ICTS ACTIVITY REPORT

2024-2025

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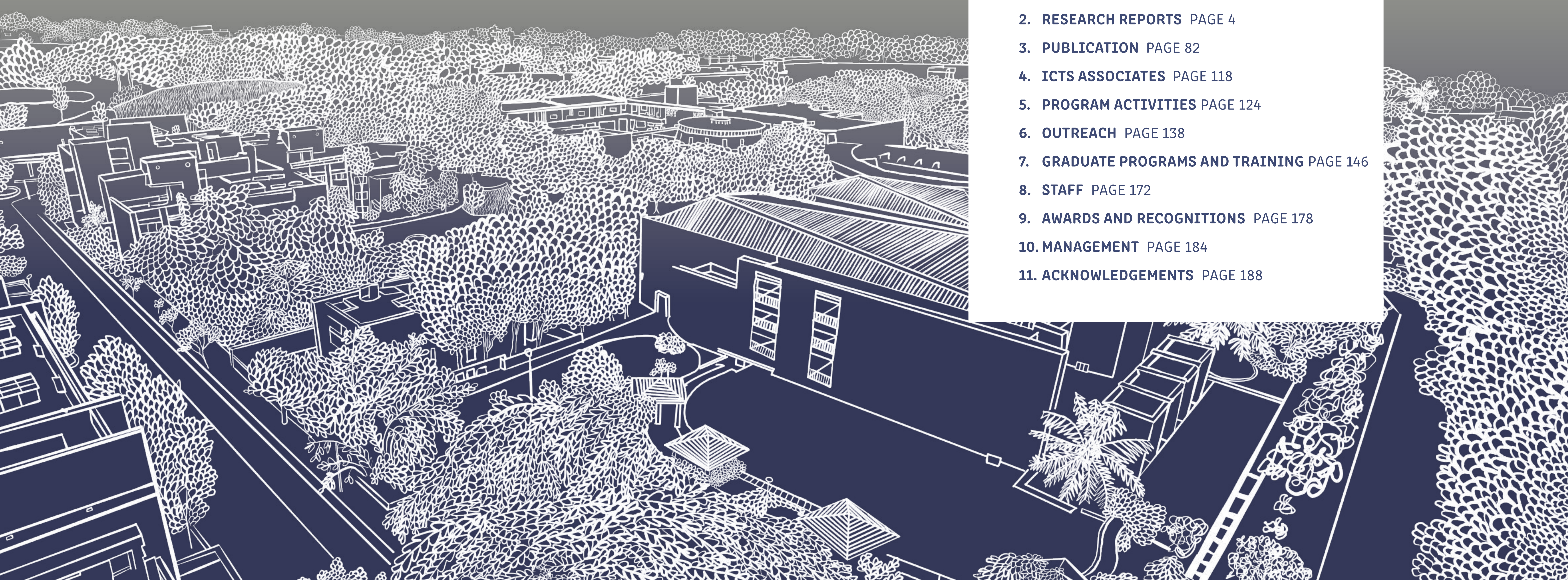


DIRECTOR'S REPORT

From the Director's Desk

"If you want to build a ship, don't drum up people to collect wood and don't assign them tasks and work, but rather teach them to long for the endless immensity of the sea."

– Antoine de Saint-Exupéry

As we turn into 2026, I am brimming with excitement about the ship that ICTS would like to build and launch in the next couple of years. The Govt. of Karnataka has reposed its trust in us to help nucleate a vibrant intellectual ecosystem, around ICTS, in the quantum as well as computational sciences. I see it as a unique opportunity to create in India a 'proof of concept' that the dialogue between fundamental science and translational research can lead to striking innovations. The rich environment for the mathematical and physical sciences that ICTS has nurtured can seed conversations that lead to the sprouting of out-of-the-box ideas which are transformative in their potential. Demonstrating this in the Indian context is important for developing a sense of confidence that this can be done here. It is an opportune time for such an experiment and ICTS is well placed to lead the creation of a Mathematical and Physical Sciences cluster much like the Life Sciences cluster around NCBS.

The additional eight acres of land from the state government will concurrently enable Phase II of ICTS. We are inviting our sister centre, the Centre for Applicable Mathematics (TIFR-CAM), to relocate to our enlarged campus. Given some of the new focus areas of CAM in computational mathematics, quantitative biology, computer science and climate sciences, there is likely to be good synergy between our centres. The presence of quality mathematicians in these subjects will significantly broaden the expertise that is available and will be a big resource for the envisioned cluster. ICTS will also anchor a multidisciplinary, computational and data science initiative together with NCBS and CAM, thus bringing together the computational activities across TIFR-Bengaluru under one roof. Other plans include an expanded outreach centre which will be the locus of our many activities in this sphere.

An exciting new ingredient in this cluster is a proposal for a privately funded translational research centre in machine learning and AI as well as quantum sciences stretching from quantum information and computing to quantum materials and quantum sensing etc. This will play a key role in the "Quantum City" that the state intends to create around ICTS. With an independent and nimble governance structure, it will seek to be a Bell Labs for the 21st century. With one foot firmly planted in the basic mathematical and physical sciences but with the other in translational space, it will be the vehicle that will demonstrate how fundamental science can lead to creative innovations that have tangible economic and social benefits for the country. All dreams as of now, but hopefully something that will soon crystallise into reality.

What has already crystallised are the stellar faculty we have attracted to ICTS in the last two years. At the junior level we have immensely strengthened our quantitative biology effort by hiring Brato Chakrabarti, biophysical fluid dynamicist, from the Flatiron Institute and Sarthak Chandra, physicist and neuroscientist from MIT. In addition, growing our condensed matter group is Aavishkar Patel, also from the Flatiron Institute and boosting our quantum field theory and quantum gravity directions is Raghu Mahajan from Stanford University, USA. I am proud to welcome such brilliant researchers to the ICTS community. At the senior level we are fortunate to count in our midst, two stalwarts of theoretical physics in India Profs. Deepak Dhar and Gautam Mandal, both holding special chairs at ICTS. To help with the future growth of ICTS we were delighted to have Profs. Kavita Ramanan and Peter Zoller join the International Advisory Board of ICTS.

We have had some very special international and national recognitions for our faculty. The highlights include the election to TWAS of Profs. Rama Govindarajan and Sumathi Rao, to the AAAS of Prof. Spenta Wadia, the hat trick of 2025 INSA Distinguished Lecture Awards to Profs. Siva Athreya, Jaikumar Radhakrishnan and Ashoke Sen. Ashoke was also a 2024 recipient of the Frontiers of Science Award. We were also specially proud of our young faculty member Sthitadhi Roy receiving the ICTP Prize. Fun fact: We currently have, as full time members at ICTS, eight out of the 50+ ICTP prize awardees.

We were greatly thrilled to receive the generous support from Shri Vishal Gupta and Maj. (retd.) Deepshikha Gupta for setting up an exciting new initiative - CALIBRE (Centre for Artificial Learning in Biological Research and Education). This is jointly with NCBS and together we will be charting new directions in the applications of AI in Biology as well as Biology for AI. The support will enable us to have visiting chairs, scientific visitors and postdocs and the computational support needed to achieve the goals. It has been heartening to see support forthcoming from a number of such generous donors who are acknowledged in this report.

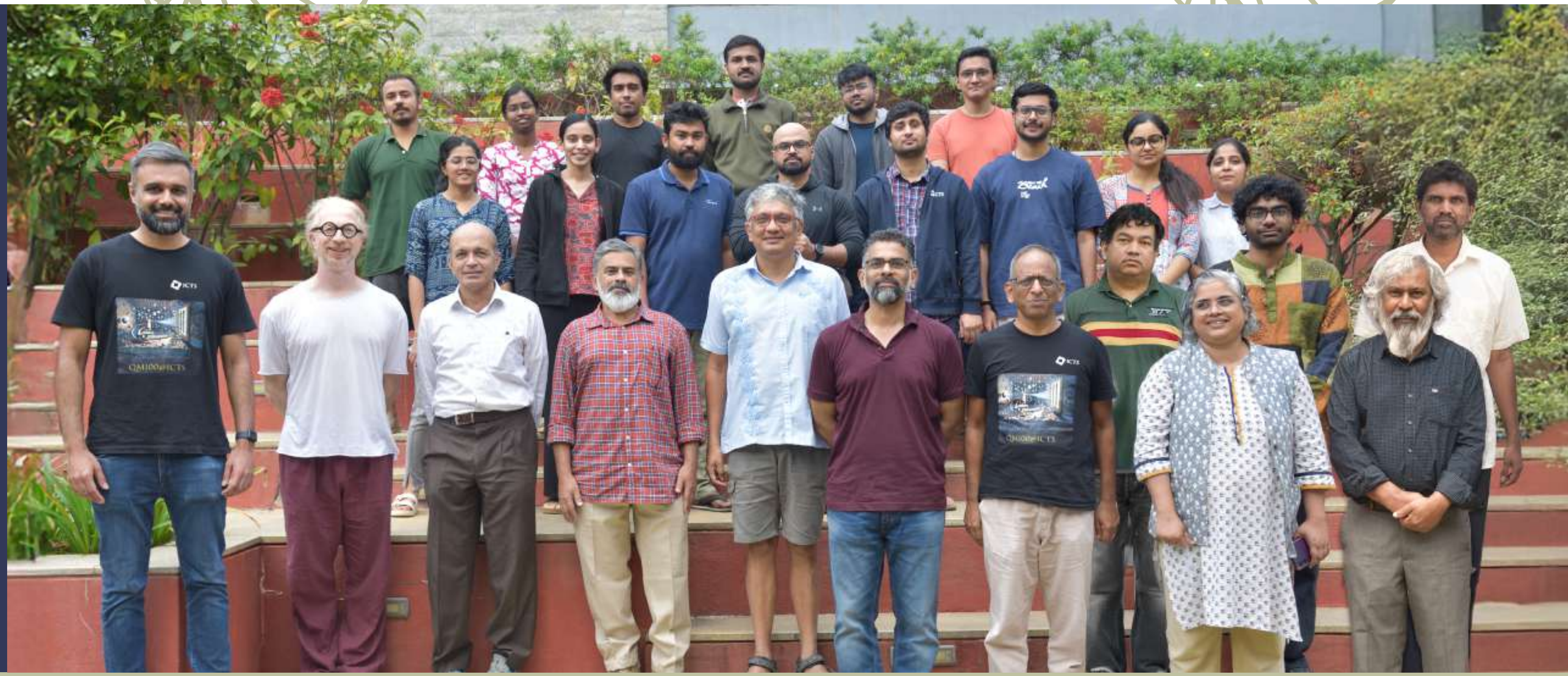
The community of students and postdocs at ICTS continues to be as vibrant as ever, organising numerous cultural and sports activities in addition to shining in their research. All of us are eagerly anticipating the completion of the hostel complex which will house the students on campus and will enliven it even more, especially after hours! I also want to put down my special appreciation for our administrative and technical staff who ensure ICTS hums along smoothly. I know the tremendous effort this takes as well as the sincerity with which they carry out their tasks in the face of multiple challenges. Their sense of belonging and ownership of our collective ship-building mission is what will sail us through the next phase. The immensity of the sea beckons us all.

Rajesh Gopakumar
April 2026

RESEARCH @ICTS

RESEARCH REPORT

MATHEMATICAL SCIENCES



Applied and Computational Mathematics

FACULTY

Siva Athreya ◈ Jim Thomas *(Joint Faculty with TIFR-CAM, Bengaluru)* ◈ Vishal Vasan

POSTDOCTORAL FELLOWS

Sanjay CP ◈ Sharath Jose ◈ Suruj Jyoti Kalita

STUDENTS

Mayank Kumar Bijay ◈ Manisha Goyal ◈ Pinak Mandal ◈ Vishal Neeraje ◈ Shashank Kumar Roy

ASSOCIATES

Govind Menon ◈ Mythily Ramaswamy

RESEARCH REPORT

Vishal VASAN

Vishal Vasan is interested in the theoretical and numerical analysis of partial differential equations as well as their applications. He has maintained an interest in inverse problems associated with dynamical systems, including state and parameter estimation from observations. A more recent interest is the question of inferring the dynamics itself from data/observations. In the past few years, he has been focussed on the development of algorithms to address these questions. The ultimate goal is to develop a theory of learning for dynamical systems.

State and Parameter Estimation

Dynamical systems serve as models across the natural sciences and engineering. A major challenge in using such models for prediction is that we often do not know the value of the parameters or coefficients for the model. Since these parameters can change qualitative and quantitative aspects of a solution, accurate estimation of parameters is of utmost importance. The typical recourse to estimate parameters is to obtain data from measurements, however usually we cannot measure not the full state. So we need to estimate the state of the system while also determining the parameters of the model. In joint work with a PhD student, Vasan developed an algorithm to determine the parameters of a dynamical system given partial observations of the state of the system. They investigated what kind of systems and which associated measurements are conducive to determining the parameters. The work adapts a well-known technique of data assimilation known as nudging and is applicable to linear and nonlinear models as well to even chaotic ones. They have obtained, for certain cases, theorems guaranteeing that their algorithm recovers the true parameters and, they are rapidly progressing towards a more complete picture of parameter estimation.

Operator-theoretic View Dynamical Systems & Data

The subject of atmospheric science presents an interesting situation, where one knows the overall fluid & thermodynamic picture but we cannot represent the full range of motions from microscopic to thousands of kilometers. Moreover, there is a lot we do not know about fundamental processes such as cloud droplet formation, ocean sea-spray and bio-geo feedback. Often it is observational data that informs us that our models are incomplete. A hugely important question then is how one should modify the models in light of the data to produce new dynamical models that one timcan test further. Can one deduce the dynamical model (or parts of it) from the observations? These are fundamentally mathematical questions regarding the relation between dynamical systems and data (i.e. functions of the state as it evolves in time). In joint work with colleagues, Vasan has undertaken an effort to answer these questions by adopting an operator-theoretic approach, in combination with ideas from control theory. Thus far, they have identified mathematical objects that can be used to represent dynamical systems and observational time-series, and they have an understanding of the sense in which a time-series identifies a dynamical system.

Computer Science

FACULTY

Jaikumar Radhakrishnan

STUDENTS

Sumukha Adiga

ASSOCIATES

Ashwin Nayak ◈ Praneeth Netrapalli

RESEARCH REPORT

Jaikumar RADHAKRISHNAN

During the period January 2024 to December 2025, Jaikumar Radhakrishnan worked on the following problems.

Quantum Search with Shallow Circuits

In the search problem, one is required to determine if a given element is present in a database of n elements. This is a well-studied problem where quantum algorithms outperform their classical counterparts, e.g., the algorithm of Grover can solve the search problem by making only $O(\sqrt{n})$ queries. Radhakrishnan (with ICTS postdoctoral fellow Rohit Sarma Sarkar) observed that this algorithm requires the registers to be maintained in superposition for the entire duration of the algorithm. They considered quantum algorithms modelled as shallow circuits, where all the registers are measured after every k queries to the database, and show that any such algorithm needs $\Omega(n/k)$ queries to the database; this bound is tight. Their bound is obtained by combining considerations of quantum fidelity with a chain rule for Hellinger distance due to TS Jayram. This matches a similar bound that was established by Hamoudi, Liu and Sinha (2023) using sophisticated and more generally applicable machinery that they developed for studying noisy circuits for collision finding.

Set Membership with Two Quantum Probes

Radhakrishnan (with Mohit Garg and Shyam Dhamapurkar) considered the problem of representing n-element subsets of {1,2,…,m} in memory so that membership queries can be answered with certainty using a small number of probes to the memory. They designed a quantum scheme that uses $O(n\sqrt{m})$ bits of memory and answers membership queries using just two quantum probes. This bound comes close to the known lower bound of $\Omega(\sqrt{nm})$; in contrast, it is known that classical schemes require $\Omega(m)$ bits of memory when n is at least log m. If the two probes to the memory need to be made non-adaptively, they showed that there is a scheme that uses $O(\sqrt{mn2^n})$ bits of memory; in contrast, such a classical scheme requires $\Omega(m)$ bits of memory even for sets of size two.

The Randomised Communication Complexity of Graph Connectivity

Radhakrishnan (with Chaitanya Reddy and Rakesh Venkat) considered the following communication complexity problem. There is an unknown n-vertex graph G whose edges are distributed between two parties A and B, who must exchange messages to determine if G is connected. A fundamental outstanding problem in this area is to determine how many bits the two parties must exchange to solve the problem with high probability. It is known that $O(n\ log\ n)$ bits of communication suffices. In 2015, it was shown that $\Omega(n\ log\ n)$ bits must be sent if the answer must be determined after just one message. In this work, Radhakrishnan and collaborators showed that $\Omega(n\ log\ n)$bits are necessary even when two messages are allowed, that is, if A sends the first message, B sends the next message, and A announces the answer.

Algebra, Geometry and Physical Mathematics

FACULTY

Rukmini Dey ◈ Pranav Pandit ◈ Joseph Samuel *(ICTS Endowed Visiting Professor)* ◈ B Sury *(ICTS Visiting Professor)* ◈ TN Venkataramana *(DAE- Raja Ramanna Chair)*

POSTDOCTORAL FELLOWS

Anu Dhochak ◈ Ken Kikuchi ◈ Amit Kumar ◈ Savita Rani ◈ Shrinit Singh

STUDENTS

Sunit Ranjan Banerjee ◈ Sam K Mathew ◈ Bhanu Kiran S

ASSOCIATES

Trishen Gunaratnam ◈ Mythily Ramaswamy

RESEARCH REPORT

Rukmini DEY

In the last two years, Rukmini Dey's research has focussed on the following:

Dey and Rahul Kumar Singh worked on interpolation of two real analytic curves by maximal surfaces. For maximal (and minimal) surfaces, they have developed a method of inverting the Björling-Schwarz formula, using the inverse function theorem for Banach spaces, to answer the interpolation problem. [Functional Analysis and Its Applications, Volume 59, pages 126–141, (2025)]

Dey, Singh and Anantadulal Paul worked on classifying algebraic constant mean curvature surfaces of revolution and in the process showed a remarkable association with elliptic curves. [Archiv der Mathematik, Volume 124, pages 137–149, (2025)]

Dey has worked on defining Berezin-type and Odzijewicz-type quantisations on arbitrary smooth manifolds. This is possible by embedding them in complex projective space and inducing the quantisation from the latter. [Int. J. Geom. Meth. Mod. Phys. (2025) arxiv: 2405.02838]

At present, Dey and her collaborators are working on the following problem: given two real analytic curves, they ask when there are zero or constant mean curvature surfaces interpolating them.

They have obtained various identities like Euler-Ramanujan identities - by studying height functions of minimal surfaces. This adds to their previous work on decomposition of height functions of minimal surfaces.

Dey and her collaborators had earlier defined two types of quantisation, namely the Berezin-type and Odzijewicz-type quantisations on arbitrary compact smooth manifolds. They embed the arbitrary smooth manifold in question into a manifold which has an appropriate "quantisation", a Hilbert space corresponding to the "quantisation" and a Poisson structure. A "local" Poisson structure is needed on the arbitrary compact smooth manifold and it is induced from the Poisson structure of the manifold in which it is embedded, which could be $\mathbb{CP}^n$ or $\mathbb{C}^n$ or some other suitable manifold. The quantisation is induced from the ambient manifold, which could be $\mathbb{CP}^n$ or $\mathbb{C}^n$ (depending on whether we expect a finite or an infinite dimensional Hilbert space).

At present they are exploring the possibility of extending Fedosov Deformation Quantisation and Kontsevich Deformation Quantisation to smooth manifolds, by embedding them into $\mathbb{CP}^n$ or $\mathbb{C}^n$. They are also interested in questions of hidden symmetry which force a system to settle on a smaller subsystem.

RESEARCH REPORT

Pranav PANDIT

Pranav Pandit's research over the past biennium concerns stability and metric structures in categorical and derived settings, motivated by questions arising in geometry, representation theory, and string theory, particularly from the geometry of D-branes.

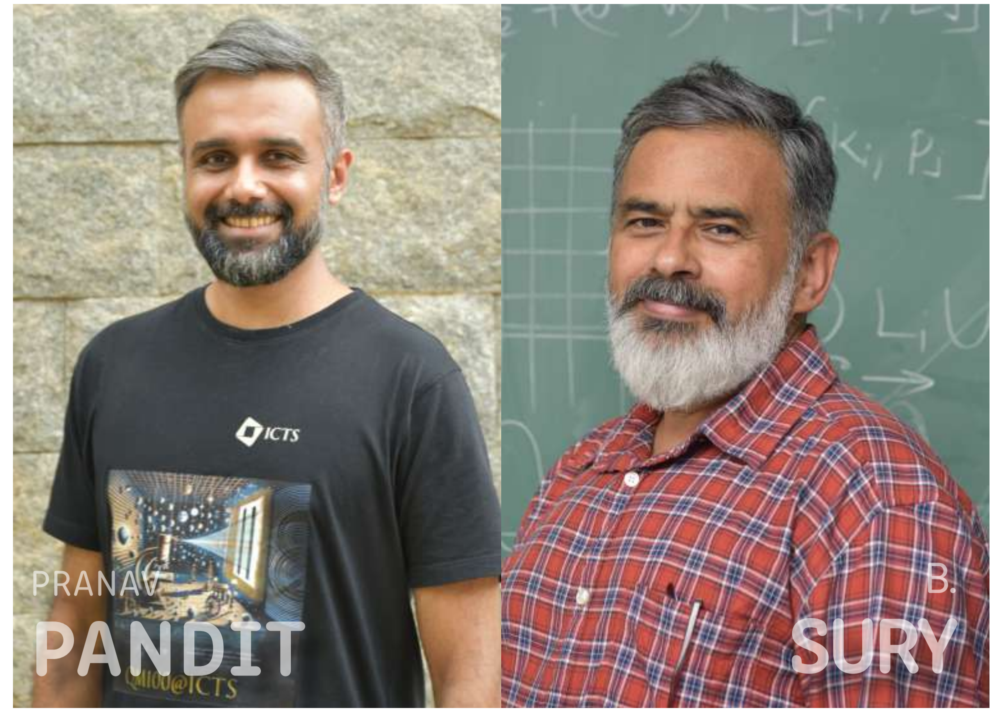
Categorical Kähler Geometry and Higher Algebraic Structures

A central theme of Pandit's work — developed in joint work with Fabian Haiden, Ludmil Katzarkov, and Maxim Kontsevich — is the study of categorical Kähler geometry, understood as a categorical analogue of classical Kähler geometry. In classical geometry, Kähler structures organise complex, symplectic, and metric data and underlie analytic characterisations of algebraic stability. In categorical settings, geometric spaces are replaced by derived or triangulated categories, and objects behave like generalised vector bundles. The research studies how features familiar from Kähler geometry — such as stability, mass, and preferred representatives — can be formulated in this categorical context.

