a glance



Transfer Record of Alumni



School of Mathematics



The great success of modern science can be largely attributed to mathematics, which provides the foundation for the models used to analyze various natural and social phenomena. Because the most significant mathematical discoveries have often benefited from the cross-fertilization of ideas from different mathematical fields, 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 of Mathematics is to create new mathematical knowledge and nurture young mathematicians by providing them with a vibrant environment that covers the full spectrum of mathematical sciences.

Faculty and Research Fellows

Position	Name	Research Interest
Distinguished Professor	Zelmanov, Efim I.	Algebra, Group Theory
	Huh, June E	Combinatorics, Algebraic Geometry
Professor Emeritus	Choe, Jaigyoung	Differential Geometry
	Choi, Youn-Seo	Analytic Number Theory
Professors	Choi, Kyeongsu	Partial Differential Equations
	Kang, Nam-Gyu	Analysis, Probability
	Kiem, Young-Hoon	Algebraic Geometry
	Kim, Hyun Kyu	Physical Mathematics
	Kim, Inkang	Hyperbolic Geometry
	Kim, Sang-hyun	Geometric Group Theory
	La, Joonhyun	Partial Differential Equations
	Oh, Sung-Jin	Nonlinear Partial Differential Equations
	Park, Jinsung	Global Analysis
KIAS Scholars	Ciocan-Fontanine, Ionut	Algebraic Geometry
	Catanese, Fabrizio	Algebraic Geometry
	Alberts, Thomas	Two-Dimensional Conformally Invariant Systems
	Jang, Juhi	Analysis and Partial Differential Equations
	Kim, Hyeongsin	Number Theory
	Lee, Kyungyong	Algebra, Combinatorics, Data Science, and Mathematical Physics
	Oh, Hee	Dynamical Systems
	Reid, Alan	Hyperbolic Manifolds, Geometric Group Theory and Low-Dimensional Topology
	Zhang, Genkai	Representation Theory
Research Fellows	Moon, Hyunsuk	Algebraic Geometry
	Choe, Junho	Algebraic Geometry
	Wen, Yaoxiong	Algebraic Geometry
	Lee, Youngmin	Number Theory
	Lee, Jaehoon	Differential Geometry
	Park, Hyangdong	Partial Differential Equations
	Han, Jiyoung	Partial Differential Equations
	Huang, Jiuzhou	Algebraic Combinatorics
	Chen, Hsin-Ku	Algebraic Geometry
	Ji, Yong-Gwan	Spectral Analysis, PDEs
	Seol, Seokbong	Noncommutative Differential Geometry, Higher Structures
	Song, Kyeong	Partial Differential Equations
	Kim, Joonhee	Model Theory
	Lee, Jung-Kyoung	Probability

Position	Name	Research Interest
Research Fellows	Kim, Minkyu	Algebraic Topology
	Lee, Sangjin	Symplectic Topology
	Nyberg Brodda, Carl-Fredrik	Algebraic Geometry
	Lee, Sin-Myung	Representation Theory
	Seo, Jinsol	Analysis, PDE
	Lee, Sanghoon	Differential Geometry
	Yun, Hyungsung	Algebraic Geometry
	Hwang, Byung-Hak	Algebraic Combinatorics
	Lee, Juyoung	Harmonic Analysis
	Lee, Se-Chan	PDEs
	Kim, Taehyeong	Homogeneous Dynamics
	Choy, Jaeyoo	Algebraic Geometry
	Lee, Taehun	Algebraic Geometry
	Kim, Jeong-Seop	Algebraic Geometry

Algebraic Geometry

Members of the Korea Institute for Advanced Study (KIAS) Algebraic Geometry group cover a wide range of research areas, including birational geometry, projective geometry, K-stability, Gromov–Witten theory, and Donaldson–Thomas theory.

In 2024, we hosted three international conferences on algebraic geometry:

(1) Hyeonjun Park and Young-Hoon Kiem organized the "Workshop on Moduli Spaces, Virtual Invariants, and Shifted Symplectic Structures 2024" in July, which attracted leading international experts on enumerative geometry and derived algebraic geometry.
(2) In December, Young-Hoon Kiem and Hyeojun Park organized the conference "Enumerative Geometry in East Asia 2024", in which 17 speakers, including Gang Tian, Ravi Vakil, and Dominic Joyce, covered many recent exciting developments.
(3) In January, Young-Hoon Kiem and Kimyeong Lee organized the interdisciplinary conference "Mirror Symmetry and Related Topics," in which major players operating at the intersection of algebraic geometry and string theory, such as Bong Lian, Shuai Guo, and Seung-Joo Lee, shared their insights.

We also hosted four domestic conferences on algebraic geometry in 2024:

(1) In January and December, Young-Hoon Kiem and Kangjin Han organized two conferences, "Symposium in Algebraic Geometry 2023" and "Symposium in Algebraic Geometry 2024," that recruited domestic experts on algebraic geometry to promote collaboration.
(2) In October, Young-Hoon Kiem and Kyoung-Seog Lee organized a "Mini-Workshop on Shifted Symplectic Structures and Enumerative Geometry" to spread new knowledge about interactions between derived symplectic geometry and enumerative geometry.
(3) In July, In-Kyun Kim co-organized the "Joint Workshop on Algebraic and Complex Geometry" to facilitate the exchange between algebraic and complex geometers. With 12 lectures delivered by six experts from each field, the participants engaged in a variety of discussions to address questions of mutual interest.

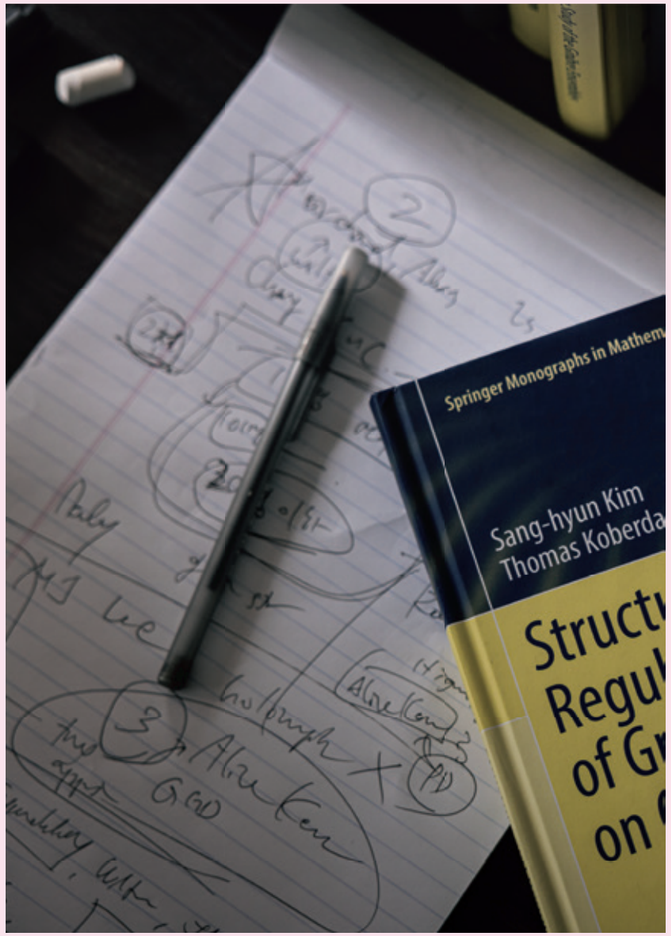
A regular algebraic geometry seminar series was also organized by Jeongseop Kim, Junho Choe, Hyunsuk Moon, and Hyeonjun Park, which served as a meeting ground for all members to share new developments.

The individual research activities directed by algebraic geometry group members in 2024 are presented below in alphabetical order.

Hsin-Ku Chen mainly works on birational geometry of threefolds. He published the paper "Chern Numbers of Terminal Threefolds" (with Paolo Cascini) in *International Mathematics Research Notices* and completed two preprints, "Minimal Resolutions of Threefolds" and "On the Divisorial Contractions to Curves of Threefolds" (with Jheng-Jie Chen and Jungkai Alfred Chen), both of which are available at arXiv.

Motivated by Aprodu-Farkas-Papadima-Raicu-Weyman's proof of Green's conjecture for general canonical curves, Junho Choe investigated linear syzygies of tangent varieties and their counterparts of higher secant varieties to higher osculating varieties. He is also nearing completion of two joint manuscripts: "Green-Lazarsfeld Index of Gaussian Graphical Models" (with Kangjin Han) and "A Fröberg Type Theorem for Higher Secant Complexes" (with Jaewoo Jeong). Additionally, he participated in the KAIST Thematic Program on Syzygies & Secants, giving a talk and discussing his work with leading experts. Furthermore, he submitted two papers: "Syzygies of Secant Varieties of Smooth Projective Curves and Gonality Sequences" (with Sijong Kwak and Jinhyung Park) and "Castelnuovo-Mumford Regularity of Unprojections and the Eisenbud-Goto Regularity Conjecture."

Young-Hoon Kiem published three papers in 2024. With Jun Li and Michail Savvas, he published a paper entitled "Generalized Donaldson-Thomas Invariants via Kirwan Blowups" in the *Journal of Differential Geometry*. With Donggun Lee, he published two papers, "Birational Geometry of Generalized Hessenberg Varieties and the Generalized Shareshian-Wachs Conjecture" in the *Journal of Combinatorial Theory Series A* and "Geometry of the Twin Manifolds of Regular Semisimple Hessenberg Varieties and Unicellular LLT Polynomials" in *Algebraic Combinatorics*. He delivered 17 lectures at various places around the world, including Shanghai, Vienna, Utrecht, Oxford, Cambridge, and Suzhou.



In-Kyun Kim published a paper on the anticanonical polar cylinder of Fano varieties. The paper, "K-unstable Singular Del Pezzo Surfaces without Anticanonical Polar Cylinders," co-authored with Jaehyun Kim and Joonyeong Won, was published in *International Mathematics Research Notices*. Additionally, they completely determined the existence of anticanonical polar cylinders in quasi-smooth log del Pezzo surfaces of index one. In another work, In-Kyun Kim, Yuchen Liu, and Chengxi Wang described the K-moduli spaces of weighted hypersurfaces of degree 2(n + 3) embedded in the weighted projective space with weights 1, 2, n+2, and n+3. Finally, Seung-Jo Jung, In-Kyun Kim, Morihiko Saito, and Youngho Yoon introduced the notion of the Tjurina subspectrum of a hypersurface isolated singularity. They proved that the difference between the Steenbrink spectrum and the Tjurina subspectrum exhibits canonical graded symmetry.

Jeong-Seop Kim published a paper on a compact moduli space of rational quartic plane curves in collaboration with Kiryong Chung, and another paper on the bigness of the tangent bundles of Fano threefolds with Picard number 2 in collaboration with Hosung Kim and Yongnam Lee. In addition, he gave invited talks at several events, including the YeungNam Workshop on Algebraic Geometry and a conference that took place at TSIMF in Sanya, China.

Yaoxiong Wen completed and posted several preprints at arXiv. Together with M. Shoemaker and N. Priddis, he investigated the quiver mutation conjecture for two resolutions of determinantal varieties. At the same time, they studied the wall-crossing phenomenon in Grassmannian flops. In collaboration with B. Wang and X. Wen, he conducted a thorough study of SYZ and topological mirror symmetries for parabolic Hitchin systems of types B and C. Alongside W. Gu, J. Guo, L. Mihalcea, and X. Yan, he explored the connection between quantum K-theory and equivariant quantum cohomology theory for Grassmannians. Yaoxiong Wen presented seminar talks at IASM and an invited talk at MCM on mirror symmetries for parabolic Hitchin systems. Additionally, he delivered an invited talk at the workshop Mirror Symmetry and Related Topics on the quiver mutation conjecture.

Physical Mathematics

The Physical Mathematics group, led by Prof. Hyun Kyu Kim, works on various mathematics topics related to physics, especially quantum aspects of geometry and the topology of low-dimensional manifolds, such as Teichmüller spaces and the higher Teichmüller spaces of surfaces, their cluster variety structures and quantization thereof, skein algebras, mapping class groups, and three-dimensional quantum gravity, as well as quantum algebra topics, such as the structures and representation theory of quantum groups and super quantum groups. Dr. Dongwook Choa moved to IBS-CGP as a research fellow in September 2024, and Dr. Yat-Hin Suen moved to National Cheng Kung University in Taiwan as an assistant professor in September 2024.

Prof. Hyun Kyu Kim, in the paper "A Quantization of Moduli Spaces of 3-Dimensional Gravity" jointly published with Carlos Scarinci, established a mathematically rigorous deformation quantization of the moduli space of certain versions of three-dimensional pure gravity theory in theoretical physics. This work is built on and generalizes Fock and Goncharov's theory of the quantization of cluster varieties. In particular, the framework developed in this paper opens a new direction of research on general cluster varieties. One consequence of this study that might be of interest to scholars in different areas is the new family of unitary projective representations of the mapping class groups of surfaces on Hilbert spaces.

Dr. Sin-Myung Lee, in the paper "Oscillator Representations of Quantum Affine Orthosymplectic Superalgebras" jointly published with Jae-Hoon Kwon and Masato Okado, studied a new family of irreducible representations of quantum affine superalgebras of type D. They proved a result that can be viewed as a quantum (untwisted) affine analogue of the correspondence between an irreducible oscillator and irreducible finite-dimensional representations of classical Lie algebras arising from Howe's reductive dual pairs. Dr. Dongwook Choa and Dr. Sangjin Lee, in their joint paper "Exotic Families of Symplectic Manifolds with Milnor Fibers of ADE-type" with Dogancan Karabas, gave infinitely many diffeomorphic families of different Weinstein manifolds. The diffeomorphic families consist of well-known Weinstein manifolds that are Milnor fibers of ADE-type, and Weinstein manifolds constructed by taking the end connected sums of Milnor fibers of A-type. Dr. Sangjin Lee, in the solo paper "Towards a Higher-dimensional Construction of Stable/Unstable Lagrangian Laminations", generalized some properties of surface automorphisms of pseudo-Anosov-type. As an application, he computed the Lagrangian Floer homology of some Lagrangians on plumbings of cotangent bundles of spheres. Dr. Yat-Hin Suen published the joint paper "Lagrangian Multi-sections and their Toric Equivariant Mirror" with Yong-Geun Oh, in which they proved a folklore statement in the SYZ conjecture saying that Lagrangian multi-sections would be a mirror to holomorphic vector bundles.

Members of the Physical Mathematics group were also invited to give talks at international conferences and seminars. Prof. Hyun Kyu Kim was invited to give a talk at the special session of Geometric Structures and Representation Spaces, held as part of the 2024 KMS Spring Meeting in Daejeon, Korea, in April 2024. Prof. Kim was invited to give a series of lectures in the School on Lie Theoretical Methods in Symplectic Geometry and Mirror Symmetry held by QSMS (at SNU) in Busan in April. Dr. Sin-Myung Lee was invited to give a talk at the conference Dualities in Quantum Groups held at the Osaka Metropolitan University in February, at the 1st MMS Workshop for Young Researchers held at Kyoto University in November, and at the Seoul–Tokyo Conference in Mathematics 2024 held at KIAS in November. Dr. Sangjin Lee was invited to give a talk at the MATRIX–IBS CGP Workshop on Symplectic and Low-dimensional Topology held jointly by MATRIX (from Australia) and IBS-CGP in June.

Prof. Hyun Kyu Kim has organized the semi-regular seminar Geometry, Algebra and Physics Seminar at KIAS. Prof. Kim has uploaded some talks to the YouTube channel for this seminar and has made them available to the public.

Prof. Hyun Kyu Kim and Dr. Sin-Myung Lee organized the international conference Physical Mathematics and Beyond: The First Workshop in January. There were eight speakers from China, Germany, Taiwan, Japan, Hong Kong, the Netherlands, and Singapore. Two of them gave mini-course lectures, and the other six gave single talks on their research. We aimed to invite active scholars in the fields of mathematics that are related to physics, from Korea and from overseas and provided an opportunity for scholars at various levels, including students, to share, learn, and discuss ideas. The topics included representation theory of quantum groups, geometric representation theory, cluster algebras/varieties and their quantization, skein modules and algebras, quiver varieties, conformal field theory, vertex algebras, ordinary and higher Teichmüller spaces, and various other topics in quantum geometry. Prof. Hyun Kyu Kim plans to make this workshop an annual series. The second workshop of this series was organized in June and hosted seven speakers in total, from the UK, the US, Korea, and Taiwan. Again, two of the members gave mini-course lectures, while the others delivered single presentations on their research. For both of these workshops, we uploaded the videos of the lectures to the YouTube channel for the KIAS School of Mathematics. In June, Dr. Dongwook Choa, Dr. Sangjin Lee, Dr. Seokbong Seol, Dr. Yat-Hin Suen, and Prof. Hyun Kyu Kim held the Summer School in Geometry and Physics. There were two mini-course speakers from Hong Kong and Korea, and 10 more speakers from Korea, Hong Kong, and the US who gave research talks. In November, Prof. Hyun Kyu Kim hosted the 2024 Seoul–Tokyo Conference as part of the annual Seoul–Tokyo/Tokyo–Seoul conferences. This year's theme was mathematical physics, and there were four speakers from Korea and four speakers from Japan. For each of these conferences, workshops, and schools, the total number of participants exceeded 40.

Differential Geometry & Analysis

The KIAS Differential Geometry and Analysis group consists of Professor Jinsung Park, Professor Kyeongsu Choi, Dr. Jaehoon Lee, Dr.

Sanghoon Lee, Dr. Taehun Lee, Dr. Sewook Oh, Dr. Jaehyeon Ryu, and Dr. Jiuzhou Huang. The research group focuses on mathematical physics in terms of analytic aspect, geometric flows, minimal surfaces, Yang-Mills theory, and maximal functions on hypersurfaces.

Prof. Kyeongsu Choi classified every ancient noncollapsed mean curvature flow in Euclidean 4-space, which provides the full list of possible singularities of noncollapsed mean curvature flow. He also proved the uniqueness of tangent flows at infinite for the curvature shortening flow with finite-entropy, which is the first result for geometric flows handling backward limits with multiplicity. Furthermore, he characterized every translating surface using the sub-affine-critical powers of the Gauss curvature.

Prof. Jinsung Park worked on the energy of generalized Gauss maps from the maximal disc in the Anti de Sitter 3-space, whose boundary is given by the graph of quasisymmetric homeomorphism on the circle. In particular, it was proved that this energy is related to the Liouville action of the quasisymmetric homeomorphism under the Weil-Petersson class condition.

Dr. Jaehoon Lee mainly focused on a joint study with Dr. Eungbeom Yeon on desingularizing a two-dimensional plane passing through the waist circle of a Lagrangian catenoid in R^4, similar to the Costa-Hoffman-Meeks surface in Euclidean 3-space. A preprint is currently in preparation. From August 25 to December 16, Dr. Lee visited Stanford University as part of a KIAS overseas short-term research program for research collaboration.

Dr. Sanghoon Lee, in collaboration with Jaehwan Kim, proved the existence of an infinite-dimensional family of solutions to the Yang-Mills flow that converge to the SO(n)-equivariant homothetically shrinking soliton constructed by Weinkove. Additionally, in joint work with Fang Wang, he established a rigidity theorem for Poincaré-Einstein manifolds, demonstrating that the standard upper half-plane model of hyperbolic space is the only Poincaré-Einstein manifold close to itself in a certain sense.

Together with Prof. Kyeongsu Choi, Dr. Taehun Lee and Dr. Jiuzhou Huang constructed an I-family of ancient graphical mean curvature flows over minimal hypersurfaces with finite total curvature. These solutions exhibit rich geometric properties, including finite total curvature, finite mass drop, and, in one family, mean convexity.

Dr. Sewook Oh established the boundedness of the maximal operator associated with averages over hypersurfaces for all finite-type hypersurfaces. He also resolved the problem of obtaining optimal maximal bounds for hypersurfaces with a Fourier decay rate of one-half.

Together with Prof. Andreas Seeger, Dr. Jaehyeon Ryu established a boundedness result for maximal averages over a tilted sphere on a two-step nilpotent Lie group. This result demonstrates a striking phenomenon that the maximal average behaves completely differently from that over a non-tilted sphere in terms of its boundedness.

PDE & Probability

The KIAS Partial Differential Equation and Probability group consists of Professor Sung-jin Oh, Professor Joonhyun La, Dr. Yong-Gwan Ji, Dr. Hyangdong Park, Dr. Kyeong Song, Dr. Sechan Lee, Dr. Hyungsung Yun, and Dr. Jinsol Seo. The research group focuses on mathematical physics and fluids, geometric flows, minimal surfaces, spectral analysis, and regularity theory for PDEs.

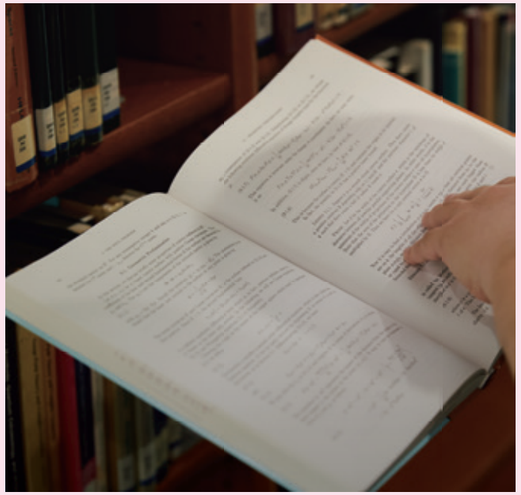
Professor Sung-jin Oh, in collaboration with Jonathan Luk, posted a preprint that puts forth a new general method for determining and establishing the precise late-time tail of nonlinear waves on dynamic asymptotically flat spacetime of odd spatial dimensions. In particular, it revealed an interesting deviation from the previously well-established picture in the linear stationary case referred to as Price's law. Prof. Oh, in collaboration with Sohrab Shahshahani, proved the nonlinear asymptotic stability of the 3D catenoid under the hyperbolic vanishing mean curvature equation, which significantly extended the prior result confined to radial symmetry. Prof. Oh, jointly with Kihyun Kim and Soonsik Kwon, gave a new construction of blow-up solutions to the radial self-dual Chern-Simons-Schrodinger equation with a continuum of blow-up rates. Prof. Oh, together with In-Jee Jeong, proved new well- and ill-posedness results for quasilinear dispersive models from plasma physics (electron and Hall-MHD). Prof. Oh, together with Mimi Dai, proved a new BKM-type continuation criterion for these models with resistivity.

Professor Joonhyun La investigated wave turbulence theory. In collaboration with Pierre Germain and Zhiyuan Zhang, Professor La proved the local well-posedness of a kinetic wave equation derived from a toy model of wave turbulence theory. In addition, with Pierre Germain and Angeliki Menegaki, Professor La proved the well-posedness and equilibration of a kinetic wave equation derived from the Fermi-Pasta-Ulam model of weakly anharmonic chains.

Dr. Kyeong Song, in collaboration with Sun-Sig Byun and Yeonghun Youn, proved regularity estimates for elliptic irregular obstacle problems involving measure data. In particular, Dr. Song proved optimal pointwise bounds for solutions and their gradient for these problems under the sharp assumption for the growth exponent.

Dr. Yong-Gwan Ji obtained results on gradient estimates for closely located conductors with imperfect bonding in joint work with Prof. Shota Fukushima, Prof. Hyeonbae Kang, and Prof. Xiaofei Li. In particular, Dr. Ji proved that the gradient of the solution is bounded regardless of the distance between two circular conductors. This contrasts with the case of perfect bonding, where the gradient blows up as the distance between two conductors tends to zero.

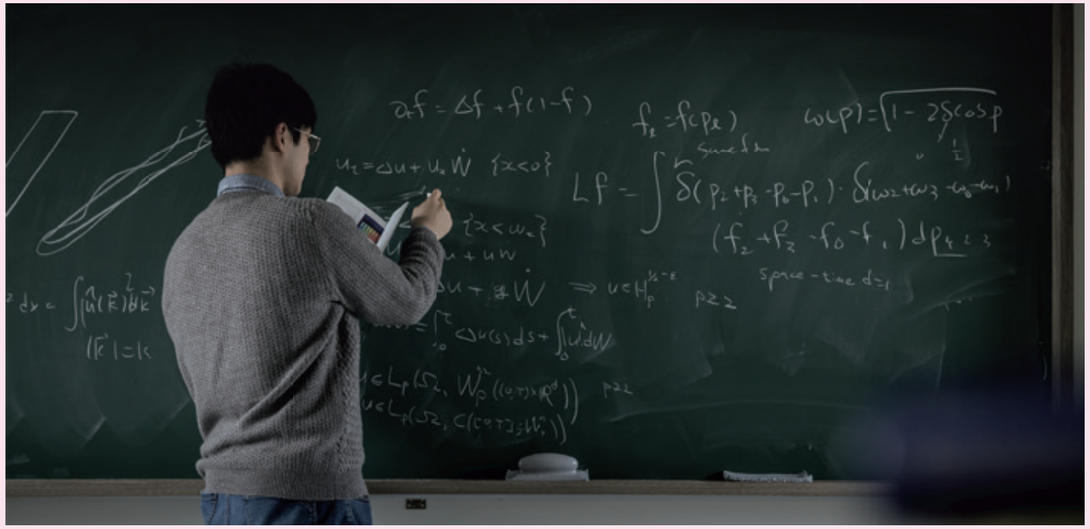
Dr. Sechan Lee studied singularities for solutions to nonlocal nonlinear equations and the homogenization of obstacle problems with highly oscillating obstacles. First, Dr. Lee investigated the removable and isolated singularity theorems for fractional p-Laplacian operators based on an adaptation of the Di Giorgi-Nash-Moser theory for nonlocal equations. Second, Dr. Lee proved the homogenized effect in a periodic setting with oscillating coefficients and obstacles. The key novelty was a new corrector capturing the singular behavior of solutions near each hole.



Dr. Hyangdong Park proved the stability of supersonic compressible flows with nonzero vorticity in a three-dimensional divergent nozzle. In doing so, Dr. Park improved on previous results for the three-dimensional cylinder problem.

Dr. Hyungsung Yun established a regularity theory for the porous medium equation in bounded domains via generalized Schauder theory. In addition, Dr. Yun established global C^(2,α) regularity for viscosity solutions to fully nonlinear porous medium-type equations by developing new techniques to handle the nonlinearity, allowing Schauder-type estimates.

Dr. Jinsol Seo studied Poisson, heat, and stochastic heat equations. Dr. Seo is currently conducting research on three different topics: a stochastic Lagrangian solution for the Vlasov-Poisson-Fokker-Planck equation with integrable initial data, the establishment of L^p-theory for solutions to the heat equation describing boundary behavior on a polyhedral domain, and the establishment of general of L^p-theory for solutions to stochastic heat equations on non-smooth domains and its application to nonlinear stochastic heat equations.



Topology

Sang-hyun Kim proved that a countable orderable group of subexponential growth always admits a C1-action on a compact interval. Moreover, with his collaborators, he showed that an arbitrary one-dimensional action of such a group can be blown up to a C1–action. He also computed an exact value for the smallest possible *m* such that a convex fundamental polygon of the congruence subgroup Gamma0(*p*) can be constructed with vertices whose denominators are at most *m*, for each prime *p*.

Sang-hyun Kim, Sanghoon Kwak, and Carl-Fredrik Nyberg-Brodda organized the international Dynamical Group Theory V workshop titled KIAS Workshop on One Relator Groups and Other Aspects of GGT. These three also organized Dynamical Group Theory IV (KIAS-Rice Workshop), in which Chris Leininger gave a minicourse on purely pseudo-Anosov surface subgroups of mapping class groups. Other notable senior speakers in this event included Alan Reid (Rice), David Fisher (Rice), and Inkang Kim (KIAS). Sang-hyun Kim and Carl-Fredrik Nyberg-Brodda organized Dynamical Group Theory III (New Methods in Group Actions on Manifolds) with talks on manifold diffeomorphism groups, and also Dynamical Group Theory II (Korea–France Workshop), featuring talks by French and Korean dynamicists.

Inkang Kim published the paper “Convexity of Energy Functions of Harmonic Maps Homotopic to Covering Maps of Surfaces,” showing the strict convexity of the energy function of harmonic maps at the critical points. Consequently, Morse theory shows that the energy function has a unique critical point. He also concretely constructed the SRB measure on real projective manifolds, and proved that the exponential growth of the periods of the Lebesgue measure on the boundary of the convex domain is 1. He also established the relationship between the entropy and the volume of the involved manifolds, namely that the convergence of the SRB entropy to zero implies that the Hilbert volume of the manifold tends to infinity.

Joonhee Kim, with his collaborators Byunghan Kim and Hyoyoon Lee, proved that, in NSOP1 theories, the Kim-independence induced by non-forking Morley sequences satisfies the existence axiom over an arbitrary set. In January, as an organizer, he participated at Korea Logic Day 2024. He also organized a special session of the KMS spring meeting in April. Both meetings aimed to gather researchers who study mathematical logic, computational logic, and the logic of philosophy and encourage them to exchange and discuss their research and ideas.

Sanghoon Kwak, together with his collaborators Elizabeth Field and Mladen Bestvina, gave a bound [2n-7, 2n-2] for the maximal dimension of the projective length functions on a minimal Fn-R-tree. On the other hand, together with Ryan Dickmann and Hannah Hoganson, he also established a Dehn-Nielsen-Baer type theorem for infinite-type surfaces with a noncompact boundary. To do this, they established a complete characterization of surfaces that are properly homotopy equivalent to graphs.

Minkyu Kim proved an equivalence between analytic exponential functors on the category of free groups and c̈onilpotent cocommutative Hopf algebras. This was a joint study with Christine Vespa (Université d’Aix-Marseille), which was uploaded to arXiv as “On Analytic Exponential Functors on Free Groups”. Minkyu Kim extended the notion of the eigenring, which originated from Ore, for the study of modules over categories. He proved that the generalized eigenring construction gives a canonical adjunction of the categories of associated modules. Moreover, he presented numerous examples stemming from the category of free groups and free modules. This research is available on arXiv under the title “On Eigenring Construction for Free Groups and Free Modules.” Minkyu Kim has authored two introductory articles, one in *Korean Newsletter* that introduces topological quantum field theories with examples and the other in *KIAS Horizon* that discusses the relationship between division and groupoid cardinality.

Jiyoung Han obtained the weight decomposition of SL(d,R) with respect to the adjoint representation of SO(p,q), mainly in order to derive the classification of intermediate subgroups in her other collaborative work on the quantitative Oppenheim conjecture of systems of forms. She also proved that the distribution of the number of primitive lattice points in the symmetric convex body in a *d*-dimensional real vector space converges as *d* goes to infinity i) to a Poisson distribution if the volume of each convex body is fixed or ii) to a normal distribution if the volume of each convex body diverges subexponentially. She and her collaborators derived similar theorems for the asymptotic behavior of the distribution of the number of affine lattice points and lattice points with congruence conditions, respectively, by establishing higher moment formulas for the relative Siegel transforms.

Jiyoung Han and Taehyeong Kim jointly aimed to establish the S-arithmetic version of the Khintchine-Groshev theorem using the ubiquity technique. Indeed, they were able to develop local ubiquity, which is the main step in the ubiquity technique, and they believe this will lead to the S-arithmetic version of the Khintchine-Groshev theorem.

Taehyeong Kim, with Ron Mor and Elon Lindenstrauss, showed certain large deviation estimates for diagonal flows on homogeneous spaces, which implies the effective uniqueness of the measure of maximal entropy.

Carl-Fredrik Nyberg-Brodda found a simple proof for the abelianization of SL_2 over Z[1/m] for an arbitrary *m*. He computed the growth and integral cohomology of free regular *-monoids and, with collaborators, computed the growth of free inverse monoids. With other collaborators, he investigated ergodic densities of regular languages in subshifts and gave a complete classification of when the submonoid membership problem is decidable in Artin groups. Finally, on the history of mathematics, he wrote an article on G. S. Tseytin’s seven-relation semigroup with an undecidable word problem, which appeared in a Festschrift for Tseytin.

Carl-Fredrik Nyberg-Brodda, with Sang-hyun Kim, organized the international conference Semigroups, Groupoids, and C*-algebras, where Volodymyr Nekrashevych gave a minicourse on self-similar groups. Carl-Fredrik Nyberg-Brodda also organized the first Graduate Student Meeting in Pure Mathematics at KIAS, which featured talks from a large number of graduate students from across Korea.

Visiting Scientists

Amini, Omid
CNRS, Ecole Polytechnique

Atobe, Hiraku
Kyoto Univ.

Bae, Myoungjean
KAIST

Bae, Younghan
Universiteit Utrecht

Baker, Matthew
Georgia Institute of Technology

Beltran, Johel
Pontificia Universidad Católica del Perú

Buciumas, Valentin
POSTECH

Buczynski, Jarek
IMPAN (Warsaw)

Byun, Sungsoo
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Campo, Livia
Univ. of Vienna

Chai, Xiaoxiang
POSTECH

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Chen, Yimin
Pusan Nat'l Univ.

Choi, Jaehwan
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Choi, Jinwon
Sookmyung Women's Univ.

Chung, Kiryong
Kyungpook National Univ.

Ciocan-Fontanine, Ionut
Academia Sinica

Coti Zelati, Michele
Imperial College London

Daskalopoulos, Panagiota
Columbia Univ.

