



Postdoc Workshop V

Speaker: Antons Pribitoks, ARENAS
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Chitradipa Chakraborty, Dipanjan
Dey, GUPTA SHUBHAM, Ivan Sechin,
Jacob Adam Harcourt Kryczka,
KADYAN MONU, OTANI TAKUMI,
SAHOO SATYABRAT, SHIM
MYUNGBO, TELPUKHOVSKIY IVAN,
贾博名, 李高瞻, 李韞, 李智凡, 刘熠, 卫星月,
闫旗军, 叶铸, 张景宣, 赵启弦, 周坤, 朱秀武

Sep. 13-14
C548, Shuangqing



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Postdoc Workshop V 2025

Date

September 13-14, 2025

Venue

清华大学双清综合楼C548
Room C548, Shuangqing Complex Building, Tsinghua University

Zoom

Meeting ID: 892 226 4912
Password: YMSC

Purpose

Promote interaction and communication among postdocs and researchers.

Scientific and Organizing Committee

清华大学丘成桐数学科学中心博士后工作组

Support Fundings

清华大学丘成桐数学科学中心博士后活动经费
Funds for Postdoc Academic Activities, YMSC, Tsinghua University

Contact information

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Timetable

September 13, Saturday

Time	Welcome to Tsinghua	
9:40 - 9:50	丘成桐 Shing-Tung Yau	Opening
Chair: Don Zagier		
9:50 - 10:15	赵启弦 Qixian Zhao	Affine vertex algebras and an affine analog of the Barbasch-Vogan construction
10:15 - 10:35	Break and Group Photo, Chair: Heng Du	
10:35 - 11:00	Gabriel Arenas-Henriquez	Radiation in fluid/gravity and the flat limit
11:00 - 11:25	Jacob Krynica	Derived Moduli Spaces of Non Linear PDES
11:25 - 11:50	Monu Kadyan	Generalized Ramanujan Sums and Spectra of integral Cayley Graphs
Lunch		
Chair: Yi Huang		
13:30 - 13:55	Shubham Gupta	Fourier analytic approach to discrete Hardy inequalities
13:55 - 14:20	Ivan Sechin	Spectral duality for Gaudin systems associated with reflection equation
14:20 - 14:45	卫星月 Xingyue Wei	Weyl symmetry in 5-brane web of (D_4, D_4) conformal matter
14:45 - 15:10	Ivan Telpukhovskiy	Volumes of moduli spaces of flipped surfaces
15:10 - 15:30	Break	
15:30 - 15:55	贾博名 Boming Jia	Grassmannians, Nilpotent Orbits, and Toric Varieties
15:55 - 16:20	Takumi Otani	Algebraic Stability Conditions for Acyclic Quivers
16:20 - 16:45	李韞 Yun Li	Hard-to-soft edge transition for the Laguerre beta-ensembles
16:45 - 17:10	Chitradipa Chakraborty	A Latent Class Bayesian Model for Multivariate Zero-inflated Longitudinal Outcomes in the Health and Retirement Study
Dinner		

September 14, Sunday

Time	Welcome to Tsinghua	
Chair: Yueke Hu		
9:30 - 9:55	叶铸 Zhu Ye	First Betti number rigidity of open manifolds with nonnegative Ricci curvature
9:55 - 10:20	Dipanjan Dey	Invariant Definition of Photon Surfaces in General Relativity
10:20 - 10:40	Break	
10:40 - 11:05	Satyabrat Sahoo	Asymptotic Fermat equation of signatures $(r, r, p), (p, p, 3)$ over totally real fields
11:05 - 11:30	李高瞻 Gaozhan Li	Soliton gas for the modified Camassa-Holm equation and its transient asymptotics
11:30 - 11:55	李智凡 Zhifan Li	Multitask Learning for the Reconstruction of Gene Regulatory Networks
Lunch		
Chair: Weifeng Sun		
13:30 - 13:55	朱秀武 Xiuwu Zhu	Class group statistics and the BSD conjecture
13:55 - 14:20	闫旗军 Qijun Yan	On the functorial behavior of Ekedahl-Oort strata for unitary and orthogonal Shimura Varieties
14:20 - 14:45	Anton Pribytok	Superchiral GLSM and Chern-Simons theory with order defects
14:45 - 15:05	Break	
15:05 - 15:30	张景宣 Jingxuan Zhang	Dynamics of quantum fluctuation
15:30 - 15:55	周坤 Kun Zhou	Optimal Quantum (r, δ) -Locally Repairable Codes via Classical ones
15:55 - 16:20	刘熠 Yi Liu	Recent Advances in GeoAI and Quantum-Enhanced Geographic Computing
16:20 - 16:45	Myungbo Shim	Toward 3d Integrability from TQFTs
Dinner		