Particular attention is given to situations where categorical stability governs the structure of moduli spaces, allowing comparisons between algebraic, symplectic, and categorical descriptions of the same underlying geometric data.

Within this framework, stability conditions on categories are treated as geometric data rather than as purely algebraic inputs. One considers categorical notions of mass, phase, and energy, together with flows or extremality conditions analogous to canonical metric equations. This perspective allows a common treatment of examples from algebraic geometry, symplectic geometry, and mathematical physics, and keeps the categorical structures close to their classical geometric origins. Concrete classes of examples include categories arising from quiver-type constructions and from symplectic geometry, where categorical stability reflects familiar geometric constraints.

A second strand of the research concerns En-monoidal categories, which encode higher-dimensional generalisations of associativity and commutativity. Such structures arise naturally in the description of observables and extended operators in quantum field theory. In joint work with his PhD student Bhanu Kiran Sandepudi, Pandit has studied how these higher monoidal structures deform and how their deformation behavior can be organised in a systematic way. This work focuses on structural properties rather than explicit classification and provides a technical framework supporting the geometric considerations above. These deformation-theoretic considerations are used to study categorical descriptions of boundary conditions in three-dimensional topological quantum field theories. In this setting, categorical equivalences and deformations provide a way to compare boundary conditions obtained from different geometric or algebraic constructions.



Overall, the research studies categorical analogues of Kähler geometry and their interaction with higher algebraic structures, with an emphasis on geometric intuition and on maintaining close contact with classical notions while working within modern categorical frameworks. The work is connected with broader research

RESEARCH REPORT

B. SURY

B. Sury's areas of research interest include algebraic groups over global and local fields, arithmetic groups, division algebras, and combinatorial aspects of group theory and number theory. In the last few years, his work has dealt mainly with questions on distribution of class groups of number fields, applications of elliptic curves to the study of some classical number-theoretic problems going back to Sylvester, and combinatorial number theory.

Cohen-Lenstra Heuristics

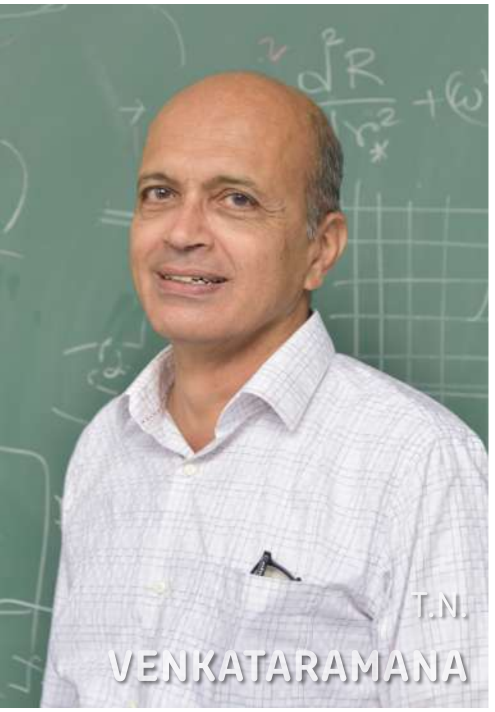
In 1984, based on some numerical evidence, Cohen and Lenstra made striking conjectures on the structure of the odd part of the class group, and on divisibility properties for class numbers of quadratic fields. In 1987, F. Gerth modified the Cohen-Lenstra heuristics to the prime 2 by considering the square of the class group. E. Fouvry and J. Kluners confirmed Gerth's conjecture on the 4-ranks of class groups of quadratic fields. In recent work with K. Babu, R. Bera and J. Sivaraman, Sury dealt with the general case of quadratic extensions of a class of number fields that have certain nice properties.

Sylvester's Problem

The classical Diophantine problem of determining which integers can be written as a sum of two rational cubes has a long history; from the earlier works of Sylvester, Selmer, Satgé, Lieman etc. and up to the recent work of Alpöge-Bhargava-Shnidman. In particular, Sylvester's conjecture that infinitely many primes congruent to 1 mod 9 are sums of two rational cubes was one of the difficult open problems. In collaboration with S. Jha and D. Majumdar, Sury used binary cubic forms to study the rational cube sum problem. The problem involves a family of elliptic curves. Among other things, they also proved unconditionally for the first time that for any positive integer d, infinitely many primes in each of the residue classes 1 modulo 9d and -1 modulo 9d are sums of two rational cubes.

Davenport Constant

The Davenport constant arose in the context of class groups of algebraic number fields where it gives information on the number of prime ideals appearing as factors of any non-zero ideal. In collaboration with K. Babu, R. Bera and M. Ghosh, Sury defined new variants of the Davenport constant of a general finite group. These constants aid in computing the Davenport constant and are of independent interest. They computed these constants for some non-abelian groups, and demonstrated that unlike abelian groups they can each be distinct. They obtained some cases of a conjecture of J. Bass, they also posed a conjecture for metacyclic groups and provided evidence.



Ramanujan Sums, Frobenius Numbers

Sury and collaborators also investigated some questions such as counting the number of solutions of many variable linear congruences subject to certain restriction conditions. The number of solutions to such congruences was expressed in terms of Ramanujan sums. They proved analogues for function fields over finite fields too. Further, they obtained the p-Frobenius number of triples including primitive Pythagorean triples. This work was in collaboration with K. Babu and R. Bera, and with T. Komatsu, respectively.

RESEARCH REPORT

T.N. VENKATARAMANA

T.N. Venkataramana's research work during the last two years is summarised below.

A new proof of an old result of Venkataramana and M.S. Raghunathan on unipotent generators of higher-rank arithmetic groups was given. The proof used the methods from the congruence subgroup problem and was published in conference proceedings in honour of Gopal Prasad. The work was begun in TIFR, Mumbai and was completed at ICTS.

It was proved that for $n \geq 3$, a Zariski dense discrete subgroup of $\mathrm{SL}(n,\mathbb{R})$ which intersects the top left-hand corner $\mathrm{SL}(3,\mathbb{R})$ in $\mathrm{SL}(3,\mathbb{Z})$ (or a finite index subgroup thereof) is conjugate to a finite index subgroup of $\mathrm{SL}(n,\mathbb{Z})$ and is, in particular, a lattice. This work was done jointly with Indira Chatterji (Nice, France). It was published in the Journal of the Ecole Polytechnique*,* France, in November 2025.

It was proved that if N is a commensurated subgroup of a non-uniform irreducible lattice Γ in a real semi-simple Lie group G, then N has finite index in Γ. This settles a conjecture of Margulis and Zimmer in the case of non-uniform lattices; this is joint work with Yehuda Shalom of Tel Aviv University and George Willis of Newcastle University in Australia. The paper is in preparation.

Probability Theory

FACULTY

Siva Athreya ◈ Anirban Basak ◈ Riddhipratim Basu ◈ Vivek Borkar *(ICTS Endowed Visiting Professor since 1 August 2025)* ◈ Jaikumar Radhakrishnan

STUDENTS

Pradeeptha R Jain ◈ Shaibal Karmakar

ASSOCIATES

Bhaswar Bhattacharya ◈ Frank den Hollander ◈ Subhajit Goswami ◈ Trishen Gunaratnam ◈ Govind Menon ◈ Dootika Vats

RESEARCH REPORT

Siva ATHREYA

Siva Athreya's research during the period 2024-2025 is summarised below.

Stochastic Partial Differential Equations

The publication titled "Well-posedness of the Stochastic Heat Equation with Distributional Drift and Skew Stochastic Heat Equation," co-authored with Oleg Butkovsky, Khoa Lê, and Leonid Mytnik, was published in Communications on Pure and Applied Mathematics. It develops a precise notion of solution for stochastic reaction–diffusion equations with highly irregular (distributional) drift terms and establishes both existence and uniqueness of strong solutions under broad conditions by exploiting the regularisation effects of white noise and advanced tools like the stochastic sewing lemma.

Athreya also co-edited (with Abhay G. Bhatt and B.V. Rao) the book Probability and Stochastic Processes: A Volume in Honour of Rajeeva L. Karandikar (Springer, Indian Statistical Institute Series). This edited volume collects survey and research contributions spanning modern topics in probability and stochastic processes and was published in August 2024.

"The Ising model at 100: some modern perspectives" was co-edited with C. Giardinà. The issue, published in the journal Mathematical Physics, Analysis and Geometry, celebrates a century of research on the Ising model, covering its definition, phase transitions, universality, and key mathematical and physical developments.

Combinatorial Probability

Athreya co-authored "On a Generalisation of the Coupon Collector Problem," with Satyaki Mukherjee and Soumendu Sundar Mukherjee; it was published in the Journal of Theoretical Probability (2025). This paper investigates an extension of the classical coupon collector model by defining "super-coupons" as s-subsets of an n-element universe and analyzing the time required to collect these under both independent random draws and temporally dependent (Markovian) sampling schemes.

Population Genetics

In the paper "The Moran model with random resampling rates," co-authored with Frank den Hollander and Adrian Röllin, he analysed a two-type Moran population where individuals have heterogeneous stochastic resampling rates. Despite this microscopic variability, the large-population limit of the empirical rate distribution among type-1 individuals converges to a Fisher–Wright diffusion with an effective diffusion constant determined by the resampling rate distribution. This appeared in the journal Annals of Applied Probability.

Random Walk in Trap Environment

In the paper "An Invariance Principle for a Random Walk Among Moving Traps via Thermodynamic Formalism" joint with Alexander Drewitz and Rongfeng Sun, he proved that a random walk on the d-dimensional lattice, in a Poisson field of mobile traps, when conditioned on survival, satisfies a diffusive invariance principle in dimensions larger than 6, converging to Brownian motion with positive diffusion constant using extended thermodynamic formalism methods. This appeared in the journal Communications in Mathematical Physics.

Public Health

Athreya is one of the PIs in the project titled: "Hub for Livestock Disease Surveillance and Modelling in India" funded by the Office of the Principal Scientific Adviser to the Government of India. The project establishes a national hub integrating livestock disease modelling and environmental surveillance to support India's animal health programs. It is a joint effort led by IISc, ICTS, and ARTPARK, it builds data-driven capacity, pilots FMD surveillance, informs vaccination and control strategies, and embeds scientific modelling into government policy and practice.

RESEARCH REPORT

Anirban BASAK

During the period covered by this report, Anirban Basak has pursued research on random matrix theory and statistical physics.

Large Deviations in Sparse Random Graphs and Matrices

Over the last five years, Basak has worked on large deviation problems in random graphs and random matrices. The quantities of interest in these areas are typically highly nonlinear functions of many independent random variables and therefore lie beyond the scope of classical large deviation theory, necessitating the development of new mathematical tools and techniques. In an earlier work, Basak resolved a long-standing open problem by identifying the upper tail large deviation probabilities for counts of regular subgraphs in sparse Erdős-Rényi random graphs in the so-called localized regime. Building on this program, Basak, with his PhD student Shaibal Karmakar, has recently obtained sharp results on upper tail large deviations for irregular subgraph counts. Ongoing work aims to extend these methods to random graph models with dependencies among edges, significantly broadening the scope of the theory.

In another joint work, Basak studied upper tail large deviations of the largest eigenvalue of sparse supercritical Wigner matrices. The model consists of symmetric matrices whose entries are products of sub-Gaussian random variables and Bernoulli (p) variables, with $\log n/n \ll p \ll 1$. This work also identified the typical structure of the matrix conditioned on an atypically large largest eigenvalue.

Spectral Properties of Random Perturbations of Non-normal Matrices

Non-normal matrices arise naturally in many systems, ranging from open quantum systems to non-conservative dynamical models. Their spectra are highly unstable, with eigenvalues that may change drastically under small perturbations, rendering classical spectral analysis inadequate. Since realistic systems are typically subject to stochastic rather than adversarial noise, random perturbations offer a natural framework for studying typical spectral behavior and for uncovering robust features such as limiting spectral distributions, spectral outliers, and localisation phenomena.

Basak has contributed significantly in this direction. In an earlier work, he established universality of the limiting spectral distribution of finitely banded Toeplitz matrices under polynomially vanishing (in dimension) random perturbations, identifying the limit as the Brown measure of unitary operator pushed forward by the symbol associated with the Toeplitz matrices. His recent work extends this universality to general Toeplitz matrices with continuous symbols under sub-exponentially vanishing perturbations. It further shows that for exponentially vanishing perturbations, the limiting distribution - while still universal with respect to the noise - depends on the decay rate and exhibits a richer structure.

Statistical Physics Models on Locally Tree-like Graphs

A recurring theme in statistical physics is that the macroscopic behaviour of ferromagnetic spin systems on large, sparse graphs should be encoded in a small set of effective parameters arising from local interactions. For graphs that are locally tree-like, this intuition leads to a description in terms of belief propagation fixed points and an associated Bethe-type variational functional. From this perspective, the limiting free energy density is expected to be determined by the most energetically favorable of these fixed points. When a single such configuration dominates, the system exhibits a well-defined thermodynamic phase, whereas the presence of several competing configurations signals phase coexistence and results in a mixture in the infinite-volume limit. Translating this physically compelling picture into rigorous mathematics is highly nontrivial, and has been achieved only in a limited number of settings. In a recent joint work, Basak and collaborators validated this framework for ferromagnetic Potts and random cluster models with an external field on sequences of sparse graphs converging locally to the infinite regular tree.

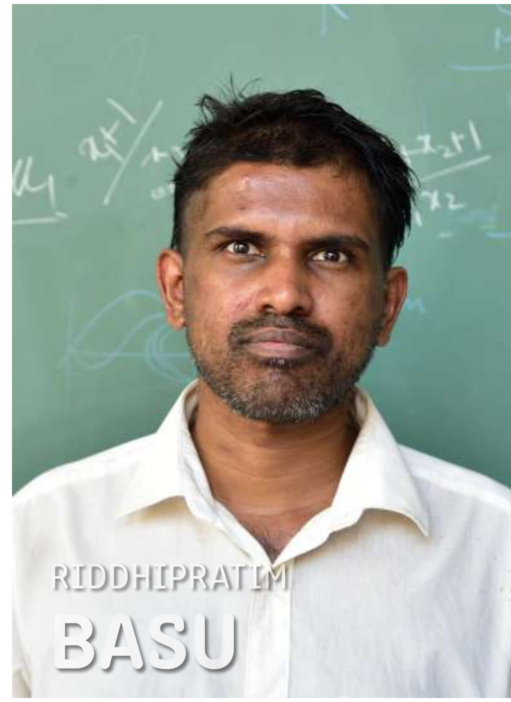
RESEARCH REPORT

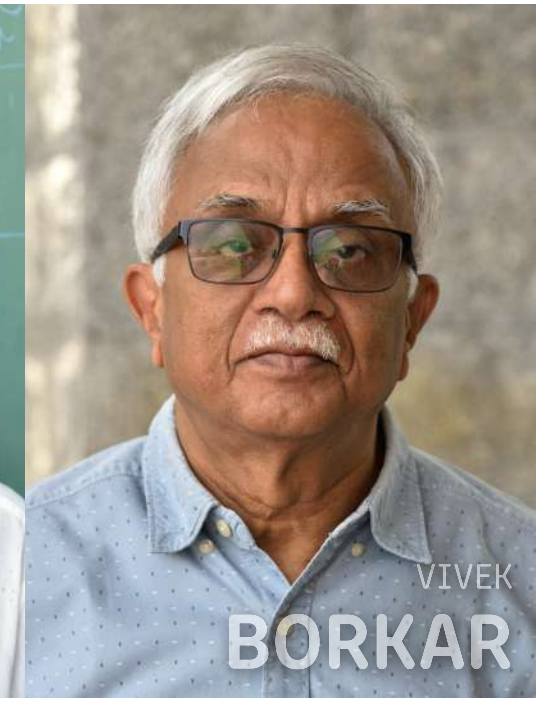
Riddhipratim BASU

During the last two years, Riddhipratim Basu has been working on the geometry of the Kardar-Parisi-Zhang (KPZ) universality class.

In particular, during this period, his research focussed on obtaining sharp tail estimates in certain random matrix models and applying them to solve several questions in the growth models in the KPZ universality class. In joint work with Jnaneshwar Baslingker, Sudeshna Bhattacharjee and Manjunath Krishnapur, Basu proved optimal tail estimates for largest eigenvalues of Gaussian and Laguerre β ensembles with the correct constant (up to 1+o(1) multiplicative error) in front of the exponent. Some of these estimates were previously missing in the classical GUE/LUE cases. For the classical cases corresponding to β =1,2,4 there is some well-known correspondence between the distribution of largest eigenvalues and certain statistics in exactly solvable last passage percolation models in the KPZ class. Using this connection, the sharp tail estimates and some geometric understanding of the last passage percolation model, they gave a complete proof of the conjectured law of iterated logarithm for passage times in the exponential last passage percolation, answering a question of Ledoux.

In a follow up work, they proved a law of fractional logarithm for the largest eigenvalues for the GUE minor process and the length of the top row of the Plancherel growth process answering two questions of Kalai as well as a conjecture of Paquette and Zeitouni. As other applications of the sharp estimates, limit theorems were proved for extrema of Airy_1 and Airy_2 processes in a joint work with Bhattacharjee and sharp deviation estimates were proved for geodesics in exponential LPP in a joint work with Pranay Agarwal. A large deviation principle was proved for the midpoint of the geodesic in general LPP models in another joint work with Tom Alberts, Sean Groathouse and Xiao Shen. In another direction, in a joint work with Mahan Mj, Basu studied geodesics in first passage percolation on hyperbolic groups.





RESEARCH REPORT

Vivek BORKAR

Vivek Borkar worked on the following project, during his visits to ICTS, jointly with Siva Athreya and Sumith Reddy Anugu of TU Ilmenau, Germany.

Ongoing work on deriving an explicit expression for the rate function for large deviations associated with jump diffusions driven by Levy processes for large times. This uses some control-theoretic ideas. The work is still in progress. The problem is much more difficult than that for classical diffusions, studied earlier by Hwang and Sheu under somewhat restrictive conditions and subsequently extended by Biswas and Borkar, because of the absence of exponential moments. This eliminates the possibility of establishing the classical large deviations principle as enunciated by S. R. S. Varadhan. Instead, taking a cue from some recent work of Rhee, Blanchet and Zwart (Ann. Prob., 2019), a weak large deviations principle is established.

PHYSICAL & NATURAL SCIENCES

RESEARCH REPORT

ASTROPHYSICS & RELATIVITY

FACULTY

Parameswaran Ajith ◈ Pallavi Bhat ◈ Bala Iyer *(ICTS Endowed Visiting Professor, till June 2025)* ◈ Prayush Kumar ◈ Rajaram Nityananda *(ICTS Endowed Visiting Professor, till June 2025)*

POSTDOCTORAL FELLOWS

Rajes Ghosh ◈ Anuj Mishra ◈ Samik Mitra ◈ Venkata Sai Saketh Muddu *(NPDF)* ◈ Samanwaya Mukherjee ◈ Prasad R

STUDENTS

A Chandranathan Anandavijayan ◈ Ankur Barsode ◈ Soummyadip Basak ◈ Uddeepta Deka ◈ Ritesh Purushottam Harshe ◈ Souvik Jana ◈ Alorika Kar ◈ Vinay Kumar ◈ Akash Maurya ◈ Koustav Narayan Maity ◈ Muhammed Irshad P ◈ Santhiya P S ◈ Aditya Kumar Sharma ◈ Neha Sharma ◈ Mukesh Kumar Singh ◈ Priyanka Sinha ◈ Aditya Vijaykumar

ASSOCIATES

Rana Adhikari ◈ Bala Iyer ◈ Rajaram Nityananda ◈ BS Sathyaprakash ◈ Tejaswi Venugopal Nerella *(ICTS Visiting Professor)*

RESEARCH REPORT

Parameswaran AJITH

The primary focus of Parameswaran Ajith's recent research is the gravitational lensing of gravitational waves (GWs).

Over the past decade, the LIGO and Virgo observatories have detected over 300 GW signals from merging binaries of black holes and neutron stars. In the coming decade, the number of GW detections is expected to exceed tens of thousands. A small fraction of these events (~0.1–1%) will be gravitationally lensed by intervening galaxies, clusters, and compact objects. Ajith's work involves developing techniques to identify lensing signatures in GW signals, performing searches for lensed GWs in LIGO–Virgo data, and using their current non-detection to constrain astrophysical and cosmological models. His research also explores how future lensing observations can be used as new probes of gravity, astrophysics, and cosmology.