Doan, Nhat Minh
Institute of Mathematics, VAST

Dolce, Michele
École Polytechnique Fédérale de Lausanne

Fisher, David
Indiana Univ.

Fukushima, Shota

Furukawa, Katsuhisa
Josai Univ.

Genz, Volker
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Han, Kangjin
DGIST

Hedenmalm, Haakan
KTH

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Horinaga, Shuji
NTT Institute for Fundamental Mathematics

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Jang, Seunguk
Univ. of Rennes

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Kyushu Univ.

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Univ. of Virginia

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Technische Universität Dresden

Kwon, Soonsik
KAIST

Landim, Claudio
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Chonnam Nat'l Univ.

Lee, Norton
IBS-CGP

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Univ. of Edinburgh

Lee, Wonwoong
Univ. of Hong Kong

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Zhejiang Univ. of Technology

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Nat'l Tsing Hua Univ.

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Oxford Univ.

Lorscheid, Oliver
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Univ. of Oviedo

Matte Bon, Nicolas
Université Lyon 1

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Univ. of Nice - Mathematics Laboratory JA Dieudonné

Min, Hyunki
Univ. of California Los Angeles

Nam, Kyeongsik
KAIST

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Hanyang Univ.

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Ohshika, Kenichi
Gakushuin Univ.

Pan, Wenyu
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Kongju Nat'l Univ.

Park, Sung Gi
IAS

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Harvard Univ.

Seo, Dong-Hwi
Univ. of L'Aquila

Seo, Seong-Mi
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Shin, YongJoo
Chungnam Nat'l Univ.

Sohn, Youngtak
Brown Univ.

Suriajaya, Ade Irma
Faculty of Mathematics, Kyushu Univ.

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Univ. of Manchester

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Tong, Bolun
Harbin Engineering Univ.

Van Garrel, Michel
Univ. of Birmingham

Wang, Gaoming
Tsinghua Univ., Yau Mathematical Science Center

Wang, Botong
Univ. of Wisconsin-Madison

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Wong, Helen
Claremont McKenna College

Woo, Kwan
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Yamauchi, Takuya
Tohoku Univ.

Yau, Yu-Tung
Univ. of Michigan

Yoo, Minha
NIMS

Yoon, Seokbeom
Southern Univ. of Science and Technology

Youn, Yeonghun
Yeungnam Univ.

Yuan, Tianyu
Beijing Int'l Center for Mathematical Research

Zhang, Ruobing
Princeton Univ.

Conferences and Workshops

2023 Symposium in Algebraic Geometry
Jan. 03 – Jan. 05

Physical Mathematics and Beyond
Jan. 29 – Jan. 31

The 19th KIAS Winter School on Geometry
Feb. 18 – Feb. 23

Korea-France Workshop on Dynamical Group Theory
Feb. 29

2024 KMS Spring Meeting
Apr. 18 – Apr. 20

Physical Mathematics and Beyond: the 2nd workshop
Jun. 17 – Jun. 19

2024 1st KWMS-KIAS Summer School
Jun. 24 – Jul. 05

Summer School in Geometry And Physics
Jul. 08 – Jul. 12

KIAS Graduate Student Meeting in Pure Mathematics
Oct. 21

2024 KMS Annual Meeting
Oct. 24 – Oct. 26

2024 KIAS Advanced Basic Science Research Development Workshop
Oct. 31 – Nov. 01

2024 Korean Association of Senior Scientists and Engineers Fall Meeting
Nov. 06

Seoul-Tokyo Conference in Mathematics 2024
Nov. 29 – Nov. 30

The 8th KIAS Alumni Workshop in Mathematics
Dec. 23

Publications

Kim, Hyun Kyu
Naturality of SL3 quantum trace maps for surfaces • QUANTUM TOPOLOGY

Cho, Cheol-Hyun; **Lee, Sangwook**
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HIGHER MOMENT FORMULAE AND LIMITING DISTRIBUTIONS OF LATTICE POINTS • JOURNAL OF THE INSTITUTE OF MATHEMATICS OF JUSSIEU

Kim, Kyeong-Hun; **Park, Daehan**
A Sobolev Space Theory for Time-Fractional Stochastic Partial Differential Equations Driven by Levy Processes • JOURNAL OF THEORETICAL PROBABILITY

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A Curvature Estimate for Stable Marginally Outer Trapped Hypersurface With a Free Boundary • INTERNATIONAL MATHEMATICS RESEARCH NOTICES

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Park, Heesang; **Shin, Dongsoo**
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Kim, Daejun; Lee, Seok Hyeong
Lifting problem for universal quadratic forms over totally real cubic number fields • BULLETIN OF THE LONDON MATHEMATICAL SOCIETY

Kim, Takwon; Lee, Ki-Ahm; **Yun, Hyungsung**
Generalized Schauder theory and its application to degenerate/singular parabolic equations • MATHEMATISCHE ANNALEN

Jia, Jia; **Meng, Sheng**
Equivariant Kahler model for Fujiki's class • JOURNAL OF GEOMETRIC ANALYSIS

Alberts, Tom; **Byun, Sung-Soo**; **Kang, Nam-Gyu**; Makarov, Nikolai G.
Pole dynamics and an integral of motion for multiple SLE(0) • SELECTA MATHEMATICA-NEW SERIES

Lee, Juyoung; Lee, Sanghyuk; **Oh, Sewook**
The elliptic maximal function • JOURNAL OF THE NEUROLOGICAL SCIENCES

Choi, Kyeongsu; Kim, Minhyun; **Lee, Taehun**
Curvature bound for Lp Minkowski problem • ADVANCES IN MATHEMATICS

Kirsten, Klaus; **Lee, Yoonweon**
The zeta-determinant of the Dirichlet-to-Neumann operator on forms • ANNALS OF GLOBAL ANALYSIS AND GEOMETRY

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Kim, Sang-hyun; Koberda, Thomas; Rivas, Cristobal
Virtual Critical Regularity of Mapping Class Group Actions on the Circle • TRANSFORMATION GROUPS

Landim, Claudio; **Lee, Jungkyoung**; Seo, Insuk
Metastability and Time Scales for Parabolic Equations with Drift 1: The First Time Scale • ARCHIVE FOR RATIONAL MECHANICS AND ANALYSIS

Kang, Jaehoon; **Park, Daehan**
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Kim, Henry H.; Wakatsuki, Satoshi; Yamauchi, Takuya
Distribution of Hecke eigenvalues for holomorphic Siegel modular forms • ACTA ARITHMETICA

Mohammadpour, Reza; **Park, Kiho**
Uniform quasi-multiplicativity of locally constant cocycles and applications • STUDIA MATHEMATICA

Chen, Hsin-Ku
Minimal resolutions of threefolds • ELECTRONIC RESEARCH ARCHIVE

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GENERALIZED DONALDSON-THOMAS INVARIANTS VIA KIRWAN BLOWUPS • JOURNAL OF DIFFERENTIAL GEOMETRY

Nyberg-Brodda, Carl-Fredrik
The abelianization of SL2(Z[1/m]) • JOURNAL OF ALGEBRA

Chodosh, Otis; **Choi, Kyeongsu**; Mantoulidis, Christos; Schulze, Felix
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Global Cauchy problem for the Vlasov-Riesz-Fokker-Planck system near the global Maxwellian • JOURNAL OF EVOLUTION EQUATIONS

Choi, Kyeongsu; Haslhofer, Robert; Hershkovits, Or
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Meng, Sheng; Zhong, Guolei
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Chai, Xiaoxiang; **Pyo, Juncheol**; Wan, Xueyuan
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Lee, Ki-Ahm; **Lee, Taehun**
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Chodosh, Otis; **Choi, Kyeongsu**; Mantoulidis, Christos; Schulze, Felix
Mean curvature flow with generic initial data • INVENTIONES MATHEMATICAE

Choi, Beomjun; **Choi, Kyeongsu**; Daskalopoulos, Panagiota
UNIQUENESS OF ANCIENT SOLUTIONS TO GAUSS CURVATURE FLOW ASYMPTOTIC TO A CYLINDER • JOURNAL OF DIFFERENTIAL GEOMETRY

Byun, Sun -Sig; **Song, Kyeong**; Youn, Yeonghun
Singular elliptic measure data problems with irregular obstacles • NONLINEAR ANALYSIS-THEORY METHODS & APPLICATIONS

Lee, Taehun
An Eigenvalue Problem for Prescribed Curvature Equations • INTERNATIONAL MATHEMATICS RESEARCH NOTICES

Oh, Sung-Jin; Pasqualotto, Federico
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Kim, Hyun Kyu; Scarinci, Carlos
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Lee, Mikyoung; Ok, Jihoon; **Pyo, Juncheol**
Calderón-Zygmund estimates for nonlinear equations of differential forms with BMO coefficients • JOURNAL OF DIFFERENTIAL EQUATIONS

Lee, Minju; **Oh, Hee**
Dichotomy and Measures on Limit Sets of Anosov Groups • INTERNATIONAL MATHEMATICS RESEARCH NOTICES

Jeong, In-Jee; **Kim, Junha**
STRONG ILL-POSEDNESS FOR SQG IN CRITICAL SOBOLEV SPACES • ANALYSIS & PDE

Kwon, Jae-Hoon; **Lee, Sin-Myung**; Okado, Masato
Oscillator Representations of Quantum Affine Orthosymplectic Superalgebras • COMMUNICATIONS IN MATHEMATICAL PHYSICS

Kiem, Young-Hoon; Lee, Donggun
Birational geometry of generalized Hessenberg varieties and the generalized Shareshian-Wachs conjecture • JOURNAL OF COMBINATORIAL THEORY SERIES A

Chai, Xiaoxiang
Inverse mean curvature flow with a free boundary in hyperbolic space • CALCULUS OF VARIATIONS AND PARTIAL DIFFERENTIAL EQUATIONS

Guan, Pengfei; **Huang, Jiuzhou**; Liu, Jiawei
Non-homogeneous fully nonlinear contracting flows of convex hypersurfaces • ADVANCED NONLINEAR STUDIES

Chung, Kiryong; **Kim, Jeong-Seop**
An SL(3, C)-equivariant smooth compactification of moduli space of rational quartic plane curves • JOURNAL OF ALGEBRA

Oh, Yong-Geun; **Suen, Yat-Hin**
Lagrangian multi-sections and their toric equivariant mirror • ADVANCES IN MATHEMATICS

Hui, Shyamal Kumar; **Pyo, Juncheol**; Saha, Apurba
The first nonzero eigenvalue of the (p, q)-Laplace system along the inverse mean curvature flow with forced term • JOURNAL OF MATHEMATICAL ANALYSIS AND APPLICATIONS

Lee, Sanghun; Park, Sangwoo; **Pyo, Juncheol**
Rigidity results of weighted area-minimizing hypersurfaces • ANNALS OF GLOBAL ANALYSIS AND GEOMETRY

Choi, Jae-hwan; Kang, Jaehoon; **Parks, Daehan**
A REGULARITY THEORY FOR PARABOLIC EQUATIONS WITH ANISOTROPIC NONLOCAL OPERATORS IN SPACES • SIAM JOURNAL ON MATHEMATICAL ANALYSIS

Landesberg, Or; **Oh, Hee**
On denseness of horospheres in higher rank homogeneous spaces • ERGODIC THEORY AND DYNAMICAL SYSTEMS

Park, Kiho
Construction and applications of proximal maps for typical cocycles • ERGODIC THEORY AND DYNAMICAL SYSTEMS

Kim, Yong-Cheol
NONLOCAL HARNACK INEQUALITIES FOR NONLOCAL p-LAPLACIAN TYPE SCHRODINGER OPERATORS WITH A1 p-MUCKENHOUPT POTENTIALS • COMMUNICATIONS ON PURE AND APPLIED ANALYSIS

Benedetto, Robert l.; **Ih, Su-ion**
DISCRETENESS OF POSTCRITICALLY FINITE MAPS IN p-ADIC MODULI SPACE • TRANSACTIONS OF THE AMERICAN MATHEMATICAL SOCIETY

Kim, Hyunseok; Zhou, Yong
Local existence results in Sobolev spaces for generalized magnetohydrodynamics equations • MATHEMATICAL METHODS IN THE APPLIED SCIENCES

Edwards, Sam; Lee, Minju; **Oh, Hee**
Torus counting and self-joinings of Kleinian groups • JOURNAL FUR DIE REINE UND ANGEWANDTE MATHEMATIK

Choy, Jaeyoo
Saw varieties • JOURNAL OF ALGEBRA

Lee, Jihyeon; Nam, Eungmo; **Pyo, Juncheol**
Rigidity theorems of λ-translating solitons in Euclidean and Lorentz-Minkowski spaces • ANNALI DI MATEMATICA PURA ED APPLICATA

Ahn, Jinhoo; **Kim, Joonhee**
SOP1, SOP2, and antichain tree property • ANNALS OF PURE AND APPLIED LOGIC

Herr, Sebastian; Sanwal, Akansha; **Schippa, Robert**
Low regularity well-posedness of KP-I equations: The three-dimensional case • JOURNAL OF FUNCTIONAL ANALYSIS

Kim, Seongyeon; Lee, Yoonjung; Seo, Ihyeok
Sharp weighted Strichartz estimates and critical inhomogeneous Hartree equations • NONLINEAR ANALYSIS-THEORY METHODS & APPLICATIONS

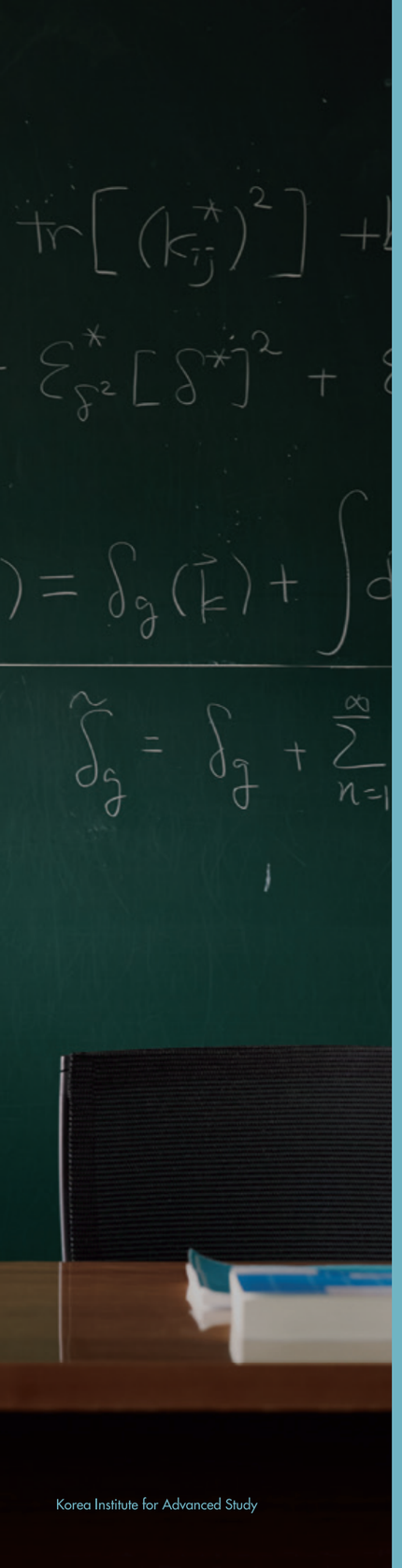
Ho, Pak Tung; **Pyo, Juncheol**
First eigenvalues of free boundary hypersurfaces in the unit ball along the inverse mean curvature flow • DIFFERENTIAL GEOMETRY AND ITS APPLICATIONS

Jeong, Eunhee; Lee, Sanghyuk; **Ryu, Jaehyeon**
Bounds on the Hermite spectral projection operator • JOURNAL OF FUNCTIONAL ANALYSIS

Ho, Pak Tung; **Pyo, Juncheol**
Evolution of the first eigenvalue along the inverse mean curvature flow in space forms • JOURNAL OF MATHEMATICAL ANALYSIS AND APPLICATIONS

Choi, Geunsu; **Jung, Mingu**; Kim, Sun Kwang; Martin, Miguel
Weak-star quasi norm attaining operators • JOURNAL OF MATHEMATICAL ANALYSIS AND APPLICATIONS

School of Physics

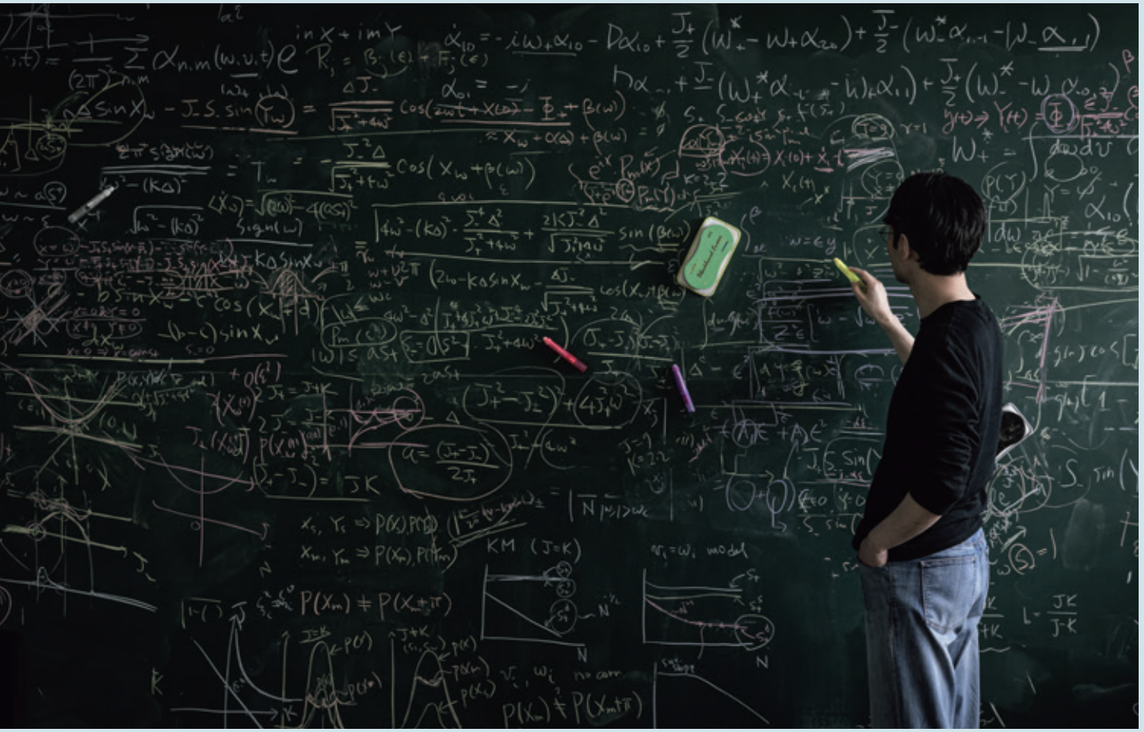


Over the last two centuries, the world has witnessed great improvements in the quality of life, many of which have been driven by accomplishments in natural sciences, physics in particular. Discoveries in physics have led to advancements in all fields of science and to the development of new technologies that have dramatically transformed the modern world. It is difficult to envision our technology-driven world without the foundation of modern physics, from the significant paradigm shifts brought about by the theory of relativity and quantum mechanics to the invention of semiconductors. The Korea Institute for Advanced Study (KIAS) aspires to serve as a source of fundamental knowledge that will play a pivotal role in advancing human civilization. With this aim, the School of Physics today conducts research in broad areas of theoretical physics, including string theory, field theory, particle physics, statistical physics, condensed matter physics, astrophysics, and cosmology.

Faculty and Research Fellows

Position	Name	Research Interest
Distinguished Professor	Mukhanov, Viatcheslav	Theoretical Physics, Cosmology
Professor Emeritus	Lee, Kimyeong	Theoretical Physics
Professors	Chun, Eung Jin	Particle Physics
	Jeong, Donghui	Astrophysics
	Kim, Yong Baek	Condensed Matter Physics
	Ko, Pyungwon	Theoretical High Energy Physics
	Lee, Jae Sung	Statistical Physics
	Lee, Seung Joon	Particle Physics
	Lee, Sungjay	String Theory, Quantum Field Theory
	Park, Changbom	Astrophysics, Cosmology
	Park, Kwon	Condensed Matter Physics, Strongly Correlated Electron Systems
	Yi, Piljin	String Theory
KIAS Scholars	Pomarol, Alex	Theoretical Particle Physics
	Pichon, Christophe	Astrophysics
	Tong, David	Theoretical Physics
KIAS Fellow	Hwang, Kyusung	Condensed Matter Theory
Research Fellows	Lee, Sangyun	Nonequilibrium Statistical Physics
	Kim, Suro	Particle Physics
	Dutka, Tomasz P.	Particle Physics
	Lu, Yongchao	String Theory
	Pal, Priyo Shankar	Statistical Physics
	Mandal, Sanjoy	Particle Physics
	Li, Linfeng	String Theory
	Dupuy, Alexandra	Astrophysics
	Goyal, Priya	Astrophysics
	Kim, Youngjae	Condensed Matter Theory
	Chun, Hyun-Myung	Statistical Physics
	Kawana, Kiyoharu	Particle Physics
	Kim, Sungjoon	Fields and String Theory
	Kim, TaeHun	Particle Physics
	Jepsen, Christian Baadsgaard	Quantum Field Theory, String Theory
	Lee, Kyungsun	String Theory
	Hampton, Shaun David	String Theory
	Zheng, Yu-Hui	Paricle Physics
	Awasthi, Shakul	Statistical Physics

Position	Name	Research Interest
Research Fellows	Mishra, Preetish	Astrophysics
	Singh, Varinder	Statistical Physics
	Davari Dolatabadi, Zahra	Cosmology
	Ban, Kayoung	Particle Physics
	Lu, Philip	Astroparticle Physics
	Agrawal, Aayushi	Theoretical Condensed Matter
	Salim, Shahrukh	Condensed Matter Physics
	Kim, Jinheung	Particle Physics
	Vos, Gideon	String Theory
	Lin, Ban	String Theory, Quantum Field Theory
	Youn, Taewook	Particle Physics
	Yu, Bingrong	Particle Physics



Statistical & Condensed Matter Physics

The Statistical & Condensed Matter Physics group started in 2024 with three professors: Prof. Kwon Park, Prof. Yong Baek Kim, and Prof. Jae Sung Lee. The group had one QUC Distinguished Professor, Prof. Hyunggyu Park, one Korea Institute for Advanced Study (KIAS) fellow, Dr. Kyusung Hwang, and eight research fellows, Dr. Youngjae Kim, Dr. Aayushi Agrawal, Dr. Shahrukh Salim, Dr. Sangyun Lee, Dr. Priyo Shankar Pal, Dr. Hyun-Myung Chun, Dr. Shakul Awasthi, and Dr. Varinder Singh.

Dr. Sangyun Lee returned to KIAS in September 2024 after a visit to the laboratory of Prof. Christopher Jarzynski at the University of Maryland, which started in November 2023 and was supported by KIAS. Two new members also joined the condensed matter physics group: Dr. Aayushi Agrawal joined as a research fellow in September 2024, moving from Birla Institute of Technology and Science (BITS) Pilani, India, while Dr. Shahrukh Salim joined as a research fellow in October 2024, moving from the Indian Institute of Technology Delhi.

Various research activities were pursued by the members of the group during the year. Here is a summary of selected work.

Prof. Jae Sung Lee focused on stochastic and quantum thermodynamics and thermodynamic trade-off relations. Together with Euijoon Kwon and Prof. Yongjoo Baek, he discovered a unified hierarchical relationship among various previously identified thermodynamic trade-off relations. This work was published in *Physical Review E*. In collaboration with Prof. Hyunggyu Park and Prof. Jong-Min Park, he derived the stochastic differential equation for a system coupled to a thermostatic bath via an arbitrary interaction Hamiltonian. This work was also published in *Physical Review E*. Working with Dr. Priyo and Prof. Hyunggyu Park, he analytically and numerically demonstrated that self-propelled motion in active particles can enhance target search with resetting in a thermal environment by reducing search times. This study was published in *Physical Review E*. Finally, in collaboration with Dr. Sangyun Lee and Prof. Hyukjoon Kwon, he proposed a novel method for estimating quantum entanglement entropy using a variational quantum circuit, supported by classical neural networks. Together, they applied this method to identify the quantum transition point. This work was published in *Physical Review E*.

Prof. Yong Baek Kim established a theory of quantum spin ice, a three-dimensional quantum spin liquid, in dipolar–octupolar pyrochlore systems. He and his collaborators classified possible quantum spin ice states in these systems and presented the static and dynamical spin structure factors. He collaborated with neutron scattering experimentalists to investigate the signatures of fractionalized excitations and emergent photons in these quantum magnets, including $Ce_2Zr_2O_7$ and $Ce_2Sn_2O_7$. They identified promising signals that are consistent with the theoretical predictions. The results were published in *Physical Review Letters* and *Nature Physics*.

Prof. Kwon Park, in collaboration with Dr. Byungmin Kang (MIT), Dr. Hyunwoong Kwon (KIAS), and Prof. Vito Scarola (Virginia Tech), developed an efficient *quantum* algorithm for the Gutzwiller projection that is quadratically faster than the naïve projection method, using quantum computers to solve high-temperature superconductivity. The Gutzwiller-projected BCS state, also referred to as the resonating valence bond (RVB) state, can act as an excellent trial wave function for high-temperature superconductivity. This work was supported by the US–Korea Quantum Initiative under the project title "Hybrid Quantum Algorithms for Quantum Many-Body Physics." Dr. Kyusung Hwang introduced solvable open quantum systems for Kitaev spin liquid and toric code coupled to environments via the Lindblad master equation. Using exact solutions and numerical approaches, Dr. Hwang demonstrated the dynamical occurrence of anyon condensation via decoherence and dissipation, resulting in a topological transition from the initial state spin liquid to the steady state spin liquid. This work was published in *Quantum*. Dr. Youngjae Kim, in a collaborative paper with Prof. Jae-dong Lee at DGIST and Prof. Jong-Hwan Kim at POSTECH, conducted theoretical analysis for the high-order harmonic emission in graphene. Dr. Kim proposed a new method for measuring the decoherence time for electron–hole pairs in solid environments. This work was published in *Nano Letters*.

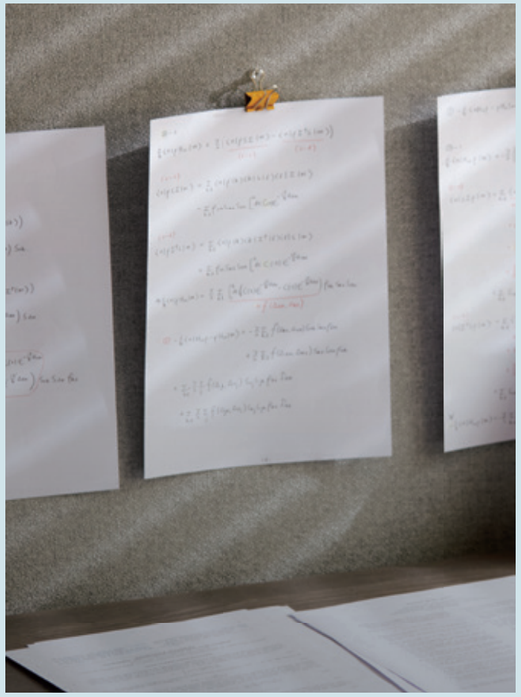
Prof. Kwon Park co-organized the Quantum Materials Symposium 2024 (QMS24) with the Korean Physical Society (KPS) and the Asia-Pacific Center for Theoretical Physics (APCTP). The symposium, held at Yongpyong Resort from February 18 to 23, 2024, focused on various strongly correlated condensed matter physics topics, including quantum magnetism, superconductivity, topological matter, two-dimensional materials, and chiral phonons. With more than 200 participants from various countries, including Korea, the USA, Japan, Germany, Taiwan, and Switzerland, QMS24 is one of Korea's most important international conferences for condensed matter physics. QMS24 was jointly held with a satellite meeting of Brain-Link X-day titled "Recent Progress in Superconductivity." In addition, Prof. Kwon Park co-organized the 15th APCTP-IACS-KIAS Joint Conference on Emergent Phenomena in Novel Oxide Materials and Low-Dimensional Systems, which was held at Nine Tree Premier Hotel Insadong from November 19 to 21, 2024. Novel oxide materials and low-dimensional systems have attracted significant interest in condensed matter research due to their various physical properties, which are important for basic research and various applications. The main objective of this conference was to showcase and discuss cutting-edge theoretical and experimental works on novel and emerging materials, as well as to facilitate the exchange of ideas and collaboration among researchers from India and Korea. The primary discussion topics included transition metal oxides, topological matter, novel superconductors, two-dimensional materials, and nonequilibrium phenomena.

In the field of statistical physics, Prof. Jae Sung Lee organized several schools and workshops in 2024. The first was the 21st KIAS-APCTP Winter School on Statistical Physics (January 8–12), focusing on stochastic processes, network science, and clustering dynamics in percolation and synchronization primarily for graduate students. The second event was the 10th Nonequilibrium Statistical Physics of Complex Systems (July 22–25) to present new ideas in statistical physics and related fields and to facilitate scientific exchanges and collaboration among leading scientists as well as students and postdocs. The third event was the 12th Workshop on Nonequilibrium Fluctuation Theorems (August 26–28), addressing various issues related to quantum and stochastic thermodynamics. The final event was the 8th KIAS School and Workshop on Quantum Information and Thermodynamics (November 6–9), providing a platform for the next generation of students and researchers to understand the significant progress made in our understanding of nonequilibrium thermodynamics within the context of quantum information. Additionally, he regularly organized 28 Non-Equilibrium Statistical Mechanics Theory (NEST) meetings, a weekly gathering for in-depth discussions on various topics in statistical physics, as well as the 142nd and 144th Statistical Physics Monthly Meetings, a monthly event for members of the statistical physics division of the Korean Physical Society.

Astrophysics and Cosmology

The Astrophysics and Cosmology group is headed by Profs. Changbom Park and Donghui Jeong and Research Profs. Juhan Kim and QUC Fellow Jeong-Gyu Kim. Postdocs in the group include Drs. Alexandra Dupuy, Priya Goyal, Jaewon Yoo, Preetish Mishra, Zahra Davari, and Jie Li.

In 2024, Prof. Park, after measuring the dark energy equation of state parameter $w=-0.902\pm0.023$ under the paradigm of the wCDM cosmologies, continued to constrain various dark energy models. In 2024, significant effort was put into developing new multiverse simulations of the CPL models in preparation for constraining time-evolving w models such as the DPL models. Prof. Park is also leading the Korea Dark Energy Survey (KDES) program, which aims to uncover the nature of the dark energy component of the universe. He is a member of the Dark Energy Spectroscopic Instrument (DESI) consortium as part of the program. Using the HR5 simulation, he is working on many scientific projects, such as defining galaxy proto-clusters and revealing the evolution of galaxy morphologies throughout the history of the universe. He is working together with many astronomers in Korea to conduct multi-object spectroscopic surveys of galaxies. This includes the All-sky Spectroscopic Survey of the Nearby Universe (A-SPEC), which is led together with KASI and SNU and aims to make spectroscopic observations of nearby galaxies out to a redshift of about 0.15 over the whole sky. It is expected that the first light from the program will arrive in late 2025. There is also a plan to build a telescope system with an effective diameter of 9.2 m dedicated to spectroscopic observations.



Prof. Donghui Jeong continued his data analysis using the HETDEX galaxy survey for dark energy studies and Cosmic-Flow 4 data for local dark matter mapping. On the theoretical front, a collaboration paper comparing various large-scale structure statistics came out of the Beyond-2pt collaboration, which was formed at an Aspen Center for Physics workshop that he co-organized in 2022. With his former graduate student James Gurian, he computed the estimation of the mass of the first generation star as a function of the formation redshift and hosting halo mass, as well as the total infalling radius and mass for a radiatively cooling gas cloud. With his current graduate student Zhenyuan Wang, he worked on modeling non-linearities (bispectrum) in cosmological density fields and novel observables utilizing a specific form of nonlinear coupling, known as the soft limit, to probe the primordial spectator fields called clustering fossils. He has also completed a new calculation of the renormalization of perturbative galaxy bias.

CAC Research Professor Juhan Kim, along with graduate students Gain Lee and Minseong Kwon, incorporated a dynamic dark energy model into N-body and hydrodynamic simulation codes. He also developed a cosmological initial condition generation program to create matter distributions with sub-percent accuracy for use in cosmological simulations. He is also developing a new algorithm to improve the efficiency and accuracy of the galaxy-finding method in the DARWIN cosmological galaxy formation research project.

Dr. Alexandra Dupuy is reconstructing both dark matter density and peculiar velocity fields from observed peculiar velocities derived from the Cosmicflows-4 (CF4) catalog of galaxy distances by means of a convolutional neural network, which is a form of deep learning, trained samples prepared using the A-SIM simulation halo, and galaxy catalogs. A first manuscript using corrected radial peculiar velocity is currently being finalized. She is also starting the next step of the project, which involves incorporating observational bias treatment into the deep learning approach. Additionally, she worked with Hélène Courtois and other collaborators on projects involving the WALLABY survey and CF4++ catalog.