List of Abstracts

September 13, Saturday

Affine vertex algebras and an affine analog of the Barbasch-Vogan construction

赵启弦 *Qixian Zhao*

YMSC

A well-known story in classical representation theory is a "duality" relation between certain pieces in the category \mathcal{O} of a semisimple Lie algebra \mathfrak{g} and Springer fibers associated to the Langlands dual Lie algebra of \mathfrak{g} . It lifts the Barbasch-Vogan duality on nilpotent orbits. In this talk, I will review this story, and explain an affine analog of this picture (partially conjectural), where one replaces Springer fibers by their affine versions, and replaces the category \mathcal{O} of \mathfrak{g} by the category \mathcal{O} of affine vertex algebras. In particular, we propose conjectures for simple modules and associated varieties for simple affine vertex algebras at non-admissible integer levels. This is based on joint work with Peng Shan and Wenbin Yan.

Radiation in fluid/gravity and the flat limit

Gabriel Arenas-Henriquez

YMSC

We investigate asymptotically locally anti-de Sitter spacetimes exhibiting radiative behavior, using null gauges that admit well-defined flat limits. The radiative content in the bulk is captured by the boundary Cotton and stress tensor, which we collect into a radiative vector. We reinterpret this vector holographically in terms of fluid variables in the dual boundary theory. For algebraically special solutions, we uncover a close connection between bulk radiation and dissipative corrections in the boundary stress tensor, demonstrating a direct link between radiation and entropy production in the boundary fluid. We then investigate the flat limit of this correspondence in the context of flat-space holography. In this setting, we construct a Carrollian analogue of the radiative vector and show that bulk radiation sources the Carrollian viscous stress tensor and heat current, which encodes the Bondi news in this framework. We illustrate our results with explicit examples, including Robinson-Trautman spacetimes and accelerating black holes.

Derived Moduli Spaces of Non Linear PDES

Jacob Kryczka

BIMSA

In this talk I will summarize my work on the derived and homotopical geometry of non linear PDES. After briefly motivating why such generality is needed I will describe some results and their surprising implications in geometric analysis, non perturbative approaches to quantization of gauge systems, homological mirror symmetry and the theory of integrable systems. Time permitting I will share some perspectives on my future research directions. Based on series of joint works with V. Rubtsov, A. Sheshmani and S-T. Yau.

Generalized Ramanujan Sums and Spectra of integral Cayley Graphs

Monu Kadyan

YMSC

In this talk, I will introduce a generalization of the classical Ramanujan sum to the setting of finite groups. For a finite group G , a character χ of G , and an element $x \in G$, the generalized Ramanujan sum is defined as

$$C_\chi(x) := \frac{1}{\chi(\mathbf{1})} \sum_{s \in [x^G]} \chi(s),$$

where $\langle x^G \rangle$ denotes the normal subgroup generated by the conjugacy class of x . I will present an explicit formula for this character sum and explain how it extends the classical Ramanujan sum. As an application, I will discuss how this formula provides the eigenvalues of the Cayley graph $\text{Cay}(G, [x^G])$.

Fourier analytic approach to discrete Hardy inequalities

Shubham Gupta

YMSC

Hardy inequalities, being one of the first mathematical formulation of uncertainty principles, have been intensively studied in the continuum. I will talk about their less studied discrete counterparts, and show how Fourier analytic tools can be used to make progress on some classical problems.

Spectral duality for Gaudin systems associated with reflection equation

Ivan Sechin

BIMSA

Two classical integrable systems are called spectrally dual if they are defined on the same phase space (or if there exists a Poisson map between their phase spaces), and the spectral curves of these two systems (given by the equation $\Gamma(z, w) = 0$) are related via the change of coordinates z and w . I will give an elementary proof of the spectral duality of two classical Gaudin models: the first one is associated with the orthogonal Lie algebra, while the second one is constructed from the reflection equation for the general linear Lie algebra.