Searches for Gravitationally Lensed GWs

In collaboration with graduate students A. Barsode, K. Maity, and S. Goyal, Ajith developed a fast and efficient Bayesian method to search for strongly lensed GWs. This approach is an improved version of an earlier method developed by the ICTS group and achieves detection efficiencies comparable to joint parameter-estimation methods that are computationally much more expensive. They demonstrated that this method can effectively suppress the quadratically increasing false-alarm rate, making the first detection of strongly lensed GWs achievable in the next few years. Their group is currently reanalysing archival LIGO-Virgo data using this improved method to search for strongly lensed GW events. Ajith also played a leadership role within the LIGO-Virgo-KAGRA Collaboration in searching for lensing signatures in data from the first part of the fourth observing run (O4a).

Constraining Astrophysical and Cosmological Models Using the Non-detection of GW Lensing

Ajith's group, led by graduate student A. Barsode in collaboration with S. J. Kapadia, used the non-detection of strongly lensed GWs to constrain the fraction of dark matter in the form of supermassive compact objects. In more recent work led by graduate student R. Harshe and postdoctoral researcher R. Prasad, they showed that current data are inconsistent with astrophysical models predicting a large fraction of lensed GW events, and that the high-mass black holes observed by LIGO and Virgo cannot be explained by lensing magnification.

GW Lensing as a New Tool for Astrophysics and Cosmology

In a series of papers in collaboration with graduate students S. Jana and K. Maity, and with collaborators S. J. Kapadia, T. Venumadhav, and S. More, Ajith is pursuing a research program aimed at developing future observations of strongly lensed GWs as probes of cosmology and dark matter. Their recent work demonstrated that lensing observations with next-generation detectors will place strong constraints on warm and fuzzy dark matter models. Their earlier work showed that GW lensing observations provide a new avenue for cosmography. More recently, they investigated various sources of systematic error in these analyses and proposed strategies to mitigate them. They also demonstrated that modest constraints on cosmological parameters can be achieved using data from upcoming observing runs of current-generation detectors.

RESEARCH REPORT

Pallavi BHAT

Over the past two years, Pallavi Bhat's research group has focussed on understanding the generation, evolution, and dynamical consequences of magnetic fields in astrophysical plasmas, with particular emphasis on the intertwined roles of turbulence, magnetic reconnection, and dynamo action across a wide range of physical environments.

A central theme of the group's work has been the role of magnetic reconnection as a governing process in magnetically dominated systems. Through direct numerical simulations of decaying MHD turbulence, the group demonstrated that reconnection controls the relaxation of both helical and nonhelical systems, driving inverse transfer of magnetic energy to larger scales. By combining scaling arguments with morphological analysis using Minkowski functionals, the group showed that three-dimensional decaying turbulence exhibits quasi-two-dimensional behavior, explaining the striking similarity between decay laws in 2.5D and fully 3D systems. These results provide a physical explanation for inverse transfer phenomena that have important implications for early universe magnetic fields inferred from gamma ray astronomy.

Complementing this, Bhat and her group investigated magnetic reconnection at a more fundamental level by extending the classical tearing instability to three dimensions. Using a flux-tube-like equilibrium, they established the existence of a genuine 3D tearing instability even in the absence of a guide field. Their analysis revealed how three-dimensional modulation alters resistive layer properties and reduces growth rates relative to 2D, while preserving key scaling behaviors. This work advances the theoretical understanding of reconnection in realistic 3D plasma configurations relevant to astrophysical and laboratory plasmas.

Building on their expertise in reconnection physics, they also proposed magnetic reconnection as a viable mechanism for particle acceleration in galaxy clusters. Using particle-in-cell simulations of plasmoid-dominated reconnection in collisionless, nonrelativistic plasmas, they showed that electrons are efficiently accelerated to form power-law energy spectra consistent with observations of radio halos. The predicted acceleration timescales and synchrotron luminosities agree well with cluster observations, offering a compelling alternative to shock- and turbulence-based acceleration models.

Another major thrust of the group has been dynamo action in evolving backgrounds. It developed a general analytical framework for turbulent dynamos in collapsing media and supported it with numerical simulations. The group's results showed that gravitational collapse dramatically accelerates dynamo growth, leading to super-exponential magnetic field amplification, far exceeding expectations from flux freezing or stationary turbulence. They further demonstrated that the saturated magnetic field strength scales as ($B \propto \rho^{0.83}$), implying that dynamically important magnetic fields can arise much earlier during star and galaxy formation than previously assumed.

Finally, Bhat and her group extended these ideas to global GRMHD simulations of black hole accretion disks, exploring how MRI-driven dynamos regulate jet formation. By employing novel "sub-SANE" initial conditions that rapidly lose magnetic memory through reconnection, they demonstrated that large-scale dynamos can self-consistently generate the fields required for jet launching. Crucially, the group identified the coherence of the magnetic field at the black hole horizon as the key parameter controlling jet longevity, establishing a direct and previously unexplored dynamo–jet connection in accreting black hole systems.

RESEARCH REPORT

Bala IYER

During the last two years, Bala Iyer has worked with the LIGO, Virgo and KAGRA collaborations.

The first part of the fourth observational run of LIGO, Virgo and KAGRA from May 2023 to December 2024 was a further consolidation leading to the GWTC-4 catalogue containing 128 new confident gravitational wave signals from merging binary black holes and neutron stars.

Exceptional events included a neutron star binary with an unknown compact object with mass between 2.5-4.5 $M_\odot$ (GW230529), the most massive black hole binary detected by GW (GW231123), a loud gravitational wave signal detected by LIGO Livingston (GW230814), a high signal to noise BBH system making possible the test of Hawking's area theorem, Kerr nature of the black holes, black hole spectroscopy and test of gravity (GW250114) and finally two rapidly spinning equal mass systems (GW241011, GW1110).

Like in O3, the O4a Gravitational Wave (GW) data was used to issue Open Alerts but with lower latency to look for electromagnetic and neutrino counterparts of GW sources, search for new exceptional events, update the O3 catalog of GW transients, provide parameters of the new signals and rates of compact binary coalescences for binary black holes, binary neutron stars and black hole neutron star binaries, infer population properties and formation channels, perform tests of gravity in fundamental physics or set constraints on cosmic expansion history in cosmology. The collaboration also searched for GW lensing signatures, GW from burst sources like core collapse supernovae SN 2023ixf, GW from 2024 Vela pulsar glitch, all sky search for long duration transients and short duration bursts, continuous GW from known pulsars and unknown neutron stars in a binary system, upper limits on isotropic GW background, directional searches for persistent GW, direct multi-model dark matter search, and finally exotica like planetary mass ultra compact objects or ultralight vector boson clouds around merger remnants and galactic black holes. These led to improved upper limits on the GW strain of continuous GW sources and on the eccentricities of the involved neutron stars.

RESEARCH REPORT

Prayush KUMAR

Over the past two years, Prayush Kumar's research has focussed on expanding the understanding of the most violent events in the universe: the collisions of black holes and neutron stars. While standard search methods assume these objects spiral toward each other in perfect circles, Kumar specialises in "eccentric" binaries — systems that collide on erratic, oval-shaped orbits often found in crowded stellar environments. These complex dances are notoriously difficult to detect, so Kumar and collaborators developed advanced computer models and artificial intelligence tools designed to recognise their unique gravitational-wave patterns. A major part of this effort involved building next-generation simulation software (SpECTRE) that uses novel mathematical techniques to model these cosmic crashes with unprecedented speed and accuracy, ensuring that these rare signals can be identified amidst the noise of the universe.

Beyond theoretical modeling, Kumar applied these advancements directly to real-world discovery and the search for new physics. His work demonstrated that we can predict the arrival of eccentric signals earlier than previously thought, providing a crucial "early warning" that allows astronomers to point their telescopes at neutron star collisions before they happen. He also investigated how extreme magnetic fields and alternative theories of gravity might leave distinct fingerprints on these signals. As a key contributor to the global LIGO-Virgo-KAGRA collaboration, he helped analyze the latest observational run, which successfully doubled our catalog of known gravitational-wave events. To support future discoveries, Kumar and collaborators also released a massive public library of over 3,000 black hole simulations, providing the worldwide scientific community with the resources needed to interpret the data from current and future gravitational-wave detectors.

Kumar's research fundamentally broadens the horizon of gravitational-wave astronomy by unlocking the ability to detect and interpret "eccentric" binary collisions — violent events formed in dense stellar clusters that standard models fail to capture. By pioneering next-generation simulation infrastructure (SpECTRE) and releasing the largest-ever public catalog of black hole waveforms, he has equipped the global scientific community with the essential tools needed to maximise the scientific return of observatories like LIGO, Virgo, and KAGRA. This work not only enhances our ability to test General Relativity in extreme regimes but also leverages artificial intelligence to provide early warnings of neutron star mergers, enabling astronomers to capture electromagnetic counterparts and significantly deepening our understanding of the universe's most energetic processes.

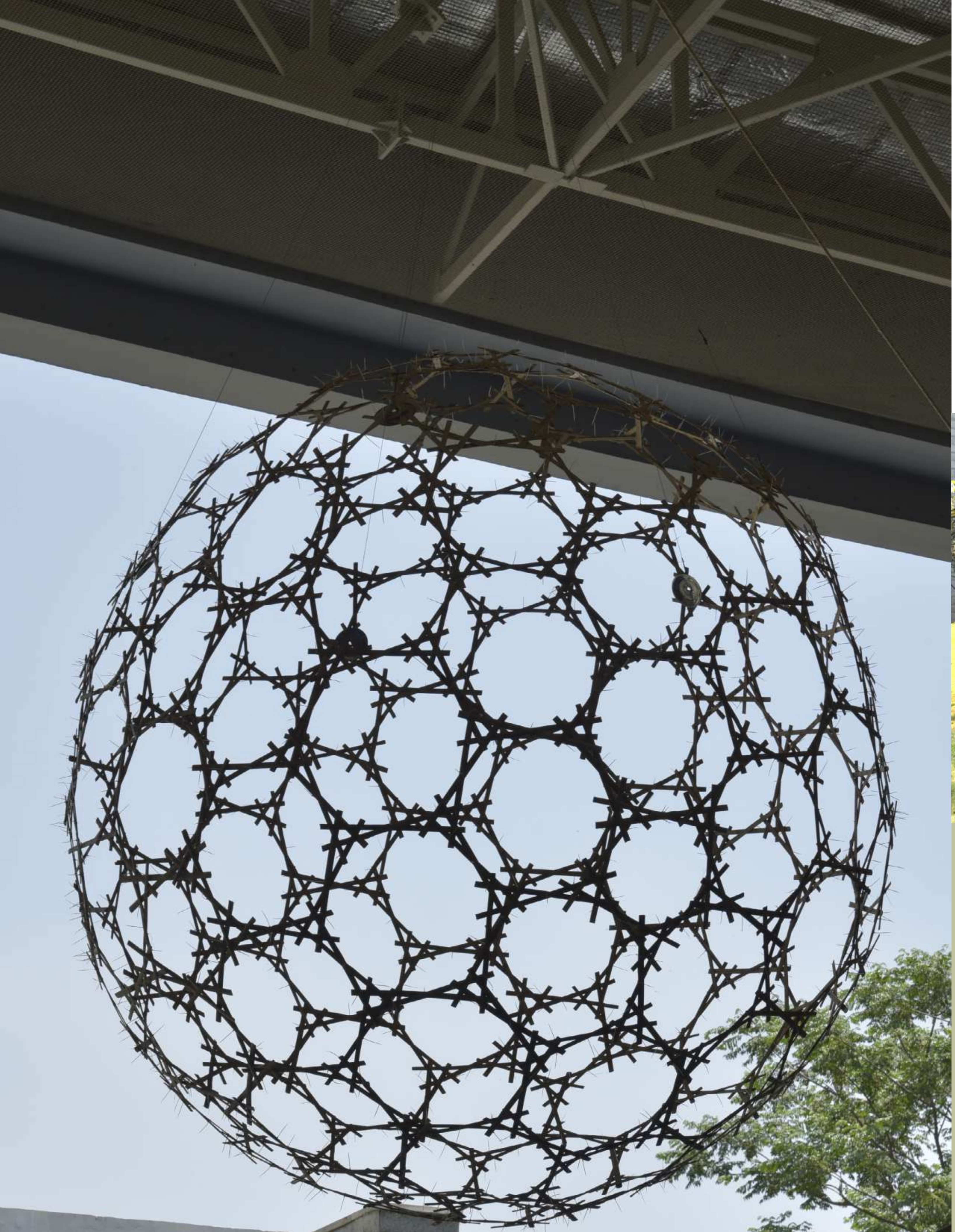
RESEARCH REPORT

Rajaram NITYANANDA

Rajaram Nityananda's research during the period of the report is summarised below.

The work on closure invariants for polarised radio interferometry with Joseph Samuel and Vinay Kumar was completed and published [J. Astrophys. Astr. (2025) 46:56]. This work was itself a continuation of a gauge theory approach developed with Samuel and Nithyanandan Thyagarajan, now generalised to an incomplete graph. The problem of computing the likelihood function for the data, in the form of closure invariants, given a model, was not solved. This is required in implementations of Bayesian inference for model parameters. The difficulty is that the probability distribution of the noise on these invariants is highly correlated and non gaussian, and needs to be recomputed every time the model is updated, by direct simulation and sampling of a high dimensional probability distribution.

The following alternative was explored. The underlying measurements of Fourier components of the visibility, although corrupted by unknown gain parameters, have gaussian uncorrelated noise. A formulation was therefore developed using only these measurements, which greatly reduces the computational effort needed to compute the likelihood function. In conventional statistical terminology, this can be viewed as maximising with respect to unknown 'nuisance parameters' about which the data tell us nothing. It also has an interesting analogy with a classic work on Euclidean field theory by Parisi and Wu which chooses not to fix the gauge at all. This is being prepared for publication.



RESEARCH REPORT

STATISTICAL PHYSICS AND CONDENSED MATTER

FACULTY

Subhro Bhattacharjee ◈ Chandan Dasgupta *(ICTS Endowed Visiting Professor)* ◈ Abhishek Dhar ◈ Deepak Dhar *(INSA Distinguished Professor)* ◈ HR Krishnamurthy *(ICTS Endowed Visiting Professor)* ◈ Manas Kulkarni ◈ Anupam Kundu ◈ Aavishkar Patel *(Joined 1 September 2025)* ◈ Apoorva Patel *(ICTS Visiting Professor)* ◈ Sumathi Rao *(ICTS Endowed Senior Professor)* ◈ Sthitadhi Roy ◈ Joseph Samuel *(ICTS Endowed Visiting Professor)*

POSTDOCTORAL FELLOWS

Tista Banerjee ◈ Mahesh Chandrasekhar Gandikota ◈ Amit Kumar ◈ Rekha Kumari ◈ Debojyoti Kundu ◈ Souvik Kundu ◈ Indranil Mukherjee ◈ Mainak Pal ◈ Madhumita Saha ◈ Krushna Chandra Sahu ◈ Indrajit Sau *(NPDF)*

STUDENTS

Seema Chahal ◈ Ankush Chaubey ◈ Varun Dubey ◈ Priyangshu Goswami ◈ Sparsh Gupta ◈ Manish Jain ◈ Jitendra Kethepalli ◈ Umesh Kumar ◈ Saptarshi Mandal ◈ Basudeb Mondal ◈ Atharva Sanjay Naik ◈ Harsh Nigam ◈ Bikram Pain ◈ Saurav Pandey ◈ Mahaveer Prasad ◈ Tamoghna Ray ◈ Bibek Saha ◈ Saikat Santra ◈ Alan George Sherry ◈ Sahil Kumar Singh ◈ Priyadharshini V

ASSOCIATES

Adhip Agarwala ◈ Bijay Agarwalla ◈ Sumilan Banerjee ◈ Urna Basu ◈ Shailesh Chandrasekharan ◈ Debasish Chaudhuri ◈ Kedar Damle ◈ Sourin Das ◈ Sreejith GJ ◈ Sarang Gopalakrishnan ◈ Jedediah H. Pixley ◈ Yasir Iqbal ◈ Prashant Kumar ◈ Mahesh Bandi ◈ Junaid Majeed Bhat ◈ Subroto Mukerjee ◈ Ganapthy Murthy ◈ Shobhana Narasimhan ◈ Archak Purkayastha ◈ Shankar R ◈ Sanjib Sabhapandit ◈ Srikanth Sastry ◈ Arnab Sen ◈ Herbert Spohn

RESEARCH REPORT

Subhro BHATTACHARJEE

During 2024–2025, Subhro Bhattacharjee's group focussed on several core areas: novel quantum phases of matter (including spin liquids and correlated metals), emergent low-energy phenomena, and the interplay of spin, orbit, and charge degrees of freedom under strong interactions. These contribute to a deeper understanding of materials with unconventional electronic phases.

In particular, building on their previous work, Bhattacharjee and collaborators investigated the fate of non-trivial embedding of microscopic (lattice level) symmetries in the low energy (continuum) effective field theories due to strong spin-orbit coupling in context of a class of honeycomb transition metal halides where they studied the nature of both the intermediate coupling superconducting phases as well as strong coupling insulating phases. With regard to the superconductor, they obtained the entire classification of charge-2e superconductors that are allowed by symmetry in the ensuing SU(8) spin-orbit coupled Dirac semimetal. For the insulating phases, they showed that in the natural spin-liquid candidates — U(1) Dirac spin liquids — the intertwining of real and spin spaces leads to novel symmetry fractionalisation in the spin liquids that leads to characteristic experimental signatures in the dynamic spin-structure factor measured in neutron scattering.

In a separate work, Bhattacharjee also proposed a class of variational wave functions for strongly correlated metals that lack low energy landau quasiparticles. Such wave functions, in one dimension, capture the properties of the Tomonaga-Luttinger liquid and provide computational tools to capture non-Fermi liquid behaviour and strong correlation effects via momentum space diagonalization. In two dimensions, these wave functions interpolate between the phenomenology of fermi-liquid and a non-fermi liquid via superposition of fermi surfaces at a constant filling.

Apart from the above research in correlated quantum condensed matter, Bhattacharjee and collaborators investigated aspects of classical many-body chaos and emergent tensor electromagnetism in granular solids. With regards to the former, they applied their recently developed ideas of characterising many-body chaos to study the Reynolds number scaling of the Lyapunov exponent in classical fluids with fully developed turbulence. For the latter, they revealed the effect of microscopic length scales in gauge theoretic description of the mechanical response of granular solids (previously developed by us) to obtain a more quantitative characterisation of the same near the unjamming transition. The above research was conducted in collaboration with students and postdoctoral fellows at ICTS as well as other researchers in India and abroad.

RESEARCH REPORT

Chandan DASGUPTA

Chandan Dasgupta's research during the last two years can be summarised as below.

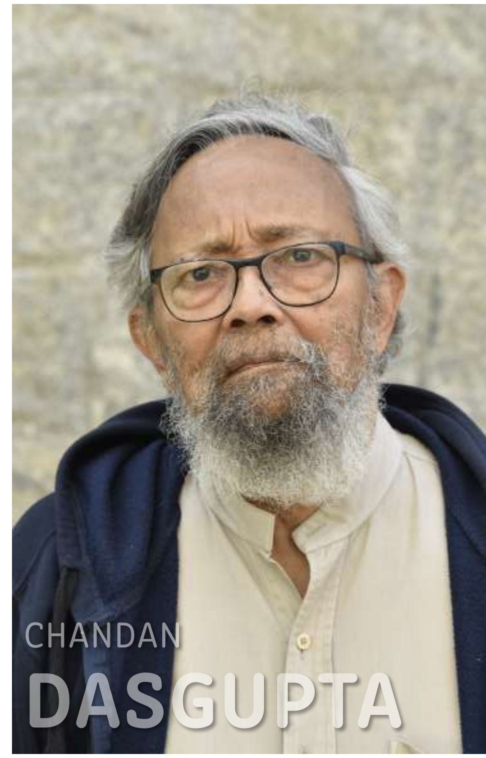
Active Systems

Several properties of active systems consisting of objects that can convert energy from environmental or internal sources to systematic motion were studied. The nature of motility-driven glassy dynamics in confluent cell monolayers was elucidated. Dasgupta and collaborators extended their earlier study of the dynamics of dense active liquids, based on the random first-order transition theory, to glassy behaviour in models of confluent cell monolayers [Soft Matter 20, 6160]. The slowing down of the dynamics in such models was shown to be well-described by the mode coupling theory [Phys. Rev. E. 111, 054416]. The crystal to liquid crossover in a one-dimensional system of active particles with inverse-square power-law interactions [J. Stat. Phys: Theory and Experiment, 033203] was analysed.

Dasgupta's ongoing work [arXiv:2509.00376] shows that the liquid and jammed states of persistent active matter in which the directions of the self-propulsion forces do not change with time are qualitatively different from those of passive systems. Velocity correlations in the liquid state obtained for large values of the active force decay slowly with distance and the length scale associated with these correlations increases linearly with system size. The active liquid undergoes a jamming transition as the magnitude of the active force is decreased below a critical value. The jamming process exhibits intermittency and a strong dependence on the system size.

Melting and Dynamics of Two-dimensional Systems

Dasgupta's study of the melting transition in a two-dimensional system of particles with random pinning [Phys. Rev. E 109, L062101] shows that a random distribution of pinning centres forces a hexatic-like low-temperature phase that transits into a liquid at a single melting transition, whereas pinning centres located at randomly chosen sites of a perfect crystal anchors a solid at low temperatures which undergoes a direct transition to the liquid. The dynamics of this system shows unusual behaviour characterised by non-Fickian diffusion and non-Gaussian distribution of displacements. Dasgupta and collaborator's work [submitted to Phys. Rev. Lett. [arXiv:2411.15654] shows that this behaviour arises from correlated motion of particles. They have also shown [Soft Matter 21, 6458] that the melting of rods confined on the surface of a sphere exhibits an intermediate hexatic phase.