Dr. Priya Goyal is examining the morphology of HR5 simulation galaxies in the cosmic noon epoch ($\sim6<z<1$). She is also investigating the fundamental plane relation for HR5 early-type galaxies to understand its redshift evolution and the origin of its scatter by examining the galaxies' physical and dynamical properties. Additionally, she has been collaborating with Dr. Stephen Appleby (APCTP) and Prof. Pravabati Chingangbam (IIA, Bangalore), investigating the impact of massive neutrinos on the morphology and topology of large-scale structures using Minkowski functionals and Minkowski tensors.

Dr. Preetish Mishra is studying the relationship between galaxy properties, dark matter halo mass, and large-scale environments using the Horizon Run 5 (HR5) simulation. His research focused on understanding the origin of the critical mass scale at which many galaxy scaling relations change, specifically investigating how baryonic processes shape the stellar mass–halo mass relation and establish this mass threshold. He has also contributed to studies on the radial distribution of galaxy morphologies in clusters within the HR5 collaboration. Additionally, he was involved in the detection of a hidden dwarf galaxy within a larger galaxy, identified by its chemical signature in MUSE IFU data.

Dr. Zahra Davari joined the astrophysics group in early 2024 and is researching w-tension using the Alcock-Paczyński test in late quintessence dark energy models. She extends Dr. Fuyu Dong's work by refining constraints on scalar field quintessence models. She has published several papers analyzing DESI BAO 2024 measurements in different dark energy contexts and recently studied the impact of a modified Compton effect on CMB anisotropies using Planck 2018 data.

String Theory

The String Theory group consists of two full-time faculty members, Prof. Sungjay Lee and Prof. Piljin Yi, as well as one KIAS Scholar, Prof. David Tong of the University of Cambridge. The group currently

includes eight KIAS research fellows: Dr. Shaun Hampton, Dr. Minsung Kim, Dr. Christian Jepsen, Dr. Sungjoon Kim, Dr. Kyungsun Lee, Dr. TaeHwan Oh, Dr. Ban Lin, and Dr. Gideon Vos.
In 2024, Prof. Kimyeong Lee retired and moved to BIMSA (China) for a faculty position. Dr. Rui Sun joined the University of Chinese Academy of Sciences as a junior faculty member in the Department of Mathematics. Dr. Sunjin Choi and Dr. Jia Qiang relocated to IPMU (Japan) and KAIST (Korea) to serve as research fellows. The group also welcomed two new postdoctoral researchers: Dr. Ban Lin from Tsinghua University and Dr. Gideon Vos from CEICO (Czech).

Some of the group's research highlights are summarized below.

Prof. Piljin Yi co-authored three research papers, each with distinct juniors, all concerning the subtle questions of anomalies: the axial anomaly of certain exotic tensor theories in six dimensions, a relook at Witten's discrete gauge anomaly in the context of the Yang-Mills instanton, and a careful restudy of the diffeomorphism anomaly. In the last project, in particular, the authors unearthed a factor 1/2 misunderstanding that was surprisingly left unaddressed for four decades. The ongoing projects for two graduate text-books continued steadily throughout the year as well.

Dr. Shaun Hampton has primarily focused on elucidating aspects of the black hole microstructure and describing dynamics in orbifold conformal field theories (CFTs). In his first project, he investigated massless geodesic probes of existing geometrical constructions known as superstrata, a class of smooth horizonless microstates of three-charge black holes. One set of probes was found to exist anywhere within the geometry, while another set, for a specified background momentum range, provided a characterization of the black hole bound, becoming trapped deep in the interior region. For his second project, he constructed a new set of superstrata by developing a bootstrap technique to solve BPS equations of six-dimensional supergravity and identified their states in the holographic CFT. In his third project, Dr. Hampton computed higher-point correlation functions in orbifold CFTs to describe new aspects of dynamical

vacuum transitions, with the underlying goal of better understanding time-dependent D-brane and string interactions.

Dr. Minsung Kim explored defects in 5d supersymmetric quantum field theories and utilized them to study quantum curves of 5d theories, including non-toric and non-Lagrangian theories. He also examined the effects of transitions, such as S-duality and Hanany-Witten transitions, on supersymmetric defect partition functions and quantum curves, revealing non-trivial relationships between distinct physical observables. This may provide new insights into the interactions between defects, quantum curves, and integrable models.

In 2024, Dr. Christian Jepsen saw the completion of three QFT and string theory projects with various collaborators. The first identified extremal RG fixed points of perturbation theory as a lamppost effect and corrected some misconceptions about bounds on operator dimensions. The second project derived formulas for the uplift of the Veneziano string amplitude and its monodromy and KLT relations to brane amplitudes. The third extended the formalism of p-adic AdS/CFT to finite-temperature CFTs.

Dr. Sungjoon Kim worked out the building blocks of 3d N=4 supersymmetric IR dualities, particularly for adjoint SQCD theories. Remarkably, the duality of adjoint SQCD can be proven by assuming the well-known Seiberg duality in 3d. Interestingly, the S-confinement phenomena of 4d N=2 Argyres-Douglas theories played a key role, which can also be proven in 3d by assuming duality building blocks.

In 2024, Dr. Kyungsun Lee studied the edge modes (also known as would-be gauge modes) in both gravitational and gauge theory contexts. A key contribution, published with Akhil Sivakumar and Junggi Yoon, demonstrated how the super-Schwarzian theory emerges from Jackiw-Teitelboim supergravity's boundary as a gravitational edge mode action. They developed this analysis using both pure gravitational formalism and BF gauge theory approaches.

Dr. TaeHwan Oh studied the construction of a twistor worldline action model using coadjoint orbits. To formulate actions of half-integer spin, it is necessary to consider the double covering group. AdS spaces with specific dimensions have well-defined isomorphisms that describe twistor particles. Twistor descriptions of other maximally symmetric spacetimes can be derived from dimensional reduction of an AdS twistor. This work can be applied to the computation of scattering amplitudes and the construction of higher-spin models.

The String Theory group hosted two seasonal schools: PSI2024, aimed at graduate students in theoretical physics, and the KIAS-SNU Winter Camp, designed for general physics undergraduate students. The group also organized the interdisciplinary workshop FTP2024, which brought together prominent geometers and quantum field theorists for a round-table discussion. Perhaps the most prominent academic activity was the inaugural joint workshop with French physicists—the Korea-France Joint Workshop on String Theory—which marked the beginning of a bilateral biennial series.

High Energy Physics

In the fall of 2024, Prof. Seung Joon Lee from Korea University joined the High Energy Physics (HEP) group, which also includes two existing full-time faculty members, Prof. Eung Jin Chun and Prof. Pyungwon Ko, and one KIAS Scholar, Prof. Alex Pomarol (Barcelona). Four members have moved to other places: Jongkuk Kim to Chung-Ang University, Dibyendu Nanada to Bhubaneswar, India, Shu-Yu Ho to Academia Sinica in Taiwan, and Sumit Ghosh to Maulana Azad National Institute of Technology, Bhopal, India. New members who have joined the HEP group include Philp Lu from

SNU, Kayong Ban from Yonsei University, and Jinheung Kim from Konkuk University.

Prof. Pyungwon Ko worked on various topics related to dark matter, including light dark sectors motivated by the Belle II excess in B → Kνν decay with Jongkuk Kim and Shu-Yu Ho (KIAS) and gauged Q-ball dark matter with Si-Yu Jiang and Fa Peng Huang (National Sun Yat-Sen University at Zhuhai, China). He also worked out two-component WIMP DM scenarios and the interaction between DM and Higgs inflation with Jinsu Kim (Tongli University, China) and Sarif Khan (Gottingen University), considering the role of the dark Higgs boson. With Gabriela Barenboim (U of Valencia) and Wan-Il Park (Jeonbuk National Univ), he proposed a cosmological model based on classical scale invariance, Type-I seesaw for neutrino masses and mixing, and U(1) Peccei-Quinn symmetry that is broken by gravity through non-minimal coupling to the U(1) PQ-charged Higgs fields. Within this setup, the axi-Majoron becomes dark matter, and the model could address most cosmology and particle physics puzzles in a one-shot scenario.

Prof. Eung Jin Chun investigated the possibility of a common origin for baryon asymmetry and dark matter of the universe in connection with neutrino mass generation with Tae-Hyun Jeong, who moved to IBS, and worked on the phenomenology of the neutrino magnetic operator with Sanjoy Mandal.

Prof. Seung Joon Lee has worked on topics including beyond the standard model of phenomenology, collider physics, cosmology and astroparticle physics. His work "New Horizons in the Holographic Conformal Phase Transition" explored out-of-equilibrium dynamics of conformal phase transition, while he investigated collider signatures for gapped continuums in "Collider Signatures of Near-continuum Dark Matter". In his paper, "Cosmological Quasiparticles and Cosmological Collider", he explored the interaction between cosmology and strongly coupled dynamics, which can yield transient spectral features that vanish at late times but which may leave behind phenomenological signatures in the spectrum of primordial fluctuations.

In 2024, Prof. Ko was invited to the Rencontres du Vietnam (Quy-Nhon, Vietnam), DM@LHC workshop (CERN), the XVIth Quark Confinement and Hadron Spectrum Conference (QCHSC24, Cairnes, Australia), CORFU2024 (Corfu, Greece), the 4th Asian-European Institutes Workshop for BSM at Shanghai, and the 4th International Joint Workshop (Sydney, Australia) for talks on dark matter and dark sectors in various contexts. In October 2024, he visited the T.D. Lee Institute at Shanghai, China for four weeks, where he delivered extensive lectures and a seminar on dark matter model building and phenomenology. He served as an International Advisory/Organizing Committee Member for the Dark Side of the Universe (DSU), SUSY Conference, and AEPSHEP, among others. Prof. Eung Jin Chun gave lectures on introductory particle physics at IBS, on looking beyond the standard model at the summer school at the Rencontres du Vietnam, and on leptogenesis and baryogenesis at the Indian Institute of Science, Bangalore. He was also invited to give a plenary talk on flavonic dark matter at FLASY 2024, UC Irvine. Prof. Seung Joon Lee presented his work on the CERN BSM forum under the title of "Two Tales of DM: Conformal Forbidden DM & Axion DM from Inflation-driven QPT" and subsequently gave a presentation on axion dark matter from inflation-driven QPT to the Cornell University particle theory group. Prof. Lee was also invited to the Rencontres du Vietnam (Quy-Nhon, Vietnam), the 4th International Joint Workshop (Sydney, Australia), and the CTPU-CKC joint focus program for plenary talks on topics related to dark matter. Prof. Seung Joon Lee was also invited as a keynote speaker to the Korean Society of High Energy Physics (KSHEP) 2024 Spring Meeting and the 2024 Samsung Annual Forum. He served as an International Advisory/Organizing Committee Member for the International Workshop on Top Quark Physics and the LHCP, among others.

Dr. Tomasz Dutka completed a project with Prof. Chang Sub Shin and Dr. Taehyun Jung related to numerical lattice simulations of first-order phase transitions (FOPTs), which exhibit terminated supercooling. They showed that, despite the thin potential barrier in these theories being unable to trap the scalar field, the flatness of the potential required by supercooling is sufficient to localize the field around the origin such that the phase transition proceeds via critical bubble formation and expansion. This predicted stochastic gravitational wave signal was estimated to be detectable. This study has been submitted to the *Journal of High Energy Physics*. Additionally, there are works in progress related to gravitational positivity bounds and the standard model neutrino sector, as well as leptogenesis during an FOPT. In 2024, he also presented research at a number of workshops and conferences, including international talks in Kyoto, Shanghai, and Sydney. He also attended the University of Melbourne as a visiting researcher.

Sumit Ghosh has been involved in the construction of models featuring light mediators and exploring the non-standard interactions of neutrinos. Specifically, along with his collaborator, he proposed a low-energy scale model involving two light bosons—one vector boson and one scalar boson particle. This model is designed to explain some recent experimental anomalous results. Sumit also conducted research on the impact on neutrino oscillations, focusing on CP measurements at DUNE in the presence of scalar-mediated non-standard neutrino interactions.

In 2024, Dr. Shu-Yu Ho cooperated with Dr. Jongkuk Kim and Prof. Pyungwon Ko on the B→Kνν rare decay process reported by the Belle II experiment. In their work, they consider the simplest UV-complete U(1)_(Lμ−Lτ)-charged complex scalar dark matter model with a dark Higgs boson, which can successfully explain the B→Kνν excess, muon anomalous magnetic dipole moment g-2 announced by Fermilab, and the observed relic density of dark matter. They submitted their work to *Physical Review D Letters*, which is under review now. Dr. Shu-Yu Ho also gave many talks about this work at several workshops held in Japan, Taiwan, and Europe, where he received valuable feedback that improved their work.

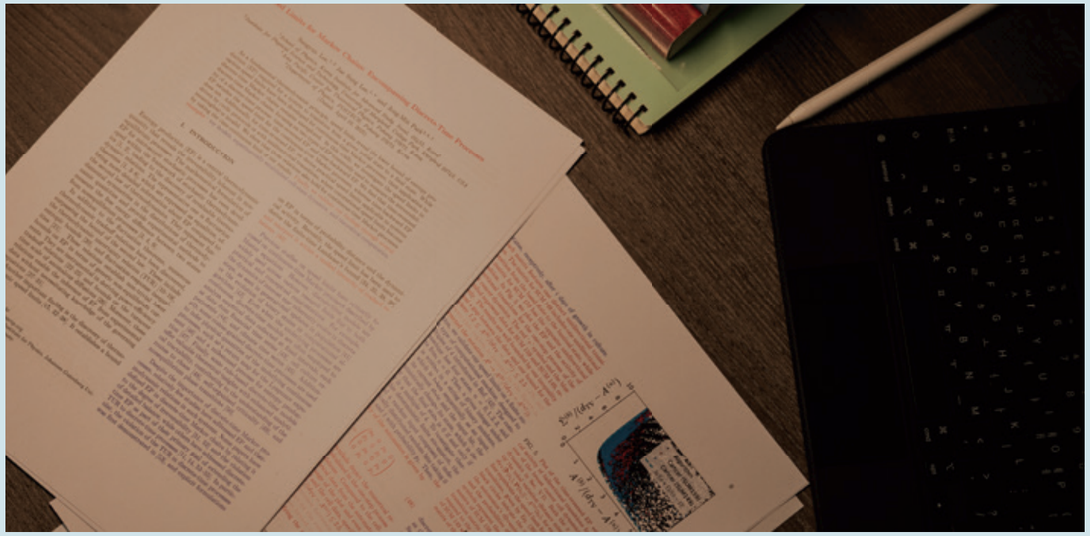
In 2024, Dr. Kiyoharu Kawana worked on several projects. In 2407.1115, along with his partners at KIAS, he studied the instability of the Friedberg-Lee-Sirlin (FLS) Q-ball in the presence of attractive force. They found that there exists a maximum charge for a given coupling of attractive force beyond which the Q-ball is

classically unstable. In 2404.06096, he discussed the realization of the Higgs Alignment using the multi-critical point principle in the two Higgs doublet model. In 2406.03670, he proposed a field theory of closed p-brane Cp interacting with a (p+ 1)-form gauge field Ap+1. This is a generalization of the Ginzburg-Landau theory (Abelian-Higgs model) for superconducting particles to higher-dimensional superconducting branes.

In 2406.15033, he investigated the structure of 4-dimensional bulk space constructed from the O(N) invariant critical φ4 model in three dimensions using conformal smearing.

Dr. Jongkuk Kim has worked on excess signals reported in experimental data related to dark matter physics. He collaborated with Prof. Pyungwon Ko on three different projects in 2024. The first project involved pseudo-Nambu-Goldstone boson dark matter phenomenology with linear breaking. In this work, heavy dark matter mass O(10)TeV was studied. The second project was related to the Belle II $B\to K\nu\nu$ excess. The Belle II collaboration recently announced the first observation of the $B\to K\nu\nu$ decay process, reporting a 2.7σ deviation from standard model predictions. In this work, he considered the simplest UV-complete gauged $U(1)L\mu-L\tau$-charged complex scalar dark matter model, which provides a comprehensive solution addressing the $B\to K\nu\nu$ excess at Belle II, the muon $g-2$ anomaly, the thermal relic density of dark matter, and the Hubble tension. The third project focused on the galactic 511 keV gamma-ray excess. To explain both the 511 keV excess and the observed dark matter relic density, he introduced a dark $U(1)$ symmetry with a Dirac fermion. By considering both the freeze-in mechanism and the super-WIMP mechanism, he successfully obtained the correct relic density. Additionally, the 511 keV excess can be explained through the late decay of vector dark matter. He has given invited talks at the 4th Asian-European-Institutes Workshop for BSM (Shanghai), the 12th KIAS Workshop on Particle Physics and Cosmology, the 2024 Korea-France STAR Workshop (Seoul), and the 2024 Seoul Particle Theory Workshop (Seoul). He has also given talks at the IJW Workshop (Sydney), the 19th Patras Workshop (Greece), Light Dark World 2024 (Daejeon), and the 2024 CAU-PNU BSM Workshop (Seoul).

Dr. Suro Kim completed a project with Prof. Pyungwon Ko on phenomenological applications of the gravitational positivity bound, which gives constraints on effective field theories from the consistency conditions with gravity. In this work, they applied this bound to milli-charged dark matter and compared this with relevant observational constraints. He also completed a project on pseudo-Hermitian systems with Dr. Yao Bai, Ting-Long Feng, Dr. Cheng-Yang Lee, Prof. Lei-Hua Liu, Dr. Wangping Zhao, and Prof. Siyi Zhou. In this work, they calculated the cosmological correlators of the spin-0 fermion, which is the characteristic particle in pseudo-Hermitian systems.



Dr. Dibyendu Nanda has actively worked in dark matter and neutrino physics. In collaboration with Prof. Pyungwon Ko and Shu-Yu Ho (KIAS), he studied the impact of non-standard cosmology on light thermal self-interacting dark matter, which has been published in JCAP. With Anish Ghoshal (Warsaw U.), and Abhijit Kumar Saha (IACS, Kolkata), he showed that the production of non-thermal relics (such as heavy right-handed neutrinos) during reheating can have a significant impact on the CMB observable. This work has been published in *Physical Letters B*.

Dr. Yu-Hui Zheng has primarily been studying dark matter models with nonzero spins and massive dark photons using the on-shell amplitude method with Professor Ko and Dr. Jaehoon Jeong. He obtained the constraints on renormalizable models by studying tree-level unitarity. They were then able to reconstruct some unusual models, such as Higgsless models and inelastic DM models. In addition, he is also collaborating with Professor Jiang-Hao Yu (ITP, CAS) and Professor Ming-lei Xiao (National Sun Yat-sen University) to systematically analyze the angular momentum decomposition and renormalization group in the effective field theory and expand the recursion relation to the Chiral perturbation theory.

Dr. Sanjoy Mandal is working on the phenomenology of neutrino and dark matter physics. He investigated the electron scattering of dark and freeze-in mechanisms in the framework of a light gauge boson mediation, and a way of testing TeV seesaw mechanisms at the mu TRISTAN experiment.

Dr. Taehun Kim works on cosmology and primordial black hole physics, presenting creative ideas on the origin of dark matter from primary black holes and the formation of non-topological charged solitons and their impact on the black hole production.

In 2024, Dr. Taewook Yoon published his work, “Spontaneous CP Breaking in a QCD-like Theory” and “A Generative Modeling Approach to Reconstructing 21 cm Tomographic Data”. He also gave talks in various places, including Syracuse University, the Rencontres du Vietnam (Quy-Nhon, Vietnam), and Pheno2024.

In 2024, Dr. Bingrong Yu cooperated with Prof. Seung Joon Lee on Axion dark matter from inflation-driven quantum phase transitions. Dr. Bingrong Yu published his papers “The Neutrino Force in Neutrino Backgrounds: Spin Dependence and Parity-violating Effects” and “A Cosmological Sandwiched Window for Lepton-number Breaking Scale”. He also gave talks in various places, including New York University, the University of Maryland, and the Rencontres du Vietnam (Quy-Nhon, Vietnam).

Visiting Scientists

Akhond, Mohammad
YITP

Aoki, Shuntaro
Chung-Ang Univ.

Bourgine, Jean-Emile
Univ. of Melbourne

Caputo, Andrea
Sapienza Univ.

Chang, Jae Hyeok
UIC, Fermi Lab

Chen, Xingang
Harvard-Smithsonian Center for Astrophysics

Cherman, Aleksey
The Univ. of Minnesota

Choi, Changha
Perimeter Institute

Christodoulidis, Perseas
Ehwa Womans Univ.

Colless, Matthew
Australian Natl. Univ.

Hong, Deog Ki
Pusan Natl. Univ.

Das, Mousumi
Indian Institute of Astrophysics

Ghim, Dongwook
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Gobat, Raphael
Pontificia Universidad Cat´ olica de Valpara´ıso

Gu, Jie
Southeast Univ.

He, Minxi
IBS

He, Temple
California Institute of Technology

Rieger, Heiko
Saarland Univ.

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Conferences and Workshops

21th KIAS-APCTP Winter School on Statistical Physics
Jan. 08 – Jan. 12

High1 Workshop on Particle, String and Cosmology
Jan. 21 – Jan. 27

Commemorative Workshop for the 90th Birthday of Prof. C. W. Kim
Feb. 05

Quantum Materials Symposium 2024
Feb. 19

KPS Spring Meeting-Plenary Lecture 2024
April. 04

Advances in String Theory and Quantum Field Theory
May. 30 – May. 31

Focused research on the origin and evolution of the Universe
Jun. 17 – Jun. 21

NSPCS 2024
Jul. 22 – Jul. 25

2024 Korea-Japan Joint Workshop on Cosmology, Gravitation and Particle Physics
Aug. 05 – Aug. 08

Pyeong-Chang Summer Institute 2024
Aug. 25 – Aug. 31

The KIAS Summer Camp on Particle Physics
Aug. 20 – Aug. 23

Korea-France Joint Workshop on String Theory
Sep. 23 – Sep. 27

KPS Fall Meeting-OPEN KIAS Special Lecture 2024
Oct. 24

Remedial Mini-Courses on Quantum Field Theories: Part 1+2
Oct. 30 – Jan. 22

The KIAS Physics Colloquia Series 2024
Nov. 06

Emergent Quantum Matter with Topology and Correlation
Nov. 25 – Nov. 28

KIAS-SNU Physics Winter camp
Dec. 23 – Dec. 31

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Predicting the linear response of self-gravitating stellar spheres and discs with <monospace>LinearResponse.jl</monospace> • MONTHLY NOTICES OF THE ROYAL ASTRONOMICAL SOCIETY

Singh, Ankit; Davessar, Shreya; Gulati, Mamta; Bagla, Jasjeet Singh; Prajapati, Meenu
Study of dependence of ram pressure stripping on the orbital parameters of the galaxies • MONTHLY NOTICES OF THE ROYAL ASTRONOMICAL SOCIETY

Chowdhury, Talal Ahmed; Ezzat, Kareem; Khalil, Shaaban; Ma, Ernest; **Nanda, Dibyendu**
Higgs quadruplet impact on W mass shift, dark matter, and LHC signatures • PHYSICAL REVIEW D

Lee, Sangyun; **Kwon, Hyukjoon**; **Lee, Jae Sung**
Estimating entanglement entropy via variational quantum circuits with classical neural networks • PHYSICAL REVIEW E

Ho, Shu-Yu; **Ko, Pyungwon**; **Nanda, Dibyendu**
Light thermal self-interacting dark matter in the shadow of non-standard cosmology • JOURNAL OF COSMOLOGY AND ASTROPARTICLE PHYSICS

Li, Heqiu; **Kim, Yong Baek**; Kee, Hae-Young
Intertwined Van Hove Singularities as a Mechanism for Loop Current Order in Kagome Metals •PHYSICAL REVIEW LETTERS

Shim, Junsup; **Pichon, Christophe**; Pogosyan, Dmitri; Appleby, Stephen; Cadiou, Corentin; **Kim, Juhan**; Kraljic, Katarina; **Park, Changbom**
Probing cosmology via the clustering of critical points • MONTHLY NOTICES OF THE ROYAL ASTRONOMICAL SOCIETY

Jackson, R. A.; Kaviraj, S.; Yi, S. K.; Peirani, S.; Dubois, Y.; Martin, G.; Devriendt, J. E. G.; Slyz, A.; **Pichon, C.**; Volonteri, M.; Kimm, T.; Kraljic, K.
The formation of cores in galaxies across cosmic time - the existence of cores is not in tension with the ΛCDM paradigm • MONTHLY NOTICES OF THE ROYAL ASTRONOMICAL SOCIETY

Aoki, Sinya; Shimada, Kengo; Balog, Janos; **Kawana, Kiyoharu**
Bulk modified gravity from a thermal CFT by the conformal flow • PHYSICAL REVIEW D

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Yoo, Jaewon; **Park, Changbom**; Sabiu, Cristiano G.; **Singh, Ankit**; Ko, Jongwan; **Lee, Jaehyun**; **Pichon, Christophe**; Jee, M. James; Gibson, Brad K.; Snaith, Owain; Kim, Juhan; Shin, Jihye; Kim, Yonghwi; Kim, Hyowon
Spatial Distribution of Intracluster Light versus Dark Matter in Horizon Run 5 • ASTROPHYSICAL JOURNAL

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Twisted elliptic genera • JOURNAL OF HIGH ENERGY PHYSICS

Hutauruk, Parada T. P.; **Kang, Dong Woo**; **Kim, Jongkuk**; Okada, Hiroshi
Muon g-2, dark matter, and neutrino mass explanations in a modular A4 symmetry • PHYSICS OF THE DARK UNIVERSE

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Disentangling the primordial nature of stochastic gravitational wave backgrounds with CMB spectral distortions • MONTHLY NOTICES OF THE ROYAL ASTRONOMICAL SOCIETY

Choi, Ki-Young; **Kim, Jongkuk**; Lkhagvadorj, Erdenebulgan
Non-thermal WIMPy baryogenesis with primordial black hole • JOURNAL OF COSMOLOGY AND ASTROPARTICLE PHYSICS

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Rahman, Fazlu; **Chingangbama, Pravabati**; Ghoshd, Tuhin
Statistical properties of galactic synchrotron temperature and polarization maps - a multi-frequency comparison • JOURNAL OF COSMOLOGY AND ASTROPARTICLE PHYSICS

Sen, Manibrata; **Smirnov, Alexei Y.**
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Won, Ho-Yeon; **Kim, Hyun-Chul**; Kim, June -Young
Flavor structure of the energy-momentum tensor form factors of the proton • PHYSICS LETTERS B

Ghoshal, Anish; **Nanda, Dibyendu**; Saha, Abhijit Kumar
CMB imprints of high scale non-thermal leptogenesis • PHYSICS LETTERS B

Kraljic, Katarina; Renaud, Florent; Dubois, Yohan; **Pichon, Christophe**; Agertz, Oscar; Andersson, Eric; Devriendt, Julien; Freundlich, Jonathan; Kaviraj, Sugata; Kim, Taysun; Martin, Garreth; Peirani, Sebastien; Otero, Alvaro Segovia; Volonteri, Marta; Yi, Sukyoung K.
Emergence and cosmic evolution of the Kennicutt-Schmidt relation driven by interstellar turbulence • ASTRONOMY & ASTROPHYSICS

Baek, S.; **Kersten, J.**; **Ko, P.**; **Velasco-Sevilla, L.**
An unfamiliar way to generate the hierarchy of standard model fermion masses • JOURNAL OF HIGH ENERGY PHYSICS

Gurian, James; **Jeong, Donghui**; Liu, Boyuan
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Kim, Keun-Young; Kim, Minkyoo; **Lee, Kyung-Sun**
Structure constants of a single trace operator and determinant operators from hexagon • JOURNAL OF THE KOREAN PHYSICAL SOCIETY

Chau, Tuan Khanh; Choi, Youngsu; **Hwang, Kyusung**; Oh, Gyounghoon; Akhtar, Sophia; Kim, Jeongyong; Choi, Kwang-Yong; Lee, Hyun-Yong; Hong, Sung Ju; Suh, Dongseok
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Shin, Heechang; Katiyar, Ajit Kumar; Hoang, Anh Tuan; Yun, Seok Min; Kim, Beom Jin; Lee, Gwanjin; **Kim, Youngjae**; Lee, Jaedong; Kim, Hyunmin; Ahn, Jong-Hyun
Nonconventional Strain Engineering for Uniform Biaxial Tensile Strain in MoS2 Thin Film Transistors • ACS NANO

Lee, Kyoung-Soo; Gawiser, Eric; **Park, Changbom**; Yang, Yujin; Valdes, Francisco; Lang, Dustin; Ramakrishnan, Vandana; Moon, Byeongha; Firestone, Nicole; Appleby, Stephen; Artale, Maria Celeste; Andrews, Moira; Bauer, Franz; Benda, Barbara; Broussard, Adam; Chiang, Yi-Kuan; Ciardullo, Robin; Dey, Arjun; Farooq, Rameen; Gronwall, Caryl; Guaita, Lucia; Huang, Yun; Hwang, Ho Seong; Im, Sang Hyeok; Jeong, Woong-Seob; Karthikeyan, Shreya; Kim, Hwihyun; Kim, Seongjae; Kumar, Ankit; Nagaraj, Gautam R.; Nantais, Julie; Padilla, Nelson; **Park, Jaehong**; Pope, Alexandra; Popescu, Roxana; Schlegel, David; Seo, Eunsuk; Singh, Akriti; Song, Hyunmi; Troncoso, Paulina; Vivas, A. Katherina; Zabludoff, Ann; Zenteno, Alfredo
The One-hundred-deg2 DECam Imaging in Narrowbands (ODIN): Survey Design and Science Goals • ASTROPHYSICAL JOURNAL

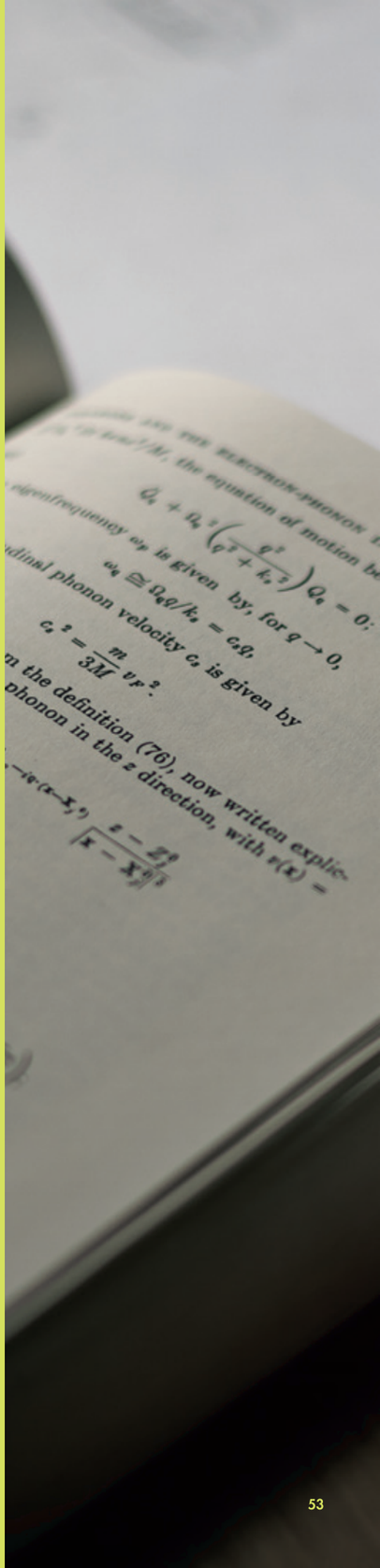
Kim, Youngjae; Kim, Min Jeong; Cha, Soonyoung; Choi, Shinyoung; Kim, Cheol-Joo; Kim, B. J.; Jo, Moon-Ho; Kim, Jonghwan; Lee, Jaedong
Dephasing Dynamics Accessed by High Harmonic Generation: Determination of Electron-Hole Decoherence of Dirac Fermions • NANO LETTERS

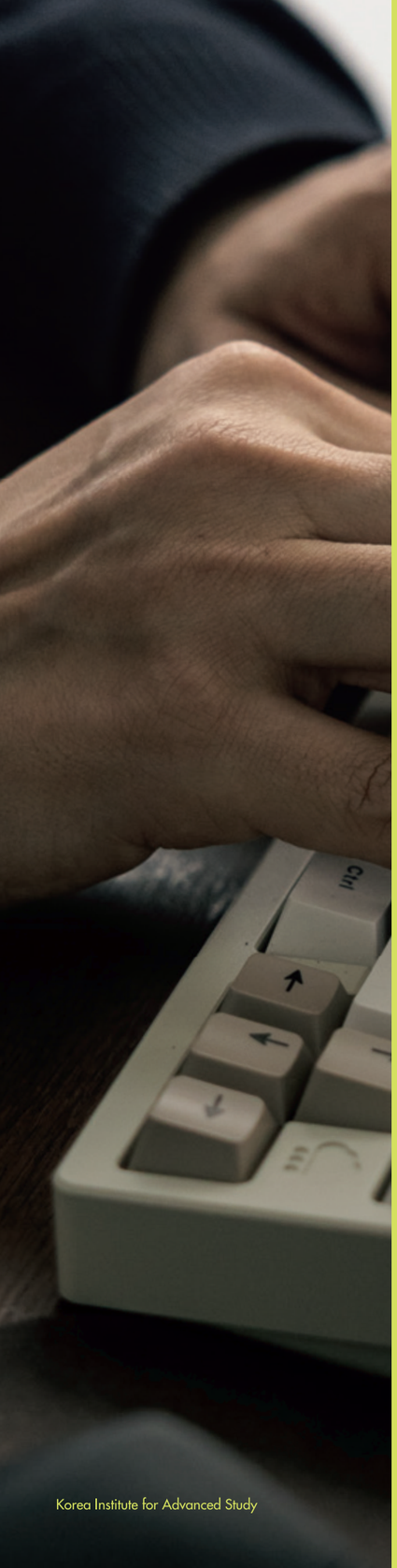
Lee, Jaehyun; **Park, Changbom**; **Kim, Juhan**; **Pichon, Christophe**; Gibson, Brad K.; Shin, Jihye; Kim, Yonghwi; Snaith, Owain N.; Dubois, Yohan; Few, C. Gareth
Identification of Galaxy Protoclusters Based on the Spherical Top-hat Collapse Theory • ASTROPHYSICAL JOURNAL