Weyl symmetry in 5-brane web of (D_4, D_4) conformal matter

卫星月 Xingyue Wei

YMSC

We study the enhanced global symmetry of general rank (D_4, D_4) conformal matter theories compactified on a circle by carefully investigating the Weyl symmetry in their 5-brane web constructions. With the help of the so-called quadrivalent gluing for 5-brane webs, we find hidden flop transitions in the 5-brane web constructions of these theories. These flop transitions are nontrivial for rank $N \geq 2$ theories, and they play a crucial role in endowing the theories with a global affine E_8 symmetry.

Volumes of moduli spaces of flippered surfaces

Ivan Telpukhovskiy

YMSC

The Weil-Petersson (WP) volumes of moduli spaces of hyperbolic surfaces of genus g with boundary components of fixed lengths L_1, \dots, L_n are polynomials in $\mathbb{Q}[\pi^2, L_1^2, \dots, L_n^2]$ due to Mirzakhani. A natural generalization of the WP volume form to the moduli spaces of surfaces with boundary punctures (crowned hyperbolic surfaces) yields *infinite* volumes. To remedy this, in 2024 Chekhov introduced an action functional that makes the moduli space volumes finite. We give a geometric interpretation of Chekhov's action and determine volumes for all moduli spaces of non-contractible crowned surfaces. Further, we consider a natural class of surfaces with richer local geometry around boundary punctures that we call *flippered* hyperbolic surfaces. We generalize Chekhov's action to this setting and prove that the moduli spaces of flippered hyperbolic surfaces have finite volumes. This is joint work with Yi Huang.

Grassmannians, Nilpotent Orbits, and Toric Varieties

贾博名 *Boming Jia*

YMSC

We first explain how the homogeneous coordinate ring of the Grassmannian $Gr(2, n+3)$ is related to the T -equivariant cohomology of the toric variety associated to the cluster fan of type A_n . Then we prove an analogous result for the minimal nilpotent adjoint orbit in $\mathfrak{sl}_{n+1}(\mathbb{C})$ and the cluster toric variety of type C_n . A peculiar bijection between the almost positive roots of type C_n and the roots of type A_n is obtained. This talk is based on a recent joint work with Li, Yu.

Algebraic Stability Conditions for Acyclic Quivers

Takumi Otani

YMSC

The notion of a stability condition on a triangulated category was introduced by Bridgeland. In several settings, the existence of stability conditions is already known. Broadly speaking, there are three types of (conjectural) stability conditions, originating from algebraic geometry, symplectic geometry, and algebra.

Bridgeland also proved that the space of stability conditions has the structure of a topological manifold (in fact, a complex manifold). A natural question is whether all stability conditions can be obtained from these known examples in some way.

In this talk, I will explain that every stability condition on the derived category of a finite acyclic quiver can be obtained from an algebraic heart by rotation. I will also discuss two corollaries. The first is the connectedness of the space of stability conditions. The second is the existence of a full stable exceptional collection for any stability condition. This talk is based on joint work with Dongjian Wu.

Hard-to-soft edge transition for the Laguerre beta-ensembles

李韞 Yun Li

YMSC

The size n Laguerre beta-ensemble is a two-parameter family of distributions that generalizes the joint eigenvalue distribution of the classical Wishart matrices. It is indexed by the inverse temperature $\beta > 0$ and the dimension difference $a_n > -1$. It is known that when a_n is constant or grows at least linearly with n , the local scaling limits near the lower spectral edge are described by the Bessel (hard edge, indexed by a) and Airy (soft edge) point processes, respectively. In this talk, I will present ongoing joint work with Jiaming Xu and Benedek Valkó. We investigate the remaining regime in which $a_n \rightarrow \infty$ sublinearly, and we show that the soft-edge Airy limit emerges near the “hard” edge when a_n grows at least logarithmically.