RESEARCH REPORT

Abhishek DHAR

Abhishek Dhar's research during the last two years is summarised below.

The Dynamics of Entanglement During Free Expansion of a Fermionic Gas

Stephen Hawking (1975) showed that a black hole emits thermal radiation, leading to the famous paradox that the information contained in a black hole is completely lost. Don Page (1993) pointed out that the entropy of a black hole has to start decreasing at some time. The present work at ICTS considers a toy model of a gas that is released from a box into the vacuum. The authors compute the entanglement entropy between the system and the environment and show explicitly that it follows the prediction of Page, while the semi-classically computed entropy of the radiation keeps increasing. The study thus offers a possible resolution of the black hole information paradox in a simple setting. [M. Saha, M. Kulkarni, A. Dhar, Physical Review Letters 133 (23), 230402 (2024)]

In a subsequent work, the above research was extended to the case where interactions between the electrons is taken into account and it is shown that the evolution of entanglement is significantly different though the overall form of the Page curve is retained. [T. Ray, A. Dhar, M. Kulkarni, Physical Review B 112 (17), 174309]

Observation of Multiple Attractors and Diffusive Transport in a Periodically Driven Klein-Gordon Chain

This work is motivated by recent experiments on the transmission of light through an array of superconductive qubits which act effectively as nonlinear oscillators. It was observed in the experiment that there was a sharp drop in light transmission as the light amplitude was increased. Dhar's group has followed an earlier work which attempted to understand the results using a semi-classical approach. They considered an array of coupled nonlinear oscillators which is driven at one end and dissipates energy at the other end. Observing the energy flux across the chain, it was found that there is a range of parameters of the driving amplitude for which the system can be in multiple steady states. One state corresponded to a periodic one, with a high current while the other state was a chaotic one with a small value of the current. It was demonstrated that the two states were stable under addition of small noise in the dynamics. [U. Kumar, S. Mishra, A. Kundu, A. Dhar, Physical Review E 109 (6), 064124]

RESEARCH REPORT

Deepak DHAR

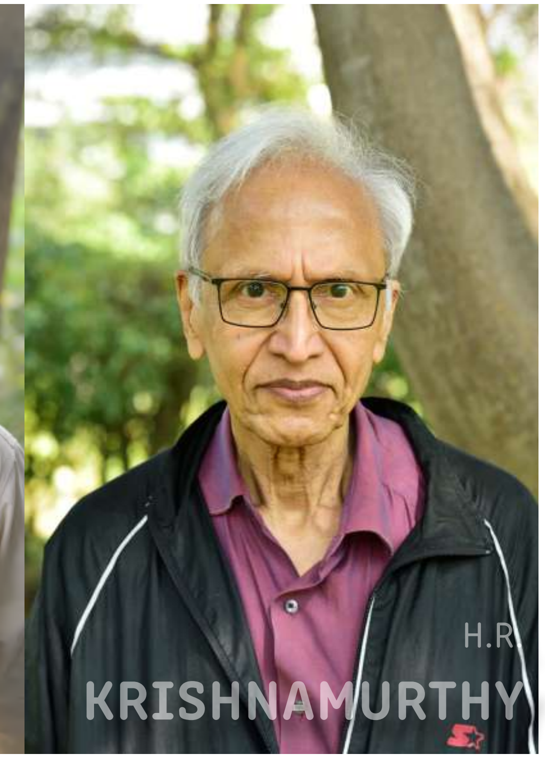
Deepak Dhar's research during the last two years is summarised below.

Dhar and collaborators presented a simple 1-d stochastic model of an interface evolution with two control parameters and a surprisingly rich zoo of phase transitions. The model is – for suitable initial conditions – in the Edwards-Wilkinson (EW) or in the Kardar-Parisi-Zhang (KPZ) universality class. These fronts can be "pushed" or "pulled", depending on the control parameters. For pulled fronts, the lateral spreading is in the directed percolation (DP) universality class, while it is of a novel type for pushed fronts, with yet another novel behaviour in between. There is also a mapping of this model to the avalanche propagation in a directed Oslo rice pile model in specially prepared backgrounds. [Physical Review E 107 (2023), 044112]

Dhar studied a system of equal-sized circular discs each with an asymmetrically placed pivot at a fixed distance from the centre. The pivots are fixed at the vertices of a regular triangular lattice. The discs can rotate freely about the pivots, with the constraint that no discs can overlap with each other. Dhar's Monte Carlo simulations showed that the one-point probability distribution of orientations has multiple cusp-like singularities. The system showed order-disorder transitions, with a disordered phase at large lattice spacings, a phase with spontaneously broken orientational lattice symmetry at small lattice spacings, and an intervening Berezinskii-Kosterlitz-Thouless phase in between. [Phys. Rev. E 108, 044110 (2023)]

Dhar and collaborators studied a one-dimensional correlated-hopping model of spinless fermions in which a particle can hop between two neighboring sites only if the sites to the left and right of those two sites have different particle numbers. This model shows strong Hilbert space fragmentation (HSF). Within this fragment, they provided numerical evidence that only a weak version of the eigenstate thermalization hypothesis (ETH) remains valid; they called this subspace-restricted ETH. To understand the out-of-equilibrium dynamics of the model, correlation functions exhibit a different behaviour near the boundary compared to the bulk. [Phys. Rev. B 110, 045418 (2024)]

Dhar and collaborators studied the asymmetric simple exclusion process (ASEP) in which particles with hard-core interactions perform biased random walks, on the supercritical percolation cluster. They studied the probability distribution in the steady state of the waiting time T_w of a randomly chosen particle, in a side branch since its last step along the backbone. The probability distribution of $\log T_w$ has multiple well separated peaks. For the percolation case, they argued that the probability that the waiting time is greater than T_w varies as $\mathrm{Prob}(T > T_w) \sim \exp(-c\sqrt{\log T_w})$ for large T. [Physical Review Letters, 134, 027102 (2025)]



In a pedagogical review article, written as a chapter in a book (100 Glorious Years of the Ising Model, edited by Prof. M. Acharyya), Dhar and collaborators provided an overview of studies of hysteresis in models of magnets. They discussed the shape of the hysteresis loop, dynamical symmetry breaking, and the dependence of the area of the loop on the amplitude and frequency of the driving field. The Barkhausen noise in the hysteresis loop may be modelled by the wide distribution of sizes of magnetization jumps in the random-field Ising model. [European Physical Journal B 98, 230 (2025)]

RESEARCH REPORT

H.R. KRISHNAMURTHY

A major research area H.R. Krishnamurthy has been engaged in for the past several years, in collaboration with Manish Jain (IISc) and his students (some of it by way of theoretical support for experiments by colleagues at IISc), involves theoretical work on the amazing properties of Moiré materials obtained when two (or more) layers of 2-D materials are twisted or strained relative to each other.

In this connection, there are two pieces of work published recently. The first [Phys. Rev. B 110, 125421 (2024)], presents sophisticated and ambitious calculations of phonon linewidths in twisted bilayer graphene near the magic-angle which leads to nearly flat electronic bands, arising from electron-phonon as well as phonon-phonon interactions. The second [Science Advances 11, 1680 (2025)] reports a study of the structural and electronic properties of strained transition metal dichalcogenide homo-bilayers. Relaxation effects distribute the imposed strain unevenly in the resulting Moiré superlattice, with the maximum strain energy concentrating at the highest energy stackings, leading to the formation of aster topological defects and tensile solitons in the order parameter distribution, in contrast to the vortex defects and shear solitons that appear in twisted TMDs, as well as causing the emergence of several well-separated flat bands at both band edges.

Another major focus of Krishnamurthy's research during the past couple of years has been to develop a theoretical understanding of the experimental work by Arindam Ghosh and his group at IISc, on systems of Ag nanoparticles dispersed in an Au matrix. [Nature Communications 16, Article # 61 (2025)] reports their experiments showing unprecedented enhancements of electron-phonon interactions in these systems together with a short account of our theoretical explanation [Phys. Rev. B 111, 184507 (2025)]. The mechanism responsible is the formation of (nearly) dipolar charge redistributions at the Au-Ag interfaces, and their strong coupling, via Coulomb interactions, with the breathing and other modes of vibration of the lighter Ag atoms caged inside the heavier Au matrix.

The same charge redistribution also leads to significant electric fields perpendicular to the Au-Ag interfaces. It was reported with experimental data together with their theoretical explanation showing that, depending on the density of the embedded Ag nanoparticles, this electric field can generate Rashba spin-orbit interaction with coupling strength of up to ~15 meV.Angstrom, higher than any known system preserving bulk inversion symmetry globally, and up to ~20 times increase in the spin-orbit scattering rate. [Science Advances 11, 1680 (2025)]

In another set of projects with Manish Jain and his students, Krishnamurthy is involved in the development of new techniques to facilitate the calculation of excited state properties in molecules and solids, in particular excitons, biexcitons and trions. [J. Chem. Theory Comput. 21, 12162 (2025), Phys. Rev. B 112, 245127 (2025)]

The first publication [J. Chem. Theory Comput. 21, 12162 (2025)] discusses two configuration interaction (CI) based methods for the calculation of double-excitations in organic molecules that are of significant interest as a result of their importance in singlet fission and photo-physics, namely screened configuration interaction singles and doubles (scrCISD) and screened configuration interaction singles with perturbative doubles (scrCIS(D)), applied to an effective many-body Hamiltonian that incorporates screening. For Thiel's set of molecules, whose excitations are predominantly singly excited, Krishnamurthy and collaborators found that the scrCISD method systematically underestimates the excitation energies compared to the best theoretical estimates, while the scrCIS(D) method shows good agreement with these estimates. However, for states with significant double excitation character – e.g. as in singlet fission chromophores - the scrCISD method performs well.

The second publication [Phys. Rev. B 112, 245127 (2025)] presents a symmetry-based framework for the analysis of excitonic states in crystalline semiconductors incorporating both time-reversal and space-group symmetries, and using them to obtain exciton eigenstates at symmetry-related center-of-mass momenta in the entire Brillouin zone from eigenstates calculated for center-of-mass momenta in the irreducible Brillouin zone. Furthermore, by explicitly calculating the irreducible representations of the little groups, Krishnamurthy and collaborators classified excitons according to their symmetry properties across the Brillouin zone. The framework enables significant reductions in computational cost in the calculation of optical spectra, exciton-phonon interactions, and excitonic band structure across a wide range of materials.

RESEARCH REPORT

Manas KULKARNI

The brief summary of Manas Kulkarni's research during the last two years is below.

Kulkarni worked extensively on spectral properties and random matrix approaches to both Hermitian and non-Hermitian systems. This includes studies of spectral form factors of various kinds, Lax random matrices from Calogero systems, and diagnostics based on complex eigenvalues and singular values. Through these works, he analyzed chaos, universality, and dissipation, as well as the classification of spectral phases. He also worked on assessment of spectral phases of non-Hermitian quantum systems through complex and singular values. He worked extensively on higher-order gap ratios of singular values in open quantum systems.

Kulkarni worked extensively on entanglement dynamics in closed, open, and monitored quantum systems. He studied Generalised Hydrodynamics description of the Page curve-like dynamics of a freely expanding fermionic gas. He investigated extreme dynamics and relaxation of quantum gases using a hydrodynamic approach. In works on Page-curve–like dynamics, quantum trajectories, and number entropy, he studied how entanglement and information evolve in interacting and free fermionic systems, and under measurements, dephasing, or defects. He extensively studied Page curve-like dynamics in interacting quantum spin chains.

There was work done on stochastic resetting and controlled dynamics in both classical and quantum contexts. His contributions include localization of information via stochastic resetting, control of spatiotemporal chaos, quantum resetting–induced entanglement, and adaptive search strategies such as proxitaxis. These works demonstrated resetting as a versatile mechanism to engineer correlations, optimize search, and mitigate chaos. He worked on a new search strategy called proxitaxis that is an adaptive search strategy based on proximity and stochastic resetting. He also studied ergodic and chaotic properties in Tavis-Cummings dimer: quantum and classical limit.

Kulkarni worked on emergent correlations in many-body systems, including frequency quenches and switching harmonic traps. These studies, combining theory and experiment, revealed strong dynamically generated correlations, interesting results on full counting statistics and extreme value statistics. He closely worked in an experimental collaboration involving evidence for strong emergent correlations between particles in a switching trap.

He worked extensively on non-Hermitian and open quantum systems, focusing on transport, injection of particles, dephasing, loss, and gain. His research addressed transport in open systems with lossy channels, long-ranged couplings, and dephasing probes, as well as anomalous transport near band edges and exceptional points. These studies clarified how openness and non-Hermiticity, along with presence of exceptional points modify nonequilibrium steady state transport. He studied arbitrary order transfer matrix exceptional points and van Hove singularities. He also investigated the impact of dephasing probes on incommensurate lattices.

RESEARCH REPORT

Anupam KUNDU

During the period of the report, Anupam Kundu's research has mainly involved studies on the following topics: hydrodynamic approach to understand equilibration and correlations in many particle integrable (or nearly integrable) systems, equilibrium properties of long-range interacting systems, active particles, stochastic processes and stochastic resetting.

Hydrodynamics and Transport in Low-dimensional Systems

Interest in Hydrodynamics and Generalized Hydrodynamics (GHD) in low-dimensional systems has surged over the past decade. This rise in activity is driven by both cutting-edge experiments involving cold trapped atoms and significant theoretical advancements. Key research challenges in this area include determining the correct hydrodynamic equations for specific microscopic models, clarifying the thermalization process, and characterizing the final stationary state using static and dynamic space-time correlations. Kundu's recent research has addressed some of the issues such as – Microscopic verification of generalised (Euler scale) hydrodynamics in certain integrable systems such as gas of hard-rods [Journal of Statistical Mechanics: Theory and Experiment 2024 (12), 123205 (2024)], and harmonic chain [J. Stat. Mech. 103202 (2024)], understanding thermalization in integrable systems [Journal of Statistical Physics 191 (6), 66, (2024)]. Kundu and collaborators have also formulated a large deviation theory to describe large-scale fluctuation and compute correlations among hydrodynamic observables [J. Stat. Mech. (2025) 103203]. Such a theory is then applied to study stochastic motion of quasiparticles in hard-rod systems which is further supported by microscopic analysis [arXiv:2510.19693]. They also studied how heat transport in non-linear chains gets affected by periodic driving through the boundaries. Such periodic forcing helps the system transport heat from one end to the other coherently in a certain parameter regime [Physical Review E 109 (6), 064124 (2024)].

Equilibrium Properties of Long-range Interacting Systems

Understanding the properties of many particle systems interacting via long-range potential has been a subject of immense interest in both physics and mathematics. Using a large-N field theory, Kundu's group has studied full counting statistics [Journal of Statistical Mechanics: Theory and Experiment 2024 (8), 083206, (2024)] in an equilibrium classical system of particles interacting via power law interaction. The group has also looked at how the thermodynamic behaviour changes in such systems when the range of interaction is tuned [Journal of Physics A: Mathematical and Theoretical 57 (24), 245003, (2024)]. An extension to non-equilibrium setting has also been studied by considering a system of active particles interacting via power law interaction. Kundu's group found that activity prints a deep impact on the macroscopic properties of the system. [Journal of Statistical Mechanics: Theory and Experiment 033203 (2025)]

Kundu and collaborators have also found a remarkable class of random matrices rooted in the elegant mathematical framework of classical integrable systems, for example, the Calogero family of models. These random matrices naturally arise from Lax matrices associated with integrable systems. The central agenda of this study was the fundamental question about the distribution of eigenvalues [Journal of Statistical Mechanics: Theory and Experiment 2025 (3), 033101]. In this paper, they have shown that the rich interplay between integrability and randomness, allows one to reinterpret the problem as a generalized form of well-known random matrix models.

Tracer Particle Diffusion in Active Systems

The motion of a tagged particle in one dimension gets hemmed in by the presence of other particles and hence moves sub-diffusively. What happens to the motion of the tracer particle if the medium is active? This question is addressed in a recent work of Kundu's group [Journal of Statistical Mechanics: Theory and Experiment 2024 (6), 063204, (2024)], where it has been shown that the motion of the tracer particle is subdiffusive. However, in contrast to the passive medium, the coefficient contains contributions from higher-order microscopic correlations which cannot be captured by an effective hydrodynamic description.

Stochastic Process and Stochastic Resetting

While studying macroscopic properties of many interacting systems is crucial for broader application, it is equally important to understand the dynamics of individual particles as well. Such microscopic studies often guide one to build intuition to describe large-scale motion at collective level. Kundu and collaborators have studied the stochastic motion of single active particles in one dimension trapped [Physical Review E 110 (4), 044107, (2024)] or not trapped [Journal of Nonlinear Science 35 (3)]. They mainly looked at the effect of inertia on the motion of the active particle. Such models of inertial active motion have recently been useful to describe motion of active robots, insects, Janus particles etc.

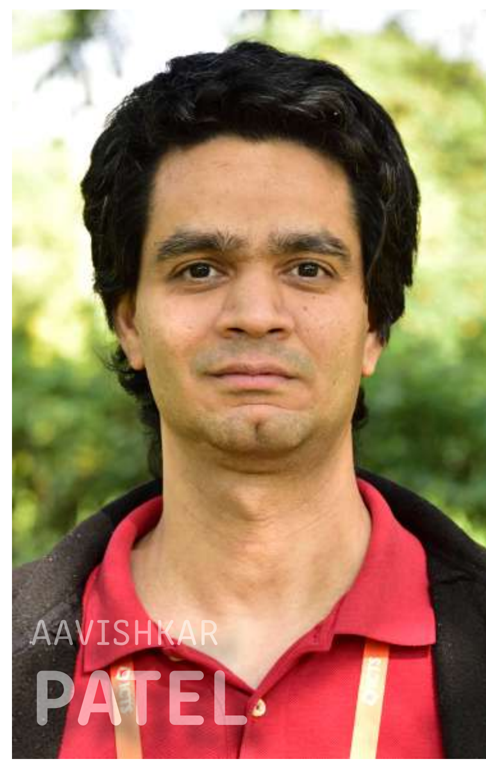
Kundu also studied geometric properties of passive (non-active) particle trajectories. In particular, he and his collaborators have found analytical results on the statistics of the number of minima in a random-walk trajectory either to fixed time [Physical Review E 110 (2), 024137, (2024)] or till the first passage time

[Journal of Physics A: Mathematical and Theoretical 58 (3), 035002]. Most of the theoretical studies of stochastic resetting so far have focussed on instantaneous resetting which is, however, a major impediment to practical realisation or experimental verification in the field. In recent work, Kundu and collaborators have shown that stochasticity in returns can expedite classical first passage under resetting. [Physical Review E 110, L042110, (2024), Physical Review E 111 (1), 014142, (2025)]

As a leading researcher, Kundu was invited to serve as a guest editor of a special issue in JPhys A on stochastic resetting. He has written a preface to the special issue on the topic by providing the current status to the subject and possible future directions. [Journal of Physics A: Mathematical and Theoretical 57 (6), 060301, (2024)]

RESEARCH REPORT

Aavishkar PATEL



Aavishkar Patel has focussed heavily on the theoretical underpinnings of strange metals, quantum criticality, and non-Fermi liquid behavior in strongly correlated electron systems in 2024 and 2025. A primary theme of his work during this period is the role of spatially random interactions (disorder) in generating strange metal behavior. In 2024 and 2025, Patel and collaborators expanded upon a "universal theory" of strange metals, demonstrating how microscopic irregularities in materials can modify electron interactions to produce the linear-in-temperature resistivity characteristic of these exotic phases. Key contributions and papers from 2024–2025 are summarised below.

Disorder and Transport in Strange Metals

In Proceedings of the National Academy of Sciences (2024), Patel published work on the localization of overdamped bosonic modes, exploring how transport properties are affected when the critical modes mediating electron interactions become localised by disorder. This was followed by a 2025 study in Physical Review X titled "Strange Metals and Planckian Transport in a Gapless Phase from Spatially Random Interactions", which argued that strange metallicity can arise from a gapless phase with antiferromagnetic fluctuations lacking long-range correlations, rather than solely from a quantum critical point.

Yukawa-SYK Models and Superconductivity

Extending the Sachdev-Ye-Kitaev (SYK) framework to two dimensions, Patel co-authored a Physical Review Letters (2024) paper investigating the Yukawa-SYK model. This research analyzed the competition and coexistence between strange metal behavior and superconductivity, providing insights into how high-temperature superconductors might emerge from non-Fermi liquid normal states.

Quantum Phase Transitions

In 2025, he investigated Fermi-volume-changing quantum phase transitions, publishing findings on thermopower in Physical Review B. This work addressed how thermodynamic properties evolve across transitions between Fermi liquids and "fractionalised" phases without symmetry breaking, relevant to the pseudogap phase of cuprates.

Hubbard Model Extensions

His Physical Review Letters (2025) paper titled "Enhanced Strange Metallicity due to Hubbard-U Coulomb Repulsion" incorporated strong local Coulomb repulsion (Hubbard U) into theories of strange metals, showing that such interactions can stabilize and enhance the strange metal regime.

Overall, Patel's research in 2024–2025 has been instrumental in moving the field of non-Fermi liquids beyond the traditional "patch" theories, emphasizing that realistic

RESEARCH REPORT

Apoorva PATEL

During the last two years, Apoorva Patel has worked on the following problems.