Hidaka, Yoshimasa; **Kawana, Kiyoharu**
Effective brane field theory with higher-form symmetry • JOURNAL OF HIGH ENERGY PHYSICS

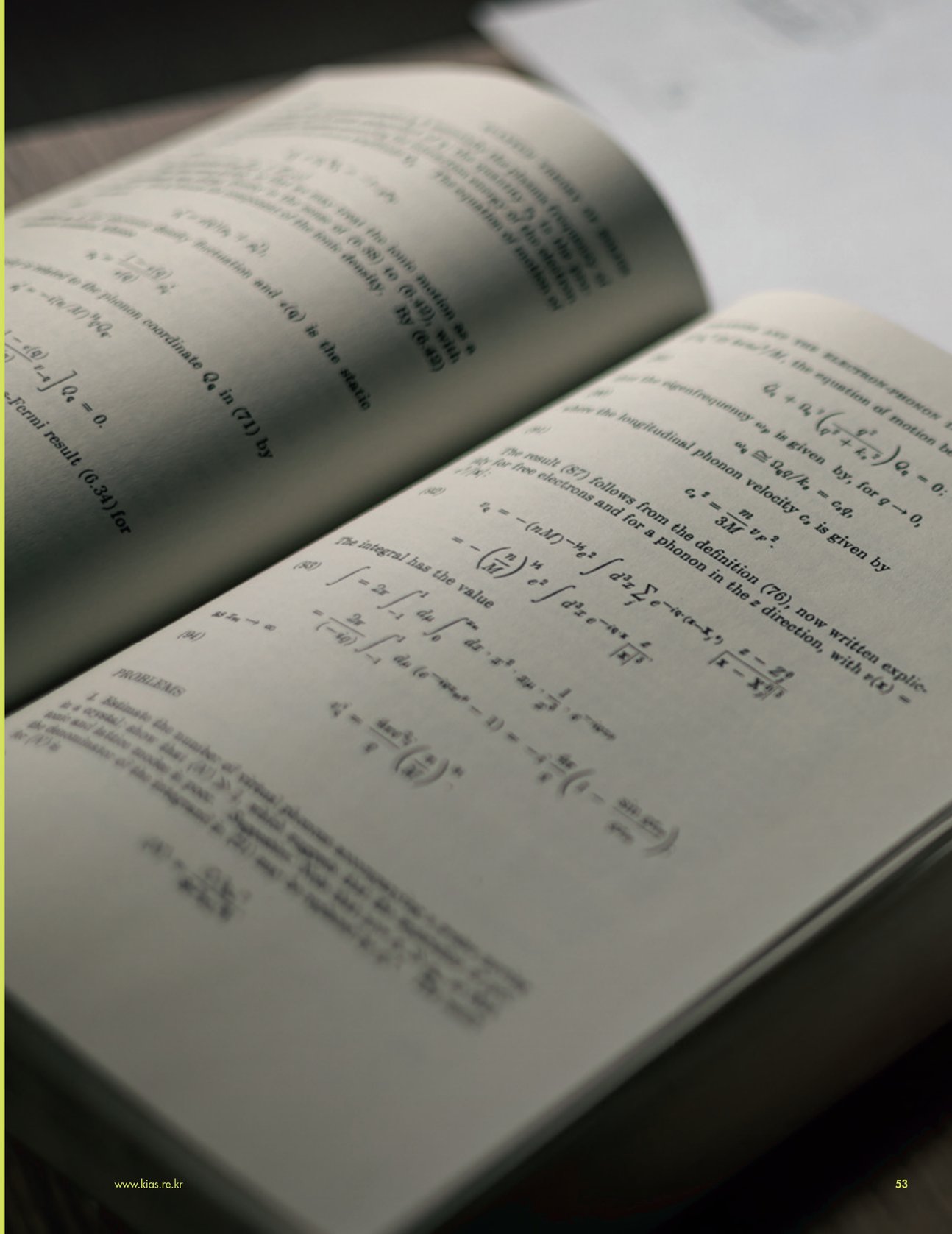
Lee, Kimyeong; Sun, Kaiwen; Wang, Haowu
On intermediate Lie algebra E7+1/2 • LETTERS IN MATHEMATICAL PHYSICS

School of Computational Sciences





In an age of increasing complexity in scientific research, computation has taken center stage as a major research tool in exploring nature. The School of Computational Sciences, established in 2000, is a product of the institute's endeavors to embrace this rapid paradigm shift in scientific investigations. The School supports research in a broad range of fields where computational methods are appropriate, including theoretical and computational physics, materials science, data science, biophysics, quantum materials and information science, and combinatorics and discrete mathematics. The School is thus uniquely positioned to promote interdisciplinary research and cross-pollination of ideas between different disciplines.



Faculty and Research Fellows

Position	Name	Research Interest
Professor Emeritus	Kim, Dae Mann	Micro- and Nano-electronic Devices
	Lee, Jooyoung	Protein Folding, Bioinformatics, Global Optimization
Professors	Choi, Sangkook	Quantum Materials and Quantum Information Science
	Hyeon, Changbong	Theoretical and Computational Biophysics
	Kim, Jeong Han	Combinatorics, External Graph Theory, Random Structure
	Kim, Myungshik	Quantum Information
	Kwon, Hyukjoon	Quantum Information
	Lee, Deok-Sun	Data Science
	Son, Young-Woo	Theory Materials
KIAS Scholars	Czaplewski, Cezary	Protein Folding, Bioinformatics, Global Optimization
	Ha, Bae-Yeun	Biophysics
	Jang, Seogjoo J.	Theoretical and Computational Biophysics
KIAS Fellow	Lee, Changmin	Algorithm
KIAS Assistant Professor	Kim, Minjae	Theoretical and Computational Materials Science
	Kim, Choong Hyun	First-principles Investigation of Quantum Materials
	Park, Changwon	Theoretical and Computational Materials Science
Research Fellows	Yi, Sudo	Statistical Physics
	Lee, Hyun gyu	Data Science
	Jung, Narina	Computational Biological Physics
	Giraldo Munoz, Andrus Allan	Dynamical Systems
	Kechrimparis, Spyridon	Quantum Information
	Yee, Ki Hyuk	Quantum Information
	Han, Mancheon	Quantum Information Science
	Moon, Sunyo	Combinatorics
	Kang, Sungmo	Theoretical and Computational Materials Science
	Yananose, Kunihiro	Theoretical and Computational Materials Science
	Heo, Cheolwon	Graph Theory, Matroid Theory
	Lee, Eunwoo	Quantum Information
	Ahn, Jungho	Graph Theory, Algorithms
	Ko, Taehee	Stochastic Algorithms
	Lee, YeongKyu	Theoretical and Computational Biophysics
	Son, Gangmin	Statistical Physics of Complex Networked Systems
	Kwon, Hyemin	Combinatorics, Graph Theory
	Goh, Segun	Biological Physics
	Lim, Youngrong	Quantum Information
	Bae, Eunok	Quantum Information

Research Activities

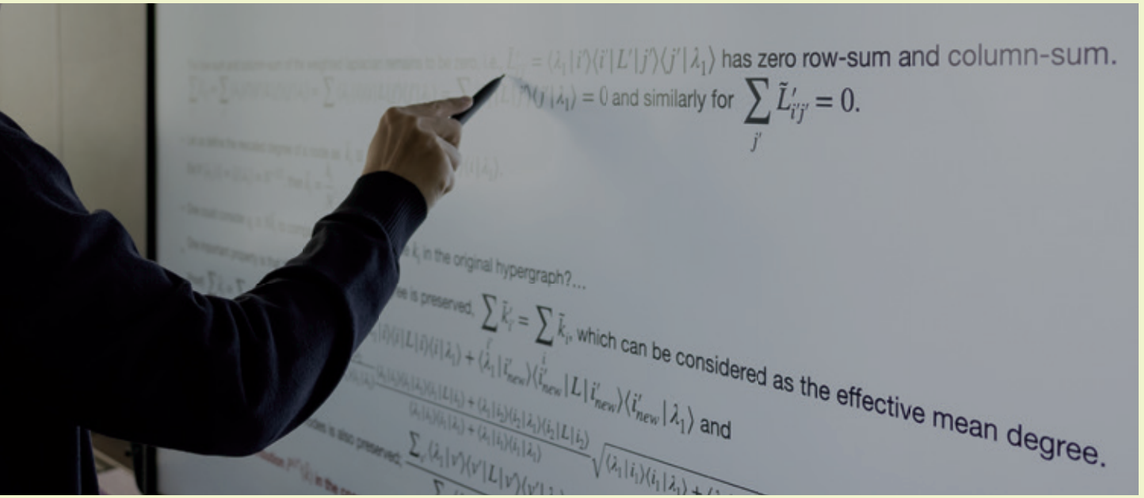
Theoretical and Computational Materials Science

The Theoretical and Computational Materials Science group in the Korea Institute for Advanced Study (KIAS) School of Computational Sciences consists of three research fellows, Drs. Wooil Yang, Kunihiro Yananose, and Seongmo Kang, and three assistant professors, Drs. Choonghyun Kim, Minjae Kim, and Changwon Park. Together, they have studied several interesting issues associated with first-principles calculation methods and their applications to reveal the interesting physics of nanomaterials and low-dimensional crystal systems. In this annual report, the following three topics investigated in 2024 are highlighted.

First, in collaboration with researchers at Fudan University, the group discovered an intriguing metal to Mott insulator transition in 1T-$TaSe_2$ that defies conventional wisdom. Specifically, it was found that dimensionality crossover, instead of reduced screening, drives the transition in atomically thin 1T-$TaSe_2$. A dispersive band crossing the Fermi level was found to be responsible for the bulk metallicity in the material. Reducing the dimensionality, however, effectively quenches the kinetic energy of these initially itinerant electrons and drives the material into a Mott insulating state. The dimensionality-driven metal to Mott insulator transition resolves the long-standing dichotomy between the metallic bulk and insulating surface of 1T-$TaSe_2$. This work further reveals a new pathway for modulating two-dimensional materials that enables exploring strongly correlated systems across uncharted parameter space. This work was published in *National Science Review*.

The group also developed a new computational method incorporating machine learning to generate empirical pseudopotentials that characterize the local screened interactions in the Kohn-Sham Hamiltonian. This approach incorporates momentum-range-separated rotation-covariant descriptors to capture crystal symmetries and crucial directional information for the bonds, thus realizing accurate descriptions of anisotropic solids. Trained empirical potentials are shown to be versatile and transferable, with the calculated energy bands and wave functions without cumbersome self-consistency reproducing conventional *ab initio* results even for semiconductors with defects, thus facilitating faster and more reliable data-driven material research. This work was published in *Physical Review B*.

The group also applied the first-principles computational method to understand solids with strong spin-orbit coupling (SOC) and extended the pseudohybrid functional approach developed by Agapito-Curtarolo-Buongiorno Nardelli to implement self-consistent extended Hubbard energy functionals for noncollinear spin states. With this, the energy bands of semiconductors with various SOC strengths, such as Si, Ge, GaAs, GaSb, CdSe, and PdO, can be obtained, agreeing with results from fully relativistic *GW* approximation (FR-GWA) and experiments. The energy gaps for HgTe, $CuTlS_2$, and $CuTlSe_2$ were also calculated, and they were correctly classified as topological insulators, an improvement on the characteristic



failures observed when judging topological properties using typical hybrid functionals. The group demonstrated the feasibility of their method in handling large systems by computing the surface bands of topological insulators Bi_2Se_3 and Bi_2Te_3 with varying thicknesses up to eight quintuple layers. Considering its low computational cost compared to conventional *ab initio* methods and improved accuracy for FR-GWA, this new method provides an opportunity to efficiently and reliably study large-scale correlated systems with strong SOC. This work was published in *Physical Review B*.

Theoretical and Computational Biophysics

The Theoretical and Computational Biophysics Group led by Prof. Changbong Hyeon works on problems involving biological systems. The primary research interest is understanding how the interactions between self-organized biopolymers contribute to defining living systems at non-equilibrium. The group is currently working on (1) non-equilibrium statistical mechanical principles underlying biological systems, (2) the structure, dynamics, and function of human chromosomes, (3) the neuroscience of olfaction, and (4) polymer physics-related problems. Selected publications from 2024 are described below.

Desensitization of G-protein-coupled receptors (GPCRs) is a general regulatory mechanism adopted by biological organisms against overstimulation of G protein signaling. Although the details of the mechanism have been extensively studied, it is not easy to gain an overarching understanding of the process because it is made up of a multitude of molecular events operating at vastly differing time scales. To offer a semiquantitative yet predictive understanding of the mechanism, Dr. Won Kyu Kim considered essential biochemical steps from ligand binding to receptor internalization and formulated a kinetic model for G protein signaling and desensitization. Internalization, followed by receptor depletion from the plasma membrane, attenuates the downstream signal. Together with a kinetics model and the full numerics for an expression derived for the dose–response relation, the approximated expression derived from this study clarified the role played by individual biochemical processes and led to the identification of four distinct regimes for downregulation that emerge from the balance between phosphorylation, dephosphorylation, and the cellular level of β-arrestin. This study was published in *J. Phys. Chem. Lett.* (2024, 15, 6137–6145).

For many living organisms with a circadian rhythm, their intake of energy often occurs in a periodic manner. Glycolysis is a prototypical biochemical reaction that exhibits self-sustained oscillations under the continuous injection of glucose. Dr. Pureun Kim studied the effect of the periodic injection of glucose on glycolytic oscillations from a dynamical systems perspective. In particular, she employed Goldbeter's allosteric model of phosphofructokinase (PFK) as a model system for glycolytic oscillations and explored the effect of periodic substrate influx of varying frequencies and amplitudes by building phase diagrams for Lyapunov exponents and oscillatory periods. When the driving frequency is tuned around the harmonic and sub/super-harmonic conditions of the natural frequency, the system is entrained to a frequency-locked state, forming an entrainment band that broadens with an increase in the driving amplitude. On the other hand, if the amplitude is substantial, the system may transition, albeit infrequently, to a chaotic state that defies both predictions and the control of dynamical behavior. Dr. Kim's study was published in *J. Roy. Soc. Interface* (2024, 21, 20230588), offering an in-depth understanding of the controllability of glycolytic oscillations and explaining the physical mechanisms that enable synchronous oscillations among a dense population of cells.

In another study, the group analyzed the inner brain of *Drosophila*, looking at the synaptic junctions between projection neurons (PNs) in the mushroom body (MB) calyx and Kenyon cells and between Kenyon cells and MB output neurons (MBONs) in order to understand how olfactory information is transferred and recovered. It turns out that the expansion and shrinkage of dimensions occur across these three information processing units, with the sensing matrix defined across these three units satisfying the condition of *compressed sensing,* a concept introduced and proven by a group of engineers and mathematicians in the mid-2000s. In particular, an odor perception projected to the inner brain of *Drosophila* can reconstruct the olfactory signal encoded in the glomeruli even if the situation pertains to solving the problem of underdetermined linear algebra. It was shown that most of the olfactory signals encoded in the glomeruli (or PNs in the MB calyx) can be uniquely identified using information on the neural activation of MBONs by minimizing the L1 distance of the signals in the PNs in the MB calyx. The study highlights the importance of sparse coding in the receptor space for the identification of odors, shedding light on how odor perception varies with concentration. The group also explored the capacity and limitations of this neural architecture in signal retrieval by mixing multiple signals from different types of odor. When the olfactory system is exposed to multiple odorants simultaneously, the neural activity profile of the PNs becomes saturated, which impairs signal recovery and leads to a perceptual state similar to "olfactory white." This result was published in *Phy. Rev. Research* (PRR 6, 023298, 2024).

Combinatorics

The Combinatorics Group at KIAS consists of Prof. Jeong Han Kim and Research Fellows Drs. Jungho Ahn, Cheolwon Heo, Hyemin Kwon, and Sunyo Moon. Their research interests include extremal/probabilistic combinatorics, algorithmic/structural graph theory, graph coloring theory, spectral graph theory, and matroid theory. Recent results from Dr. Sunyo Moon are summarized below.

A *signed graph* is a generalization of a simple graph where each edge is assigned a sign, either even or odd. The *Laplacian matrix* of a signed graph generalizes the classical Laplacian matrix of an unsigned graph. For a signed graph, the Laplacian matrix is defined as the difference between the diagonal degree matrix and the signed adjacency matrix.

The study of Laplacian eigenvalues in graphs is fundamental to spectral graph theory because it provides key insights into graph structure. A significant development in the study of Laplacian eigenvalues was the work of So (1999) and Kirkland (2004), who investigated conditions under which the Laplacian eigenvalues of a graph change by integer amounts when a new edge is added. This property, known

as *spectral integral variation*, characterizes graphs where Laplacian eigenvalues change by integer amounts when an edge is added. Kirkland (2005) also introduced the concept of *integrally completable graphs*, meaning that a graph can be recursively extended into a complete graph by adding new edges in a specific way that maintains spectral integral variation.

Dr. Sunyo Moon, in collaboration with Dr. Jungho Ahn and Dr. Cheolwon Heo, characterized the spectral variation of Laplacian spectra in signed graphs when an even or odd edge is added. Furthermore, for every fixed signed complete graph, they fully classified the set of signed graphs that can be recursively extended by edge additions while preserving spectral integral variation. (preprint: arXiv:2401.02639). This generalizes Kirkland's results on integral completability in unsigned graphs to the signed graph setting, providing deeper insights into the spectral behavior of signed Laplacians. In addition, Dr. Moon, in collaboration with Dr. Cheolwon Heo, is studying graphs that are constructed from an empty graph by adding a sequence of edges in such a way that each time a new even or odd edge is added, spectral integral variation occurs in the resulting graph.

Quantum Information Science

The 2024 research activities of the Quantum Information Science group at KIAS were led by Hyukjoon Kwon (HK), Spiros Kechrimparis (SK), Ki Hyuk Lee (KL), Youngrong Lim (YL), Jeeun Lee (JL), James Moran (JM), Minki Han (MH), Eunok Bae (EB), Eunuo Lee (EL), Giorgos Eftaxias (GE), Shrobona Bagchi (SB), Prabuddha Roy (PR), Myungshik Kim (MK, jointly affiliated with Imperial College London), and Jaewan Kim (JK, jointly affiliated with Yonsei University).

JL left KIAS to join AlpacaNetworks, a network security company. MH joined UT Austin as a Postdoctoral Researcher, and EB joined the Electronics and Telecommunications Research Institute (ETRI). All of them continue to research classical and quantum information science and quantum computing.

HK has conducted research on quantum algorithms and the simulation of quantum dynamics. HK published two papers on Gaussian boson sampling in realistic situations (PRA 109, 013707 & PRA 109, 023708) and one paper on photonic error mitigation (PRA 110, 022622) in collaboration with MK. HK also collaborated with Jae Sung Lee and Sangyun Lee from the School of Physics at KIAS on a quantum entropy estimation algorithm (PRE 109, 044117). HK and MK published a paper on snapshotting quantum dynamics (Nat. Commun. 15, 8900) in collaboration with Kihwan Kim's group at Tsinghua University. Additionally, HK, in collaboration with Hyunseok Jeong's group at Seoul National University, published a paper on a new classical algorithm to simulate quantum circuits (PRL 133, 220601). HK has also started a project on quantum pseudochaos in collaboration with Gil Young Cho at KAIST (arXiv:2410.21268 & arXiv:2411.03974).

SK, along with JM and HK, studied both known and newly introduced supermaps exhibiting indefinite causal order and explored their implications for the task of discriminating quantum states (New J. Phys. 26, 123030) and for the task of probabilistic channel distillation.

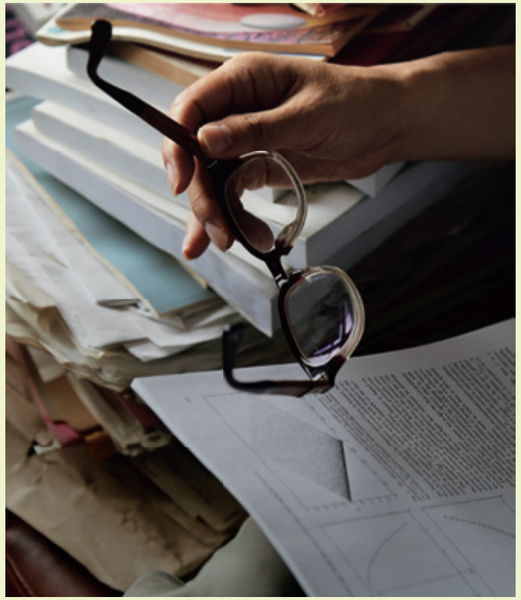
JM, SK, and HK collaborated on problems in quantum state discrimination. In their publication (arXiv:2409.08032), the fundamental differences between discrete-outcome and continuous-outcome measurements were studied, and a purely continuously labeled non-Gaussian measurement scheme was developed to discriminate between two optical coherent states.

JM, YL, and HK together worked on extending the non-destructive discrimination protocols developed by YL and HK to continuous-variable systems in collaboration with Mijung So (Ph.D. student, Korea University). Some bounds on the trade-off between success probability and fidelity for the discrimination of two two-mode squeezed states have been found, and the ultimate performance of schemes based on Gaussian local operations and classical communication is currently under investigation.

YL conducted research on error mitigation in metrology (PRA 109, 022410) and quantum-inspired algorithms for molecular vibronic spectra (Nat. Phys. 20, 225). YL and HK have made progress in non-destructive state discrimination, as presented in two papers (PRA 110, 042407; arXiv:2308.16032v2; updated in 2024).

KL and HK are investigating an experimental scheme based on cavity optomechanics to discriminate between two different commutative relations resulting from the linear generalized uncertainty principle (GUP). In collaboration with Hyunchul Nha (Texas A&M University at Qatar), KL and HK are developing an experimental scheme based on cavity optomechanics to detect an additional geometric phase induced by a square root operator in the linear GUP.

EB and HK have worked on analyzing the performance of QAOA and recursive QAOA to solve the MAX-CUT problem on complete graphs (QIP 23, 78) and bipartite graphs (arXiv:2408.13207). A modified recursive QAOA was proposed in the latter work, and its optimal performance was proven. EB also investigated the controlled teleportation capability of quantum states with respect to k-separability (PRA 109, 062403). EB and HK together worked on a parameter-tuning strategy of level-1 QAOA for Ising models. This approach was validated using recursive QAOA, consistently surpassing both coarsely optimized recursive QAOA and semidefinite programs in all tested QUBO instances (arXiv:2501.16419).



EL worked on the optimization of quantum local Hamiltonians, specifically the Heisenberg antiferromagnetic Hamiltonian on an arbitrary input graph (quantum MAX-CUT) (arXiv:2401.03616). This work presents an algorithm that approximates quantum MAX-CUT to the best-known ratio and was presented at the Theory of Quantum Computation (TQC) and International Colloquium on Automata, Languages, and Programming (ICALP) conferences. EL has also started working on the optimization of Schrödinger Hamiltonians.

GE and HK have been collaborating with Roger Colbeck (University of York, UK) and Mirjam Weilenmann (University of Geneva, Switzerland) to develop a theory- and device-independent technique for finding the quantum bounds of multipartite Bell inequalities.

SB worked on the connection between the quantum speed limit and the Lieb-Robinson bound in many-body physics (arXiv:2411.04930). SB and HK formulated the Kraus operators for depolarizing error channels using six measurement operators. SB, PR, GE, and HK have started another project on the interesting and relevant open problem of Bell non-locality in the triangle network.

PR and HK have worked on multiparameter estimation in quantum metrology and its connection to quantum resources, aiming to identify potential directions for future research.

Computational Quantum Many-Body Theory

In materials with a large number of electrons, the quantum mechanical interactions between these particles often dictate the material's properties. This phenomenon, referred to as electron correlation, can lead to a variety of emergent phenomena, such as transitions from metal to insulator states, colossal magnetoresistance, and high-temperature superconductivity. Recently, materials with noticeable electron correlation, referred to as correlated quantum materials, are of particular importance for realizing the second quantum revolution because they can act as next-generation qubit materials. At the core of correlated quantum materials lies the quantum many-body problem, which must be resolved to fully understand and exploit these materials.

In order to address this issue, the Computational Quantum Many-body Theory Group was established on September 1, 2022, at KIAS. The group members are Dr. Johan Jonsson, Dr. Mancheon Han, Dr. Taehee Ko, Mr. Seongjun Mo, Mr. Chulwan Lee, and Prof. Sangkook Choi. The group is developing classical and quantum algorithms to solve the quantum many-body problem and investigate the potential of correlated quantum materials for quantum information science. Based on these research activities, the group published two papers last year, with two other papers under review.

Among these, the most important achievement has been the development of an *ab initio* fully self-consistent GW+EDMFT methodology. This work represents the first-ever realization of the GW+EDMFT approach from first principles and marks a critical step forward in the accurate modeling of correlated quantum materials. The group is currently preparing this computational package for open-source release with an improved user interface, which will make this powerful tool accessible to the wider research community. The other notable publication, appearing in *Physical Review Letters*, investigates the role of electron correlation in the topological properties of FeSeTe alloys. These materials have been identified as potential candidates for hosting topological qubits. In this work, we demonstrated how strong electron correlations modify the topological characteristics of these materials, using state-of-the-art computational methodologies developed by our group. This research is particularly significant in the context of quantum information science because it demonstrates how quantitative theoretical tools can be used to understand next-generation qubit host materials.

Since joining KIAS, the group has developed a growing interest in quantum computing. Classical computers have long been indispensable tools for solving quantum many-body problems. However, they are fundamentally limited when it comes to simulating quantum systems. Digital quantum computers offer a fundamentally new approach to solving these problems and have the potential to provide quantum advantages over classical methods. However, despite their promise, quantum computers face several challenges, including the efficient representation of quantum mechanical operators using unitary gates and the need to overcome noise errors that affect calculations. To address these challenges, the group proposed two new quantum algorithms aimed at solving quantum many-body problems. The first algorithm, Quantum Zeno Monte Carlo, is designed to calculate both static and dynamical observables of generic Hamiltonians. What makes this method particularly promising is its resilience to both device noise and Trotter errors, which are major limitations of current quantum computing hardware. The second algorithm, the Quantum Random Power Method, provides an innovative approach for finding ground-state wave functions of quantum systems, a crucial task in many-body physics. Both of these works are currently under review at *npj Quantum Information* and *PRX Quantum*, respectively.

The group leader is working actively to build the group's capacity. For example, together with Prof. Hyowon Park's group at the University of Illinois at Chicago, he was awarded computational resources amounting to 10K CPU node hours and 100 GPU node hours from the National Energy Research Scientific Computing Center (NERSC) of the U.S.

To serve the domestic and international research community in the field of correlated quantum materials, the group leader hosted the second international workshop on the computational quantum many-body theory at KIAS. With 24 domestic and international participants, the three-day workshop was successful, and it is planned to continue this activity annually.

The group leader holds a consultant position at Brookhaven National Lab in the U.S. He is also working as a US-DOE grant reviewer. In addition, he is working actively as a member of various committees. One example is his role as a steering committee member for the DMFT-QE symposium series hosted by the Flatiron Institute.

The group leader delivered eight invited talks at both domestic and international conferences and seminars last year. He served as one of the lecturers at the international summer school on computational quantum materials in Sherbrooke, Canada.

Data Science

The Data Science group at the KIAS School of Computational Sciences, led by Prof. Deok-Sun Lee, consists of Dr. Sudo Yi, Dr. Hyun Gyu Lee, Dr. Andrus Giraldo, Dr. Gangmin Son, and Dr. Jibeom Choi. This group's research focuses on uncovering the organizational and functional principles of macroscopic complex systems by analyzing large-scale datasets from biological, ecological, economic, and social systems. The members employ data science, statistical physics, and network science methodologies to explore these intricate networks. This year, the Data Science group made significant contributions to the study of ecological and biological networks, publishing three key papers on biodiversity, metabolic evolution, and mutualistic interactions.

In collaboration with Inha University and Gyeongsang National University, a heterogeneous dynamical mean-field theory (HDMFT) was developed to model species abundance in ecosystems with diverse interaction structures. Traditional models assume fully connected interactions, which fail to capture the complexity of real-world ecological networks. The proposed approach accounts for structural heterogeneity, revealing that cooperative interactions can unexpectedly reduce biodiversity—a phenomenon not observed in homogeneous models. This new framework improves the understanding of ecological stability and has broader applications in complex network analysis. This study was published in *Physical Review Letters*.

In collaboration with Hanyang University, the group also investigated the evolution of metabolic reactions across bacterial species, uncovering the fundamental mechanisms behind their heterogeneous prevalence. While bacterial species contain similar numbers

of metabolic reactions, their distribution follows a power-law pattern, meaning some reactions are nearly universal, while others are rare. The proposed evolutionary model, integrating species phylogeny and reaction inheritance, demonstrates that metabolic diversity naturally emerges from the exponential growth of species and constrained reaction recruitment. This work bridges empirical data with evolutionary theory, offering a unifying explanation for the structure of metabolic networks. This study was published in *Physical Review Letters*.

Additionally, the Data Science group explored bifurcations and multistability in mutualistic ecological networks, particularly in plant–pollinator systems. Using dynamical systems theory, key interaction strength thresholds that determine species persistence or extinction were identified. Surprisingly, it was found that increasing mutualistic interactions does not always enhance biodiversity; instead, it can lead to alternative stable states, where different sets of species coexist depending on initial conditions. This finding challenges traditional ecological models and offers new insights for biodiversity conservation. This study was published in *Physical Review E*.

Through these studies, the Data Science group continues to advance the theoretical and computational understanding of complex systems, providing valuable insights into biodiversity, metabolic evolution, and ecological stability.

Visiting Scientists

Hwang, Wonmuk
Texas A&M Univ.

Yang, Seong-Gyu
Umeå Univ.

Kim, Jiseung
Jeonbuk Nat'l Univ.

Park, Hyejin
Inha Univ.

Lie, Seok Hyung
UNIST

Yun, Gunsu
POSTECH

Kim, Han Young
UC Davis

Nha, Hyunchul
Texas A&M Univ. at Qatar

Choi, Wonseok
Purdue Univ.

Song, Minjeong
Centre for Quantum Technologies

Jhun, Bukyoung
Central European Univ.

Lee, Mi Jin
Hanyang Univ. ERICA

Goh, Kwang-Il
Korea Univ.

Goh, Segun
Forschungszentrum Jülich

Kim, Won Kyu
Seoul Nat'l Univ.

Kim, Minjae
APCTP

Kahng, Byungnam
KENTECH

Ji, Hyunwoong
NEOWIZ

Kim, Dongwoo
Dongguk Univ.

Park, Hyowon
Univ. of Illinois at Chicago

Lim, Tongseok
Purdue Univ.

Kim, Taeyoon
Purdue Univ.

Krishnagopal, Sanjukta
UCLA

Song, Yong Hyun
New York Structural Biology Center

Parekh, Ojas
Sandia National Labs

Lee, Seok-Hyung
Univ. of Sydney

Rondon, Irving
Pinellas County Schools

Jeong, Hyeong-Chai
Sejong Univ.

Ghim, Cheol-Min
UNIST

Lee, O-chul
POSTECH

Scarani, Valerio
Nat'l Univ. of Singapore

Miettinen, Markus
Univ. of Bergen

Mallmin, Emil
Max Planck Institute for Evolutionary Biology

Son, Yongha
Sungshin Women's Univ.

Oh, Changhun
Univ. of Chicago

Min, Byungjoon
Chungbuk Nat'l Univ.