A Latent Class Bayesian Model for Multivariate Zero-inflated Longitudinal Outcomes in the Health and Retirement Study

Chitradipa Chakraborty

BIMSA

Latent class models have been successfully used to handle complex datasets in different disciplines. For longitudinal outcomes, we often get a trajectory of the outcome for each individual, and on that basis, we cluster them for a powerful statistical inference. Latent class models have been used to handle multivariate longitudinal outcomes coming from biology, health sciences, and economics. In this paper, we propose a Bayesian latent class model for multivariate outcomes with excess zeros. We consider a Tobit model for zero-inflated continuous outcomes such as out-of-pocket medical expenses (OOPME), a two-part model for financial debt, and a ZIP model for count outcomes with excess zeros. We develop a Bayesian mixture model and employ an adaptive Lasso-type shrinkage method for variable selection. We analyze data from the Health and Retirement Study conducted by the University of Michigan and consider modeling four important outcomes measuring the physical and financial health of the aged individual: the number of hospital stays, out-of-pocket medical expenses, total financial assets, and total financial debt. Our analysis detects several latent clusters for different outcomes. It is based on an efficient implementation of MCMC, and the results are validated through extensive simulation studies.

September 14, Sunday

First Betti number rigidity of open manifolds with nonnegative Ricci curvature

叶铸 **Zhu Ye**

Department of Mathematical Sciences

A classical theorem of Bochner asserts that a compact n -manifold M with nonnegative Ricci curvature satisfies the first Betti number estimate $b_1(M) \leq n$; moreover, equality holds if and only if M is a flat torus T^n . In this talk, we will present some extensions of the Bochner rigidity to open (i.e., complete and noncompact) manifolds with nonnegative Ricci curvature.

Invariant Definition of Photon Surfaces in General Relativity

Dipanjan Dey

BIMSA

In this talk, I will present photon surface conditions formulated in terms of Cartan scalars within an invariant spin frame, which provides a fully frame-independent characterization of the local spacetime geometry. This invariant approach allows us to obtain novel insights into the geometry and dynamics of photon surfaces, independent of the global structure of the spacetime. I will begin by discussing the photon surface conditions in Petrov type-D spacetimes, and then show how these conditions simplify under the assumption of spherical symmetry. Using the spherically symmetric conditions, I will analyze the dynamics of photon surfaces in static spacetimes, as well as in dynamical scenarios such as collapsing Lemaitre-Tolman-Bondi (LTB). Finally, I will also discuss our recent attempt to investigate photon surface dynamics in the more general nonspherical Szekeres collapsing spacetime.

Asymptotic Fermat equation of signatures (r, r, p) , $(p, p, 3)$ over totally real fields

Satyabrat Sahoo

YMSC

In 1994, Wiles proved the famous Fermat's Last Theorem by using the modular method. Since then, substantial progress has been made in the study of generalized Fermat equation of signature (p, q, r) , namely $Ax^p + By^q = Cz^r$, where p, q, r are rational primes and A, B, C are non-zero coprime integers. In this talk, inspired by Wiles's modular method, we study the asymptotic solutions of the generalized Fermat equation of signature (r, r, p) and $(p, p, 3)$ i.e., $x^r + y^r = dz^p$ and $Ax^p + By^p = Cz^3$ over totally real fields K , where $r, p \geq 5$ are rational primes and $d, A, B, C \in \mathcal{O}_K \setminus \{0\}$.

Soliton gas for the modified Camassa-Holm equation and its transient asymptotics

李高瞻 *Gaozhan Li*

Department of Mathematical Sciences

In this paper, we investigate the soliton gas for the modified Camassa-Holm (mCH) equation with the eigenvalues of the Lax pair of mCH equation accumulating symmetrically on unit circle and imaginary axis. Based on the Riemann-Hilbert problem characterizing the mCH soliton gas, we provide a complete analysis on the long-distance and long-time asymptotic behavior of the mCH soliton gas. Especially the long-time behavior of the mCH soliton gas is described by genus-3, genus-7 or genus-11 hyperelliptic wave under different velocity. It is the first time that we give the long-time asymptotics for the soliton gas solution in three kinds of transitional regions which are found to be connected with the Laguerre polynomials, Painlevé XXXIV equation and Painlevé II equation, respectively.