Understanding Nature's Selection of Genetic Languages

All living organisms use two universal genetic languages in their molecular biology machinery, one containing four nucleotide bases in its alphabet, and the other containing twenty amino acids in its alphabet. These can be understood as the optimal encodings of genetic information for the tasks they carry out, i.e. replication/transcription for DNA/RNA and translation for polypeptide chains. These tasks select needed letters of the alphabet by complementary nucleotide base-pairing, from a collection of molecules in the cell. The computer science paradigm for this process is a database search; various algorithms for it can be constructed and compared according to the number of attempts (or queries) they need to make to find the correct nucleotide base-pairing. Grover's search algorithm, based on oscillatory wave dynamics, perfectly fits the number of queries needed to search the genetic alphabets, and it is more efficient than the best Boolean search algorithm (i.e. binary tree search) that needs a larger number of queries. This result strongly suggests that the universal genetic languages have been selected by evolution as the optimal alphabets for the tasks they carry out, and are not accidents of history. The outstanding challenge is to demonstrate how Grover's search algorithm would be executed in vivo by the living organisms. [BioSystems 250, Article 105428 (2025)]

Limitations of Quantum Advantage in Unsupervised Machine Learning

Machine learning models are used for pattern recognition analysis of big data, without direct human intervention. The task of unsupervised learning is to find the probability distribution that would best describe the available data, and then use it to make predictions for observables of interest. Classical models generally fit the data to Boltzmann distribution of Hamiltonians with a large number of tunable parameters. Quantum extensions of these models replace classical probability distributions with quantum density matrices. An advantage can be obtained only when features of density matrices that are absent in classical probability distributions are exploited. Such situations depend on the input data as well as the targeted observables. Explicit examples are discussed that bring out the constraints limiting possible quantum advantage. The problem-dependent extent of quantum advantage has implications for both data analysis and sensing applications. [Proceedings of the 2025 IEEE International Conference on Quantum Control, Computing and Learning, Hong Kong, June 2025, pp. 39-42 (2025)]

RESEARCH REPORT

Sumathi RAO

In the last couple of years, Sumathi Rao has worked on edge states of quantum Hall systems and Majoranas, helical Luttinger liquids, bilayer and twisted bilayer graphene and Weyl semimetals. She has also been studying some aspects of quantum computation and most recently, she has started working on altermagnetism, a phase which includes aspects of both ferro and antiferromagnetism.

Rao and collaborators studied edge reconstruction in a quantum Hall system and found that a smooth edge potential could lead to edge reconstruction of a $\nu = 1$ QH state, resulting in an additional $\nu = 1/3$ QH side strip, which, in turn, may yield either Majorana or parafermion zero modes at the domain wall of the superconductor and ferromagnet on the edge. They studied the two-channel Kondo problem in the context of two interacting helical liquids coupled to a spin−1/2 magnetic impurity and showed that the interactions between the two helical liquids could significantly affect the phase diagram and other observable properties. They studied magnon transmission across gate-controlled junctions of graphene in the $n = 0$ manifold of Landau levels, in the presence of both spin and valley Zeeman fields. Specifically, they considered the $\nu = 1| - 1|1$ sandwich geometry. Using the Hartree-Fock approximation, they found that either the spin or the valley degrees of freedom of the occupied one-body states rotate across the interfaces. If the interfaces exhibit spin rotation, magnon transmission is suppressed at high energies, while if the interfaces have valley rotation, magnon transmission becomes perfect at high energies. Their analysis, along with the experimental measurements, can be used to determine the anisotropic couplings in the sample.

More recently, Rao has focussed on twisted bilayer graphene. As is well-known, twisted bilayer graphene at the magic angle has flat bands and leads to a plethora of phases experimentally. While most of the theoretical studies have focussed on including Coulomb interactions, Rao and collaborators have tried to include short-range interactions systematically to distinguish between correlated states which are close by energetically. They have expanded their interest to Moiré bilayers where the low energy Dirac point lies at the M-point of the Brillouin zone, instead of the K or K′ points. They investigated magnetotransport across an interface between two Weyl semimetals (finite in both directions) whose Weyl nodes projected onto two different surfaces which are twisted with respect to each other before being coupled. This gave rise to a novel contribution to the conductance through the junction purely through Fermi arc states, even in the absence of a magnetic field perpendicular to the junction. When the perpendicular magnetic field was included, they found that for mesoscopic or smaller samples, the transverse Fermi arc states had a significant contribution to the conductance for experimentally relevant fields. They also investigated the transport properties of thin-film Weyl semimetals using linear response theory. Specifically, they studied the temperature dependence of the Drude peak and the low-frequency characteristics of the conductivity within the first-order Born approximation, in the presence of weak disorder. They also investigated the dimensional crossover of the conductivity in different ranges of frequencies in terms of the scaling rule with respect to the disorder strength and compared it with the one dimension, two dimensions, and three-dimensional cases separately.

Rao is also working on understanding transport via Fermi arcs in thin films of Weyl semimetals in the presence of periodic driving using Floquet theory. She shed light on a Dirac semi-metal and broke time-reversal invariance to get Weyl nodes and then studied the transport signatures of Floquet induced surface states. She has also been looking at some problems in quantum dynamics - more specifically looking for operator probes such as the growth of entanglement, coherence and magic in various Hamiltonian models and also in quantum circuit models. She found that the growth of magic is able to distinguish between integrable, interacting integrable and chaotic dynamics.

RESEARCH REPORT

Sthitadhi ROY

Sthitadhi Roy's research over the last two years has centered on providing microscopic foundations for emergent phenomena such as thermalization, its breakdown in the Many-Body Localised (MBL) phase, and the complex process of quantum information spreading (scrambling). The work has been structured around two primary themes: Thermalisation, Many-Body Localisation (MBL) and the Structure of Eigenstates, and Projected Ensembles and the Structure of Entanglement therein.

Thermalisation, Many-Body Localisation, and Eigenstate Structure

This theme presents a series of theoretical and numerical advances in understanding the microscopic mechanisms governing Many-Body Localisation (MBL) and the MBL transition, particularly through the lens of eigenstate correlations and scaling theory.

The key achievement is the development of a microscopic theory for entanglement growth in the MBL regime that avoids the phenomenological l-bit picture. This theory demonstrates that the characteristic logarithmic-in-time growth of entanglement in MBL systems [Phys. Rev. B 110, 224201] and the logarithmic lightcone of entanglement spreading [Phys. Rev. B 111, 174206] are directly caused by dynamical correlations among quartets of four or more eigenstates. Specifically, the spatial structure and hierarchy of timescales/energy scales within these special quartets conspire to produce ultraslow entanglement growth, thus providing a richer spacetime picture of MBL dynamics.

This framework is extended to the general problem of information scrambling in chaotic systems. It is shown that statistical correlations among sets of at least four eigenstates of the time-evolution operator provide a unified framework for all measures of scrambling, including Out-of-Time-Ordered Correlators (OTOCs) and operator entanglement. Analytical results for minimal chaotic models (Floquet dual-unitary circuits) reveal that the eigenstates encode the full spatiotemporal anatomy of quantum chaos, including the butterfly effect and the lightcone, going beyond the traditional Eigenstate Thermalization Hypothesis (ETH). [arXiv:2507.02853]

The MBL transition itself is analyzed using a scaling theory based on emergent, characteristic energy scales derived from the spectral decomposition of eigenstates. The scaling of these energy scales across the transition is found to be consistent with a Kosterlitz-Thouless-type scenario. [Phys. Rev. B 111, 184201] Furthermore, new classes of models are introduced that host robust and unusual multifractality induced by disorder correlations (termed "radial disorder" on graphs like trees and hypercubes). This multifractality is shown to arise from an interplay between conventional Anderson localization on emergent one-dimensional chains and the exponential growth of sites, revealing that the typical Inverse Participation Ratio (IPR) is the appropriate diagnostic quantity. [Phys. Rev. B 112, 184202]

Projected Ensembles and the Structure of Entanglement

This theme explores deep thermalisation — a stronger form of ergodicity — and quantum correlations using projected ensembles (PEs), which are ensembles of pure states on a subsystem conditioned on projective measurements on its complement.

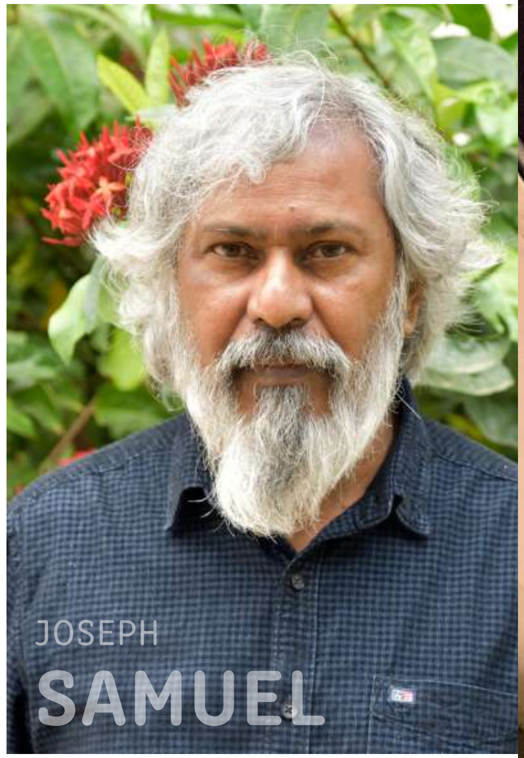
The research establishes the Projected Ensemble (PE) as a higher-order probe of thermalization and information structure. In strongly disordered MBL systems, the PE (constructed from time-evolved states) is found to converge to a Scrooge ensemble at late times, except when the measurement basis is close to the conserved charges. This is contrasted with ergodic systems and is linked to the emergence of the Porter-Thomas distribution in measurement probabilities. [Phys. Rev. B 111, 144302]

A new paradigm, the Partial Projected Ensemble (PPE), is introduced to study the imprints of spatiotemporal scrambling on ensemble structure. The PPE consists of mixed states induced by measuring a spatially separated part of the complement and tracing out the remainder (discarded outcomes). Statistical fluctuations of the PPE are shown to faithfully track the causal lightcone (linear in ergodic systems, logarithmic in MBL systems), demonstrating its power as a probe of scrambling dynamics and deep thermalisation [arXiv:2508.05632]. The associated probabilities of bit-string probabilities (PoPs) are also introduced as an experimentally accessible diagnostic.

Furthermore, another work reveals the existence of three distinct dynamical phases characterised by qualitatively different quantum correlations between two disjoint subsystems. A new phase transition is identified within the entangled phase, separating correlations that are invisible or visible to measurements on one subsystem. [Phys. Rev. B 111, L180301] This concept is rigorously formalised using the Holevo information in the generalised partial projected ensemble framework, leading to an information-phase diagram for Haar-random states. This diagram reveals a phase where the Holevo information decays exponentially with system size, rigorously establishing a measurement-invisible, quantum-correlated phase — a new manifestation of scrambling with no bipartite analogue. [arXiv:2511.10595] Finally, a new paradigm for deep thermalisation in mixed initial states is introduced, distinct from the pure-state framework, where the deep thermal ensemble arises from tracing out auxiliary degrees of freedom from a maximum-entropy ensemble on an augmented system. [arXiv:2507.14135]

RESEARCH REPORT

Joseph SAMUEL



Joseph Samuel's research during the last two years is summarised below.

Closure Invariants for Polarised Radio Interferometric Observations: A Graph Theoretical Approach

Aperture synthesis observations with full polarisation have long been used to study the magnetic fields of synchrotron emitting sources. Recently proposed closure invariants give us a powerful method for extracting information from measured visibilities which are corrupted by antenna and polarisation dependent gains. In this paper, a formalism developed earlier for complete graphs (where all visibilities are available) is extended to incomplete graphs. The formalism provides a complete and independent set of closure invariants from the measured visibilities in a general situation where not all visibilities are available. Samuel, with Rajaram Nityananda and Vinay Kumar, showed in a simulated, quasi-realistic case that the invariants developed here contain usable information even in the presence of noise.

Analogue Fluid Experiment for Rotation in General Relativity

A recent laboratory experiment studying ripples around a vortex reveals a curious feature: nodal lines in the ripples appear to rotate like the blades of a propeller. Samuel and Mahesh Bandi's group at OIST used this analogy to view this fluid dynamics experiment through the lens of general relativity. They showed that the analogue experiment exhibits the Lense-Thirring effect of frame dragging in the behaviour of ripples. They applied the general principles of symmetry, coordinate invariance and topology to gain an understanding of the nodal lines that form the blades of the propeller. The nodal lines are understood in terms of wave-front dislocations described by Nye and Berry. Their rotational angular velocity is as predicted by the Lense-Thirring effect. A general insight that follows from the treatment is that the problem of ripples in a gradient flow can be reduced by coordinate transformations to ripples in still water.

Spin, Statistics and the Geometric Phase

The spin-statistics theorem has a long history and acquired a variety of proofs, with different assumptions. However, the consensus is that one does not yet understand the spin-statistics connection in its most elementary form. Here Samuel tried to fill this gap by giving an intuitive, topological proof based on the idea that the histories of spinning elementary particles can be modeled as ribbons. This idea was then shown to emerge from group theoretical and geometric considerations. In a quantum theory, elementary particles can be described by Unitary Irreducible Representations (UIRs) of an invariance group G, which in this paper, was the Poincare group. This identifies the classical phase space of the system as the space of co-adjoint orbits of G. The quantum phase space of the system was based on Perelomov coherent states. The spin and statistics emerged naturally from geometric phase arguments and are shown to be identical.

Photo credit: Godwin Martin

Photo credit: A. S. Sumukh.

RESEARCH REPORT

FLUID DYNAMICS AND TURBULENCE

FACULTY

Rama Govindarajan ◈ Samriddhi Sankar Ray ◈ Debasis Sengupta (*ICTS Endowed Visiting Professor*) ◈ Jim Thomas (*Joint Faculty with TIFR-CAM, Bengaluru*)

POSTDOCTORAL FELLOWS

Prateek Anand ◈ Sanjay CP ◈ Subham Ghosh ◈ Suruj Jyoti Kalita ◈ Dylan James Reynolds ◈ Durbar Roy ◈ Arun Kumar Varanasi

STUDENTS

Mayank Kumar Bijay ◈ Rajarshi Chattopadhyay ◈ Anwesha Dey ◈ Divya Jaganathan ◈ Harshit Joshi ◈ Anikat Kankaria ◈ Saumav Kapoor, ◈ Anup Kumar ◈ Ritwik Mukherjee ◈ Mrinal Jyoti Powdel ◈ Rukmani R ◈ Mukesh Singh Raghav ◈ Sandip Sahoo

ASSOCIATES

Narayanan Menon ◈ Jason Picardo ◈ Mahendra Verma

RESEARCH REPORT

Rama GOVINDARAJAN

Rama Govindarajan's research during the last two years is summarised below.

Small Particles in Flow

Understanding the dynamics of small particles in flow is important for a range of applications: from dust storms to clouds. Since these flows are impossible to solve directly, we need to use analytical and semi-analytical methods, and also innovative descriptions. Govindarajan and her group's efforts are described below.

Particles in Stokes flow come in many shapes, but are almost always approximated as spheres or spheroids. Harshit Joshi asked what happens if you remove just one more symmetry of the particle and make it a "di-bilateral". He showed that these particles can be drifters, settlers or flutterers depending on their shape, and a Floquet analysis can show when the dynamics is quasiperiodic. This is very different from what a spheroid would do. Harshit and former student Rahul Chajwa, theoretically and experimentally, showed a clear boundary between clumping and pairing behaviour in cooperatively settling spheroids.

Continuum descriptions of particles in flow fail when caustics (collisions) occur. And the consequences of caustics in coalescence and big changes in overall dynamics which ensue are missed. There are some recent studies which are able to take a continuum description all the way to caustics, i.e., to where the divergence in the particle velocity field diverges. These studies are all for infinite particle density (heavy particle limit). Rajarshi has extended this description to account for finite-density particles and shown how lower-density particles need to enter regions of larger strain in 2D turbulence to form caustics. Further he was able to distinguish the difference in physics between "survivor" particles which enter such strain regions and yet do not form caustics and those that do.

Dylan Reynolds has built a continuum description of interacting particles, which makes it possible to carry out stability analyses for a variety of particle-laden flows.

Durbar Roy has created an experiment to study underwater sand dunes including Particle Imaging Velocity measurements. He combined experimental findings with theoretical descriptions to understand the dynamics of sand dunes.

In work done with collaborators at IITM Pune, Govindarajan's group showed evidence for our older hypothesis of cloud turbulence: of particle inertia leading to inhomogeneous temperature, and thence to increased small-scale turbulence.

A collaboration with Tomek Jaroslawski and Beverley McKeon at Stanford showed why it is not always a good idea to use the high-school Stokes flow formula for a tiny falling sphere.

Dynamics of Larger Ellipsoids in Fluid

Andrew Boyd, working with Prashant Valluri and Govindarajan, has shown that two spheroids in inviscid flow can execute chaotic dynamics, whereas a single spheroid cannot.

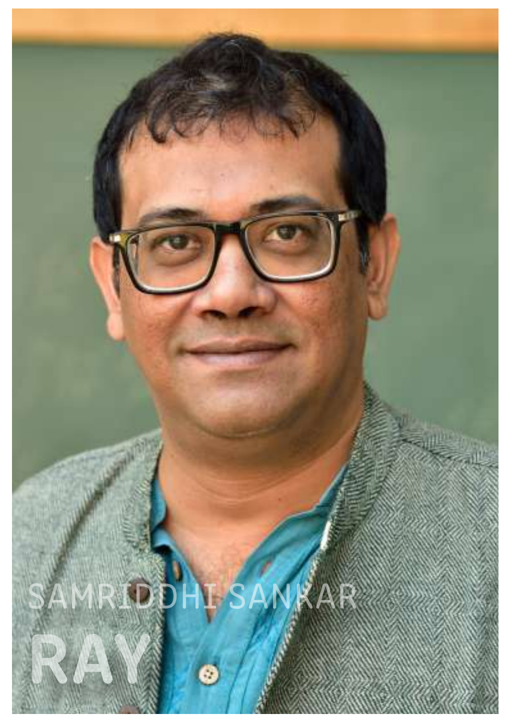
Viscosity-varying Flow

A collaboration with Arjun Sharma and others showed that there is a very rich phase space displayed by just a particle in viscosity-gradient falling under gravity.

In a collaboration with Anagha Madhusudanan and Simon Illingworth, Govindarajan showed how viscosity variation fundamentally alters the lift-up mechanism which creates streamwise invariant structures in shear flow.

RESEARCH REPORT

Samriddhi Sankar RAY



The work of Samriddhi Sankar Ray during the period of the report can be summarised broadly as follows.

Intermittency in High and Low Reynolds Number Turbulence

A central strand of this body of work concerns the geometry, origin, and consequences of intermittency in turbulent flows. In particular, the authors demonstrate [Physical Review Letters 132, 184002 (2024)] that multifractality in turbulence is spatially heterogeneous, overturning the conventional assumption of uniform multifractal scaling. By introducing local coarse-graining tools, they show that regions with identical global Reynolds numbers can exhibit markedly different singularity spectra, thereby identifying intermittency patches as fundamental structural units of turbulence.

More recently, they also find a link between intermittency and the Lyapunov properties of turbulent flows [arXiv:2505.09538] and how such extreme fluctuations determine the scaling of finite-time Lyapunov exponents with Reynolds number and help explain why classical mean field arguments fail. This work provides an important bridge between modern ideas of many-body chaos and turbulence.

The universality of intermittency — going well beyond conventional wisdom of longitudinal and transverse structure functions — is explored [arXiv: 2511.06439] through a class of correlation functions which probe the geometry of fully developed turbulence. In particular, the authors succeed in uncovering ways in which a form of incipient mutliscaling, even in the inverse cascade of two-dimensional turbulence, can be unearthed.

Intermittency also plays a role in dense bacterial, low Reynolds number suspensions. The authors uncover [Physical Review Letters 134, 088302 (2025)] how active stresses, rather than inertial cascades, trigger the first appearance of intermittent multiscale events in low-Reynolds-number active turbulence. They identify a threshold in activity beyond which non-Gaussian fluctuations and multiscaling suddenly appear.

Particles in Turbulence

Two papers during this period focus on how particulate matter interacts with turbulence. One of them [Journal of Fluid Mechanics 1009, A69 (2025)] is a high-resolution study of non-spherical particles transported by turbulence while settling under gravity. The work shows that turbulence can strongly modify orientational dynamics leading to non-trivial clustering and collision properties crucial for cloud microphysics and industrial suspensions.

The role of two-way coupling is also examined and the authors demonstrate [ArXiv: 2510.10463] that feedback from particles to the flow dramatically alters cascade properties, generating modified enstrophy fluxes and new regimes of clustering. They identify parameter ranges where two-way coupling is essential and regimes where it can be safely neglected, clarifying long-standing ambiguities in dusty-gas modelling.

Geophysical Flows

Samriddhi's group also study the turbulent deformation of scalar interfaces on a β-plane and show [arXiv: 2507.23493] that mid-latitude planetary turbulence generates rough, scale-dependent interface fluctuations, whose statistics encode jet–eddy interactions. The work connects interface roughness with barotropic cascade properties, providing a new perspective on mixing barriers in geophysical flows and the multifractal nature of interjet interfaces.

In a very different context of geophysical flows, Samriddhi and collaborators derive a general d dimensional closure model to uncover [arXiv: 2408.01266] an upper and lower critical dimension, above and below which small-scale dynamo action is suppressed. Though theoretical, this result has implications for magnetised astrophysical turbulence and highlights how dimensionality shapes large-scale geophysical and astrophysical magnetic-field generation.

Finally, many of these ideas were extended [arXiv: 2509.00399] to hydrodynamic quantum gases, uncovering extreme-events, shock-like structures, and their relaxation.