Conferences and Workshops

The 4th KIAS-APCTP Electronic Calculations Winter School
Jan. 17 – Jan. 19

The 4th Workshop of the Division of Biological Physics
Jan. 29 – Jan. 31

2024 KIAS-FUB International Bio-Soft Matter Theory Workshop
Feb. 20 – Feb. 23

The 9th Korean-Polish Conference on Protein Folding: Theoretical and Experimental Approaches
Feb. 26 – Feb. 28

The 30th KIAS Combinatorics Workshop
Mar. 08 – Mar. 09

2024 KIAS Computational Sciences Workshop
Mar. 27 – Mar. 29

KIAS-NCTS Workshop on ab initio approaches to quantum materials
Apr. 17 – Apr. 19

The 31st KIAS Combinatorics Workshop
May 30 – Jun. 01

Computational Sciences Colloquium (Prof. Jejoong Yoo)
Jun. 12

Computational Sciences Colloquium (Prof. Mnkyung Baek)
Jun. 13

International Workshop on New Advances in Theoretical and Computational Molecular Sciences for Complex and Quantum Processes (TMCQ 2024)
Jul. 8 – Jul. 12

The 20th KIAS Electronic Structure Calculation Workshop
Jul. 11 – Jul. 12

Computational Sciences Colloquium (Prof. Euiwoong Lee)
Jul. 15

Computational Quantum Many-body Theory
Jul. 17 – Jul. 19

KIAS-KRISS Quantum Information Sciences Workshop
Jul. 18 – Jul. 19

Complex Systems Summer School
Jul. 20 – Jul. 21

KIAS Quantum Information Workshop
Aug. 12 – Aug. 13

Computational Sciences Colloquium (Prof. Se-Bum Paik)
Sep. 05

Computational Sciences Colloquium (Prof. Jinyoung Park)
Sep. 06

KIAS Quantum Information Workshop
Sep. 26 – Sep. 27

Computational Sciences Colloquium (Prof. Hongseok Yang)
Oct. 18

The 4th Workshop on Theory of Materials
Oct. 31

KIAS-KU International Workshop: Theoretical Challenges in Network Science 2024
Nov. 04 – Nov. 08

The 32nd KIAS Combinatorics Workshop
Dec. 19 – Dec. 21

Publications

Giraldo, Andrus; **Lee, Deok-Sun**
Bifurcations and multistability in empirical mutualistic networks • PHYSICAL REVIEW E

Kechrimparis, Spiros; **Moran, James**; Karsa, Athena; Lee, Changhyoup; **Kwon, Hyukjoon**
Enhancing quantum state discrimination with indefinite causal order • NEW JOURNAL OF PHYSICS

Shin, Myeongjin; Lee, Seungwoo; Lee, Junseo; Lee, Mingyu; Ji, Donghwa; Yeo, Hyeonjun; **Jeong, Kabgyun**
Disentangling quantum neural networks for unified estimation of quantum entropies and distance measures • PHYSICAL REVIEW A

Il Park, Jong; **Lee, Deok-Sun**; Lee, Sang Hoon; Park, Hye Jin
Incorporating Heterogeneous Interactions for Ecological Biodiversity • PHYSICAL REVIEW LETTERS

Park, Guedong; **Kwon, Hyukjoon**; Jeong, Hyunseok
Extending Classically Simulatable Bounds of Clifford Circuits with Nonstabilizer States via Framed Wigner Functions • PHYSICAL REVIEW LETTERS

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Kim, Minwoo; Kim, Seungtae; **Hyeon, Changbong**; **Yu, Ji Woong**; Choi, Siyoung Q.; Lee, Won Bo
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Hwang, Wonmuk; Austin, Steven L.; Blondel, Arnaud; Boittier, Eric D.; Boresch, Stefan; Buck, Matthias; Buckner, Joshua; Caflisch, Amedeo; Chang, Hao-Ting; Cheng, Xi; Choi, Yeol Kyo; Chu, Jhih-Wei; Crowley, Michael F.; Cui, Qiang; Damjanovic, Ana; Deng, Yuqing; Devereux, Mike; Ding, Xinqiang; Feig, Michael F.; Gao, Jiali; Glowacki, David R.; Gonzales, James E.; Hamaneh, Mehdi Bagerhi; Harder, Edward D.; Hayes, Ryan L.; Huang, Jing; Huang, Yandong; Hudson, Phillip S.; Im, Wonpil; Islam, Shahidul M.; Jiang, Wei; Jones, Michael R.; Kaser, Silvan; Kearns, Fiona L.; Kern, Nathan R.; Klauda, Jeffery B.; Lazaridis, Themis; Lee, Jinhyuk; Lemkul, Justin A.; Liu, Xiaorong; Luo, Yun; MacKerell Jr, Alexander D.; Major, Dan T.; Meuwly, Markus; Nam, Kwangho; Nilsson, Lennart; Ovchinnikov, Victor; Paci, Emanuele; Park, Soohyung; Pastor, Richard W.; Pittman, Amanda R.; Post, Carol Beth; Prasad, Samarjeet; Pu, Jingzhi; Qi, Yifei; Rathinavelan, Thenmalarchelvi; Roe, Daniel R.; Roux, Benoit; Rowley, Christopher N.; Shen, Jana; Simmonett, Andrew C.; Sodt, Alexander J.; Topfer, Kai; Upadhyay, Meenu; van der Vaart, Arjan; Vazquez-Salazar, Luis Itza; Venable, Richard M.; Warrensford, Luke C.; Woodcock, H. Lee; Wu, Yujin; Brooks, Charles L.; Brooks III, Bernard R.; Karplus, Martin
CHARMM at 45: Enhancements in Accessibility, Functionality, and Speed • JOURNAL OF PHYSICAL CHEMISTRY B

Choi, Jonghyeon; Park, Jungmin; Noh, Seunghyeon; Lee, Jaebyeong; Lee, Seunghyun; Choe, Daeseong; Jung, Hyeonjung; Jo, Junhyeon; Oh, Inseon; Han, Juwon; Kwon, Soon-Yong; Ahn, Chang Won; Min, Byoung-Chul; Jin, Hosub; **Kim, Choong H.**; Kim, Kyoung-Whan; Yoo, Jung-Woo
Non-volatile Fermi level tuning for the control of spin-charge conversion at room temperature • NATURE COMMUNICATIONS

Yang, Wooil; **Son, Young-Woo**
Effects of self-consistent extended Hubbard interactions and spin-orbit couplings on energy bands of semiconductors and topological insulators • PHYSICAL REVIEW B

Ahn, Cheong-Eung; Lee, Wonjun; **Yananose, Kunihiro**; Kim, Youngwook; Cho, Gil Young
Non-Abelian fractional quantum anomalous Hall states and first Landau level physics of the second moiré band of twisted bilayer MoTe2 • PHYSICAL REVIEW B

Wang, Pengfei; **Kwon, Hyukjoon**; Luan, Chun-Yang; Chen, Wentao; Qiao, Mu; Zhou, Zinan; Wang, Kaizhao; **Kim, M. S.**; Kim, Kihwan
Snapshotting quantum dynamics at multiple time points • NATURE COMMUNICATIONS

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Introduction to new views of allostery • JOURNAL OF CHEMICAL PHYSICS

Taylor, Adam; Bressanini, Gabriele; **Kwon, Hyukjoon; Kim, M. S.**
Quantum error cancellation in photonic systems: Undoing photon losses • PHYSICAL REVIEW A

Bilash, Bohdan; **Lim, Youngrong**; **Kwon, Hyukjoon**; Kim, Yosep; Lim, Hyang-Tag; Song, Wooyeong; Kim, Yong-Su
Nondestructive discrimination of Bell states between distant parties • PHYSICAL REVIEW A

Banasik, Michal; Napolitano, Valeria; Blat, Artur; Abdulkarim, Karim; Plewka, Jacek; **Czaplewski, Cezary**; Gieldon, Artur; Kozak, Maciej; Wladyka, Benedykt; Popowicz, Grzegorz; Dubin, Grzegorz
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Chae, Sunhee; **Jeong, Hyeong-Chai**
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Dziadek, L. J.; Sieradzan, A. K.; **Czaplewski, C.**; Zalewski, M.; Banas, F.; Toczek, M.; Nisterenko, W.; Grudinin, S.; Liwo, A.; Gieldon, A.
Assessment of Four Theoretical Approaches to Predict Protein Flexibility in the Crystal Phase and Solution • JOURNAL OF CHEMICAL THEORY AND COMPUTATION

Jo, Junghyo; Wagemakers, Alexandre; Periwal, Vipul
Annealing approach to root finding • PHYSICAL REVIEW E

Kim, Yeongjin; **Kim, Won Kyu**; **Jeon, Jae-Hyung**
Active Diffusion of Self-Propelled Particles in Semiflexible Polymer Networks • MACROMOLECULES

Shi, Chen; Liu, Lei; **Hyeon, Changbong**
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Kim, Cook Hyun; **Lee, D. -S.**; Kahng, B.
Entropy-induced phase transitions in a hidden Potts model • PHYSICAL REVIEW E

Choi, Minjin; Shin, Jeonghyeon; Lee, Gunho; **Bae, Eunok**
Investigating controlled teleportation capability of quantum states with respect to k-separability • PHYSICAL REVIEW A

Kim, Jin Hong; **Kang, Seoung-Hun**; Yoon, Duhee; Kim, Hakseong; Kim, Jin-Soo; Haidari, Mohd Musaib; Jang, Dong Jin; Ko, Jin-Yong; **Son, Young-Woo**; Park, Bae Ho; Choi, Jin Sik
Twist angle-dependent transport properties of twisted bilayer graphene • NPG ASIA MATERIALS

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Kim, Ha Eum; **Jeong, Kabgyun**
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Mo, Seongjun; Seo, Jaeuk; Son, Seok-Kyun; **Kim, Sejoong**; Rhim, Jun-Won; Lee, Hoonkyung
Engineering Two-Dimensional Nodal Semimetals in Functionalized Biphenylene by Fluorine Adatoms • NANO LETTERS

Quero, Carlos Osorio; Leykam, Daniel; Ojeda, **Irving Rondon**
Res-U2Net: untrained deep learning for phase retrieval and image reconstruction • JOURNAL OF THE OPTICAL SOCIETY OF AMERICA A-OPTICS IMAGE SCIENCE AND VISION

Sorgenfrei, Felix; Alouani, Mebarek; Schoett, Johan; **Joensson, H. Johan M.**; Eriksson, Olle; Thunstroem, Patrik
Theory of x-ray absorption spectroscopy for ferrites • PHYSICAL REVIEW B

Kim, Sejoong
DFT plus U plus V Study of Magnetic Ordering in Single-Layer Pentahexoctite: Implications for Magnetic Device Platforms • ACS APPLIED NANO MATERIALS

Lee, Suho; **Bak, Ji Hyun**; **Lee, Yuno**; Jeong, Dae-Woong; Lee, Jaehee; Lee, KeunMin Ken; Cho, Hasaeam; Lee, Hyun Hwi; **Hyeon, Changbong**; Choi, Myung Chul
Water Hydrogen-Bond Mediated Layer by Layer Alignment of Lipid Rafts as a Precursor of Intermembrane Processes • JOURNAL OF THE AMERICAN CHEMICAL SOCIETY

Kim, Ye Won; **Park, Jejune**; Park, Jeong Hyeon; Han, Eul; Jung, Younjae; Jang, Yong Woon; Lee, Min Yung; Jeon, Woojin
Self-isolating electrode deposition process using the area-selective MoO2 and MoO3 atomic layer deposition technique • APPLIED MATERIALS TODAY

Cho, Kwang Hyun; **Jang, Seogjoo J.**; Rhee, Young Min
Dynamic embedding of effective harmonic normal mode vibrations in all-atomistic energy gap fluctuations: Case study of light harvesting 2 complex • JOURNAL OF CHEMICAL PHYSICSS

Lee, Mi Jin; **Yi, Sudo**; **Lee, Deok-Sun**
Correlation-enhanced viable core in metabolic networks • CHAOS SOLITONS & FRACTALSS

Kim, Minjae; **Choi, Sangkook**; Brito, Walber Hugo; Kotliar, Gabriel
Orbital-Selective Mott Transition Effects and Nontrivial Topology of Iron Chalcogenide • PHYSICAL REVIEW LETTERS

Lee, Sangyun; **Kwon, Hyukjoon**; **Lee, Jae Sung**
Estimating entanglement entropy via variational quantum circuits with classical neural networks • PHYSICAL REVIEW E

Kim, Donghan; Sohn, Byungmin; Lee, Yeonjae; Song, Jeongkeun; Kim, Mi Kyung; **Kim, Minjae**; Noh, Tae Won; Kim, Changyoung
Strain tunable electronic ground states in two-dimensional iridate thin films • APPLIED SURFACE SCIENCE

Kadota, Kenji; **Kim, Jeong Han**; **Ko, Pyungwon**; **Yang, Xing-Yu**
Gravitational wave probes on self-interacting dark matter surrounding an intermediate mass black hole • PHYSICAL REVIEW D

Ocetkiewicz, Krzysztof M.; **Czaplewski, Cezary**; Krawczyk, Henryk; Lipska, Agnieszka G.; Liwo, Adam; Proficz, Jerzy; **Sieradzan, Adam K.**; Czarnul, Pawel
Multi-GPU UNRES for scalable coarse-grained simulations of very large protein systems • COMPUTER PHYSICS COMMUNICATIONS

Lee, Mi Jin; **Lee, Deok-Sun**
Heterogeneous Popularity of Metabolic Reactions from Evolution • PHYSICAL REVIEW LETTERS

Kim, Rokyeon; **Son, Young-Woo**
Transferable empirical pseudopotenials from machine learning • PHYSICAL REVIEW B

Kwon, Hyukgun; Oh, Changhun; **Lim, Youngrong**; Jeong, Hyunseok; Jiang, Liang
Efficacy of virtual purification-based error mitigation on quantum metrology • PHYSICAL REVIEW A

Tang, Hao; Shang, Xiao-Wen; Shi, Zi-Yu; He, Tian-Shen; Feng, Zhen; Wang, Tian-Yu; Shi, Ruoxi; Wang, Hui-Ming; Tan, Xi; Xu, Xiao-Yun; Wang, Yao; Gao, Jun; **Kim, M. S.**; Jin, Xian-Min
Simulating photosynthetic energy transport on a photonic network • NPJ QUANTUM INFORMATION

Bressanini, Gabriele; **Kwon, Hyukjoon**; **Kim, M. S.**
Gaussian boson sampling with click-counting detectors • PHYSICAL REVIEW A

Choi, Soohwan; Kim, Hyung Suk; Min, Kyueng-Whan; **Noh, Yung-Kyun**; Lee, Jeong-Yeon; Moon, Ji-Yong; Jung, Un Suk; Kwon, Mi Jung; Kim, Dong-Hoon; Son, Byoung Kwan; Pyo, Jung Soo; Ro, Sun Kyun
JAK2 Loss Arising From Tumor-Spread- Through-Air-Spaces (STAS) Promotes Tumor Progression by Suppressing CD8+T Cells in Lung Adenocarcinoma: A Machine Learning Approach • JOURNAL OF KOREAN MEDICAL SCIENCE

Yoo, Semin
Combinatorics of Euclidean Spaces over Finite Fields • ANNALS OF COMBINATORICS

Kim, Sejoong
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Guenin, Bertrand; **Heo, Cheolwon**
Recognizing pinch-graphic matroids • MATHEMATICAL PROGRAMMING

Guenin, Bertrand; **Heo, Cheolwon**
Small separations in pinch-graphic matroids • MATHEMATICAL PROGRAMMING

Tian, Ning; Huang, Zhe; **Jang, Bo Gyu**; Guo, Shuaifei; Yan, Ya-Jun; Gao, Jingjing; Yu, Yijun; Hwang, Jinwoong; Tang, Cenyao; Wang, Meixiao; Luo, Xuan; Sun, Yu Ping; Liu, Zhongkai; Feng, Dong-Lai; Chen, Xianhui; Mo, Sung-Kwan; **Kim, Minjae; Son, Young-Woo**; Shen, Dawei; Ruan, Wei; Zhang, Yuanbo
Dimensionality-driven metal to Mott insulator transition in two-dimensional 1T-TaSe2 • NATIONAL SCIENCE REVIEW

Oh, Changhun; **Lim, Youngrong**; Wong, Yat; Fefferman, Bill; Jiang, Liang
Quantum-inspired classical algorithms for molecular vibronic spectra • NATURE PHYSICS

Kim, Jaesun; Jung, Jisu; Kim, Sookyung; **Han, Seungwu**
Predicting melting temperature of inorganic crystals via crystal graph neural network enhanced by transfer learning • COMPUTATIONAL MATERIALS SCIENCE

Bressanini, Gabriele; **Kwon, Hyukjoon**; **Kim, M. S.**
Gaussian boson sampling at finite temperature • PHYSICAL REVIEW A

Kim, Pureun; **Hyeon, Changbong**
Glycolytic oscillations under periodic drivings • JOURNAL OF THE ROYAL SOCIETY INTERFACE

Lee, Yeon-Hee; Won, Jong Hyun; Auh, Q. -Schick; **Noh, Yung-Kyun**; Lee, Sung-Woo
Prediction of xerostomia in elderly based on clinical characteristics and salivary flow rate with machine learning • SCIENTIFIC REPORTS

Shin, Myeongjin; Lee, Junseo; **Jeong, Kabgyun**
Estimating quantum mutual information through a quantum neural network • QUANTUM INFORMATION PROCESSING

Kim, Ha Eum; **Jeong, Kabgyun**
Port-based entanglement teleportation via noisy resource states • PHYSICA SCRIPTA

Kim, Hyung-Suk; **Noh, Yung-Kyun**; Min, Kyueng-Whan; Kim, Dong-Hoon
Low CDKN1B Expression Associated with Reduced CD8+ T Lymphocytes Predicts Poor Outcome in Breast Cancer in a Machine Learning Analysis • JOURNAL OF PERSONALIZED MEDICINE

Jun Park, Jung; Baek, Kyunghyun; **Kim, M. S.**; Nha, Hyunchul; **Kim, Jaewan**; Bang, Jeongho
T-depth-optimized quantum search with quantum data-access machine • QUANTUM SCIENCE AND TECHNOLOGY

Choi, Taeseung
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Ahn, Jinhoo; **Kim, Joonhee**
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Moon, Sunyo; Yoo, Hyungkee
On the Laplacian spectrum of k-symmetric graphs • DISCRETE MATHEMATICS

June E Huh Center for Mathematical Challenges

Introduction

The June E Huh Center for Mathematical Challenges (HCMC) was established by the Korea Institute for Advanced Study (KIAS) to resolve mathematical challenges and present emerging strategies in new fields. The HCMC also seeks to serve as a global hub for solving mathematical problems and satisfying the intellectual curiosity of young and adventurous mathematicians worldwide.

The HCMC aspires to exhibit international leadership by focusing on well-known mathematical challenges and creating synergy as a national brand for South Korea. It will contribute to enhancing national competitiveness in basic science and technology, which will ultimately have a positive impact on humanity.

The HCMC deals with problems in the following challenging and emerging research fields:

- P-PARITY CONJECTURE
- REFINED IWASAWA THEORY
- K-STABILITY OF FANO VARIETIES
- RATIONALITY OF CUBIC FOURFOLD
- SERRE'S UNIFORMITY CONJECTURE
- SPECIAL VALUES OF AUTOMORPHIC L-FUNCTIONS
- HERON-ROTA-WELSH CONJECTURE
- LAGRANGIAN GEOMETRY OF MATROIDS
- YANG-MILLS EQUATIONS
- CHERN-SIMONS THEORIES
- CONSTRUCTIVE CONFORMAL FIELD THEORY AND SLE
- INCOMPRESSIBLE EXTENDED MHD EQUATIONS
- UNIVERSALITY CONJECTURES FOR RANDOM NORMAL MATRIX THEORY
- SIMPLICITY OF DIFFEOMORPHISM GROUPS
- CRITICAL REGULARITY OF GROUP ACTIONS
- K3 SURFACE
- BCOV CONJECTURE
- MEEK CONJECTURE
- HOPF CONJECTURE
- YAU'S CONJECTURE
- VOLUME CONJECTURE
- MOCK THETA FUNCTION
- MIRROR CONJECTURE
- ENTROPY ZERO SYSTEMS
- TWIN PRIME CONJECTURE
- MOD P LANGLANDS PROGRAM
- ISOPERIMETRIC INEQUALITY FOR MINIMAL SURFACES
- GROMOV BOUNDED COHOMOLOGY AND SIMPLICIAL VOLUME
- GENERALIZED POINCARE CONJECTURE
- GEOMETRIC FLOWS

Research Activities

In 2024, its twelfth year of operation, the HCMC successfully promoted research exchanges by organizing 24 domestic and international conferences and 45 seminars, including events focused on a single thematic core. In doing so, the HCMC has taken another step toward becoming a place for mathematicians to share their research and ultimately to solve important mathematical problems.

Conferences and Workshops

■ Fluids in Seoul 2024

In January, Nam-Gyu Kang and Joonhyun La, together with two external colleagues In-Jee Jeong and Junha Kim, organized a conference on recent developments in fluid mechanics and related fields. Including Alexey Cheskidov, Mimi Dai, Michele Coti Zelati, Koji Okhitani, Moon-Jin Kang, and Bongsuk Kwon, 23 speakers covered recent developments in the mathematical aspects of fluid mechanics.

■ Random Matrices and Related Topics in Jeju

Jointly organized by Professor Nam-Gyu Kang (KIAS), Professor Kyeongsik Nam (KAIST), and Professor Sung-Soo Byun (Seoul National University), the conference Random Matrices and Related Topics in Jeju was held from May 6 to May 10, 2024, at Jeju Lotte Hotel. The conference was attended by 65 probabilists from both Korea and abroad, including 32 speakers such as Peter Forrester (Melbourne), Arno Kuijlaars (KU Leuven), Gernot Akemann (Bielefeld), and Seong-Mi Seo (Chungnam National University). The conference focused on topics including random point processes, orthogonal polynomials, random graphs, log-correlated fields, the KPZ universality class, and random Schrödinger operators. Professor Peter Forrester presented on Jack polynomials and general beta. Professor Arno Kuijlaars gave a talk on the strong asymptotics of the orthogonal polynomials in the Ginibre random matrix model with two point insertions. Professor Gernot Akemann discussed Fermions in low dimensions and non-Hermitian random matrices. Professor Seong-Mi Seo presented on Free energy expansion for determinantal and Pfaffian Coulomb gases. During the discussion sessions, participants exchanged insights on the research presentations and shared updates on recent developments in the field.

■ Semigroups, Groupoids, and C*-algebras

This conference was attended by approximately 50 participants from four continents. One of the central focuses of the conference was the three minicourses given by world-leading experts in C*-algebras and groupoid theory: V. Nekrashevych (Texas A & M), C. Bruce (Newcastle), and N. Szakács (Manchester). Originally, the third minicourse was scheduled to be given by L. Orloff-Clark (Auck-

Fluids in Seoul 2024 (January 15–19)

Semigroups, Groupoids, and C*-algebras (July 1–5)

Random Matrices and Related Topics in Jeju (May 6–10)

Workshop on Moduli Spaces, Virtual Invariants and Shifted Symplectic Structures 2024 (July 22–26)

land) but, due to unforeseen circumstances, this had to be cancelled. These minicourses covered a vast breadth of recent research in a broadly accessible way, and many of the participants informed the organizers how valuable and informative they found the courses. V. Nekrashevych spoke about groupoids, semigroups, and groups arising in a dynamical setting, C. Bruce spoke about C*-algebras and groupoids arising via algebraic actions, including number-theoretic origins, and N. Szakács spoke about simplicity of inverse semigroup- and ample groupoid-algebras. In addition to the minicourses, each day featured several invited talks and contributed talks from speakers at all career stages, including PhD students, e.g., A. Mundey (Wollongong), and world-renowned experts, e.g., N. Ozwaka (RIMS Kyoto). Many of the talks were followed by lengthy discussions, which often extended into the lunch or coffee breaks. Finally, a spell of good weather in the middle of the rainy season happened to coincide with the half-day excursion to the palaces, which was much appreciated by all participants (who remained dry).

■ **Workshop on Moduli Spaces, Virtual Invariants and Shifted Symplectic Structures 2024**

The Workshop on Moduli Spaces, Virtual Invariants and Shifted Symplectic Structures 2024 was held on July 22–26 in KIAS. The purpose of this workshop was to invite experts in enumerative geometry and derived geometry to present cutting-edge results and encourage discussions between the two groups. The program consists of 16 lectures on Donaldson-Thomas theory, Gromov-Witten theory, and shifted symplectic geometry. This workshop was the second edition of the previous workshop in 2023 with the same purpose.

■ **Dynamical Group Theory III - New Methods in Group Actions on Manifolds**

This conference was attended by approximately 50 participants, with major cohorts from Korea, China, and the United States. A central pillar of the workshop was a minicourse given by E. Militon (Nice), who gave an in-depth and user-friendly three-part introduction to the theory of how the group of homeomorphisms of a surface acts on its fine curve graph. This minicourse was very well received and provided an invaluable source of hands-on experience in an exciting new area of mathematics. In addition to the minicourse, there were five invited speakers from four continents. C. Bleak (St Andrews), a world-renowned expert on Thompson's groups, gave a warm introduction to a smorgasbord of results for these groups. L. Chen (Maryland) discussed the mapping class group of circle bundles over a surface (joint research with B. Tshishiku and A. Beaini). T. Koberda (Virginia) discussed what the first-order theory of the homeomorphism group of a manifold can tell us, which turned out to be very much indeed (joint project with J. de la Nuez-Gonzalez). A. Nies (Auckland) walked us through the theory of finitely axiomatisable groups, a notion that he introduced 20 years ago and which has since grown into a rich area of research. Finally, J. de la Nuez-Gonzalez (KIAS) gave a talk about the lattice of group topologies on the diffeomorphism group of a manifold. A lightning session was also hosted, where eight early-career researchers (mostly PhD students) gave very rapid talks about a small component of their research. The timing of 5 minutes (strictly enforced by way of a plastic hammer) was difficult for some speakers, but it provided valuable experience in giving talks, and the audience certainly enjoyed it.

■ **Dynamical Group Theory IV - KIAS-Rice Workshop on Geometric Topology**

The KIAS-Rice Workshop on Geometric Topology took place from September 24 to 27, 2024, at the HCMC, jointly organized by faculty from KIAS and Rice University.

Leading mathematicians from Rice University and KIAS, including Chris Leininger, David Fisher, and Alan Reid, presented groundbreaking research on low-dimensional topology and geometric group theory, attracting over 40 participants from graduate students to professors. This workshop fostered new international collaborations between Korean scholars and Rice University, while reaffirming the ability of HCMC to host high-level scientific conferences.

■ **Workshop on Mathematical Challenges 2024**

A workshop was held from October 17 to 19, with 20 professors and researchers from KIAS participating. The event aimed to facilitate interaction and communication among KIAS members. The program consisted of lectures given by eight researchers who had been newly appointed over the past year. This provided an opportunity for them to present their work and engage with colleagues.

■ **Workshop on Probability and Mathematical Physics in Gimhae 2024**

From December 15 to 20, 2024, the Workshop on Probability and Mathematical Physics in Gimhae 2024 was successfully held at Lotte Hotels & Resorts Gimhae. In this event, 22 specialists from all over the world, including Brazil, Peru, USA, Portugal, Italy, China, Russia, Taiwan, and Japan, were invited to give talks, and a total of 44 researchers participated to exchange detailed mathematical agendas and ideas. Thanks to this event, Korean probabilists, especially the researchers at KIAS, were able to discuss the latest research directions and methodologies with global experts and thus establish solid global networks and collaboration opportunities in the future.

■ **Enumerative Geometry in East Asia**

In December, Young-Hoon Kiem and Hyeojun Park organized the conference Enumerative Geometry in East Asia 2024, in which 17 internationally leading scholars, including Gang Tian, Ravi Vakil and Dominic Joyce, spoke about recent exciting developments and shared their insights with participants. EGEA is an annual

Dynamical Group Theory III - New Methods in Group Actions on Manifolds (August 13–16)

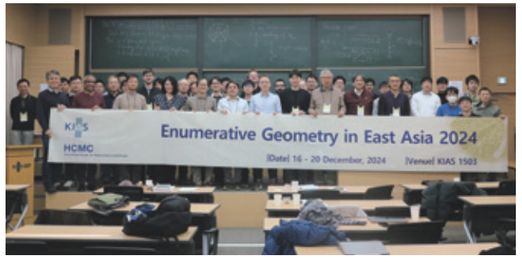
Dynamical Group Theory IV - KIAS-Rice Workshop on Geometric Topology (September 24–27)

Workshop on Mathematical Challenges 2024 (October 17–19)

Workshop on Probability and Mathematical Physics in Gimhae 2024 (December 15–20)

conference series that recruits experts in areas related to enumerative geometry, and this was the second meeting after the first one in Taipei in 2023.

Including this one, a total of 24 conferences were held in 2024. These conferences spurred the intellectual curiosity of researchers and provided opportunities for in-depth communication and interaction between mathematicians from all over the world.



Enumerative Geometry in East Asia (December 16–20)

- Fluids in Seoul 2024 (Jan. 15–19)
- Mirror Symmetry and Related Topics (Jan. 15–18)
- Conference on Singularities and Binational Geometry (Jan. 17–26)
- 2024 HCMC Focus Program on Function Theory, Operator Theory and Applications (Mar. 8–May 31)
- 2024 Spring Public Lecture Series, June E Huh Center for Mathematical Challenges, KIAS (Mar. 30–Jun. 22)
- Random Matrices and Related Topics in Jeju (May 06–10)
- Workshop on Algebraic Geometry in Busan (May 14–16)
- Colloquium: Challenging Mathematical Problems (Jun. 13–Dec. 20)
- 2024 International Workshop on Function Theory, Operator Theory and Applications (Jun. 20–22)
- Workshop on Combinatorics and Probability (Jun. 27–28)
- Semigroups, Groupoids, and C*-algebras (Jul. 01–05)
- Workshop on Moduli Spaces, Virtual Invariants and Shifted Symplectic Structures 2024 (Jul. 22–26)
- Stochastic PDE in Seoul 2024 (Aug. 12–16)
- Dynamical Group Theory III - New Methods in Groups Actions on Manifolds (Aug. 13–16)
- [Thematic Programme on Mathematics and Society] Workshop on Mathematics and Literature (Aug. 26–30)
- Colloquium: Challenging Mathematical Problems (Sep. 05–Dec. 12)
- Lecture Series on Vector-valued Function Theory, von Neumann Algebras, and Composition Operators (Sep. 06–Nov. 29)
- 2024 Fall Public Lecture Series, June E Huh Center for Mathmatical Challenges, KIAS (Sep. 07–Dec. 07)
- Dynamical Group Theory IV - KIAS-Rice Workshop on Geometric Topology (Sep. 24–27)
- Workshop on Mathematical Challenges 2024 (Oct. 17–19)
- Dynamical Group Theory V - KIAS Workshop on One Relator Groups and Other Aspects of GGT (Nov. 19–22)
- Workshop on Probability and Mathematical Physics in Gimhae 2024 (Dec. 15–20)
- Enumerative Geometry in East Asia (Dec. 16–20)
- Symposium in Algebraic Geometry 2024 (Dec. 26–28)

HCMC Faculty and Research Fellows

Keum, JongHae
CMC Distinguished Professor

Kim, Minhyong
CMC Distinguished Professor

Lee, Woo Young
CMC Distinguished Professor

Kim, Seonwoo
June E Huh Fellow

Park, Hyeonjun
June E Huh Fellow

De la Nuez Gonzalez, Javier
CMC Fellow

Jung, Mingu
CMC Fellow

Kwak, Sanghoon
CMC Fellow

Kim, In-Kyun
CMC Fellow

Lee, Chul-hee
CMC Fellow

Oh, Jaeseong
CMC Fellow

Oh, Sewook
CMC Fellow

Ryu, Jaehyeon
CMC Fellow

Publications

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Quantum Universe Center

The Quantum Universe Center (QUC) aims to become a research center that focuses on developing and sharing new insights into the fundamental properties of matter and physical forces, condensed matter and emergent phenomena, quantum information, and quantum-inspired mathematics. We hope these activities lead to a deeper understanding of nature and result in new real-world applications.

The QUC, established in 2014, engages in five fields of research: cosmology and astrophysics (the Korea Dark Energy Survey [KDES]), information science and technology, quantum gravity and superstring and M-theory, elementary particle physics, and quantum states of matter.

The KDES is headed by Prof. Changbom Park, along with QUC fellow Dr. Jeong-Gyu Kim, research fellows Dr. Jaewon Yoo, and Dr. Jie Li.

The Information Science and Technology Group is led by three professors, Prof. Jaewan Kim, Prof. Hyukjoon Kwon, Prof. Sangkook Choi, and Prof. Myungshik Kim, who are aided in their work by QUC fellow, research fellows Dr. Minki Hhan, Dr. James Moran, Dr. Nikolaos Georgios Eftaxias, Dr. Bagchi Shrobona, and Dr. Prabuddha Roy.

The Quantum Gravity and Superstring & M-Theory Group consists of three professors – Prof. Kimyeong Lee, Prof. Piljin Yi, and Prof. Sungjay Lee with research fellows Dr. Xin Wang, Dr. Minsung Kim, and Dr. TaeHwan Oh.

The Elementary Particle Physics Group is led by Prof. Pyungwon Ko, Prof. Eung Jin Chun, and Prof. Lee, Seung Joon with research fellows Dr. Jae Hoon Jeong, Dr. Xing-Yu Yang and Dr. Raymundo Ramos.

The Quantum States of Matter Group consists of three professors – Prof. Hyunggyu Park, Prof. Jae Sung Lee, Prof. Kwon Park, and Prof. Young-Woo Son – and research fellow Dr. Wooil Yang.