Multitask Learning for the Reconstruction of Gene Regulatory Networks

李智凡 *Zhifan Li*

BIMSA

Networks are fundamental to understanding complex systems that involve numerous interacting components. We develop a generalized statistical physics model to reconstruct informative, dynamic, omnidirectional, and personalized networks (idopNetworks) for various domains of complex systems. In this article, we integrate multi-task learning (MTL) and idopNetwork reconstruction to form a unified framework, by which a subset of the most significant entities (acting as predictors) for each dependent entity are simultaneously selected for all entities on a system of linearized nonlinear mixed ordinary differential equations (nMODEs). Our MTL-nMODE framework, providing a new insight of machine learning, enhances the reconstruction precision of modular and sparse idopNetworks, which, to a larger extent, approximate the intricate and multifaceted nature of complex systems. We perform computer simulation to validate the statistical property of our framework. We apply the model to learn gene regulatory idopNetworks from transcriptional data, identifying regulatory roles of several genes in mediating malaria infection. Our proposed method is available at github: <https://github.com/ChangjianFa/MTODE/>

Class group statistics and the BSD conjecture

朱秀武 *Xiuwu Zhu*

BIMSA

In 1979, Goldfeld conjectured that in any quadratic twist family of an elliptic curve over \mathbb{Q} , exactly 50% of the twists have analytic rank 0 and 50% have analytic rank 1. Current work toward this conjecture proceeds along two complementary lines. The first studies the distribution of Selmer groups within the twist family—in particular, the density of curves with arithmetic rank 0 and those with arithmetic rank 1, both conjectured to be 50%. The second seeks to relate Selmer group to the curve's L-function via the BSD conjecture. Together, these directions address two central themes in contemporary number theory: the statistical behavior of arithmetic objects in natural families, and the deep links between arithmetic and analytic invariants. In this talk I will present progress from my postdoctoral work on both fronts.

On the functorial behavior of Ekedahl-Oort strata for unitary and orthogonal Shimura Varieties

闫旗军 *Qijun Yan*

YMSC

The Ekedahl-Oort stratification of moduli spaces of abelian varieties in characteristic p is defined by isomorphism classes of their p -kernels. This stratification naturally extends to more general Shimura varieties. For good reductions of unitary and orthogonal Shimura varieties, these strata often admit an elementary parametrization; in ambient cases, for example, by $\{1, 2, \dots, n\}$, with each number i representing an i -dimensional EO stratum. In this talk, I will report some numerical results on the functorial behavior of these strata under the Kudla embedding. This is joint work with Chao Zhang.

Superchiral GLSM and Chern-Simons theory with order defects

Anton Pribytok

BIMSA

We construct novel supersymmetric deformation of \mathbb{CP}^1 sigma model and derive its dual counterpart as a generalized Gross-Neveu model. It is discovered that the renormalizability and supersymmetric invariance is guaranteed by the new Nahm-type condition. Moreover this field-theoretic formalism appears particularly useful for the study of renormalization properties and especially for calculation of such observables as β -function and correlators. We study the RG flow of the new class and find special UV conformal points from both sides of the new Chiral/Sigma model correspondence. We further explore novel relations of our construction through mirror symmetry and dimensional reductions. From the first principles we derive the complete functional integral and demonstrate new sigma model emergence from the four-dimensional TQFT with defects. In addition, to study the IR regime, we construct the associated surface operators, develop discretization schemes and provide new spin chain systems. Independently, we investigate new supersymmetric sigma models related to the compactified S-class models, whose target space is represented by B- and mixed branes arising from the genus two character varieties.

Dynamics of quantum fluctuation

张景宣 *Jingxuan Zhang*

YMSC

In typical superfluid phenomena of Bose gases, a macroscopic fraction of particles occupies the same quantum state, forming the Bose-Einstein condensate. The dynamic of the condensate is governed by the Gross-Pitaevskii equation, while the remaining particles exhibit quantum fluctuations around this macroscopic dynamic. Global estimates for such fluctuations have been established in the seminal works of Erdős, Schlein, and Yau. In this talk, we investigate local properties of quantum fluctuations. Specifically, we present new ballistic propagation bounds, demonstrating that quantum fluctuations around the condensate spread at most linearly in time. These results offer a finer understanding of the space-time behavior of fluctuations beyond the global framework. Based on joint work with M. Lemm and S. Rademacher.