RESEARCH REPORT

Debashis SENGUPTA

Since joining ICTS, Debashis Sengupta's research has focussed on the following:

Strong winds and convection due to surface heat loss enhance upper ocean turbulence during a tropical cyclone passage. Sengupta, with D. Falor, B. Gayen, and D. Chaudhuri, showed from moored observations and large-eddy simulation (LES) that a synergy between convection and vertical shear of ocean currents drives changes in the upper ocean during the passage of Cyclone Phailin, 8-12 October 2013 across the northern Bay of Bengal. This is the first detailed study of ocean turbulence and mixing processes under momentum, heat and freshwater forcing during cyclone passage. They found that under realistic time-varying surface forcing, salinity makes a significant contribution to buoyancy-forced convection and turbulent mixing in the ocean. [Geophysical Research Letters, 51(22), p.e2024GL111925]

Diurnal changes in air-sea fluxes drive changes in ocean temperature, salinity, turbulence and mixing. Moored measurements and LES show that during daytime, a shallow warm layer and salinity inversion develop in the upper 10m, leading to double diffusive salt-fingering instability. Nighttime convection due to surface cooling and evaporation (which leaves salt behind) enhances turbulence, deepening the ocean mixed layer. Sengupta, with D. Falor, B. Gayen, and G.N. Ivey, found that salinity influences convective instability during both transitions between day and night.[Ocean Sciences Meeting. American Geophysical Union]

Freshwater from rivers and rain enhances ocean stratification, influencing sea surface temperature and climate. Sengupta, with Nihar Paul, Manikandan Mathur, Jai Sukhatme, J. Thomas Farrar, used satellite-derived ocean currents to study (i) transport of low-salinity water from the Bay of Bengal to the Arabian Sea, and (ii) chaotic, eddy-mediated lateral stirring at the ocean surface. Tracer release simulations and Lyapunov exponents indicate that residence time of Bay of Bengal water in the eastern Arabian Sea is 1.5-2 months. While eddy kinetic energy in the Arabian Sea has increased by 10% in the past three decades in response to enhanced wind forcing, lateral stirring rates have grown by a modest 1-5%. [Geophysical Research Letters (in revision)].

RESEARCH REPORT

Jim THOMAS

The work of Jim Thomas during the period of the report has focussed on four specific areas. Below is a brief summary.

Submesoscale Turbulence

Submesoscales in the ocean correspond to roughly O (10 km) scales. The flow dynamics of submesoscales are relatively less understood since ocean models do not resolve them. Thomas has been pursuing research exploring wave-induced instabilities of coherent balanced vortices in submesoscale flows. This research was funded by a SERB grant and his findings have revealed the detailed mechanism by which waves can break up vortices by finite amplitude instabilities. Once instabilities kick in, vortices break up and the flow becomes fully turbulent. The dynamics of the turbulent flow at submesoscales are not straightforward to capture using simple mathematical models. With a long-term visiting student G. Krithin, Thomas explored the idea of developing data-driven-discovery based reduced partial differential equations to capture the fundamental features of submesoscale turbulent flows. [J. of Advances in Modeling Earth Systems, 16, e2024MS004438]

Wave-enhanced Tracer Dispersion

Turbulent diffusivity in the ocean is highly variable as a function of scale and understanding the details of this process is key to parameterising diffusivity in large-scale ocean and climate models. In the previous year, Thomas started exploring the role of internal waves on tracer dispersion with a long-term visiting student (Madhav Sirohi) and a postdoctoral fellow (Sanjay C. P.). They found several nontrivial results regarding the role of waves on tracer dispersion [J. of Physical Oceanography, 54, 1889–1902, JGR Oceans, 130, e2024JC021754]. This research direction was funded by a Ministry of Earth Sciences grant under the Deep Ocean Mission (DOM).

Wave Turbulence

Flows in the ocean are composed of a broad spectrum of waves that transfer energy across many decades of spatio-temporal scales. Despite this generic understanding, the detailed physical processes that assist in energy transfer of waves in a turbulent flow are still not understood. This research falls within the regime of wave turbulence and Thomas's first paper in this direction was published in the J. of Fluid Mechanics and was highlighted as a special paper under the Focus on Fluids series (Thomas and Ding 2023). Further research in this direction is being pursued and a second paper on the same theme was published [J. of Fluid Mechanics, 1000, A30]. The work that went into these papers was used to get funding from the Naval Research Board, DRDO, in 2025 to study turbulent energy cascades of internal gravity waves. This research area will be pursued for the next three years.

Data-driven Models

Thomas has been involved in developing models that can combine data-driven techniques with conventional partial differential equations for usage in geophysical turbulent flows. Mayank Kumar (PhD student) has worked with Thomas on developing neural network models for generating oceanic tracer fields with turbulent flows as input [JGR Machine Learning and Computation, 2, e2025JH000655]. Thomas is working with Souryajit Roy (PhD student) on developing neural network models that can be combined with time-evolving partial differential equations. They have successfully applied these models to acoustic scattering by turbulent eddies and work is close to completion.

RESEARCH REPORT

BIOLOGICAL PHYSICS


Photo credit: Harshith.B.S

FACULTY

Brato Chakrabarti ◈ Sarthak Chandra *(Joined 18 August 2025)* ◈ Akshit Goyal *(Simons Young Researcher & Ramanujan fellow)* ◈ Vijaykumar Krishnamurthy ◈ Shashi Thutupalli *(Joint Faculty with NCBS-TIFR, Bengaluru)* ◈ Sriram Ramaswamy *(ICTS Endowed Visiting Professor)*

STUDENTS

Diksha Arora, Vaibhavi B ◈ Naveen Kumar D ◈ Kunal Kumar ◈ Anjali Kundalpady ◈ Devadevan M M ◈ Aiswarya N S ◈ Nitesh Kumar Patro ◈ Aditya Singh Rajput ◈ Himanshu Singh ◈ Jigyasa Watwani

ASSOCIATES

Vidyanand Nanjundiah ◈ Suraj Shankar ◈ Mukund Thattai

RESEARCH REPORT

Brato CHAKRABARTI

Brato Chakrabarti's research during 2024–2025 focussed on understanding how active processes in biological and synthetic systems generate self-organised large-scale flows. A central theme across these efforts was that such flows are not merely physical curiosities — they often have functional consequences in evolution, reproduction, and developmental processes. The work spans developing continuum theory, large-scale computation, and close collaborations with experimental groups in India, Europe, and the US. Below is a summary of the major research directions pursued over this period.

Boundary-Driven Self-Organised Flows

A significant part of Chakrabarti's work has aimed to understand how boundaries — cell surfaces, membranes, or interfaces — shape the flows generated by active processes living on them. At ICTS, he has been developing coarse-grained "active carpet" [Proceedings of the National Academy of Sciences 121, e2405114121 (2024)] theories to describe how stresses generated near boundaries drive large-scale transport. Using this framework, he has been studying cytoplasmic streaming inside the Drosophila oocyte and, together with experimental collaborators, examining how geometry and boundary stresses combine to organise intracellular flows. [PRX Life 3, 023007 (2025)]

Chakrabarti and collaborators have also been exploring how nucleation and growth of filamentous structures on surfaces can generate motility. Many microorganisms and cytoskeletal systems move by polymerising and assembling filaments at boundaries; their ongoing work develops a continuum theory and computational model that reveal how such growth generates stresses leading to hydrodynamic instabilities. This work aims to provide a unifying description of surface-driven motility in various biological systems.

Collective Dynamics of Giant Sperm

A central part of Chakrabarti's research has focussed on the remarkable fruit-fly sperm, which are 2 mm long — among the longest known sperm cells. Despite their extreme aspect ratio and dense packing inside storage organs, these sperm show persistent motility, coordinated flows, and minimal entanglement.

Chakrabarti and his collaborators, with new experiments initiated, have been developing continuum theories, discrete filament-based models, and large-scale simulations to understand these emergent dynamics. Their work sought to uncover how beating mechanics, hydrodynamics, and confinement combine to prevent entanglement in such dense active assemblies, providing new physical insight into the functional consequences of active flows at a crucial juncture in development and evolution.

Torque-Driven Self-Organised Flows

Another theme concerns the instabilities and collective dynamics of torque-driven active matter. Chakrabarti and collaborators developed coarse-grained continuum theories to understand bulk suspensions of chiral particles actuated by external torques. Using tools from dynamical systems and large-scale computation, they showed how fluid-mediated long-range interactions can destabilise uniform states and generate spontaneous flow patterns [arXiv:2508.17879 (2025)]. In parallel, they examined how chiral bacterial films near boundaries drive long-range, self-organised flows. Their coarse-grained models reveal how chirality can organise these thin films into rotating and spontaneously pumping states, with potential implications for enhanced mixing and transport at low Reynolds number.

Bacterial Taxis and Emergent Dynamics

Chakrabarti studied how feedback between metabolism and chemical landscapes shapes collective behavior in bacterial aerotaxis. Using quantitative experiments, kinetic-theory models, and simulations, he found that E. coli respond not to increasing oxygen per se but to an optimal concentration set by their own consumption. This self-generated landscape produces a striking density-dependent reversal of migration — one that has no analogue in classical chemotaxis. [bioRxiv, 2025–04 (2025)]

RESEARCH REPORT

Sarthak CHANDRA

During 2024–2025, Sarthak Chandra's research investigated how structure develops in neural circuits, and how such structures confer computational and cognitive advantages. A central theme of his work was how the brain flexibly uses low-dimensional manifolds to enable robust, high-capacity computation in biological and artificial neural networks.

In 2025, a major effort culminated in Global Modules Robustly Emerge from Local Interactions and Smooth Gradients [Nature, Volume 640, 155–164 (2025)], which investigated how modular architecture emerges in natural systems. Chandra and collaborators showed that modularity (as in entorhinal grid cells) can develop from purely local interactions, through a mechanism they termed "peak selection." This mechanism precisely matches existing experimental data, but also generalises to modularity emergence in other biological systems. In related work, on neurodevelopment, they proposed a model for the visual pathway in which competitive synaptic growth driven by spontaneous activity yields modularity, hierarchical organisation, and mirror reversals, linking local developmental rules to large-scale circuit structure. [bioRxiv 2024, doi: https://doi.org/10.1101/2024.01.07.574543]

A second line of research resulted in Episodic and Associative Memory from Spatial Scaffolds in the Hippocampus. [Nature, 638 (8051):739-751] Chandra and

collaborators introduced the Vector-HaSH model, in which grid-cell dynamics provide a low-dimensional attractor scaffold while the hippocampus stores external content by heteroassociation to this scaffold. This architecture unifies spatial mapping, associative and episodic memory within a single circuit. The model reproduces key experimental signatures of hippocampal – entorhinal activity and offers a mechanistic account of how one biological system supports both navigation and episodic memory. Small extensions to the model also replicated new experimental findings on behavioral timescale drift of entorhinal representations Slow Synaptic Plasticity from the Hippocampus Underlies Gradual Mapping and Fragmentation of Novel Spaces by Grid Cells. [bioRxiv 2025doi: https://doi.org/10.1101/2025.07.30.667696]

A third thread examines how grid-like systems support abstract cognition. In Flexible Mapping of Abstract Domains by Grid Cells via Self-supervised Extraction and Projection of Generalised Velocity Signals [NeurIPS 2024, doi: 10.52202/079017-2713], Chandra and collaborators demonstrated how grid-cell-like codes can be learned for non-spatial domains by extracting generalised "velocity" signals and projecting them into a low-dimensional manifold. This connects the geometry of grid codes with conceptual learning and provides a computational basis for cognitive maps in abstract task spaces. This also motivated the development of principles for building continuous attractor networks within biologically realistic models. In a recent preprint A Theory and Recipe to Construct General and Biologically Realistic Recurrent Network Models [eLife 2025, https://doi.org/10.7554/eLife.107224.1], they provided a method to construct networks whose activity lies on manifolds with arbitrarily chosen topologies, potentially bridging mechanistic network modeling with task-driven machine-learning design.

Complementing these theoretical efforts, Chandra worked on numerical examination of large-scale brain dynamics under anesthesia, using dynamical-systems tools. [Neuron 2024, DOI: 10.1016/j.neuron.2024.06.011. This motivated new theoretical techniques to characterise the control dynamics of observed neural dynamics characterising control between interacting subsystems with deep Jacobian estimation. [NeurIPS 2025]

RESEARCH REPORT

Akshit GOYAL

Akshit Goyal's research interest is broadly in ecology and evolution. In his recent work, he worked on three themes.

Ecosystems as Living Circuits

Much of Goyal's work focuses on developing theoretical frameworks that connect microscopic interactions to emergent ecosystem properties. In collaboration with Ankit Dhanuka, Avi Flamholz, and Arvind Murugan, he developed a framework treating ecosystems as "living circuits"— analogous to electrical circuits where conductances adapt based on local energy dissipation. This seemingly simple local rule gives rise to complex global behaviour: living circuits exhibit a phase transition from equilibrium death to nonequilibrium life beyond a critical energy drive and surprisingly achieve near-maximal energy dissipation despite lacking any global optimisation principle. A key emergent property is a "save the weakest" effect, where species near extinction can be rescued through community-level feedbacks that transiently boost their energy acquisition when abundances are low. This framework reveals the fundamental physics of systems that self-organise their displacement from equilibrium. This work is currently in review. [Dhanuka et al, arXiv (2025)]

Invasions and Eco-evolutionary Dynamics

In separate work with Zhijie Feng, Emmy Blumenthal, and Pankaj Mehta, Goyal developed a general theory of ecological invasions applicable across diverse ecological models. A central innovation is the concept of "dressed invasion fitness" — which augments traditional invasion fitness by incorporating ecological feedbacks between invaders and resident communities. Goyal and collaborators' framework can predict three key invasion outcomes: which species go extinct, how surviving species' abundances shift, and the invader's final abundance. Applying this to evolution, where mutants invade as highly-correlated species, they found that parent-mutant coexistence is common (~40% even at high phenotypic similarity) because global eco-evolutionary feedbacks mediated by the full community often outweigh direct parent-mutant competition. They validated predictions against experimental datasets spanning plants to protists. [PNAS, 122 (49) e2505850122 (2025)]

Ecological Signatures of Life

In collaboration with Mikhail Tikhonov, Goyal proposed a novel biosignature for detecting life based on ecosystem-level organisation rather than specific metabolisms. Using minimal consumer-resource models, they showed that spatial stratification of chemical resources in order of decreasing energy content emerges robustly from two universal features of life: self-replication and ecological interactions. This pattern arises because self-replication creates a correlation between a resource's energy yield and its depletion rate, while ecological interactions cause spatial segregation of species. Both ingredients are necessary and sufficient for this signature to emerge. This work demonstrates how ecological theory can address fundamental questions about universal properties of living systems, proposing an "agnostic biosignature" requiring minimal assumptions about biochemical implementation. This work has been published in Nature Communications. [Nature Communications, volume 16, Article number: 2867 (2025)]

RESEARCH REPORT

Vijaykumar KRISHNAMURTHY

During the last two years, Vijaykumar Krishnamurthy's research has focussed on the following.

Mechanochemical patterns arising in the actomyosin cortex drive many cellular processes. Here Krishnamurthy and collaborators considered a hydrodynamic model for the actomyosin cortex of cells and studied the sensitivity of the emergent patterns to both physical parameters and the geometry of the confining domain. They first established a general framework for the Galerkin analysis of such patterns far from the linear stability regime on an arbitrary two-dimensional domain. In the case of a circular disk, their analytical results predicted transitions from isotropic to anisotropic patterns upon changing the strength of the active stress and the turnover rate. They confirmed the existence of this secondary bifurcation of the homogeneous state by an explicit numerical analysis of their model. Extending their numerical analysis to harmonic deformations of the circular disk, they showed that the emergent patterns are also sensitive to the curvature of the domain. In particular, the actomyosin patterns resulting from the study closely resembled those seen in cells confined to micropatterned substrates. The study demonstrates the role of geometry in controlling patterns within the context of a simple model for the actomyosin cortex. [PRE 111, 064409 (2025)]

Pattern formation in active biological matter typically arises from the feedback between chemical concentration fields and mechanical stresses. The actomyosin cortex of cells is an archetypal example of an active thin film that displays such patterns. Here, Krishnamurthy and his collaborators showed how pulsatory patterns emerge in a minimal model of the actomyosin cortex with a single stress-regulating chemical species that exchanges material with the cytoplasm via a linear turnover reaction. Deriving a low-dimensional amplitude-phase model, valid for a one-dimensional periodic domain and a spherical surface, they showed that nonlinear waves arise from a secondary parity-breaking bifurcation that originates from the nonreciprocal interaction between spatial modes of the concentration field. Numerical analysis confirmed these analytical predictions and also revealed analogous pulsatory patterns on impermeable domains. Their study provides a generic route to the emergence of nonreciprocity-driven pulsatory patterns that can be controlled by both the strength of activity and the turnover rate. [PRE 112, L022401 (2025)]

The group showed theoretically that an imposed uniaxial anisotropy leads to new universality classes for the dynamics of active particles suspended in a viscous fluid. In the homogeneous state, their concentration relaxed superdiffusively, stirred by the long-ranged flows generated by its own fluctuations, as confirmed by their numerical simulations. Increasing activity led to an anisotropic diffusive instability, driven by an active contribution to the particle current proportional to the local curvature of the suspension velocity profile. [arXiv:2510.00740]

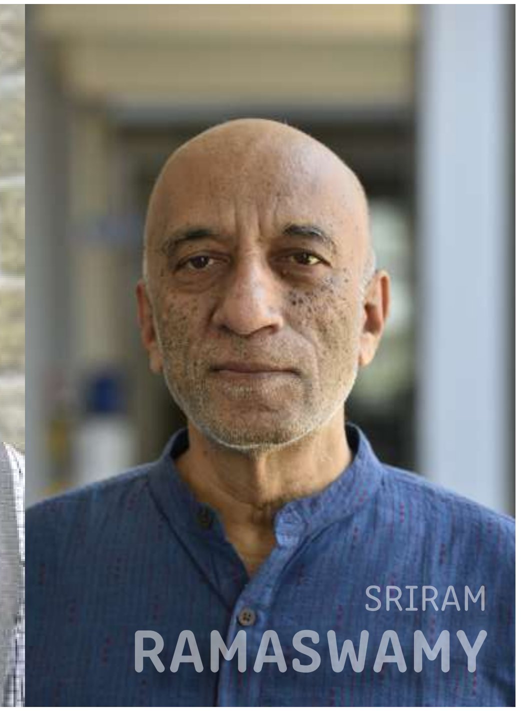
Cell division accomplishes the segregation of genetic material and involves remarkable changes in the cellular geometry culminating in cytokinesis: the cleavage of a mother cell giving rise to two daughter cells. Cytokinesis in animal cells is driven by flows resulting from cortical tension gradients in the actomyosin cortex. Here, Krishnamurthy and collaborators combined a theory for the active geometrodynamics of the cortical surface and quantitative measurements in the C. elegans zygote to reveal the physical principles of cytokinesis. At high activity, they observed the spontaneous emergence of ring-like patterns of myosin concentration and cell shape in the theory. The constriction dynamics of this self-organised pattern agree with the ingression of the cytokinetic furrow and concomitant myosin accumulation during the first division in the C. elegans embryo. Through RNAi perturbations, they quantitatively tested their theoretical predictions of myosin accumulation rates linearly varying with the ingression rate, and the emergence of asymmetric ingression. The work suggests that the self-organised geometrodynamics of active fluid surfaces underlies cytokinesis. [bioRxiv (2025), doi: 10.1101/2025.11.07.683232]

RESEARCH REPORT

Shashi THUTUPALLI

Here are two highlights from Shashi Thutupalli's recent work in 2024–2025 that illustrate the broader programme, which brings a physical perspective to synthetic and evolutionary biology in the laboratory.

Much of synthetic active matter has focussed on point-like, interacting particles. In contrast, biological active systems abound in hierarchical assemblies — polymers, tissues, organs — that behave as extended, self-morphing objects. These systems are composed of chemically active subunits whose dynamics emerge from a choreography between mechanics and self-generated guiding fields such as chemical gradients. Reproducing such freely jointed, functional assemblies in the laboratory has been a longstanding challenge, and an important step towards building synthetic material analogues of living tissues. Thutupalli and collaborators addressed this gap using self-propelled droplets. Building on a tunable active droplet system they had previously established, they developed a generic "bonding" strategy that links droplets into freely jointed linear polymers. These active polymers exhibit rich emergent dynamics arising from chemo-hydrodynamic self-interactions,



allowing them to systematically probe how mechanical connectivity, activity and hydrodynamics combine to produce complex motion and shape change. Because the linking method is modular and chemically versatile, it should be broadly applicable for building multivalent and multi-"flavoured" active assemblies, including branched and heterogeneous architectures. They viewed this as a first step towards synthetic active matter that can undergo emergent, programmable self-morphic dynamics. [Nature Communications 15, 4903 (2024)]

A second highlight from 2025 addresses a century-old question in the evolution of multicellularity: how nascent multicellular organisms overcome biophysical constraints on nutrient transport before the evolution of sophisticated vascular or flagellar systems. Classical arguments suggest that diffusion alone cannot support sustained growth in large aggregates, implying that complex transport machinery must evolve early. Thutupalli's work challenges this view.

Using 'snowflake' yeast (laboratory-evolved multicellular yeast), he showed that simple physical mechanisms can sustain exponential growth in large multicellular clusters without genetically encoded transport machinery. Thutupalli and collaborators demonstrated that metabolism-triggered buoyant instabilities in the surrounding fluid generate strong advective flows around growing clusters. A key multicellular innovation — entangled cellular architecture that increases body size — amplifies these flows, enabling efficient nutrient transport over macroscopic length scales. Crucially, these flows arise prior to any specialised transport adaptations, suggesting that latent physical processes in newly formed multicellular groups can act as "biophysical scaffolds" for subsequent evolutionary innovation. Behaviours traditionally thought to require dedicated structures may thus emerge from co-opted physical instabilities, opening new pathways for the evolution of complexity and expanding the space of plausible routes to multicellularity. [Science Advances 11, eadr6399 (2025)]

RESEARCH REPORT

Sriram RAMASWAMY

Sriram Ramaswamy has worked on active matter - the study of living or lifelike materials, whose individual constituents continually convert a free-energy supply into work - and on related nonequilibrium problems including sedimentation and nonreciprocal spin dynamics.