The QUC hosted a wide range of academic events in 2024 to fulfill the QUC's main purpose of fostering collaborative research.
QUC successfully hosted 14 academic events:

- "Survey Science Group Workshop 2024" (organized by Prof. Changbom Park)
- "6th Mini-Workshop on "CHIRALITY IN THE UNIVERSE BEYOND THE ELECTROWEAK SCALE"" (organized by Prof. Eung Jin Chun)
- "2024 ODIN Collaboration meeting" (organized by Prof. Changbom Park)
- "Quantum Korea 2024" (organized by Prof. Hyukjoon Kwon)
- "KIAS Summer School 2024 External galaxies and cosmology" (organized by Prof. Changbom Park)
- "Cosmology workshop on the crossroads of astrophysics and particle physics 2024" (organized by Prof. Donghui Jeong)
- "2024 KIAS-APCTP Amplitudes School and Workshop" (organized by Prof. Pyungwon Ko)
- "2024 Korea-Japan Joint Workshop on Cosmology, Gravitation and Particle Physics" (organized by Prof. Donghui Jeong)
- "11th KIAS Workshop on Cosmology and Structure Formation" (organized by Prof. Changbom Park)
- "The 25th Asian Workshop on First-Principles Electronic Structure Calculations (ASIAN-25)" (organized by Prof. Young-Woo Son)
- "The 8th KIAS School and Workshop on Quantum Information and Thermodynamics" (organized by Prof. Jae Sung Lee)
- "The 12th KIAS Workshop on Particle Physics and Cosmology and 2024 Korea-France STAR workshop" (organized by Prof. Pyungwon Ko)
- "15th APCTP-IACS-KIAS Joint Conference on Emergent Phenomena in Novel Oxide Materials and Low Dimensional Systems" (organized by Prof. Kwon Park)
- "KIAS-APCTP Frontiers of Theoretical Physics" (organized by Prof. Piljin Yi)

Research Activities

In 2024, national and international students, professors, and researchers participated in QUC events.

The KDES is headed by prof. Changbom Park along with QUC fellow Dr. Jeong Gyu Kim, and research fellows Drs. Jaewon Yoo and Jie Li.

QUC Research Fellow Jeong-Gyu Kim has been developing a semi-analytic model for density-bounded H II regions with photoevaporative outflows. He has mentored students, Nora Linzer (Princeton) on a research project on UV radiation fields in TIGRESS simulations of star-forming ISM, Chanjin Lee (SNU) in analyzing hydrodynamic simulations of H II regions, and Gain Lee (SNU) in running cosmological hydrodynamic simulations with varying dark energy equation of state. He has collaborated with Chang-Goo Kim (Princeton) and others on a project on quantifying the metallicity dependence of stellar feedback and star formation in disk galaxies, with Lachlan Lancaster (Columbia) and others on a project on the evolution of interstellar bubbles driven by stellar wind and radiation, and with Kedron Silsbee (Univ. Texas at El Paso) and others to study the rotational disruption of zodiacal dust.

QUC postdoc Dr. Jaewon Yoo has been studying intracluster light (ICL) as a tracer of dark matter and its connection to the dynamical evolution of galaxy clusters. Using simulated galaxy clusters from HR5, she published a study in the Astrophysical Journal demonstrating that ICL serves as an effective tracer of dark matter over cosmological timescales. She also explored the relationship between the one-dimensional profiles of dark matter and the combined profiles of the brightest cluster galaxy (BCG) and ICL in HR5, noting a discrepancy compared to results from IllustrisTNG 300. She is extending this analysis to real observational data using weak and strong lensing techniques. Additionally, she is analyzing C-EAGLE simulations with different dark matter models (CDM and SIDM) and investigating how ICL can be used to constrain dark matter models.

Dr. Jie Li has joined the group in November 2024, and is going to work on the origin and evolution of galaxy spin using the HR5 simulation.

KDES group meetings were organized by Prof. Changbom Park and Dr. Jaewon Yoo were held at KIAS every two weeks. At these meetings, there were usually two speakers, either from the KIAS astrophysics group or from outside KIAS. The meetings were informal, enabling people to freely discuss issues and exchange ideas on various topics in cosmology, including dark energy and galaxy formation.

During the year, the Statistical Physics Group held two types of regular meeting: internal and NEST group meetings. The former meetings were held every two weeks on Thursday at KIAS, and the latter were held every week on Friday. The internal group meetings were held to engage in in-depth discussions about current issues and progress in the fields of stochastic and quantum thermodynamics. In the NEST group meetings, research ideas for various issues related to statistical physics were shared by reviewing a wide range of papers. These two types of meeting were open to both non-KIAS scholars and KIAS members.

The Condensed-Matter Physics Group has held a regular series of group meetings organized by Prof. Kwon Park. In this meeting, group members discuss the progress of their research projects in

various topics, such as quantum Hall effects, topological insulators, strongly correlated superconductivity, and nonequilibrium physics.

In addition to the group meeting, the group hosted speakers from other institutes to hear about their research topics and exchange ideas.

The Elementary Particle Physics Group at KIAS has been actively engaged in research on various topics in theoretical and computational high-energy physics.

Prof. Pyungwon Ko utilized machine learning Transformer models to investigate the collider phenomenology of dark Higgs bosons and leptophobic dark photons. Dr. Jae Hoon Jeong focused on anapole dark matter couples to U(1) hypercharge and developed a general vertex structure for the HℓℓZ interactions, confirming that the Higgs boson has spin-0 and negative parity through comparison with experimental data. Dr. Raymundo Ramos solved four coupled Boltzmann equations to calculate the relic abundance of dark matter and the temperature evolution of different sectors, considering interactions with light scalars, and the Standard Model. He also explored Standard Model extensions with new scalar particles to explain dark matter, baryon asymmetry, and neutrino masses and mixings.

Current research includes quantum computing algorithms for event topology analysis in high-energy collider signals, machine learning for efficient integration of multibody phase space in Monte Carlo simulations, and deep learning-based parameter space scanning.

The group also actively organized academic events, including the APCTP-KIAS Workshop on "Amplitude Methods for Gravity and Cosmology - II" and the QUC School on AI in High Energy Physics - Amplitudes, fostering research collaborations in these fields.

Researchers in the QUC Quantum Information Group have conducted research on various topics in quantum information theory, including quantum entanglement and nonlocality, quantum communication, and quantum metrology. The group has also held meetings and seminars approximately twice a month, fostering discussions on emerging topics in quantum information science and technology. These seminars were presented by either KIAS members or invited speakers.

Throughout the year, QUC co-organized Quantum Korea 2024 (June 25–27, Ilsan, Korea), hosted by the Ministry of Science and ICT of Korea. Professor Jaewan Kim of QUC, KIAS, served as the chairperson of the organizing committee. The event featured a special lecture, three keynote speeches, the Conference on Quantum Information, the International Research and Industry Exhibition, the Exhibitor's Forum, and a public lecture.

Prof. Young-Woo Son in the Quantum States Matter Group has investigated the developments of first-principles calculation methods that can be used to understand quantum materials with coexisting strong local Coulomb interactions as well as strong covalent interactions. By developing a new computational method incorporating ab initio determination of nonlocal Hubbard interaction in the presence of strong spin-orbit interactions, his group has successfully demonstrated predictability of the new method in computing electronic properties of the quantum materials with strong correlations and spin-orbit coupling simultaneously.

Visiting Scientists

- Christophe Pichon / Institut d'astrophysique de Paris
- Pravabati Chingangbam / Indian Institute of Astrophysics
- Seo, Hee-Jong / Ohio University
- Hong, Hyunsuk / Jeonbuk National University
- Kyprianidis, Antonois / Indiana University
- Hayakawa, Ryu / Kyoto University
- Chen, Kuo-Chin / Foxconn research
- Kang, Dong Woo / Jeonbuk National University
- Spooner, Nicholas / the University of Warwick
- Um, Jaegon / POSTECH
- Tian, Jiahua / East China Normal University
- Bang, Jeongho / Yonsei University
- Baek, Kyunghyun / Yonsei University
- Arzoumanian, Doris / NAOJ
- Hwang, Jihye / KASI

Conferences and Workshops

QUC has organized a total of 14 conferences. Among them, a few representative conferences will be highlighted in detail.

■ Quantum Korea 2024

KIAS co-organized Quantum Korea 2024, held from June 25 to June 27 in Ilsan, Korea, and hosted by the Korea Ministry of Science and ICT. Professor Jaewan Kim from QUC, KIAS, served as the chairperson of the organizing committee. The event featured one special lecture, three keynote speeches, the Conference on Quantum Information, the International Research and Industry Exhibition, the Exhibitor's Forum, and a public lecture.

In the special lecture, Prof. Mikhail Lukin from Harvard University delivered a talk on atom-based quantum computing and the quantum internet. The keynote speakers included leading international scholars in quantum information science: Prof. Norbert Lütkenhaus (University of Waterloo), Prof. Hiroshi Imai (Meiji Gakuin University), and Prof. Paola Cappellaro (MIT).

These distinguished speakers provided insights into various aspects of quantum information technology, including quantum cryptography, quantum computing, and quantum sensing. Throughout the conference, global experts presented major trends and research findings across seven specialized fields.

The International Research and Industry Exhibition and the Exhibitor's Forum featured participation from more than 40 research institutes, universities, and companies, showcasing cutting-edge technologies and research advancements in quantum information science.

Quantum Korea 2024 (June 25–27)

11th KIAS Workshop on Cosmology and Structure Formation (October 27–November 2)

Beyond the scientific sessions, the event also included two public lectures and five short "Quantum Connect Talks" (SEBASI 15), delivered by speakers from various fields, further engaging a broader audience.

■ 11th KIAS Workshop on Cosmology and Structure Formation

The KIAS workshop on cosmology and structure formation has started in 2004, and this was the 20th anniversary of this meeting. During the period cosmology has changed and there have been a lot of new findings and understandings in extragalactic astronomy. Over the past 20 years the initial participants have aged together, and new faces have joined with brillient ideas and fresh energy. This workshop once again gave academic stimulation to all participants and initiate new collaborations between the participants as it has done so during the past 20 years. More than 130 astronomers have participated in the 11th workshop, and there were 83 scientific presentations in addition to discussion sessions.

The 25th Asian Workshop on First-Principles Electronic Structure Calculations (October 28–30)

The 12th KIAS Workshop on Particle Physics and Cosmology and 2024 Korea-France STAR workshop (November 18–23)

■ The 25th Asian Workshop on First-Principles Electronic Structure Calculations

The Asian Electronic Structure Conference, which has been held continuously for the past 24 years, is the most prominent conference in Northeast Asia for researchers in condensed matter physics through computational and theoretical approaches. This year's conference brought together over 250 participants, including researchers from the United States, Europe, Japan, China, Taiwan, Korea, and India. The event featured presentations on the latest advances in condensed matter physics, materials science, computational chemistry, and AI-driven materials research, along with over 100 poster presentations.

■ The 12th KIAS Workshop on Particle Physics and Cosmology and 2024 Korea-France STAR workshop

The workshop was successfully held from November 17-23, 2024, at the Korea Institute for Advanced Study (KIAS) in Seoul.

- Objectives :

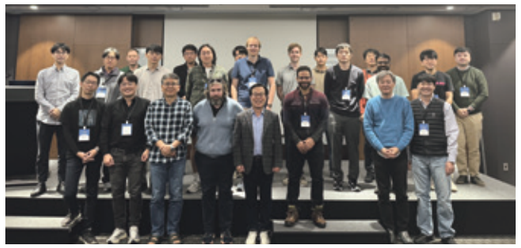
The workshop aimed to bring together a diverse group of theorists specializing in various aspects of beyond the standard model physics in both particle physics and cosmology. This gathering provided a platform for researchers to share their latest findings and engage in meaningful discussions about their current research topics.

- Achievements :

- Collaborative Sessions: The workshop featured joint sessions with the Korea-France Star Workshop, fostering interdisciplinary dialogue and collaboration between Korea and other countries, most notably with France.
- Networking Opportunities: Researchers from different institutes had numerous opportunities to collaborate on research projects and form new professional connections.
- Support for Young Researchers: The event placed special emphasis on helping young researchers gain visibility and integrate into the broader research community. Many young researchers presented their work and received valuable feedback from established experts in the field.

- Program and Discussions

The workshop's relaxed program allowed ample time for in-depth discussions and exchanges of ideas. Participants engaged in vibrant discussions on various topics, including the latest advancements in beyond the standard model physics and their implications for cosmology. Conclusion The 2024 Korea-France STAR Workshop was a significant milestone in the collaboration between Korean and French researchers. It successfully contributed to advancements in the fields of particle physics and cosmology, and strengthened the professional network among researchers. The event was well-received by all participants, who appreciated the opportunity to share their research and collaborate in a supportive environment.



KIAS-APCTP Frontiers of Theoretical Physics (November 24–29)

- Conclusion

The 12th KIAS workshop and 2024 Korea-France STAR Workshop was a milestone in the ongoing collaboration between Korean and French researchers as well as neighboring countries such as Japan and China. It successfully contributed to advancements in the fields of particle physics and cosmology, and strengthened the professional network among researchers. The event was well-received by all participants, who appreciated the opportunity to share their research and collaborate in a supportive environment.

■ KIAS-APCTP Frontiers of Theoretical Physics

The 2024 KIAS-APCTP Frontiers of Theoretical Physics workshop, held on Jeju Island from November 24 to 29, brought together leading theoretical physicists and mathematicians specializing in quantum field theory (QFT), string theory, algebraic geometry, and machine learning.

This series was initiated in 2021 as a vibrant platform for researchers to explore interdisciplinary collaborations, with quantum field theory as the core tool and key concept. In previous events, strongly correlated condensed matter physics, statistical physics, particle phenomenology, and machine learning have been represented.

At this year's event, 19 invited speakers delivered talks on enumerative geometry, machine learning, and various topics in quantum field theory with close connections to pure mathematics. The program also fostered interdisciplinary dialogue among 26 participants, encouraging them to address outstanding challenges in fundamental physics and pave the way for new solutions.

QUC Faculty and Research Fellows

Park, Hyunggyu
QUC Distinguished Professor

Kim, Jaewan
QUC Distinguished Professor

Jeong-Gyu Kim
QUC Fellow

Hhan, Minki
QUC Fellow

Jeong, Jae Hoon
QUC Research Fellow

Moran, James
QUC Research Fellow

Yang, Wooil
QUC Research Fellow

Yang, Xing-Yu
QUC Research Fellow

Yoo, Jaewon
QUC Research Fellow

Ramos, Raymundo
QUC Research Fellow

Wang, Xin
QUC Research Fellow

Nikolaos Georgios Eftaxias
QUC Research Fellow

Minsung Kim
QUC Research Fellow

TaeHwan Oh
QUC Research Fellow

Bagchi Shrobona
QUC Research Fellow

Jie Li
QUC Research Fellow

Prabuddha Roy
QUC Research Fellow

Publications

Sui, Xiao-Bin; Liu, Jing; **Yang, Xing-Yu**; Cai, Rong-Gen
Detecting the dark sector through scalar-induced gravitational waves • PHYSICAL REVIEW D

Kechrimparis, Spiros; **Moran, James**; Karsa, Athena; Lee, Changhyoup; **Kwon, Hyukjoon**
Enhancing quantum state discrimination with indefinite causal order • NEW JOURNAL OF PHYSICS

Pal, P. S.; Park, Jong-Min; Pal, Arnab; **Park, Hyunggyu**; **Lee, Jae Sung**
Active motion can be beneficial for target search with resetting in a thermal environment • PHYSICAL REVIEW E

Paudel, Sanjaya; Sabiu, Cristiano G.; Yoon, Suk-Jin; Duc, Pierre-Alain; **Yoo, Jaewon**; Mueller, Oliver
Discovery of a Rare Group of Dwarf Galaxies in the Local Universe • ASTROPHYSICAL JOURNAL LETTERS

Yang, Wooil; Son, Young-Woo
Effects of self-consistent extended Hubbard interactions and spin-orbit couplings on energy bands of semiconductors and topological insulators • PHYSICAL REVIEW B

Choi, Seong Youl; **Jeong, Jaehoon**; Kang, Dong Woo
Vetoing all the Higgs imposters in H→ l−l+Z • EUROPEAN PHYSICAL JOURNAL C

Park, Su-Chan; **Park, Hyunggyu**
Finite-size scaling of the Kuramoto model at criticality • PHYSICAL REVIEW E

Martin, Lee R.; Blain, Andrew W.; Diaz-Santos, Tanio; Assef, Roberto J.; Tsai, Chao-Wei; **Jun, Hyunsung D.**; Eisenhardt, Peter R. M.; Wu, Jingwen; Vayner, Andrey; Aranda, Roman Fernandez
CO spectra of the ISM in the Host Galaxies of the most luminous WISE-selected AGNs • MONTHLY NOTICES OF THE ROYAL ASTRONOMICAL SOCIETY

Duan, Xin-Chen; **Ramos, Raymundo**; Tsai, Yue-Lin Sming
Relic density and temperature evolution of a light dark sector • PHYSICAL REVIEW D

Park, Jong-Min; **Park, Hyunggyu**; **Lee, Jae Sung**
Stochastic differential equation for a system coupled to a thermostatic bath via an arbitrary interaction Hamiltonian • PHYSICAL REVIEW E

Chun, Kyungwon; Shin, Jihye; Ko, Jongwan; Smith, Rory; **Yoo, Jaewon**
Formation Channels of Diffuse Lights in Groups and Clusters over Time • ASTROPHYSICAL JOURNAL

Kang, Sin Kyu; **Ramos, Raymundo**
Common origin of dark matter, baryon asymmetry and neutrino masses in the standard model with extended scalars • JOURNAL OF THE KOREAN PHYSICAL SOCIETY

Bian, Ligong; Ge, Shuailiang; Shu, Jing; Wang, Bo; **Yang, Xing-Yu**; Zong, Junchao
Gravitational wave sources for pulsar timing arrays • PHYSICAL REVIEW D

Kong, Otto C. W.
On locality of quantum information in the Heisenberg picture for arbitrary states • CHINESE JOURNAL OF PHYSICS

Choi, Seong Youl; **Jeong, Jaehoon**; Kang, Dong Woo; Shin, Seodong
Hunting for hypercharge anapole dark matter in all spin scenarios • PHYSICAL REVIEW D

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Lee, Kimyeong; **Sun, Kaiwen**; **Wang, Xin**
Twisted elliptic genera • JOURNAL OF HIGH ENERGY PHYSICS

Fu, Chengjie; Liu, Jing; **Yang, Xing-Yu**; Yu, Wang -Wei; Zhang, Yawen
Explaining pulsar timing array observations with primordial gravitational waves in parity-violating gravity • PHYSICAL REVIEW D

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Schur indices forN=4super-Yang-Mills with moregeneral gauge groups • JOURNAL OF HIGH ENERGY PHYSICS

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Dimensionality-driven metal to Mott insulator transition in two-dimensional 1T-TaSe2 • NATIONAL SCIENCE REVIEW

Jun Park, Jung; Baek, Kyunghyun; **Kim, M. S.**; Nha, Hyunchul; **Kim, Jaewan**; Bang, Jeongho
T-depth-optimized quantum search with quantum data-access machine • QUANTUM SCIENCE AND TECHNOLOGY

Center for Advanced Computation

Introduction

The Center for Advanced Computation (CAC) has played a key role in providing high-performance computing resources to outstanding basic science researchers at the Korea Institute for Advanced Study (KIAS). Since its foundation in 2010, the CAC has installed eight Linux clusters (six CPU-based and two GPU-based) and massively parallel storage systems. These resources are vital to advancing research in key fields of basic sciences, including biophysics, material science, statistical physics, cosmology, and condensed matter physics.

Recognizing the importance of parallel computing and supercomputing in both current and future scientific research tools, the CAC annually hosts summer schools. These programs aim to inspire junior researchers by providing them with the knowledge and skills to effectively utilize significant computing power in their respective fields of research. To achieve this goal, senior researchers are invited to deliver lectures on parallel computing and machine learning. These sessions are designed for graduate students seeking to enhance their research skills with cutting-edge computational technologies.

Because the CAC fully understands the importance of machine learning and AI in basic sciences, it is seeking potential collaborations with AI experts outside of KIAS and looking to support research activities, including joint workshops and schools.

Research Activities

■ GPU Cluster upgrade

As part of the major research cluster performance improvement project in 2024, 10 of the latest NVIDIA H100 GPUs were added to the existing Syntax cluster.

The NVIDIA H100 GPU features 80 GB of HBM2e memory with a memory bandwidth of 2 TB/s. It delivers an FP64 performance of 26 TFLOPS, FP64 Tensor Core performance of 51 TFLOPS, and FP32 performance of 51 TFLOPS. Additionally, its TF32 Tensor Core performance reaches 756 TFLOPS, while its BFLOAT16 and FP16 Tensor Core performance is 1,513 TFLOPS each. The FP8 Tensor Core performance reaches 3,026 TFLOPS.

This enhancement is expected to significantly contribute to fundamental AI and scientific research utilizing GPUs.

Many papers have been published utilizing data from the CAC cluster, and the list is attached below.

■ The 15th CAC Summer School

The 15th CAC Summer School on Scientific Computing & Artificial Intelligence was successfully held from June 24 to 28, 2024. This annual event provides an in-depth educational program focused on the latest advancements in scientific computing and AI, offering participants a unique opportunity to enhance their computational research skills.

Approximately 120 researchers and graduate students from diverse fields of natural science, including physics, mathematics, and computational biology, attended the program. The summer school featured a series of lectures, hands-on sessions, and workshops led by prominent experts in the field, covering a wide range of topics such as machine learning applications, high-performance computing (HPC), and numerical simulations. Participants actively engaged in practical exercises utilizing cutting-edge computing resources, gaining firsthand experience in applying AI-driven methodologies to scientific problems.

In addition to the summer school, CAC provided computational support for various academic conferences and workshops, enabling researchers to perform large-scale simulations and data analysis using the center's high-performance computing infrastructure. This initiative played a crucial role in fostering collaboration and advancing research in AI-driven scientific computing.

■ Enhancing Infrastructure for High-Performance Computing

Another significant achievement was the replacement of four existing 20RT air conditioning units with 30RT units. This large-scale construction project took approximately one month to complete and required the temporary shutdown of the cluster for about ten days.

Despite the temporary inconvenience, the upgrade led to substantial improvements in energy efficiency. Previously, the facility required the operation of seven air conditioning units to maintain optimal environmental conditions but, with the new system in place, only four units are now needed, significantly enhancing energy efficiency.

Additionally, the aging outdoor units on the rooftop were redistributed, effectively reducing vibration and noise levels. As a result, the overall noise reduction in Building 7 has contributed to a more comfortable and research-friendly environment for all occupants.

Faculty and Research Fellows

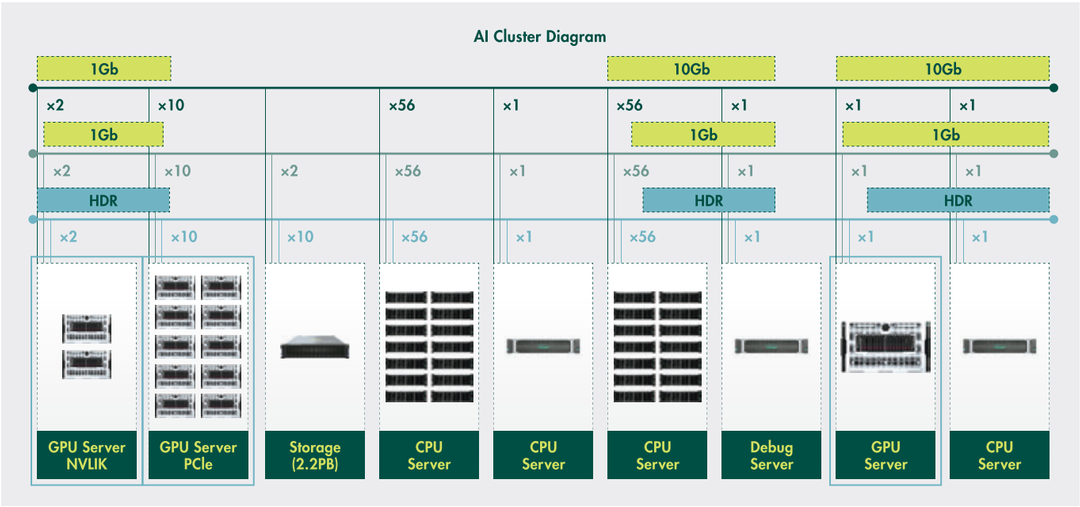
Kim, Juhan
Research Professor

Joo, Keehyoung
Research Professor

The 15th CAC Summer School



HVAC Upgrade: Replacing 20RT with 30RT Units



Cluster Configuration with Installed H100 GPU Cards

List of Papers Utilizing CAC Computing Resources

Active diffusion of self-propelled particles in semiflexible polymer networks • MACROMOLECULES

Active motion can be beneficial for target search with resetting in a thermal environment • PHYSICAL REVIEW E

Anomalous water penetration in Al3+ dissolution • JOURNAL OF PHYSICAL CHEMISTRY LETTERS

Anyon condensation and confinement transition in a Kitaev spin liquid bilayer • PHYSICAL REVIEW B

atomistic simulation of HF etching process of amorphous Si3N4 using machine learning potential • ACS APPLIED MATERIALS & INTERFACES

Correlation-enhanced viable core in metabolic networks • CHAOS SOLITONS & FRACTALS

Data-efficient multifidelity training for high-fidelity machine learning interatomic potentials • JOURNAL OF THE AMERICAN CHEMICAL SOCIETY

Defect passivation of 2D semiconductors by fixating chemisorbed oxygen molecules via h-BN encapsulations • ADVANCED SCIENCE

Dephasing dynamics accessed by high harmonic generation: determination of electron-hole decoherence of Dirac fermions • NANO LETTERS

Dimensionality-driven metal to Mott insulator transition in two-dimensional 1T-TaSe2 • NATIONAL SCIENCE REVIEW

Effects of self-consistent extended Hubbard interactions and spin-orbit couplings on energy bands of semiconductors and topological insulators • PHYSICAL REVIEW B

Emergence of the galaxy morphology–star formation activity–clustercentric radius relations in galaxy clusters • THE ASTROPHYSICAL JOURNAL

Estimating entanglement entropy via variational quantum circuits with classical neural networks • PHYSICAL REVIEW E

Finite-size scaling of the Kuramoto model at criticality • PHYSICAL REVIEW E

Glycolytic oscillations under periodic drivings • JOURNAL OF THE ROYAL SOCIETY INTERFACE

Heterogeneous popularity of metabolic reactions from evolution • PHYSICAL REVIEW LETTERS

Hi-C-guided many-polymer model to decipher 3D genome organization • BIOPHYSICAL JOURNAL

Identification of galaxy protoclusters based on the spherical top-hat collapse theory • ASTROPHYSICAL JOURNAL

Indirect-to-direct bandgap crossover and room-temperature valley polarization of multilayer MoS2 achieved by electrochemical intercalation • ADVANCED MATERIALS

Investigating cosmic homogeneity using multifractal analysis of the SDSS-IV eBOSS DR16 quasar catalogue • MONTHLY NOTICES OF THE ROYAL ASTRONOMICAL SOCIETY

Kinetic model for the desensitization of G protein-coupled receptor • JOURNAL OF PHYSICAL CHEMISTRY LETTERS

Manipulating topological quantum phase transitions of Kitaev's quantum spin liquids with electric fields • PHYSICAL REVIEW B

Merger-tree-based galaxy matching: A comparative study across different resolutions • ASTROPHYSICAL JOURNAL

Mixed-state quantum spin liquids and dynamical Anyon condensations in Kitaev Lindbladians • QUANTUM

Modified activation-relaxation technique (ARTn) method tuned for efficient identification of transition states in surface reactions • JOURNAL OF CHEMICAL THEORY AND COMPUTATION

Molecular mechanism of anion permeation through aquaporin 6 • BIOPHYSICAL JOURNAL

Non-Abelian fractional quantum anomalous Hall states and first Landau level physics of the second moiré band of twisted bilayer MoTe2 • PHYSICAL REVIEW B

Orbital-selective Mott transition effects and nontrivial topology of iron chalcogenide • PHYSICAL REVIEW LETTERS

Probing cosmology via the clustering of critical points • MONTHLY NOTICES OF THE ROYAL ASTRONOMICAL SOCIETY

Pseudospins revealed through the giant dynamical Franz-Keldysh effect in massless Dirac materials • NPJ QUANTUM MATERIALS

Scalable parallel algorithm for graph neural network interatomic potentials in molecular dynamics simulations • JOURNAL OF CHEMICAL THEORY AND COMPUTATION

Spatial distribution of intracluster light versus dark matter in Horizon Run 5 • ASTROPHYSICAL JOURNAL

Spatiotemporal characterization of water diffusion anomalies in saline solutions using machine learning force field • SCIENCE ADVANCES

star formation properties of z ~ 1 galaxy clusters and groups from Horizon Run 5 • MONTHLY NOTICES OF THE ROYAL ASTRONOMICAL SOCIETY

Stochastic differential equation for a system coupled to a thermostatic bath via an arbitrary interaction Hamiltonian • PHYSICAL REVIEW E

Strain tunable electronic ground states in two-dimensional iridate thin films • APPLIED SURFACE SCIENCE

Study of dependence of ram pressure stripping on the orbital parameters of the galaxies • MONTHLY NOTICES OF THE ROYAL ASTRONOMICAL SOCIETY

Testing Lyα emitters and Lyman-break galaxies as tracers of large-scale structures at high redshifts • ASTROPHYSICAL JOURNAL

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The environmental dependence of the stellar mass-gas metallicity relation in Horizon Run 5 • MONTHLY NOTICES OF THE ROYAL ASTRONOMICAL SOCIETY

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Hong, Sungwook E.; **Park, Changbom**; **Mishra, Preetish K.**; **Kim, Juhan**; Gibson, Brad K.; Kim, Yonghwi; Few, C. Gareth; **Pichon, Christophe**; Shin, Jihye; Lee, Jaehyun
Emergence of the Galaxy Morphology-Star Formation Activity-Clustercentric Radius Relations in Galaxy Clusters • *ASTROPHYSICAL JOURNAL*

Im, Sang Hyeok; Hwang, Ho Seong; **Park, Jaehong**; Lee, Jaehyun; Song, Hyunmi; Appleby, Stephen; Dubois, Yohan; Few, C. Gareth; Gibson, Brad K.; **Kim, Juhan**; Kim, Yonghwi; **Park, Changbom**; **Pichon, Christophe**; Shin, Jihye; Snaith, Owain N.; Artale, M. Celeste; Gawiser, Eric; Guaita, Lucia; Jeong, Woong-Seob; Lee, Kyoung-Soo; Padilla, Nelson; Ramakrishnan, Vandana; Troncoso, Paulina; Yang, Yujin
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Molecular mechanism of anion permeation through aquaporin 6 • BIOPHYSICAL JOURNAL

Lee, Seong-Kook; **Park, Changbom**; **Kim, Juhan**; **Lee, Jaehyun**; Gibson, Brad K.; Kim, Yonghwi; Few, C. Gareth
Star formation properties of z ~ 1 galaxy clusters and groups from Horizon Run 5 • MONTHLY NOTICES OF THE ROYAL ASTRONOMICAL SOCIETY

Rowntree, Aaron R.; **Singh, Ankit**; Vincenzo, Fiorenzo; Gibson, Brad K.; Gouin, Celine; Galarraga-Espinosa, Daniela; Lee, Jaehyun; **Kim, Juhan**; Laigle, Clotilde; **Park, Changbom**; **Pichon, Christophe**; Few, Gareth; Hong, Sungwook E.; Kim, Yonghwi
The environmental dependence of the stellar mass-gas metallicity relation in Horizon Run 5 • MONTHLY NOTICES OF THE ROYAL ASTRONOMICAL SOCIETY

Tonegawa, Motonari; Appleby, Stephen; Park, Changbom; Hong, Sungwook E.; Kim, Juhan
The effects of non-linearity on the growth rate constraint from velocity correlation functions • MONTHLY NOTICES OF THE ROYAL ASTRONOMICAL SOCIETY

Shim, Junsup; **Pichon, Christophe**; Pogosyan, Dmitri; Appleby, Stephen; Cadiou, Corentin; **Kim, Juhan**; Kraljic, Katarina; **Park, Changbom**
Probing cosmology via the clustering of critical points • MONTHLY NOTICES OF THE ROYAL ASTRONOMICAL SOCIETY

Jung, Minyong; Kim, Ji-hoon; Oh, Boon Kiat; Hong, Sungwook E.; **Lee, Jaehyun**; **Kim, Juhan**
Merger-tree-based Galaxy Matching: A Comparative Study across Different Resolutions • ASTROPHYSICAL JOURNAL

Yoo, Jaewon; **Park, Changbom**; Sabiu, Cristiano G.; **Singh, Ankit**; Ko, Jongwan; **Lee, Jaehyun**; **Pichon, Christophe**; Jee, M. James; Gibson, Brad K.; Snaith, Owain; **Kim, Juhan**; Shin, Jihye; Kim, Yonghwi; Kim, Hyowon
Spatial Distribution of Intracluster Light versus Dark Matter in Horizon Run 5 • ASTROPHYSICAL JOURNAL

Lee, Jaehyun; **Park, Changbom**; **Kim, Juhan**; **Pichon, Christophe**; Gibson, Brad K.; Shin, Jihye; Kim, Yonghwi; Snaith, Owain N.; Dubois, Yohan; Few, C. Gareth
Identification of Galaxy Protoclusters Based on the Spherical Top-hat Collapse Theory • ASTROPHYSICAL JOURNAL

Center for AI and Natural Sciences

Introduction

Intelligence is a phenomenon that emerges from the activity of neural networks that make up the brains of living organisms. The Korea Institute for Advanced Study (KIAS) Center for Artificial Intelligence and Natural Sciences (CAINS), which was founded in 2021, aims to develop and utilize algorithms of intelligence based on a fundamental understanding of mathematics and physics. An important axis of this research is (1) understanding the emergence of intelligence and (2) its application in individual fields of basic science.