Optimal Quantum (r, δ) -Locally Repairable Codes via Classical ones

周坤 *Kun Zhou*

BIMSA

For classical optimal Locally Repairable Codes (LRCs) with repair parameters (r, δ) , we prove that: 1.The minimum distance always satisfies $d \geq \delta$; 2.Every local protection code is an MDS code with minimum distance δ . Finally, we provide: 3.A complete characterization of optimal quantum LRCs with minimal decomposition; 4.Explicit infinite families of optimal quantum LRCs. (Joint with Meng Cao)

Recent Advances in GeoAI and Quantum-Enhanced Geographic Computing

刘熠 *Yi Liu*

BIMSA

This report presents recent progress in Geospatial Artificial Intelligence (GeoAI), highlighting methodological innovations and emerging applications in spatial data science. Building on these advances, we explore the paradigm of Quantum-Enhanced Geographic Computing, which leverages the synergy between High-Performance Computing (HPC) and superconducting quantum technologies to address computational bottlenecks in geospatial analysis and modeling. Finally, we outline prospective frontiers where AI and quantum computing converge to support global challenges, with emphasis on their contributions to the Sustainable Development Goals (SDGs).

Toward 3d Integrability from TQFTs

Myungbo Shim

YMSC

We report the current status toward 3d integrable lattice models from 3d TQFTs based on ideal triangulation. Based on this topological principle, we can solve the bicolored tetrahedron equations (BTEs). Since the BTEs do not ensure the integrability of the lattice models, we also explored the integrability conditions for the each model depending on the orientation and the shape structure. If time permits, we make a remark on the bulk-boundary correspondence for our defect rhombic dodecahedrons.

Useful Information

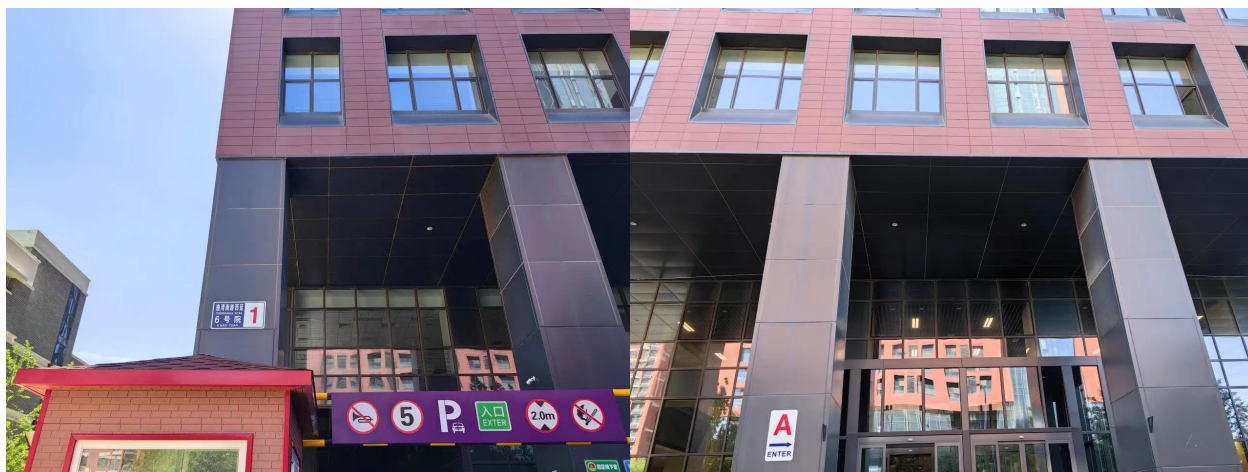
A Guide to Shuangqing Complex Building A



To commute between Jingzhai 静斋 and Shuangqing Building, one can go through the **East Gate** or **Northeast Gate**.



Then follow the red path to the Shuangqing Complex Building A (Yau Mathematics Science Center).



Exterior views of the building.

Address:

双清综合楼A座

北京市海淀区逸清南路西延6号院1号

Shuangqing Complex Building A

No. 1, Courtyard 6, West Extension of Yiqing South Road, Haidian District, Beijing

Remarks:

双清公寓马路对面、清华附小（双清校区）西侧

Across the street from Shuangqing Apartments, on the west side of Tsinghua University Primary School (Shuangqing Campus).

请持有效证件（工作证、学生证）进入。访问人员请携带身份证/护照。

Please enter with valid identification (work ID, student ID). Visitors should bring their ID card/passport.

Previous Workshop



Postdoc Workshop III 2024