The concentration field in active matter is prone to condense without attraction, through persistent directed motion and excluded volume. Ramaswamy and collaborators presented experiments and coarse-grained theory on the bulk condensation of a passively diffusing species by a minuscule - possibly sub-extensive - population of active particles. The fundamental issues thus raised will engage our interest in the coming years. [Phys Rev Lett 133, 208301 (2024)]

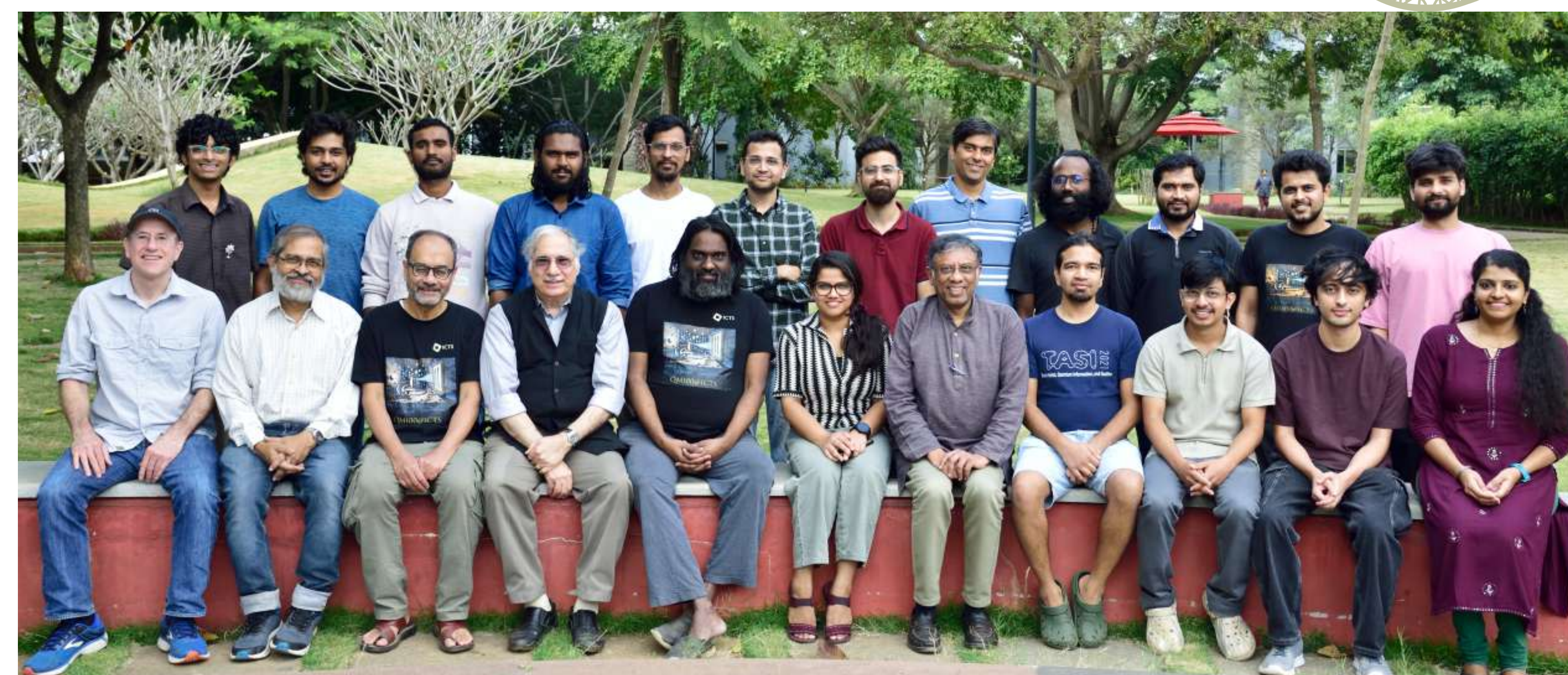
In more recent work [arXiv:2512.17240] Ramaswamy and collaborators showed that segregated active/passive mixtures of semiflexible filaments remix at high levels of activity as collisions lower their effective persistence length. They established new dynamical universality classes when an ambient fluid is present: superdiffusion and flow-driven phase separation when the medium is anisotropic [arXiv:2510.00740]; continuously varying scaling exponents for the far-field decay of concentration, encoding the shape of a static inclusion [Phys. Rev. X 14, 041034 (2024)]; novel inertial effects including wave turbulence [Phys. Rev. Lett. 133, 158302 (2024)], a transition in defect clustering [Phys Rev E 109, 024603 (2024)] and caustics [arXiv:2310.01829] when motile particles are advected by vortical flows.

Chirality conceals itself from the long-wavelength mechanics of equilibrium matter. Ramaswamy and collaborators showed that it is dramatically salient in active systems, leading to global odd-elastic oscillatory modes without mechanical inertia in 3D [PNAS Nexus 3, page 398 (2024), Phys. Rev. E 112, 055424 (2025)]; skipping orbits, active pairing, and chiral sorting in 2D [arXiv:2509.00729] and self-shear-induced melting of scarred odd crystals. [arXiv:2512.17393 (Nature Communications, accepted)]

Nonreciprocity is inescapable in the signalling and sensing that occurs in living matter. In a minimal realisation consisting of planar spins that align preferentially with the neighbours towards which they point, Ramaswamy and collaborators uncovered its dramatic consequences, including the destruction of XY order through vortex shielding and proliferation at low noise. [Phys. Rev. Lett. 135, 088303 (2025)] They also settled a fundamental issue [arXiv:2503.17064] in the scaling properties of flocking models, whose governing nonlinearity arises minimally from nonreciprocity. In a wider context, they studied the chaos propagation in nonreciprocal classical O(3) spin chains [arXiv:2512.13873], and the closely related non-normal collective sedimentation of anisotropic particles. [J Fluid Mech. 1017, A1 (2025)]

RESEARCH REPORT

STRING THEORY AND QUANTUM GRAVITY



FACULTY

Rajesh Gopakumar ◈ R. Loganayagam ◈ Raghu Mahajan *(Joined 15 August 2024)* ◈ Gautam Mandal *(DAE- Raja Ramanna Chair, Joined February 2025)* ◈ Suvrat Raju ◈ Ashoke Sen *(Infosys-ICTS Madhava Chair Professor)* ◈ Spenta R. Wadia *(Infosys-ICTS Homi Bhabha Chair Professor)*

POSTDOCTORAL FELLOWS

Mohd Ali ◈ Sri Ramesh Chandra Ammanamanchi ◈ Asrat Demise ◈ Navaneeth Krishna Gaddam ◈ Anurag Kaushal ◈ Nathan Matthew McStay ◈ Naveen Prabhakar ◈ Shanmugapriya Prakasam ◈ Muktajyoti Saha ◈ Georg Stettinger ◈ Farmal Ullah *(NPDF)*

STUDENTS

Tannu ◈ Jyotirmoy Barman ◈ Tuneer Chakraborty ◈ Chandramouli Choudhary ◈ Sarthak Duary ◈ Ritwick Kumar Ghosh ◈ Ashik H ◈ Debanjan Karan ◈ Rishabh Kaushik ◈ Babli Khatun ◈ Godwin Martin ◈ Rahul Metya ◈ Priyadarshi Paul ◈ Shivam Kumar Sharma ◈ Omkar Shetye ◈ Kaustubh Singhi ◈ Shridhar Vinayak ◈ Avi Wadhwa ◈ Abhinav Yadav

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Lakshya Bharadwaj ◈ Sourendu Gupta ◈ Sunil Mukhi *(TIFR Adjunct Professor)* ◈ Onkar Parrikar ◈ V. Ravindran ◈ Raju Venugopalan

RESEARCH REPORT

Rajesh GOPAKUMAR

The broad thrust of Rajesh Gopakumar's research continues to be the understanding and derivation of gauge-string duality in a number of contexts and extraction of general lessons from this process. Two major directions in this broad area have been as follows.

Strings from Feynman Diagrams

Together with collaborators, Rishabh Kaushik, Shota Komatsu, Edward Mazenc and Debmalya Sarkar, Gopakumar manifestly recast the gauge theory Feynman diagram expansion as a sum over dual closed strings, for a class of correlators in N=4 Super Yang-Mills theory. Each individual Feynman diagram was mapped onto a Riemann surface with specific moduli (inequivalent parameters). The Feynman diagrams thus correspond to discrete lattice points on string moduli space, rather than discretised worldsheets. This picture is valid to all orders in the 1/N expansion. Specifically, the mapping was carried out at the level of a two-matrix integral with its dual string description. It provides a microscopic picture of open/closed string duality for this topological subsector of the full AdS/CFT correspondence. At the same time, the concrete mechanism for how strings emerge from the matrix model Feynman diagrams predicts that multiple open string descriptions can exist for the same dual closed string theory. The embedding of these duals (which are described by Kontsevich-like matrix models) into the 1/2 SUSY sector of AdS/CFT is achieved by open strings on giant graviton branes. [arXiv:2412.13397]

With Matthias Gaberdiel, Gopakumar has been working on generalising his earlier proposal on the tensionless limit of string theory with NS-NS flux to that with pure RR flux. The idea is that this limit is somewhat singular and realises a different kind of tensionless limit which can be studied by deforming away from the singularity in a controlled way using the underlying D1-D5 gauge theory system. They have a proposal for the dual CFT in this limit as well as more generally for a similar limit for $AdS_3 \times S^3 \times S^3 \times S^1$. The latter case has been very mysterious from the point of view of gauge-string duality and this proposal will help to address this puzzling case.

Also with Gaberdiel and Beat Nairz, Gopakumar studied the deformation away from the tensionless limit. This was done in AdS_3 through the dual symmetric orbifold 2d CFT where there is a special exactly marginal deformation of the 2d CFT. They showed an underlying integrability in this deformed theory which had never been made precise before in the 2d CFT. In particular, they were able to characterise the interacting spectrum of large-size operators in terms of magnon-like excitations which interact via an integrable S-matrix.

RESEARCH REPORT

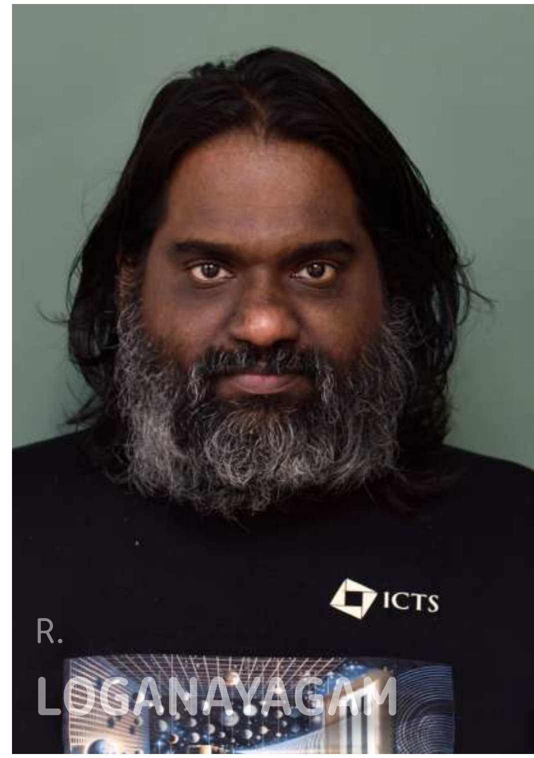
R. LOGANAYAGAM

During the last two years, R. Loganayagam has worked on three main topics: the first topic is a formalism to compute scattering outside a black hole, especially including the effects of Hawking radiation. The second topic is to compute how a moving charge particle in an exponentially expanding universe radiates energy in electromagnetic waves. The third topic concerns simple models of heat transport between quantum mechanical systems, including models for transients when two such systems are connected to each other.

In two works titled "An Exterior EFT for Hawking Radiation" [arXiv:2403.10654] and "Loops Outside a Black Hole" [arXiv:2509.03656], Loganayagam, along with ICTS students Godwin Martin and Shivam Sharma, tackled the problem of scattering outside a black hole. This process cannot be described by standard frameworks used for scattering in vacuum, because of two novel effects: dissipation due to particles falling into the blackhole and the fluctuations due to thermal Hawking particles coming out of the black hole. In these works, they developed a framework called "exterior field theory" to take both these effects into account, by doubling the fields existing outside the black hole. This framework itself is derived from Loganayagam's previous work on gravitational Schwinger-Keldysh geometry, a complex solution that allows us to compute non-equilibrium correlations outside the black hole.

In a work titled "Influence Phase of a dS Observer II: Electromagnetism" [arXiv:2503.00135] with ICTS student Omkar Shetye, Loganayagam computed the effect of an exponentially expanding(dS) universe on the radiation by a moving charge. In this work, they extended to such expanding spacetimes many notions familiar from flat space radiation theory: far zone multipole expansion, smearing effects due to time-delays within the source, near zone non-relativistic expansion, renormalisation running in classical electromagnetism existing in odd spacetime dimensions. They also provided a detailed account of the theory of vector spherical harmonics in arbitrary dimensions, deriving a variety of new results about such harmonics.

In a work titled "Solvable Models of Heat Transport in Quantum Mechanics" [arXiv:2508.09253] along with Prithvi Narayan and Swathi T.S., Loganayagam considered the following problem. Say one connects two quantum systems at different temperatures suddenly at an instant of time and one wants to figure out what happens afterwards. One expects first a transient dynamics - a "heat spark" so to speak due to sudden connection which then settles into a steady heat current after some time. The challenge is to model this heat spark as well as the approach to the steady current. Loganayagam and collaborators gave some very simple toy models capturing this physics, followed by a more detailed analysis in a more realistic but exactly solvable model: Sachdev-Ye-Kitaev model in the double scaling limit. They showed that the realistic model interpolates between the simple behaviours as we move from UV (short times/high temperatures) to IR(long times/low temperatures).



RESEARCH REPORT

Raghu MAHAJAN

Over 2024–2025, Raghu Mahajan's work focussed on nonperturbative phenomena in holography and low-dimensional string theory, and on clarifying saddle-point structure in AdS thermodynamics, alongside a pedagogical synthesis of quantum extremal surfaces (QES) and the Page curve.

ZZ Instantons in Minimal Superstrings

With V. Chakrabhavi, D.S. Eniceicu, and C. Murdia, Mahajan resolved long-standing divergences in one-loop normalisations of instanton corrections across both gapped and ungapped phases of the (2,4k) type-0B minimal superstring. Using string-field-theory input to fix ill-defined worldsheet annuli, they obtained finite, unambiguous instanton normalisations and matched them precisely to double-scaled one-matrix integrals for all k. The analysis clarifies the gap-closing (Gross–Witten–Wadia) transition and frames the $k \to \infty$ connection to super-JT gravity, including subtleties in the gapped phase. [arxiv:2406.16867]

Giant Graviton Expansion from Eigenvalue Instantons

With Y. Chen and H. Tang, Mahajan gave a matrix-model derivation of S. Murthy's convergent "giant graviton" series for finite-N partition functions and superconformal indices of purely adjoint gauge theories. Mahajan and collaborators reproduced the e^{-mN} corrections directly from eigenvalue instantons of unitary matrix integrals—bypassing the intermediate Hubbard–Stratonovich step—and connected these nonperturbative terms to trace-relation null states expected from holography. This provides a clean, calculable bridge between finite-N effects in boundary gauge theory and brane/giant-graviton physics in the bulk. [arxiv:2407.08155]

Pedagogy on QES and the Page Curve

Mahajan's lecture notes systematise a first-principles path-integral derivation of the Page curve using the QES prescription and replica wormholes. The notes emphasise the KMS viewpoint on Hawking thermality, explain entropy paradoxes for eternal and evaporating black holes, and provide worked two-dimensional models (including JT gravity) that track the early-time growth and late-time saturation of radiation entropy. The aim is a self-contained reference for students entering the black-hole information program. [arxiv:2502.01933]

Complex AdS-Schwarzschild Saddles

With K. Singhi, Mahajan examined complex black-hole solutions that persist to low temperatures in AdS. Although their real on-shell action can be smaller than that of thermal AdS (notably in $d \geq 5$), they argued — via mini-superspace and contour analysis — that these complex saddles do not contribute to the gravitational path integral, preserving the standard conclusion that thermal AdS dominates at low temperature. They also commented on the limits of the Kontsevich–Segal criterion and on the (non-)role of the unstable small black hole in the high-temperature phase. [arxiv:2509.08883]

Together, these projects tighten the nonperturbative dictionary between matrix models, worldsheet/string-field-theory amplitudes, and finite-N holography; consolidate the modern QES framework for information-theoretic observables; and sharpen our understanding of which saddles truly enter AdS thermodynamics.

RESEARCH REPORT

Gautam MANDAL

Since joining ICTS, Gautam Mandal's research interests have included the following:

Emergent Geometry from Matrix Model and its Granularity

One of the earliest examples of holographic duality between gravitational physics and non-gravitational physics, known from well before AdS/CFT, is the map between c=1 matrix model and 2D string theory. One of the attractive features of this duality is the natural emergence of a new spatial direction: while the matrix elements live only in time, the eigenvalues can be regarded as fermionic particles living in a two-dimensional space-time. In the present work, Mandal and his collaborators critically reevaluate this duality in the light of some apparent discrepancies when the 2D picture is described in terms of the fermion density. The fermion density, also called the collective variable of the matrix model, has an approximate description in terms of a relativistic scalar field. The entanglement entropy (EE) of a subregion of space, computed using this collective variable description, turns out to be divergent, whereas the original matrix model calculation produces a finite result. Similar spurious divergences appear in the collective variable description for one-loop amplitudes. They showed that a correct holographic dual of the matrix model, which resolves these issues, is one in which the emergent spatial direction is a lattice, with lattice spacing proportional to the string coupling. The lattice boson framework is based on an exact bosonization of non-relativistic Fermi gas in one dimension. The finiteness of the EE, and of the one-loop amplitudes, is a natural consequence of the finite lattice spacing. In ongoing work, Mandal (with Ajay Mohan and Adwait Gaikwad) is exploring the relation between the lattice boson framework and another exact bosonization of the Fermi gas in terms of the Wigner phase space distribution and further exploring connection with 2D string theory. [JHEP 03 (2025) 210, e-Print: 2406.07629 [hep-th]]

Non-commutative Geometry and "Holography"

Mandal and his collaborators investigated a class of 2D non-interacting fermion systems in an external potential that all have a band structure like the Landau electrons (electrons on a plane with a uniform, perpendicular, magnetic field). An example, studied in detail, is that of rotating electrons in a harmonic trap, which in a special limit reduces to the Landau system. Consider putting a large number (N) of fermions, partly filling the lowest 'Landau level' (LLL). Such a system is known to possess two interesting properties in the limit of a large number (N) of fermions: (a) the ground state fermion density has a flat-cake profile (in more general states, it has an upper bound), (b) ground state entanglement entropy (EE) for a disk of radius R is proportional to R. Both properties (a) and (b) are uncharacteristic of ordinary 2D fermion systems: the fermion density in coordinate space is ordinarily not constrained besides being positive and satisfying the total number constraint; also, the EE for a fermion system with a Fermi surface typically has a logarithmic dependence on the size of the entangling region. They showed that both (a) and (b) follow from the fact that when we restrict to the LLL, the 2D coordinate space behaves effectively like a phase space, as the LLL constraints imply an effective non-zero commutator between x and y. While this fact is well-known, they constructed for the first time an exact holographic map between the 2D quantum mechanics of the LLL system to a 1D quantum mechanics, leading to an identification of the coordinate-space fermion density to the Wigner distribution of the 1D system; property (a), namely the flat-cake profile of the former, follows from the well-known flat-cake profile of the latter. Property (b) also follows from the existence of the non-commutative structure of space for the LLL system; the short-range correlator resulting from it leads to a narrow band of EPR pairs around the periphery of the entangling region, resulting in a linear behaviour of the EE. In ongoing work (with Ajay Mohan, Takeshi Morita and Rushikesh Suroshe) Mandal is developing a description of the dynamics of the 2D LLL system in a variety of potentials in terms of a holographic 1D system and has showed thermalization to a generalised Gibbs ensemble (GGE). [e-Print: 2511.01630[hep-th]]

RESEARCH REPORT

Suvrat RAJU

Suvrat Raju's research in the past two years has focussed on three broad themes: the nature of observables in gravity, black holes, and more recently, the underlying dynamics of large language models.

With P.V. Athira, Priyadarshi Paul, and Anupam A.H., Raju studied the possibility of developing a novel asymptotic representation for interacting massive particles in asymptotically flat space at spatial infinity. This question is motivated by considerations of holography. A perfectly satisfactory asymptotic description for massive particles can be found at future and past timelike infinity. Nevertheless, spatial infinity provides a timelike boundary for flat space that might be more natural from a holographic viewpoint. This work extended previous work, in which a similar problem was studied for free fields. Raju and collaborators proposed that this representation could be obtained through a natural generalisation of the LSZ formula and found that extrapolated operators at spatial infinity were naturally represented as arithmetic means of extrapolated operators at future and past timelike infinity. They computed a number of correlators of such operators within perturbation theory.