The main focus of artificial intelligence (AI) research, largely driven by computer engineers, is currently on its application in industry. However, it is equally important to explore a new class of AI by asking fundamental questions about its mathematical foundations and physical principles. Basic sciences have advanced AI, and AI has in turn offered hints at a solution to challenging problems in fields such as material science, biology, and cosmology. This symbiotic relationship between AI and fundamental sciences fosters mutual progress and cross-fertilization. Based on an array of ideas and tools developed in advanced mathematics, theoretical physics, and computational sciences, CAINS aims to develop an interpretable and controllable AI that naturally follows the principles of nature. As an AI hub where experts from diverse backgrounds can get together to have in-depth discussions, the center also seeks to lay a foundation for pioneering AI innovation.

Conferences and Workshops

■ The 3rd KIAS Center for AI and Natural Sciences Workshop

The 3rd KIAS CAINS Workshop was held at Sea Cloud Hotel in Busan from May 27 to 29, 2024. In this three-day workshop, 18 seminars were delivered by speakers from CAINS and external institutes.

The aim of the workshop was to learn the latest research topics of AI and its application to basic sciences. Speakers invited from external institutes delivered in-depth lectures, which offered a forum for the development of the center and promoted communication among the participants.

■ The KIAS CAINS Fall Workshop

This Fall Workshop, hosted by the CAINS, was held at Nest Hotel in Yeongjongdo, Incheon, from November 4 to 8, 2024. The event brought together 13 domestic and international invited speakers, 10 contributed speakers, and around 10 poster presenters, fostering academic exchange and collaboration.

Each day began with tutorial presentations covering fundamental aspects of machine learning, providing participants with a broad understanding of AI principles and the latest research trends. The subsequent sessions featured in-depth talks exploring AI principles and case studies showcasing AI applications in natural sciences. These presentations introduced unique approaches and findings, highlighting the potential of AI in scientific research and practical applications.

Beyond the latest AI research presentations, the workshop also served as a platform for dynamic and in-depth discussions. Researchers from diverse backgrounds exchanged perspectives and collaboratively tackled challenging questions, generating new insights and ideas.

■ AI for Mathematics Workshop on Formalization

This workshop discussed the importance of formalizing mathematics and its current trends, while offering hands-on experience by formalizing several mathematical statements and proofs.

Because this topic is being actively discussed globally, it is believed that this workshop will serve as a starting point for further discussion on this important field within the domestic academic community.

For the first time in Korea, this workshop introduced the concept of mathematical formalization and automated reasoning. Dr. Soonho Kong from Amazon, a leading researcher in automated mathematical reasoning, shared insights into the latest research trends from global tech companies. Additionally, Dr. Byunghak Hwang and Dr. Yeachan Park gave talks on the significance of formalizing mathematics, how AI can assist in this process, and the current progress of leading research groups in this area. Participants also had the opportunity to gain hands-on experience in formalizing mathematical statements and proofs through a tutorial session led by Dr. Jineon Baek.

The event attracted approximately 50 participants, demonstrating strong interest in this emerging field. As the formalization of mathematics and AI-driven reasoning continue to gain global attention, this workshop served as an important starting point for further discussions and research collaborations within the domestic academic community.

■ KIAS-KU Intensive Workshop: AI and Higher-Order Interactions

This workshop presented the latest research findings on AI applications in complex systems and higher-order interactions, a topic of growing interest in network science. Leading domestic researchers in statistical physics were invited as advisory board members to provide expert feedback. Specifically, the workshop featured presentations on the following topics:

1. The second-order Kuramoto synchronization model with power grid applications in mind
2. Opinion dynamics and higher-order Ising models on hypergraphs
3. The study of complex system dynamics using neural networks
4. Network renormalization group research
5. Evolutionary games on hypergraphs.

The 3rd KIAS CAINS Workshop (May 27–29)

The KIAS Center for AI and Natural Sciences Fall Workshop (November 4–8)

AI for Mathematics Workshop on Formalization (December 18)

KIAS-KU Intensive Workshop: AI and Higher-Order Interactions (December 18–20)

Each topic was discussed in detail for 3–4 hours, with active participation and extensive Q&A sessions among all attendees. Discussions led to valuable exchanges on unresolved issues and potential solutions. For example, an idea emerged to conduct renormalization group analysis on higher-order Ising models in a two-dimensional lattice to explore the universality class of phase transitions—including continuous, discontinuous, and dual transitions. Additionally, a new candidate for a scale-invariant network model was proposed by modifying spectral dimensions through network renormalization, leading to plans for collaborative research. Ultimately, the workshop successfully achieved its goal of sharing the latest developments in network theory as a fundamental tool for studying complex systems, including AI applications, and fostering discussions on open problems.

■ **Seminars**

The main purpose of these seminars was to identify the current outstanding issues in AI-related research and to communicate with new researchers. The CAINS aims to develop a research base through in-depth discussions with experts from a diverse range of fields on current research topics.

On average, 2 or 3 seminars and special gatherings were held every month. A total of 35 seminars held by either CAINS members or invited speakers and one colloquium were organized in 2024 to encourage discussions on various topics related to the principles and applications of AI.

Visiting Program

KIAS Scholars

- Lee, Daniel D. / Cornell University
- Lee, Kyu-Hwan / University of Connecticut

Affiliated Professors

- Han, Seungwu / Seoul National University
- Kwon, Dohyun / University of Seoul
- Noh, Yung-kyun / Hanyang University
- Yoon, Hongkee / Kangwon National University

AI Faculty and Research Fellows

Hyeon, Changbong
Director / Professor

Choi, Kyeongsu
Professor

Choi, Sangkook
Professor

Kang, Nam-Gyu
Professor

Kiem, Young-Hoon
Professor

Kim, Jeong Han
Professor

Kim, Sang-hyun
Professor

Ko, Pyungwon
Professor

Lee, Deok-Sun
Professor

Lee, Jae Sung
Professor

Lee, Kimyeong
Professor

Lee, Sungjay
Professor

Park, Changbom
Professor

Son, Young-Woo
Professor

Cho, Kwang Hyun
AI Research Fellow

Choi, Jaesung
AI Research Fellow

Choi, Jaewoong
AI Research Fellow

Flacke, Thomas Dieter
AI Research Fellow

Hwang, Geonho
AI Research Fellow

Koo, Eunho
AI Research Fellow

Lee, Jaeyong
AI Research Fellow

Lee, Yonghyeon
AI Research Fellow

Park, Jun Sur
AI Research Fellow

Park, Yeachan
AI Research Fellow

Yoon, Sangwoong
AI Research Fellow

Yu, Ji woong
AI Research Fellow

Choi, Jaewoong
Project Research Fellow

Yong, Daeseong
Project Research Fellow

Publications

Park, In Ah; **Noh, Yung-Kyun**; Min, Kyueng-Whan; Kim, Dong-Hoon; Lee, Jeong-Yeon; Son, Byoung Kwan; Kwon, Mi Jung; Han, Myung-Hoon; Hur, Joon Young; Pyo, Jung Soo
p27 Cell Cycle Inhibitor and Survival in Luminal-Type Breast Cancer : Gene Ontology, Machine Learning, and Drug Screening Analysis • JOURNAL OF BREAST CANCER

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Yu, Ji Woong; Kim, Sebin; Ryu, Jae Hyun; Lee, Won Bo; Yoon, Tae Jun
Spatiotemporal characterization of water diffusion anomalies in saline solutions using machine learning force field • SCIENCE ADVANCES

Kim, Minwoo; Kim, Seungtae; **Hyeon, Changbong**; **Yu, Ji Woong**; Choi, Siyoung Q.; Lee, Won Bo
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Jung, Jisu; An, Hyungmin; Lee, Jinhee; **Han, Seungwu**
Modified Activation-Relaxation Technique (ARTn) Method Tuned for Efficient Identification of Transition States in Surface Reactions • JOURNAL OF CHEMICAL THEORY AND COMPUTATION

Lee, Jiho; Ju, Suyeon; Hwang, Seungwoo; You, Jinmu; Jung, Jisu; Kang, Youngho; **Han, Seungwu**
Disorder-Dependent Li Diffusion in Li6PS5Cl Investigated by Machine-Learning Potential • ACS APPLIED MATERIALS & INTERFACES

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Lee, Yeon-Hee; Jeon, Seonggwang; Won, Jong-Hyun; Auh, Q. -Schick; **Noh, Yung-Kyun**
Automatic detection and visualization of temporomandibular joint effusion with deep neural network • SCIENTIFIC REPORTS

Kim, Hyung Suk; **Noh, Yung-Kyun**; Min, Kyueng-Whan; Kim, Dong-Hoon; Kwon, Mi Jung; Pyo, Jung Soo; Lee, Jeong-Yeon
ASO Visual Abstract: Cancer-Associated Fibroblasts Together with a Decline in CD8+T Cells Predict a Worse Prognosis for Breast Cancer Patients • ANNALS OF SURGICAL ONCOLOGY

Jo, SeongHoon; Roh, Soonjong; Shim, Jaemin; **Yu, Ji Woong**; Jung, Youngmee; Jang, Woo Young; Seo, Bumjoon; Won, You-Yeon; Yoo, Jin
Modulating the Thermoresponsive Characteristics of PLGA-PEG-PLGA Hydrogels via Manipulation of PLGA Monomer Sequences • BIOMACROMOLECULES

Park, Yeachan; **Hwang, Geonho**; Lee, Wonyeol; Park, Sejun
Expressive power of ReLU and step networks under floating-point operations • NEURAL NETWORKS

Park, Jun Sur Richard; Cheung, Siu Wun; Choi, Youngsoo; Shin, Yeonjong
tLaSDI: Thermodynamics-informed latent space dynamics identification • COMPUTER METHODS IN APPLIED MECHANICS AND ENGINEERING

Khanal, Shalil; Liu, Yuanhang; Bamidele, Adebowale O.; Wixom, Alexander Q.; Washington, Alexander M.; Jalan-Sakrikar, Nidhi; Cooper, Shawna A.; Vuckovic, Ivan; Zhang, Song; Zhong, Jun; Johnson, Kenneth L.; Charlesworth, M. Cristine; Kim, Iljung; Yeon, Yubin; **Yoon, Sangwoong**; **Noh, Yung-Kyun**; Meroueh, Chady; Timbilla, Abdul Aziz; Yaqoob, Usman; Gao, Jinhang; Kim, Yohan; Lucien, Fabrice; Huebert, Robert C.; Hay, Nissim; Simons, Michael; Shah, Vijay H.; Kostallari, Enis
Glycolysis in hepatic stellate cells coordinates fibrogenic extracellular vesicle release spatially to amplify liver fibrosis • SCIENCE ADVANCES

Khoury, Mireille; Guo, Qianqian; Furuta, Kunimaro; Correia, Cristina; Meroueh, Chady; Lee, Hyun Se Kim; Warasnhe, Khaled; Valenzuela-Perez, Lucia; Mazar, Andrew P.; Kim, Iljung; **Noh, Yung-Kyun**; Holmes, Heather; Romero, Michael F.; Sussman, Caroline R.; Pavelko, Kevin D.; Islam, Shahidul; Bamidele, Adebowale O.; Hirsova, Petra; Ibrahim, Samar H.
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Park, Yutack; Kim, Jaesun; Hwang, Seungwoo; **Han, Seungwu**
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Kang, Wonjun; **Yong, Daeseong**; Kim, Jaeup U.
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Centralized decomposition approach in LSTM for Bitcoin price prediction • EXPERT SYSTEMS WITH APPLICATIONS

Lee, Junho; Kim, Sang Min; **Lee, Yonghyeon**; Kim, Young Min
NFL: Normal Field Learning for 6-DoF Grasping of Transparent Objects • IEEE ROBOTICS AND AUTOMATION LETTERS

Open KIAS Center

Outreach Program

■ Overview of the Outreach Program

The Korea Institute for Advanced Study (KIAS) is dedicated to achieving excellence in fundamental and theoretical scientific research while also engaging in public outreach to enhance the awareness of foundational science. As part of this commitment, KIAS organizes various programs aimed at bridging the gap between the scientific community and the public. These initiatives provide opportunities for people to explore cutting-edge scientific discoveries and understand their societal impact.

The KIAS Outreach Program has been designed to achieve a number of goals:

- Promote scientific literacy and curiosity among the general public
- Provide in-depth explanations of groundbreaking research and its implications
- Foster engagement between researchers and the community
- Inspire young students and aspiring scientists by introducing them to leading experts in various fields.

■ 2024 Nobel Prize Commentary Lecture

KIAS successfully hosted the 2024 Nobel Prize Commentary Lecture on November 2 in the Auditorium of the KIAS Main Building 1, KAIST Seoul Campus. This annual lecture series, launched in 2013, aims to provide clear and engaging explanations of Nobel Prize-winning research in the sciences.

The 2024 Nobel Prize Commentary Lecture featured three sessions, each delivered by top experts in their respective fields. These sessions provided in-depth analysis of achievements recognized by the Nobel Prize in Physics, Chemistry, and Physiology or Medicine.

Commentary Lectures on Nobel Prize Discoveries (November 2, 2024)

The session on the Nobel Prize in Physics, presented by Professor Junghyo Cho (Seoul National University), explored the intersection of machine learning and physics. He explained how foundational neural network models, such as Hopfield networks and Boltzmann machines, have evolved into modern deep learning architectures, emphasizing the role of physics in advancing artificial intelligence (AI).

Professor Minkyung Baek (Seoul National University) led the session on the Nobel Prize in Chemistry, discussing the impact of AI on protein structure prediction and design. She highlighted the significance of the RosettaFold project in revolutionizing structural biology and shared insights into the research contributions of Nobel laureate David Baker.

The Nobel Prize in Physiology or Medicine session, presented by Professor Junho Lee (Seoul National University), focused on the discovery and evolutionary significance of microRNA (miRNA). He explained how miRNA was first identified in *Caenorhabditis elegans*, its conserved biological functions, and its broader impact on genetics and medicine. He also explored the reasons why research on *C. elegans* has been recognized multiple times by the Nobel Prize Committee.

■ Science with Citizens

The Open KIAS Center initiated the Science with Citizens program in March 2023, providing opportunities for citizens to actively engage in scientific research. This initiative allows participants to contribute to data generation and analysis, fostering scientific thinking and cultural benefits while advancing scientific development through the collection of fundamental research data.

Growing public interest in science has led to increased demand for platforms offering hands-on scientific experiences, high-level lectures, and direct participation in research. The Science with Citizens program aligns with these trends, moving beyond passive knowledge consumption to enable active engagement in the research process. Participants benefit from a deeper understanding of science, an appreciation for the creation of new knowledge, and enhanced critical thinking skills.

■ Mission Galaxy

Mission Galaxy has successfully engaged the public in astronomical research by enabling participants to classify the morphology of galaxies. Through this initiative, over 1,000 citizen scientists have contributed to the classification of nearly 100,000 galaxies, generating valuable research data. By providing access to real astronomical images and guiding users through the classification process, the project has not only advanced scientific analysis but also fostered greater public interest in astronomy.

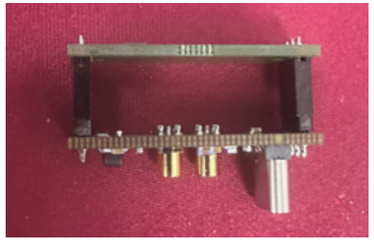
With the launch of an interactive classification platform in early 2024, the project has expanded its reach through public events, lectures, and collaborations with academic institutions and science organizations. The continuous improvement of image quality and data resources has enhanced the accuracy and efficiency of galaxy classification. As Mission Galaxy moves forward, efforts will focus on increasing participation, integrating the project into science education programs, and strengthening its role in bridging citizen science and professional research.

■ I am a Cosmic Particle Collector!

This project successfully developed and implemented a muon detection system, laying the foundation for widescale citizen participation in science. The initiative involved designing and manufacturing detection devices, establishing a data-sharing platform, and creating educational programs to introduce cosmic rays and muons in an accessible way.

Key achievements include the development and deployment of muon detectors, successful data collection through an integrated software and server system, and real-time visualization using Grafana. The

Example of a Galaxy Classification Interface



Left: Muonpi, a muon detection device; Right: SiPM (above the black block) and a preamp (below the black block)

project also tested and refined the hardware for stability and usability, ensuring that non-experts could easily assemble and operate the devices.

Moving forward, this project aims to distribute improved detectors to educational institutions, develop hands-on learning materials, and enhance public engagement through workshops and collaborative research efforts. The ultimate goal is to expand citizen participation in scientific research, aligning with the broader Science with Citizens initiative to strengthen scientific culture and education.

■ **Sound Expedition**

The EcoBiodiversity Expedition project, launched in May 2024, encourages citizen scientists to explore the relationship between the urban environment and biodiversity. Participants use portable sensors to measure environmental factors such as temperature, humidity, and light in local ecosystems, uploading their data to a central platform for analysis. The project aims to identify areas that support high biodiversity and offer strategies for preserving and enhancing ecosystems in urban settings. Since its launch, 72 teams have collected over 300,000 data points, contributing to a growing database that will help inform urban planning and environmental conservation.

Participants engaged in fieldwork during the workshop

Home page of the Sound Expedition website

In addition to data collection, the project hosted workshops in July 2024, where participants received training on using the sensors and uploading their findings. These workshops included both in-person and virtual sessions to ensure all participants could engage. A web platform is also being developed to allow participants to visualize and analyze their data through interactive tools, with a full launch expected in early 2025. The platform will include automated data quality checks to maintain accuracy and improve the efficiency of analysis.

Transdisciplinary Research Program

■ **Overview of KIAS Transdisciplinary Research Program**

The KIAS Transdisciplinary Research (TDR) Program, which has been running since 2012, aims to broaden the horizons of knowledge by fostering dynamic interactions among scholars in several disciplines related to the sciences, arts, and humanities. The TDR program consists of the Annual Theme Research Program and the Independent Research Group Program, which aim to help diverse groups of scholars to gain new insights into nature and the essence of life. It is hoped that the science community can gain new perspectives from these interactions.

As of 2024, there are four research groups in operation.

■ **Slow Science, Low Technology, and Inverted Art**

This research group aims to explore the common foundation between science and art, with members from various fields such as media art, the philosophy of science, and architecture. Artists such as Byungjoon Kwon, Jaemin Kim, and Seongho Ham experiment with various media, including sound art, robots, and AI-based performances, while scholars such as Kwonsoo Park and Jiseon Lee examine Eastern scientific traditions and the intersections between science, art, and philosophy. In 2024, the group held several seminars and performances, discussing themes such as the boundaries of science, the role of fiction in science, and the concept of reality.

A performance titled *Gong·Jung·Mae (空·中·媒)*, (December 27, 2024)

Key discussions revolved around the definition of science and its boundaries. Professor June Jeon's seminar explored the influence of social, political, and cultural phenomena on the scientific discourse, while Kwonsoo Park challenged the rigid dichotomy between "science" and "non-science" in the context of Eastern traditions. Fiction was introduced as a way to bridge the gap between scientific and artistic inquiries, suggesting that both science and art could be viewed as products of human cognition. Later seminars led by Jiseon Lee and Junho Oh examined the role of non-human actors and the materiality of media, further blurring the lines between art and science.

The group also addressed issues such as model-dependent realism, the imposition of scientific theories, and the potential of fiction to intensify the demand for reality. Finally, the concept of latent reality was explored, distinguishing between virtuality and possibility, with the former being real without being actual, emphasizing creation and divergence as principles of actualization. These discussions highlighted the fluid and interconnected nature of science, art, and reality, with the group's efforts contributing to a richer understanding of these domains.

In December 2024, the group presented a performance titled *Gong·Jung·Mae (空·中·媒) - Rising* at the Soolim Cultural Foundation, blending science, technology, and art. Director Seongho Ham described the performance as an exploration that transcends the boundaries between science and art, using text and performance to express various interpretations of reality. Professor Jaemin Kim emphasized that the audience would actively engage in the creative process, offering them a chance to view the world from a new perspective. The performance symbolized potential through the terms *gong* (空), *jung* (中), and *mae* (媒), representing emptiness filled with possibility.

The event successfully brought together scientists and artists from KIAS, combining scientific inquiry with artistic imagination. It provided a unique opportunity for the audience to explore the intersection of science and art, offering new sensory and intellectual experiences.

■ **The Nonhuman: Exploring Technological Beings beyond Humanity**

The research project "The Nonhuman: Exploring Technological Beings beyond Humanity" was launched in June 2024 as part of the KIAS Transdisciplinary Research Program. The project aims to explore the future of living with non-human beings—both technological and natural—and to address the existential questions posed by these entities. The research group is led by Kim Sangmin from Yonsei University and includes scholars from various fields such as cultural studies, media philosophy, digital literacy, and art criticism. Through its research activities, the group seeks to engage both the academic community and the public in discussions about the evolving relationship between humans and non-human entities, especially in association with global technological and natural phenomena.

2024 Public Seminar Series

In the first half of the inaugural year, the group organized five public seminars, which were well-received by an audience from various disciplines, including philosophy, law, medicine, education, and the arts. These seminars covered a range of topics illuminating the ethics, epistemology, and methodologies of nonhuman beings. For example, the first seminar, "Mapping the 'Nonhuman' Studies – Towards the Exploration of More-than-human Beings," laid the theoretical groundwork for the field. Other seminars focused on subjects such as the ethical treatment of laboratory animals, the critique of new materialism, and the intersection of robots and human labor. The group's efforts to present various viewpoints reflected the broad academic relevance of nonhuman studies.

While the seminars attracted over 200 participants, the attendance varied depending on the topic. General and methodological discussions, such as the first and third seminars, saw high engagement, while more specific and niche topics, such as the ethical considerations surrounding laboratory mice or the nature of robots, had lower turnout. This discrepancy suggests that, while the concept of nonhuman beings is becoming more prominent, it has not yet gained widespread traction within the academic community. This indicates a need to present the nonhuman discourse in a more general and compelling way that could spark broader interest and facilitate cross-disciplinary dialogue.

In response to this, the research group plans to adjust its approach in the second year of research. The goal is to expand the scope of nonhuman studies by engaging with natural sciences and facilitating a convergence of nonhuman discourse, scientific research, and artistic practice. This multidisciplinary approach will aim to make the subject more accessible and relevant to both academics and the general public. By focusing on the intersection of nonhuman beings with various fields of knowledge, the group hopes to further the conversation and make a lasting impact on both scholarly and societal perspectives.

■ **In the Age of AI, Focus on Humans Again: A Transdisciplinary Approach to Human Motivation and Desire**

The research project "In the Age of AI, Focus on Humans Again: A Transdisciplinary Approach to Human Motivation and Desire"

2024 Public Seminar Series

YouTube content on human motivation and desire from the perspectives of philosophy, art, and social science.

aims to explore human motivation and desire through an interdisciplinary lens, integrating perspectives from neuroscience, psychology, philosophy, social sciences, and the arts. The goal is to move beyond viewing motivation and desire as instinctual human characteristics and gain a deeper understanding of human behavior and society. As part of the KIAS Transdisciplinary Research Program, the group in charge of the project is conducting in-depth discussions with experts from various fields to develop a comprehensive view of these driving forces.

The group holds monthly online seminars to share knowledge, generate new ideas, and foster academic collaboration. Additionally, special lectures, public seminars, and colloquiums are organized to introduce in-depth research topics and invite experts to expand transdisciplinary research. During the initiation meeting in May, the group outlined the project's goals, schedules, and strategies and discussed efficient communication methods and the specific direction of the project's outputs. The group also aims to make complex academic research more accessible to the public by presenting findings in an easily understandable format, such as YouTube videos.

Over the first six months, the research group has strengthened its understanding of the multidisciplinary nature of motivation and desire, uncovering opportunities for collaboration between psychology, philosophy, art, statistics, and neuroscience. Moving forward, the group plans to continue academic exchanges and work towards materializing research achievements. In 2025, more specific subtopics will be chosen, and a research method that fosters collaboration across disciplines will be implemented based on in-depth discussions among multiple researchers.

Additionally, in the first half of 2025, the group plans to produce YouTube content featuring internal and external researchers discussing human motivation and desire from an in-depth perspective of philosophy, art, and social science. This content aims to share expert research with the public and enhance communication between academia and the general population, contributing to the broader dissemination of academic knowledge.

■ **Large-scale Korean Music Research**

The KIAS Large-Scale Korean Music Independent Research Group (IRG) was established on April 1, 2024, focusing on mathematical research based on extensive data from Korean traditional *jeongak* music, led by KIAS Transdisciplinary Fellow Prof. Jae-Hun Jung (POSTECH) and KIAS Fellow Dr. Myung Ock Kim (KIAS). This IRG is a continuation of the previous IRG for the Scientific Understanding of Korean Traditional Music and AI Korean Traditional Music, with a new emphasis on large-scale data research.

In 2023, the earlier IRG successfully completed the partial collection and digitization of jeongak data, which was published as part of the KIAS Transdisciplinary Research Series. The group developed a novel method for representing Korean traditional music in *jeongganbo* notation to accommodate special functions such as *sigimsae* and ornamentation symbols. The IRG expects that the mathematical analysis using the large-scale data, which is unprecedented in the Korean music community, could discover fundamental aspects of Korean music.

Throughout 2024, the group developed mathematical methods to analyze this extensive data through weekly research meetings and a focused workshop held on November 2, 2024. The first practical application of their work was showcased at the KIAS Transdisciplinary AI Gugak Concert, held at the Kim Hee Soo Art Center on December 18, 2024. For the AI Gugak generation, the topological characteristics of the collected Korean music data were analyzed. Previous research has applied topological data analysis to individual instrumental music, but this time, an integrated approach was used to analyze ensemble music composed of four or five different instruments.

The IRG is scheduled to conclude on March 31, 2025. It is highly anticipated that this large-scale data research will lead to valuable discoveries about the generative mechanisms of Korean traditional music, with the results expected to have a significant impact on the public as well.

Left: A book of collected jeongak music data; Rignt: KIAS Transdisciplinary AI Gugak Concert, (December 24, 2024)

Partnership

International

1999	International Society for Mathematical Sciences (ISMS., Former Japan Association for Mathematical Sciences)	Japan
	Mathematical Sciences Research Institute (MSRI), Berkeley	USA
	Institute for Advanced Study (IAS), Princeton	USA
	Institute of Particle and Nuclear Studies (IPNS/KEK)	Japan
2000	Research Institute for Mathematical Sciences (RIMS)	Japan
	National Center for Theoretical Sciences (NCTS)	Taiwan
2002	Pacific Institute for the Mathematical Sciences (PIMS)	Canada
	Mongolian Academy of Sciences (MAS)	Mongolia
2004	Nagoya University	Japan
	Yukawa Institute for Theoretical Physics (YITP)	Japan
2005	Graduate School of Mathematical Sciences, University of Tokyo	Japan
	Kavli Institute for Theoretical Physics (KITP)	USA
2007	Graduate School of Mathematics, Kyushu University	Japan
2008	Vietnamese Academy of Science and Technology (VAST)	Vietnam
	Institute of Physics Albert-Ludwigs-university of Freiburg	Germany
2009	Feza Gürsey Center for Physics and Mathematics	Türkiye
2010	Institute of Advanced Studies (IAS), Nanyang Technological University	Singapore
2011	Waseda Institute for Advanced Study (WIAS)	Japan
2013	Centre of excellence for Cosmology and Particle Physics Phenomenology, The Danish Institute for Advanced Study (CP^3-Origins DIAS)	Denmark
2014	University of Gdańsk	Poland
	Institute of Theoretical Physics, Chinese Academy of Sciences (ITP, CAS)	China
	Academy of Mathematics and Systems Science, Chinese Academy of Sciences (AMSS, CAS)	China
	Future Circular Collider Study hosted by European Organization for Nuclear Research (CERN FCC Study)	Switzerland
2015	Interdisciplinay Theoretical Science Research Group, Rikagaku Kenkyusho (RIKEN iTHES Group)	Japan
	Vietnam Institute for Advanced Study in Mathematics (VIASM)	Vietnam
2016	Italian Mathematica Union (UMI, Unione Matematica Italiana)	Italy
2019	Purdue University, Dept of Physics and Astronomy	USA
2023	University of Arizona	USA

Domestic

1999	Korea University	Seoul
	Ewha Womans University	Seoul
2000	Information Center for Mathematical Science, KAIST	Daejeon
	Information Center for Physics Research, SNU	Seoul
2001	Yonsei University	Seoul
	Sogang University	Seoul
	Korea Institute of Science and Technology Information (KISTI)	Daejeon
2002	Sungkyunkwan University	Seoul
2003	Kyung Hee University	Seoul
2004	Korea Academy of Science and Technology (KAST)	Gyeonggi
	Korea Research Institute of Standards and Science (KRISS)	Daejeon
	Hanyang University	Seoul
	Korea Atomic Energy Research Institute (KAERI)	Daejeon
	Korea Institute of Science and Technology (KIST)	Seoul
2007	Korea Foundation for the Advancement of Science & Creativity (KOFAC)	Seoul
2008	Ajou University	Gyeonggi
2009	Korean Women in Mathematical Sciences (KWMS)	Seoul
2010	Dongdaemun-gu Office	Seoul
	Korean Foundation for the Advancement of Science and Creativity (KOFAC)	Seoul
2012	Youngju City	Youngju
	Korea Institute of Science and Technology Information (KISTI)	Seoul
2013	Gwacheon National Science Museum	Gwacheon
	Seoul Metropolitan Office of Education	Seoul
	KAIST Department of Mathematical Sciences	Daejeon
2016	Institute for Basic Science (IBS)	Daejeon
	Kyung Hee University Healthcare System	Seoul
	College of Natural Sciences, Seoul National University	Seoul
2018	The Hong-Reung Forum/Seoul Housing and Communities Corporation	Seoul
2021	Sungkyunkwan University, Quantum Information	Seoul
	Korea Astronomy & Space Science Institute	Daejeon
	SNU R&DB Foundation, Seoul National University	Seoul
2022	University of Seoul, Dept of AI	Seoul
2023	Soorim Cultural Center	Seoul

Alumni

School of Mathematics

2024

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2023

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Shin, Jiyong

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Van Garrel, Michel
Warwick Univ.

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2016

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2014

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Jeon, Woojin

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GIST

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Kolte, Sagar
Credit Suisse

Lee, Jungyun

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Seo, Ihyeok
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Won, Joonyeong
KIAS

Yoo, HwanChul
World Quant

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Song, Minju
NeoMath

Spaeth, Peter
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Yoo, Meesue
Chungbuk Nat'l Univ.

Ziltener, Fabian
Utrecht Univ.

2012

Morabito, Filippo
KAIST

Mueller, Stefan
Georgia Southern Univ.

Park, Jong-Do
Kyung Hee Univ.

2011

Guzzetti, Davide
SISSA

Huh, Sukmoon
Sungkyunkwan Univ.

Hwang, DongSeon
Ajou Univ.

Jang, Junmyeong
Univ. of Ulsan

Jun, Hyunkeun
Korea Science Academy, Busan

Kim, Dano
Seoul Nat'l Univ.

Kim, Taejung
Korea Nat'l Univ. of Education

Lee, JaeHyouk
Ewha Womans Univ.

Lee, Jeong-Yup
Catholic Kwandong Univ.

Lee, Kang-Hyurk
Gyeongsang Nat'l Univ.

Lee, Yoonbok
Incheon Nat'l Univ.

Li, Changzheng
Sun Yat-sen Univ.

Lopez, Martin Alberto

Marelli, Giovanni
Universidad de Antioquia in Medellin, Colombia

Park, Euiyong
Univ. of Seoul

Pyo, Juncheol
Pusan Nat'l Univ.

2010

Chang, TongKeun
Mokpo Nat'l Maritime Univ.

Cheong, Daewoong
Chungbuk Nat'l Univ.

Chung, Kuerak
Korea Nat'l Univ. of Education

Kim, Byungchan
Seoul Nat'l Univ. of Science and Technology

Kim, Ji Young
Seoul Nat'l Univ.

Lee, Dong Uk
Chungbuk Nat'l Univ.

Lee, Jung-Hoon
Chonbuk Nat'l Univ.

Park, Sung-ho
Hankuk Univ. of Foreign Studies

Sun, Hae-Sang
UNIST

2009

Bender, Andreas
Univ. of Pavia

Chan, Kungho
Taiwan Nat'l Cheng Kung Univ.

Chu, HahngYun
Chungnam Nat'l Univ.

Huang, Rung- Tzung
National Central Univ.

Kim, Chang-Wan
Mokpo Nat'l Maritime Univ.

Kim, Namhoon
Hongik Univ.

Nguyen, Viet-Anh
Univ. of Lille

Seo, Keomkyo
Sookmyung Women's Univ.

Yoon, Gang Joon
NIMS

Zuo, Dafeng
Univ. of Science and Technology of China

2008

Choe, Insong
Konkuk Univ.

Choi, SoYoung
Gyeongsang Nat'l Univ.

Choy, Jaeyoo
Kyungpook Nat'l Univ.

Jo, JangHyun
Sogang Univ.

Kim, Seung Won
Kyungsung Univ.

Lau, Chi Hin
The Chinese Univ. of Hong Kong (CUHK)

Lee, Nam-Hoon
Hongik Univ.

Lee, Seok-Min
Hongik Univ.

Nagai, Yasunari
Waseda Univ.

Oh, Yong-Geun
IBS

Sato, Fumitoshi
Takamatsu Nat'l College of Technology

2007
Chae, Myeongju
Hankyoung Nat'l Univ.

Choi, Dohoon
Korea Univ.

Kang, Soon-Yi
Kangwon Nat'l Univ.

Kwon, Young-Sam
Dong-A Univ.

Li, Li
Oakland Univ.

Oh, Byung-Geun
Hanyang Univ.

Wang, Sung Ho

2006
Jeon, Daeyeol
Kongju Nat'l Univ.

Jun, Byungheup
UNIST

Kim, Dong Han
Dongguk Univ.

Kim, Hyunseok
Sogang Univ.

Kim, Jeong-Ah
Univ. of Seoul

Kim, Min Kyu
Gyeongin Nat'l Univ.

Kim, Sung-Yeon
KIAS

Lee, Hyeonmi
Hanyang Univ.

Myung, Sung
Inha Univ.

Oh, Young-Tak
Sogang Univ.

Park, Euisung
Korea Univ.

Shin, Dong-Uy
Hanyang Univ.

Song, Won Taek
Seoul Science High School

Sung, Chanyoung
Korea Nat'l Univ. of Education

Yoon, Joung-Hahn
Dong-a Univ.

2005
Hong, Kuk-Jin
Hankuk Academy of Foreign Studies

Kolesnikov, Pavel
Sobolev Institute of Mathematics

Lee, Joongul
Hongik Univ.

Lee, Sangyop
Chung-Ang Univ.

Matsumi, Kazuya

Schweizer, Andreas

Seo, Soogil
Yonsei Univ.

2004
Cho, Jin-Hwan
NIMS

Joe, Dosang
NIMS

Kang, Seok-Jin
Seoul Nat'l Univ.

Kim, Chang Heon
Sungkyunkwan Univ.

Kim, Namkwon
Chosun Univ.

Lee, Junho
Univ. of Central Florida

Park, Mi Hee
Chung-Ang Univ.

2003
Choi, Yungook
Yeungnam Univ.

Hong, Jaehyun
KIAS

Kwon, Jae Hoon
Seoul Nat'l Univ.

Lee, Sang Jin
Konkuk Univ.

Ochi, Yoshihiro
Tokyo Denki Univ.

Yun, Ki-Heon
Sungshin Women's Univ.

2002
Hong, Jin
Seoul Nat'l Univ.

Kim. Min hyong
Univ. of Oxford,
KIAS CMC

Kim, Seok Woo
Konkuk Univ.

Ouyang, Yong

Winkelmann, Joerg
RUHR-Univ. Bochum

Yoon, Jung-Rok
Clemson Univ.

2001
Byun, Dongho
Seoul Nat'l Univ.

Choi, Youn-Seo
KIAS

Kim, Joonil
Yonsei Univ.

Kim, Kyunghee
Sejong Univ.

Ku, Hyejin
New York Univ.

Kwon, Daesung
NSR

Lee, Jaesung
Sogang Univ.

Oh, Byeong-Kweon
Seoul Nat'l Univ.

Rim, Kyung Soo
Sogang Univ.

2000
Kim, Hong-Chan
Korea Univ.

Koh, Jee-Heub
Indiana Univ.

Kwak, Si-Jong
KAIST

Lee, Yong-Hah
Ewha Womans Univ.

Oh, Jangheon
Sejong University

Paeng, Seong-Hun
Konkuk Univ.

Park, Jinsung
KIAS

1999
Bae, Hyeong Ohk
Ajou Univ.

Kim, Sung Guen
Kyungpook Nat'l Univ.

Lee, Seunghun
U1 Univ.

Lee, Yongnam
KAIST

Moon, Dongho
Sejong Univ.

1998
Byeon, Jaeyoung
KAIST

Oleg, Emanouilov
Colorado State Univ.

Potemine, Igor
Universite Grenoble

1997
Kim, In Kang
KIAS

School of Physics

2024
Ho, Shu-Yu
Academia Sinica

Singh, Ankit

Qiang, Jia
KAIST

Qin, Fei
Aix-Marseille University

Lee, Kimyeong
BIMSA

Choi, Sunjin
IPMU

Sun, Rui
University of Chinese Academy of Sciences

Park, Jaehong
KASA
(Korea AeroSpace Administration)

Tian, Jiahua
East China Normal University

2023
Duan, Zhihao
Queen Mary Univ. of London

Kang, Dong Woo
Jeonbuk Nat'l Univ.

Janagal, Lavneet
Wells Fargo, India

Kim, Jongkuk
KIAS

Dong, Fuyu
Yunnan Univ.

Gouin, Celine
Institut d'Astrophysique Spatiale

Jung, Tae Hyun
IBS

2022

Park, Jong-Min
APCTP

Okazaki, Tadashi
Southeast Univ.

Kim, Yonghwi
Yonsei Univ.

Ghim, Dongwook
Kyoto Univ.

Mukherjee, Sutirtha

Leem, Jae Hoon
Samsung Electronics Co.

Yoon, Yongmin
KASI

Kang, Byungmin
Massachusetts Institute of Technology

Su, Wei
Sun Yat-Sen Univ.

Shim, Junsup
Academia Sinica

Mondal, Tanmoy
Osaka Univ.

Hwang, Kyusung
KIAS

Lu, Chih-Ting
Nanjing Normal Univ.

Jun, Hyunsung
Seoul Nat'l Univ.

2021

Dashti-Naserabadi, Hor
KENTECH

Sarkis, Matthieu
Univ. of Luxembourg

Kaneta, Kunio
Tokyo Woman's Christian Univ.

Park, Miok
IBS

Papadimitriou, Ioannis
BIMSA

Yoon, Junggi
APCTP

Lee, Jae Hyun
KIAS

Nahmgoong, June
December & Company Inc.

Yi, Sudo
KIAS

2020

Eager, Richard

Ebrahimnazhad Rahbari S.H.
Seoul Nat'l Univ.

Han, Chengcheng
Zhongshan Univ.

Nomura, Takaaki
Sichuan Univ.

Poggi, Matteo
SISSA

Rosa, Dario
KAIST

Tonegawa, Motonari
APCTP

Yun, Seokhoon
Univ. of Padova

2019

Appleby, Stephen Andrew
KIAS QUC

Bae, Jin-Beom
Univ. of Oxford

Chen, Junmou
Jinan Univ.

Evans, Jason L.
Shanghai Jiao Tong Univ.

Hong, Sungryong
KASI

Kim, Joonho
IAS

Matsui, Toshinori
KAIST

Munir, Shoaib
ICTP-EAIFR

Noh, Changsuk
Kyungpook Nat'l Univ.

Nosaka, Tomoki
SISSA

Park, Sang-A
Yonsei Univ.

Saulder, Christoph

Sciarappa, Antonio
SISSA

Snaith, Owain Nicholas
Observatoire de Paris

Song, Jaewon
KAIST

Suzuki, Ryo
Shing-Tun Yau Center of Southeast Univ.

Winding, Jacob

Wu, Peiwen
Southeast Univ.

Zheng, Yi
Sun Yat-Sen Univ.

2018

Baek, Seungwon
Korea Univ.

Cho, Gil Young
POSTECH

Das, Arindam
Osaka U.

Hwang, Chiung
Univ. of Milano-Bicocca

Kim, Kun Woo
IBS

Lee, Sang Hoon
GNTECH

Li, Jinmian
Sichuan Univ.

Natale, Alexander

Nishiwaki, Kenji
Rudjer Boskovic Institute

2017

Biswas, Sanjoy
Ramakrishna Mission Vivekananda Univ.

Durang, Xavier
Univ. of Seoul

Gobat, Raphael
PUCV

Jain, Bithika
ICTP-SAIFR

Kang, Zhaofeng
Huazhong Science and Technology Univ.

Khalilian, Hamid Reza
Institute for Advanced Studies in Basic Sciences (IASBS)

Li, Xiao Dong
Sun Yat-Sen Univ.

Lim, Jongsoo

Park, Chan Beom
IBS

Shin, Jihye
KASI

2016

Chung, Hee Joong
Tsinghua Univ.

Ito, Yuto

Jeon, Imtak
King's College London

Jeon, Jae-Hyung
POSTECH

Lee, Seokcheon
Gyeongsang Nat'l Univ.

L'Huillier, Benjamin
KASI

Salmi, Fadia

Seong, Rak-Kyeong
Tsinghua Univ.

Tang, Yong
Univ. of Chinese Academy of Science

Yagi, Futoshi
Southwest Jiaotong Univ. (China)

Yoshida, Yutaka
IPMU

2015

Ahn, Yang Hwan
Institute of High Energy Physics, China

Cervantes Sodi, Bernardo
CR,A,UNAM

Jeong, Jae-Seung
Samsung Electronics Co.

Jung, Sunghoon
Seou Nat'l Univ.

Kim, Sung-Soo
Univ. of Electronic Science and Technology of China (UESTC)

Okada, Hiroshi
APCTP

Qi, Wanming
China Univ. of Mining and Technology

Rhim, Jun Won
Seoul Nat'l Univ.

Wan, Luping
Institute of High Energy Physics, China

Yu, Chaehyun
Korea Univ.

2014

Gang, Dongmin
APCTP

Hou, Annie
Sandtable, London

Hwang, Jeong-Sun
Sejong Univ.

Kim, Sang-Woo
Institute of Theoretical Physics, CAS

Lahiri, Sourabh
Birla Institute of Technology, Mesra

Lee, Hyunjung
Seoul Science High School

Lee, Seung-Joo
CERN

Lee, Woo-Ram
The Univ. of Alabama

Ogawa, Noriaki
RIKEN Mochizuki Laboratory

Park, Wanil
Chonbuk Nat'l Univ.

Sabiu, Cristiano
Yonsei Univ.

Sharma, Pankaj
The Univ. of Adelaide

Wang, Zhaolong
Northwest normal Univ.

Yoon, Yeo Woong
Konkuk Univ.

2013

Baek, Seung Ki
Pukyong Nat'l Univ.

Hayashi, Hirotaka
Tokai Univ.

Hong, Sungwook
Univ. of Seoul

Kim, Hee Cheol
POSTECH

Kim, Kwangmoo
Seoul Nat'l Univ.

Koh, Eunkyung
Samsung Display

Lee, Hyun Min
Chung-Ang Univ.

Nam, Seung-il
Pukyong Nat'l Univ.

Park, Jong-Chul
Chungnam Nat'l Univ.

Senaha, Eibun
IBS

Um, Jaegon
POSTECH

2012

Cho, Myoung Won
Sungshin Women's Univ.

Choi, Kang Sin
Ewha Womans Univ.

Kim, Chul
Seoul Nat'l Univ. of
Science and Technology

Kumar, Jaswant
Harish Chandra Research Institute

Lee, Choongki
Yonsei Univ.

Lee, Seong-Kook
Seoul Nat'l Univ.

Omura, Yuji
Nagoya Univ.

Rossi, Graziano
Sejong Univ.

Van Putten, Maurice
Sejong Univ.

2011

Bandyopadhyay, P.
Indian Institute of
Thechnology Hyderabad

Lu, Hantao
Lanzhou Univ.

Medved, A.J. M.
Rhodes Univ.

O Colgain, Eoin
APCTP

Song, Yong-Seon
KASI

2010

Chingangbam, P.
Indian Institute of
Astrophysics

Ham, Seung Woo

Huang, Qing-Guo
Institute of Theoretical Physics, CAS

Jo, Hang-Hyun
POSTECH

Kang, Hyuk
NIMS

Kim, Yeong Gyun
Gwangju Nat'l Univ. of Education

Kim, Yong Woon
KAIST

Lee, Jae Yong
Korea Univ.

Lee, Jong-Phil
Korea Univ.

Lee, Sungjay
KIAS

Wu, Jun-Bao
Institute of High Energy Physics,
China

Yavartanoo, Hossein
Institute of Theoretical Physics, CAS

Zaballa, Ignacio
Lancaster Univ.

2009

Dutta, Sreedhar B.
IISER

Hibon, Pascale
European Southern Observatory

Hwang, Ho Seong
KASI

Jeong, Kwang Sik
Pusan Nat'l Univ.

Kihara, Hironobu
Seikei Univ.

Kim, Youngman
IBS

Kim, Young-Rae

Yang, Hyun Seok
Sogang Univ.

Zhou, Yufeng
Institute of Theoretical Physics, CAS

2008

Araya, P.
Jacobs Univ.

Choi, Yun-Young
Kyung Hee Univ.

Hosomichi, Kazuo
Japanese Nat'l
Defense Academy

Jia, Cheng long
Lanzhou Univ.

Kim, Juhan
KIAS

Kim, Mun Dae
Hongik Univ.

Kyae, Bumseok
Pusan Nat'l Univ.

Lee, Hyun Keun
Sungkyunkwan Univ.

Mawatari, Kentarou
Osaka Univ.

Nagar, Apoorva
Indian Institute of
Space Science and Technology

Park, Kwon
KIAS

Scopel, Stefano
Sogang Univ.

Wu, Xiaohong
ECUST (East China University of
Science and Technology)

2007

Jung, Dong-Won
Korea Univ.

Kim, Ki-Seok
POSTECH

Kim, Seok
Seoul Nat'l Univ.

Lee, Ji-Woo
Myongji Univ.

Park, Chan-Gyung
Chonbuk Nat'l Univ.

Park, Tae-Sun
Sungkyunkwan Univ.

Yee, Ho-Ung
Univ. of Illinois at Chicago

2006

Ha, Meesoon
Chosun Univ.

Kimura, Tetsuji
Keio Univ.

Park, Su-Chan
The Catholic Univ. of Korea

2005

Borzumati, Francesca
Tohoku Univ.

Kang, Gung Won
KISTI

Lee, Jounghun
Seoul Nat'l Univ.

Okamura, Naotoshi
International U. of Health and Welfare

Park, Jae-Suk
POSTECH

Park, Seong Chan
Yonsei Univ.

Raeymaekers, Joris
Czech Academy of Science

Suyama, Takao
KEK

Yi, Sang-Heon
Univ. of Seoul

2004

Ahn, Sang-Hyeon
KASI

Cornell, Alan
MITP Univ. of
the Witwatersrand

Hong, Hyunsuk
Chonbuk Nat'l Univ.

Kwon, Hwang-hyun
Korea Development Bank

Michishita, Yoji
Kagoshima Univ.

Sim, Heung-Sun
KAIST

Yee, Jung-Tay
Saxo Bank

Yi, Hangmo
Soongsil Univ.

2003

Akeroyd, Andrew
Univ. of Southampton

Chang, Heon-Young
Kyungpook Nat'l Univ.

Kim, Hyung Do
Seoul Nat'l Univ.

Lee, Kang Young
Gyeongsang Nat'l Univ.

Park, Jeong-Hyuck
Sogang Univ.

Rho, Mannque

Song, Jeong-hyeon
Konkuk Univ.

2002

Choi, Mahn-Soo
Korea Univ.

Lee, Chang-Hwan
Pusan Nat'l Univ.

Lee, Hyunwoo
POSTECH

Lee, Sang-Min
Seoul Nat'l Univ.

Liu, Qiu-Yu
Univ. of Science and Technology, China

Park, Sung Yong
Northwestern Univ.

Shin, Hyeonjoon
POSTECH

Yi, Insu

2001

Guslienko, Kostyantyn
Universidad del país vasco

Hyun, Seungjoon
Yonsei Univ.

Kang, Sin-Kyu
Seoul Nat'l Univ. of Science and Technology

Kim, Chanju
Ewha Womans Univ.

Lee, In-Ho
Korea Research Institute of Standards and Science

2000

Choi, Seong-Youl
Chonbuk Nat'l Univ.

Chun, Eung-Jin
KIAS

Kiem, Youngjai
KAIST

Kim, Jaekwon

Lee, Jaesik
Chonnam Nat'l Univ.

1999

Chen, Xiao-Shuang
Shanghai Institute of Technical Physics

Deng, Zhen-Yan
Shanghai Univ.

Kim, Jihn-Eui
Kyung Hee Univ.

Kim, Tae Suk
Harvard University

Liu, Chun
ITP, Chinese Academy of Science

1998

Kim, Se Yong
Sejong Univ.

School of Computational Sciences

2024

Jonsson, Johan
Nicolaus Copernicus Univ.

Chae, Min-Kyung
Korea Disease Control and Prevention Agency (KDCA)

Lee, Jeeun
AlpacaX

Kim, Won Kyu
Seoul Nat'l Univ.

Yang, Seong-Gyu
Umeå Univ.

Yoo, Semin
IBS

Rondon, Irving
Pinellas County Schools

Das, Tamoghna
Kanazawa Univ.

2023

Choi, Kiri
Yale Univ.

Kim, Jaewan
KIAS

Kim, Pureun

Oh, Jaeseong
KIAS

Kim, Minsung
Seoul Nat'l Univ of Science and Tech.

Ha, Seungwoong
Santa Fe Institute

Kim, Rokyeon

Ko, Eunjung
Soongsil Univ.

Choi, Wonseok
Purdue Univ.

Kim, BeomHyun
Seoul Nat'l Univ.

2022

Park, Jungjun
LG Electronics

Lee, Jaehak
Seoul Nat'l Univ.

Hussain, Dildar
Sejong Univ.

Ahn, JinHoo

Sohbi, Adel
ORCA Computing

Park, Jejune
Samsung Electronics Co.

Kim, Seonghoon
MolCube

Kim, Jiseung
Chonbuk Nat'l Univ.

2021

Baek, Kyunghyun
Yonsei Univ.

Song, Yonghyun
Harvard Univ.

Mand, Davinder Singh
Univ. of Toronto

Dutta, Arijit
Goethe-Universität Frankfurt am Main

Lee, Sanghoon
Samsung Display

Park, Jimin
DEARGEN

Kang, Seoung-Hun
Oak Ridge National Laboratory

Bang, Jeongho
Yonsei Univ.

2020

Huh, Jeonggyu
Chonnam Nat'l Univ.

Kim, Chanul
Samsung Electronics Co.

Kosterlitz, John M.
Brown Univ.

Tom, Anvy Moly
Devaswom Board College

2019

Bak, Ji Hyun
Univ. of California, Berkeley

Chae, Kisung
UCSD

Heo, Seungryong
Ngenebio

Kim, Heejung

Kim, Hyun-Jung
LG Display

Kim, Min Hyeok
Samsung SDS

Lee, Hyungjun
Univ. of Texas, Austin

Lee, Su-Yong
Agency for Defense Development

Liu, Lei
Zhejiang University

Nam, Gi-Moon

2018

Baik, Seung Su
Yonsei Univ.

Hwang, Wonseok
NAVER CLOVA

Jo, Junghyo
Seoul Nat'l Univ.

Kim, Hyunjin
Korea Univ.

Krah, Alexander

Lee, Chang-Woo
Aimble Inc.

Lee, Jun-Ho
Lawrence Berkeley Nat'l Laboratory

Lee, Yuno
Korea Research Institute of Chemical Technology

Nam, Sun-Young
Sogang Univ.

Siti Raudah Mohamed Lazim
Ewha Womans Univ.

Srivastava, Amit

2017

Flores-Canales, Jose
Aarhus Univ.

Hong, Seung Hwan
KAIST

Jin, Sung-Tae
Seoul Nat'l Univ.

Joo, Jaewoo
Univ. of Oxford

Na, Joohan
Samsung Advanced Institute of Technology

Ok, Seongmin
Samsung Electronics Co.

Park, Jongyook
Wonkwang Univ.

Syed Islamuddin Shah
Univ. of South Florida

2016
Jeong, Kabgyun
Seoul Nat'l Univ.

Joung, In Suk
Sookmyung Women's Univ.

Kim, Ho-Joon
Kyung Hee Univ.

Kim, Songmi

Qianyi Cheng
Univ. of Memphis

Son, Younghwan
POSTECH

Yun, Sang Jae
Lacomtech

2015
Balachandran M.
Ajou Univ.

Cho, Jaeyoon
APCTP

Choi, Chulho
Samsung SDI

Danil Bukhvalov
Hanyang Univ.

Oh, Se-Jin
Ewha Womans Univ.

Park, Hee Chul
IBS

Woo, Hyenkyun
Korea Univ. of Technology and Education

2014
Choi, Seon-Myeong
Samsung Advanced Institute of Technology

Hermant Srivastava
CSIR-Institute of Microbial Technology

Kim, Sejoong
Univ. of Science and Technology

Lee, Juhui

Moon, Pilkyung
NYU Shanghai

Park, Jung Mee

Yoon, Jeseong
Seoul Nat'l Univ.

2013
Arash Azari
Lund Univ.

Huichung Tai
Academia Sinica

Ji, Se-Wan
NSR

Park, Kihyun
KAERI

Sathiyamoorthy
Hanyang Univ.

Woo, Sungjong
Pukyong Nat'l Univ.

2012
Adeel Malik
Univ. Center for Bioinformatics

Yumlembam Hemajit
National Institute of Biomedical Innovation

Yun, Sangwoon
Sungkyunkwan Univ.

2011
Bae, Joonwoo
KAIST

Kim, Jeenu
SK Hynix Semiconductor Inc.

Lee, Ki Ho
Sungkyunkwan Univ.

Muddassar, Muhammad
COMSATS Institute of Information Technology, Islamabad, Pakistan

Park, Seungkook
Sookmyung Women's Univ.

2010
Baek, Chang-Ki
POSTECH

Eo, Hae-Seok
LG Electronics

Hur, Jin
Agency for Defense Development

Joo, Keehyoung
KIAS

Lee, Jinhyuk
Korean Bioinformation Center

Oh, Mina
Medical Device Information and Technology Assistance Center

Shin, Yong Hyun
Sookmyung Women's Univ.

Woo, Youngho
NIMS

2009
Kim, Bomsoo
Samsung Electronics Co.

Lee, Dong-il
Seoul women's Univ.

Lee, Jae Weon
Jungwon Univ.

Park, Hyungju
Ajou Univ.

Park, Poo-Sung
Kyungnam Univ.

Shin, Seungwoo
Soon Chun Hyang Univ. Hospital

Song, Daegene

2008
Chang, Jaeeon
Univ. of Seoul

Lee, Eunjeong

Lee, Kwankyu
Chosun Univ.

Podoshvedov, Sergey
Southern Ural State Univ.

2007
Ahn, Jeaman
Kongju Nat'l Univ.

Lee, Jinwoo
Kwangwoon Univ.

Nha, Hyon Cheol
Texas A&M Univ.

Pae, Sung-il
Hongik Univ.

Son, Young-Woo
KIAS

Tarakeshwar, P.
Arizona State Univ.

2006
Choi, Kyoung Jin
Univ. of Calgary

Kim, Hyung-Rae
Max Planck Institute

Kim, Yong-Hoon
KAIST

Kwon, DoYong
Chonnam Nat'l Univ.

Lee, Kyoungrim
Hanyang Univ.

Oh, Sangchul
Qatar Environment and Energy Research Institute

2005
Choi, Hyoung Joon
Yonsei Univ.

Choi, Sung Woo
Duksung women's Univ.

Katarzyna Maksimiak
Univ. College London

Kim, Seung-Yeon
Korea Nat'l Univ. of Transportation

Koh, Eunhee
Seoul Nat'l Univ.

Lee, Jawoong
ZeeAnn

Nguyen, Ba An
Vietnam Academy of Science and Technology

Song, MeeKyung
Sogang Univ.

2004
Kim, Saejoon
Sogang Univ.

Lee, Soojoon
Kyung Hee Univ.

Quan, WuYan

Yu, Hoseog
Sejong Univ.

2003
Kwon, Sungchul

Lee, Julian
Soongsil Univ.

Oh, Byeong-Kweon
Seoul Nat'l Univ.

2002
Hong, Sung-Joon
Samhwa Sukyou Co.

Kim, Jaewan
KIAS

Park, Kibeom
STEPI

Open KIAS Center

2023
Kim, Myung Ock
POSTECH

2021
Lee, Jiyeon
Korea Univ.

Kim, Jeonghwan

Lee, Jongpil
Neutune

Park, Seungsoon
Neutune

2019
Choi, In-Ryeong
Seoul Nat'l Univ.

Jun, Jin-kwon
Myongji Univ.

Kim, Sung Won

Lee, Su Jeong

2018
Cho, Namun
Korea Univ.

Park, Young-Sun
Artist

Won, Chiwook
GIST

2015
Chang, Tae Soon
Duksung Womens Univ.

Cho, Sunam
Seoul Nat'l Univ.

Yi, Doogab
Seoul Nat'l Univ.

Han, Sung Il
Seoul Nat'l Univ.

Kim, Hyoeun
Hanbat Univ.

Kim, Jaeyin
Kyunghee Univ.

June E Huh Center for Mathematical Challenges

2024
Kim, Chan-Ho
Jeonbuk Nat'l Univ.

Kim, Minhyong
University of Edinburgh

Shin, Jinwoo
Sookmyung Women's Univ.

2023
Byun, Sung-Soo
Seoul Nat'l Univ.

Lee, Jungin
Ajou Univ.

Lee, Junguk
Changwon Univ.

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2022
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Kyung Hee Univ.

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Sogang Univ.

Won, Joonyeong
Ewha Womans Univ.

Yu, Myungjun
Yonsei Univ.

2021
Koh, Kyewon

Choi, Beomjun
POSTECH

Lodha, Yash
University of Hawaii at Manoa

Haan, Jae-ho
Yonsei Univ.

2020
Hong, Jaehyun
IBS

Kim, Sung Yeon
IBS

Scarinci, Carlos
DGIST

2019
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UC Berkeley

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Park, Jinhyung
Sogang Univ.

2018
Kim, Ildoo
Korea Univ.

2017
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Kwon, Sanghoon
Catholic Kwandong Univ.

Lee, Hojoo
Jeonbuk Nat'l Univ.

Shin, YongJoo
Chungnam Nat'l Univ.

Yoon, Youngho
Chungbuk Nat'l Univ.

2016
Cho, Hyun Woong

Eum, Ick Sun
Dongguk Univ.

2015
Chan, Mario
Pusan Nat'l Univ.

Choi, Jinwon
Sookmyung Women's Univ.

Jung, Soyeun
Kongju Nat'l Univ.

Kim, Sungwoon
Jeju Nat'l Univ.

2014
Pang, Chao

Quantum Universe Center

2024
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The University of Texas at Austin

Wang, Xin
Max Planck Institute

2023
Sun, Kaiwen
Max Planck Institute

2022
Choi, Ena
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Samsung Electronics Co.

Jang, Bo Gyu
Los Alamos Nat'l Laboratory

Jueid, Adil
IBS

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Lee, Changhyoup
KRISS

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KIAS

2020
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Univ. of Melbourne

Kim, Hyun-Jung
Forschungszentrum Jülich

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KIST

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KIAS

2019
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APCTP

Kwon, HyunWoong

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Hebei Normal Univ.

Park, Jae-hyeon
KIAS

Tang, Yi-Lei
Sun Yat-Sen Univ.

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Tianjin Univ.

2018
Aluri, Pavan Kumar
Indian Institute of Technology (BHU)

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2023
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Kwon, Chul-An
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Lee, Changhoan
Pusan Nat'l Univ.

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Lee, Hyun Min
Chung-ang Univ.

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Lee, Jae Sik
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Lee, Jung Jai
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Lee, Jungil
Korea Univ.

Lee, Kanghoon
APCTP

Lee, Minchul
Kyunghee Univ.

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Gyeongnam Nat'l Univ. of Science and Technology

Lee, Sangmin
Seoul Nat'l Univ.

Lee, Seung J.
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Lee, Su Houng
Yonsei Univ.

Lee, SungBin
KAIST

Lee, Taekoon
Kunsan Nat'l Univ.

Lim, Cheho
Sogang Univ.

Moon, Eun-Gook
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Nam, Soonkeon
Kyunghee Univ.

Noh, Changsuk
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Noh, Jae-Dong
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Park, Byeong-Gon
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Park, Jae-mo
POSTECH

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Park, Jong-Min
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Park, Myeong-Gu
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Park, Q-Han
Korea Univ.

Park, Soo Chan
Catholic Univ. of Korea

Park, Soojong
Kyunghee Univ.

Park, Sung-Chan
Yonsei Univ.

Park, Wan il
Chonbuk Nat'l Univ.

Park, Young-Ah
Myongji Univ.

Park,Jeong-Hyuck
Sogang Univ.

Scopel, Stefano
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Seong, Rak-Kyeong
UNIST

Seung-Joo Lee
IBS

Shafieloo, Arman
KASI

Shin, Chang Sub
Chungnam Nat'l Univ.

Shin, Jihye
KASI

Sim, Heong-Sun
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Sin, Sang-Jin
Hanyang Univ.

Sohn, Jubee
Seoul Nat'l Univ.

Son, Minho
KAIST

Song, Jung-hyeon
Konkuk Univ.

Stephen Appleby
APCTP

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Konkuk Univ.

Yi, Juyeon
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Yoon, Junggi
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School of Computational Sciences

Bang, Junhyeok
Chungbuk Nat'l Univ.

Cho, Eunsung
Korea Univ.

Cho, Jaeyoon
APCTP

Choi, Hyoung Joon
Yonsei Univ.

Choi, Sun
Ewha Womans Univ.

Choi, Taeseung
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Eom, Young-Ho
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Goh, Gwang-Il
Korea Univ.

Hong, Suklyun
Sejong Univ.

Huh, Joonsuk
Sungkyunkwan Univ.

Hwang, Won-Young
Chonnam Nat'l Univ.

Jeong, Kabgyun
Seoul Nat'l Univ.

Jhi, Seung-Hoon
POSTECH

Jin, Hosub
UNIST

Jo, Hang-Hyun
Catholic Univ. of Korea

Jo, Junghyo
Seoul Nat'l Univ.

Kahng, Byungnam
KENTECH

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UNIST

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Inha Univ.

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Kim, Sejoong
UST

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Korea Nat'l Univ. of Transportation

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Kim, Yong-Hoon
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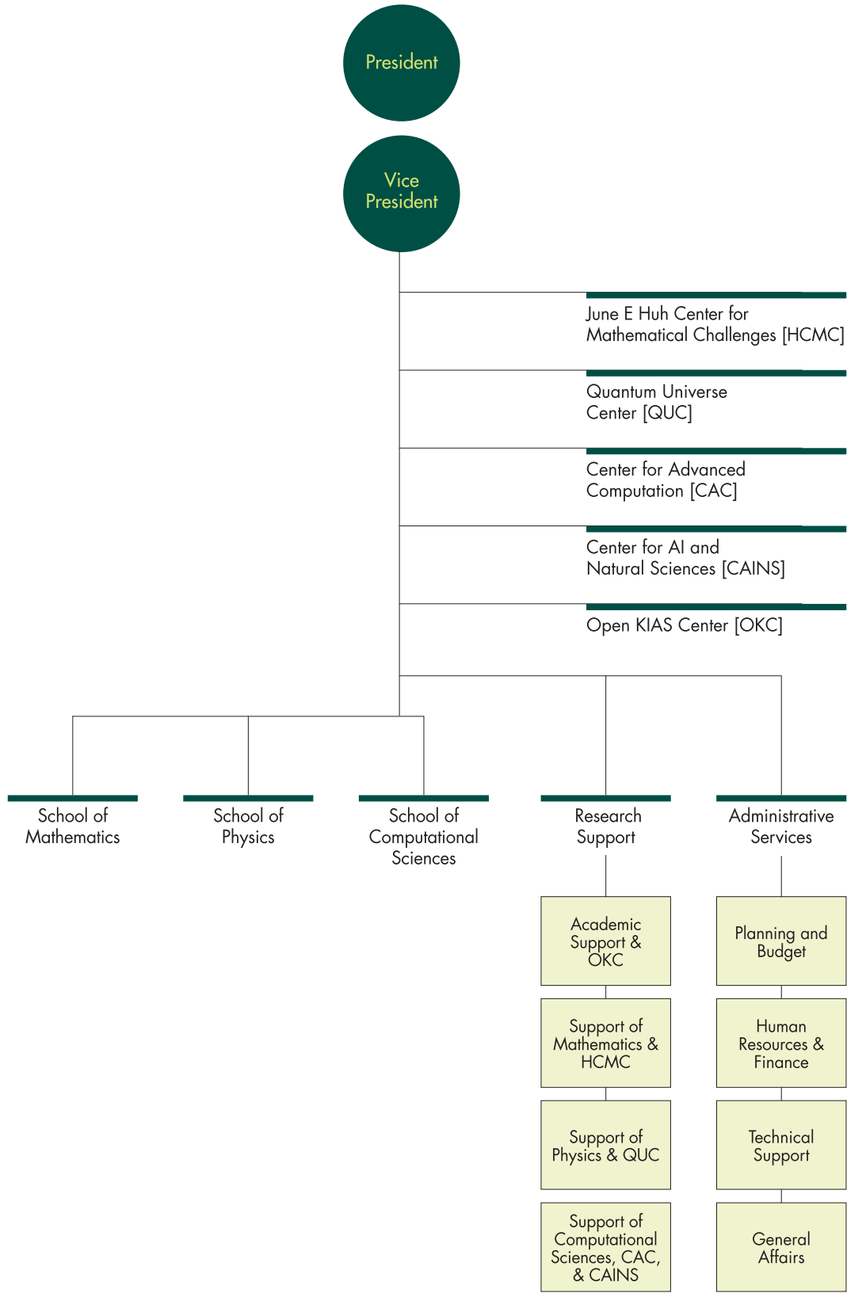
Organization



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Research Support

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Korea Institute for Advanced Study

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