With Antony Speranza and Kristan Jensen, Raju studied the definition of algebras for bounded regions in gravitational theories. In a fine-grained sense, such algebras do not make sense. Although such algebras have appeared in the recent literature, the principle of holography of information, which has been studied extensively at ICTS, implies that, in a theory of gravity, all observables in a bounded region can be represented arbitrarily well by observables in the complementary region. So it is impossible to define precisely commuting algebras for a region and its complement. Nevertheless, in the presence of a heavy background state (which plays the role of an observer), Raju and collaborators showed that it is possible to define coarse-grained algebras for bounded regions. These algebras approximately commute with similar algebras that can be defined for the complementary region. They showed that with some translation of notation, the formulas used to define these algebras go over precisely to the formulas used to define the so-called "crossed product" that has played a significant role in recent studies of algebras in gravity.

With his current student, Ashik H, and former student, Tuneer Chakraborty, Raju investigated cosmological correlators in asymptotically de Sitter space (dS). This follows up on previous work (with Tuneer Chakraborty, Priyadarshi Paul, Joydeep Chakravarty and Victor Godet) where they classified all solutions of the gravitational constraints in dS. They computed the simplest class of gravitational observables using perturbation theory. Surprisingly, they found that these observables did not correspond to the observables that one would compute in a nongravitational theory, even when the gravitational coupling was taken to be weak. They then described a new class of observables, called relational observables, that do have the correct weakly-coupled limit. This reveals a distinction in gravity between observables that are microscopically simple, and observables that take on simple values.

With Andreas Karch, Lisa Randall, Hao Geng, Marcos Riojas and Carlos Perez, Raju continued to examine the significance of the Page curve for evaporating black holes. Previously, they had proposed that a natural resolution to the information paradox is that quantum information inside the black hole can also be accessed by sufficiently fine-grained measurements outside the black hole. As a corollary, this implies that the fine-grained entropy of the exterior vanishes, rather than following a Page curve. However, a Page curve may be obtained by various artifices, including the introduction of a nongravitational bath. Recently, Antonini et al. examined Page curves in the absence of a bath. They showed that these Page curves also arise because one chooses not to measure some degrees of freedom outside the black hole. Therefore, even in the examples of Antonini et al. the entanglement entropy of the entire exterior remains vanishing.

Although Large Language Models (LLMs) are versatile models that have been successful at a variety of benchmarks, they continue to make errors. Understanding and ameliorating these errors is an important problem. With Praneeth Netrapalli, Raju examined these errors in a simple setting where LLMs are known to struggle - problems like arithmetic that traditional computers are strong at. Arithmetic is part of a class of tasks where the LLM must produce a precise output given an input comprising tokens drawn from a small set of alternatives. They found a quantitative two-parameter relationship between the error-rate of the model and the complexity of the task. The two parameters that appear here can be interpreted as a fundamental noise rate, and the mean number of erroneous "alternatives" during the model's operation. They empirically checked their proposal for a variety of models, on a large number of tasks, and found excellent agreement between the proposed formula and empirical tests. It might be possible to reduce the model's error rate by modifying the underlying architecture or through fine-tuning. This is part of a broader program that seeks to understand "why" large models function the way they do.

RESEARCH REPORT

Ashoke SEN

Ashoke Sen's work during 2024-2025 explored different aspects of string theory. These can be divided into the following broad classes:

In collaboration with Chandramouli Chowdhury, P. Shanmugapriya and Amitabh Virmani, Sen analyzed the supersymmetric index of small black holes in string theory and showed that the result matches the microscopic answer up to an overall numerical constant that could not be computed based on our current understanding. In a related work with Subramanya Hegde, P. Shanmugapriya and Amitabh Virmani, he computed higher derivative correction to black hole index in N=2 supersymmetric string compactification.

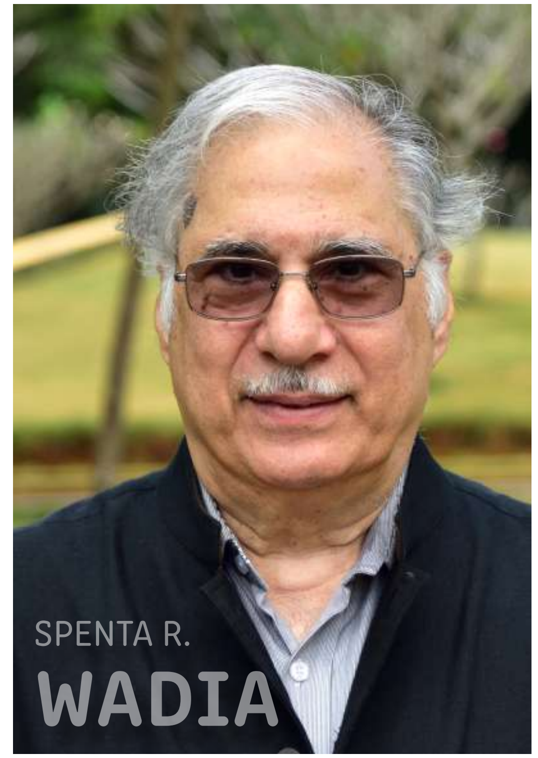
In collaboration with Barton Zwiebach, Sen used string field theory to fix the overall normalisation of all string theory amplitudes involving external open and closed strings. He also constructed the D-instanton induced effective string field theory action and showed its gauge invariance. Also in collaboration with

Bogdan Stefanski, Sen used string field theory to tame the infrared divergence problems that plague the scattering amplitude involving D0-branes and found an unambiguous result for the three-point function involving two external D0-branes and one external closed string.

With Debanjan Karan, Babli Khatun and Biswajit Sahoo, Sen found the all order electromagnetic soft theorem that determines terms of order $u - n - 1(lnu)n$ for large retarded time u during a scattering process.

Sen addressed the question of whether moduli should be regarded as vacuum expectation values or parameters in string theory, and showed that while in anti de Sitter spacetime they should naturally be regarded as parameters, in flat spacetime they should be regarded as vacuum expectation values. This also has consequences for the symmetries of the theory, e.g. duality symmetries are explicitly broken for generic values of moduli in AdS spacetime, but they are spontaneously broken gauge symmetries with observable consequences in string theory in flat spacetime.

With Ajit Bhand and Ranveer Singh, Sen constructed the generating function of the index of single centered black holes in toroidally compactified heterotic string theory.



RESEARCH REPORT

Spenta R. WADIA

During the last two years, Spenta R. Wadia's work mainly focussed on i) elucidating the notion of time in GR; and ii) a gauge invariant and unitary time evolution across the horizon of a black hole in asymptotically anti-de Sitter spacetimes.

Time and General Relativity

The invention of the idea of time and its measurement is a fundamental ingredient in the description of dynamical systems. General relativity (GR) radically changes the notion of time because the theory is invariant under spacetime diffeomorphisms. There is no obvious choice of a time coordinate to label the leaves of a foliation of spacetime. Wadia and collaborators present a general formula for 'time' in semi-classical GR, using the Einstein-Hamilton-Jacobi equation. It emerges from the geometry of the configuration space of GR via the length of the steepest descent paths, which are measured with respect to the de Witt metric. They illustrated this formula for time in various examples including de Sitter spacetime and asymptotically anti–de Sitter spacetimes. [arXiv:2405.18486; PRD 111, 106006 (2025)]

Smooth Transit Across the Horizon of a Black Hole in Asymptotically AdS Spacetimes

The quantum dynamics of matter in the presence of a black hole is an old subject beginning with Hawking's foundational work, where he calculated the temperature of the Schwarzschild black hole as a function of its mass. More recently, the generalised Ryu-Takayanagi formula for the von Neumann entropy enabled a new diagnostic of black hole evaporation in terms of the Page curve for an evaporating black hole in an AdS spacetime coupled to an external bath at its boundary. These are semi-classical bulk calculations in effective field theory without any reference to the microscopic dual degrees of freedom that reside on the boundary of AdS spacetime.

One wonders about the possibility, within the effective field theory (GR), of a unitary Hamiltonian description of the crossing of the horizon by matter field excitations. Wadia and collaborators answered this question in the affirmative. More explicitly, they studied the quantum dynamics of a probe scalar field in the background of an eternal two-sided black hole in a spacetime that is asymptotically AdS (AAdS) in the Hamiltonian formulation of GR, in the maximal slicing gauge. One of their main results is a well-defined formula, in terms of a basis of mode functions which are smooth across the horizon, for the Hamiltonian of the probe scalar in the product space of the two CFTs. This Hamiltonian describes the time development of operators/states along the maximal slices and consequently there is a unitary description of scalar field excitations crossing the horizon. They also presented a bulk reconstruction formula that evaluates an order parameter that signals horizon crossing in the boundary theory. Though they presented explicit formulas for the case of 2+1 dimensions, our main results are valid for d + 1 dimensions with d > 2. [Anurag Kaushal, Naveen Prabhakar and Spenta R. Wadia; arXiv: 2510.21920]

Solution of 2+1 Dimensional Gravity in AAdS Spacetimes with Spatial Wormhole Slices and the BTZ Black Hole

Wadia and collaborators solved Einstein's equations with negative cosmological constant in 2 + 1 dimensions in the Hamiltonian formulation when the spacetime topology is a cylinder times the real line, and the spacetime metric satisfies asymptotically AdS boundary conditions. Since the maximal slicing gauge can be ruinously fixed we explicitly solve the Hamiltonian and momentum constraints, and the gauge conditions to obtain a two dimensional reduced phase space. In AAdS spacetimes besides the standard Wheeler-DeWitt equations there is a Schrödinger equation corresponding to the boundary ADM Hamiltonian. They exhibited the wave functions and a continuous positive energy spectrum where each energy eigenvalue E corresponds to a BTZ black hole of mass M = E/2. [Anurag Kaushal, Naveen Prabhakar and Spenta R. Wadia; arXiv: 2510.21923]


Photo credit: Parul Sehgal

RESEARCH REPORT

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ICTS PUBLICATIONS 2024

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Consortium

1. *Swift-BAT GUANO Follow-up of Gravitational-wave Triggers in the Third LIGO-Virgo-KAGRA Observing Run,* Gayathri Raman, Samuele Ronchini, James Delaunay, Aaron Tohuvavohu, Jamie A. Kennea, Tyler Parsotan, Elena Ambrosi, Maria Grazia Bernardini, Sergio Campana, Giancarlo Cusumano, Antonino D'Ai, Paolo D'Avanzo, Valerio D'Elia, Massimiliano De Pasquale, Simone Dichiara, Phil Evans, Dieter Hartmann, Paul Kuin, Andrea Melandri, Paul O'Brien, Julian P. Osborne, Kim Page, David M. Palmer, Boris Sbarufatti, Gianpiero Tagliaferri, **Prayush Kumar**, et al. (1797 additional authors not shown). Astrophysical J. 980 (2) 207 (2025)
2. *Search for Continuous Gravitational Waves from Known Pulsars in the First Part of the Fourth LIGO-Virgo-KAGRA Observing Run*, The LIGO Scientific Collaboration, the Virgo Collaboration, the KAGRA Collaboration, A. G. Abac et. al. Astrophysical J. 983 (02) 99 (2025)
3. *Search for Gravitational Waves Emitted from SN 2023ixf*, The LIGO Scientific Collaboration, the Virgo Collaboration, the KAGRA Collaboration, A. G. Abac, R. Abbott, I. Abouelfettouh, F. Acernese, K. Ackley, S. Adhicary, N. Adhikari, R. X. Adhikari, V. K. Adkins, D. Agarwal, M. Agathos, M. Aghaei Abchouyeh, O. D. Aguiar, I. Aguilar, L. Aiello, A. Ain, T. Akutsu, S. Albanesi, R. A. Alfaidi, A. Al-Jodah, C. Alléné, A. Allocca, et al. (1758 additional authors not shown). Astrophysical J. 985 (02) 183 (2025)
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5. *All-sky Search for Long-duration Gravitational-wave Transients in the First Part of the Fourth LIGO-Virgo-KAGRA Observing Run,* The LIGO Scientific Collaboration, the Virgo Collaboration, the KAGRA Collaboration. Phys. Rev. D (2025), accepted arXiv:2507.12282 Dec. 2025
6. *GW231123: a Binary Black Hole Merger with Total Mass 190-265 M⊙,* The LIGO Scientific Collaboration, The Virgo Collaboration, and The KAGRA Collaboration. ApJ. Lett. 993 (1) L25 (2025)
7. *GWTC-4.0: An Introduction to Version 4.0 of the Gravitational-Wave Transient Catalog,* The LIGO Scientific Collaboration, the Virgo Collaboration, the KAGRA Collaboration, A. G. Abac, et al. arXiv:2508.18080
8. *GWTC-4.0: Methods for Identifying and Characterizing Gravitational-wave Transients,* The LIGO Scientific Collaboration, the Virgo Collaboration, the KAGRA Collaboration, A. G. Abac, et. al. arXiv:2508.18081
9. *GWTC-4.0: Updating the Gravitational-Wave Transient Catalog with Observations from the First Part of the Fourth LIGO-Virgo-KAGRA Observing Run,* The LIGO Scientific Collaboration, the Virgo Collaboration, the KAGRA Collaboration: A. G. Abac, et. al. arXiv:2508.18082 Submitted to ApJ Letters (2025). As part of the Astrophysical Journal Letters Focus Issue on the Gravitational Wave Transient Catalog.
10. *GWTC-4.0: Population Properties of Merging Compact Binaries,* The LIGO Scientific Collaboration, the Virgo Collaboration, the KAGRA Collaboration: A. G. Abac, et. al. Submitted to ApJ Letters (2025) arXiv:2508.18083 As part of the Astrophysical Journal Letters Focus Issue on the Gravitational Wave Transient Catalog.
11. *Upper Limits on the Isotropic Gravitational-Wave Background from the first part of LIGO, Virgo, and KAGRA's fourth Observing Run,* The LIGO Scientific Collaboration, the Virgo Collaboration, the KAGRA Collaboration, A. G. Abac, et. al. arXiv:2508.20721
12. *Open Data from LIGO, Virgo, and KAGRA through the First Part of the Fourth Observing Run,* The LIGO Scientific Collaboration, the Virgo Collaboration, the KAGRA Collaboration, A. G. Abac, et. al. arXiv:2508.18079
13. *Black Hole Spectroscopy and Tests of General Relativity with GW250114,* The LIGO Scientific Collaboration, the Virgo Collaboration, the KAGRA Collaboration. Submitted to Phys. Rev. Lett. (2025) arXiv:2509.08099
14. *GW230814: Investigation of a Loud Gravitational-wave Signal Observed with a Single Detector,* The LIGO Scientific Collaboration, The Virgo Collaboration, The Kagra Collaboration, Others, Submitted to ApJ Letters (2025) arXiv:2509.07348. As part of the Astrophysical Journal Letters Focus Issue on the Gravitational Wave Transient Catalog.
15. *GW250114: Testing Hawking's Area Law and the Kerr Nature of Black Holes,* The LIGO Scientific Collaboration, the Virgo Collaboration, the KAGRA Collaboration, A. G. Abac, *et. al.* Phys. Rev. Lett. 135, 111403 (2025)**. This publication is an Editor's Suggestion and was Featured in Physics.**
16. *Directed Searches for Gravitational Waves from Ultralight Vector Boson Clouds around Merger Remnant and Galactic Black Holes during the First Part of the Fourth LIGO-Virgo-KAGRA Observing Run,* The LIGO Scientific Collaboration, the Virgo Collaboration, the KAGRA Collaboration, A. G. Abac, et. al. arXiv:2509.07352
17. *GWTC-4.0: Constraints on the Cosmic Expansion Rate and Modified*

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18. *Directional Search for Persistent Gravitational Waves: Results from the First Part of LIGO-Virgo-KAGRA's Fourth Observing Run,* The LIGO Scientific Collaboration, the Virgo Collaboration, the KAGRA Collaboration, A. G. Abac, et. al. arXiv:2510.17487
19. *GW241011 and GW241110: Exploring Binary Formation and Fundamental Physics with Asymmetric, High-Spin Black Hole Coalescence,* The LIGO Scientific Collaboration, the Virgo Collaboration, the KAGRA Collaboration: A. G. Abac, et. al. Astrophys. J. Letters, 993 (1), L21 (2025)
20. *Cosmological and High Energy Physics Implications from Gravitational-wave Background Searches in LIGO-Virgo-KAGRA's O1-O4a runs,* The LIGO Scientific Collaboration, the Virgo Collaboration, the KAGRA Collaboration, A. G. Abac, et. al. arXiv:2510.26848
21. *Direct Multi-model Dark-matter Search with Gravitational-wave Interferometers using Data from the First Part of the Fourth LIGO-Virgo-KAGRA Observing Run,* The LIGO Scientific Collaboration, the Virgo Collaboration, the KAGRA Collaboration, A. G. Abac, et. al. arXiv:2510.27022
22. *All-sky Search for Continuous Gravitational-wave Signals from Unknown Neutron Stars in Binary Systems in the First Part of the Fourth LIGO-Virgo-KAGRA Observing Run,* The LIGO Scientific Collaboration, the Virgo Collaboration, the KAGRA Collaboration, A. G. Abac, et. al. arXiv:2511.16863
23. *Search for Planetary-mass Ultra-compact Binaries using Data from the First part of the LIGO-Virgo-KAGRA Fourth Observing Run,* The LIGO Scientific Collaboration, the Virgo Collaboration, the KAGRA Collaboration, A. G. Abac, et. al. arXiv:2511.19911
24. *Constraints on Gravitational Waves from the 2024 Vela Pulsar Glitch,* The LIGO Scientific Collaboration, the Virgo Collaboration, the KAGRA Collaboration, A. G. Abac, et. al. arXiv:2512.17990

RESEARCH

ICTS ASSOCIATES

ICTS ASSOCIATES

The ICTS Associates is a distinguished community of scientists whose collaboration and expertise continue to enrich the Centre's scientific mission.

ADJUNCT PROFESSORS

Swapan Chattopadhyay *[Till June 2024]*
Fermilab, Stanford University, USA
Particle; Plasma and Beam Physics; Particle Colliders; Synchrotron Radiation Sources; Free Electron Lasers; Quantum Sensors; Cavity QED and Atomic Interferometers

Sunil Mukhi
IISER Pune
String Theory, Quantum Field Theory, Particle Physics

Ravi S Nanjundiah *[Till March 2025]*
Director, Indian Institute of Tropical Meteorology, Pune
Monsoon Physics, High Performance Computing (HPC), Algorithms for Visualization, and Big Data Analytical Techniques

ICTS VISITING PROFESSOR

Tejaswi Venumadhav Nerella
Institute for Advanced Study, Princeton, USA
Astrophysics and Cosmology

ASSOCIATED FACULTY

Rana Adhikari
Caltech, USA
Gravitational-wave Physics and Astrophysics

Adhip Agarwala
IIT Kanpur
Condensed Matter Physics

Bijay Agarwalla
IISER Pune
Non-equilibrium Statistical Physics

Amit Apte
IISER Pune
Dynamical Systems and Data Assimilation

Mahesh M. Bandi
Okinawa Institute of Science and Technology, Japan
Experimental Nonlinear, Non-equilibrium and Condensed Matter Physics

Sumilan Banerjee
IISc, Bengaluru
Condensed Matter Physics, Statistical Mechanics

Kaushik Basu *[From January 2024]*
University of California, Berkeley, USA
Physics and Mathematics Education, Problem Solving Pedagogy and Inquiry-driven Curriculum Development

Urna Basu
S. N. Bose National Centre for Basic Sciences, Kolkata
Soft Condensed Matter Physics, Statistical Mechanics

Lakshya Bhardwaj
University of Oxford, UK
String Theory and Physical Mathematics

Junaid Majeed Bhat *[From August 2025]*
University of Kashmir, Kupwara
Non-equilibrium Quantum and Classical Physics

Bhaswar Bhattacharya *[From February 2025]*
University of Pennsylvania, USA
Statistics and Applied Probability

Jeremie Bec *[Till December 2024]*
CNRS, CEMEF - MINES ParisTech, France
Fluid Dynamics, Statistical Physics, Turbulence, Turbulent Transport

Sumanta Chakraborty *[Till October 2025]*
Indian Association for the
Cultivation of Science (IACS), Kolkata
Black Hole Physics and Gravitational Wave Astrophysics

Poonam Chandra *[Till April 2024]*
NCRA-TIFR, Pune
Astrophysics

Shailesh Chandrasekharan
Duke University, USA
Strongly Correlated Lattice Field Theories, Quantum Critical Phenomena, Phase Diagrams, Sign Problems, Monte Carlo Algorithms, Quantum Computation. Applications to Quantum Chromodynamics, Fermi and Non-Fermi Liquids, Magnetism, Superconductivity, Quantum Impurities

Debasish Chaudhuri
Institute of Physics, Bhubaneswar
Biological Physics, Soft Condensed Matter Physics, Nonequilibrium Statistical Mechanics and Transport

Kedar Damle
TIFR, Mumbai
Condensed Matter Physics

Sourin Das *[From March 2024]*
IISER kolkata
Quantum Condensed Matter, Quantum Information

Sreejith GJ *[From February 2025]*
IISER, Pune
Condensed Matter Physics

Sarang Gopalakrishnan
Princeton University, USA
Condensed Matter Theory, Quantum Information

Subhajit Goswami
Institut des Hautes Études Scientifiques, France
Probability and Mathematical Physics

Sourendu Gupta *[From July 2024]*
TIFR, Mumbai
Quantum Field Theory, High Performance Computing (HPC), Particle Colliders, Neutron Stars and Condensed Matter Physics

Trishen Gunaratnam *[From March 2025]*
TIFR, Mumbai
Probability Theory and Mathematical Physics

Frank den Hollander
Leiden University, Netherlands
Probability Theory, Statistical Physics, Ergodic Theory, Population Genetics, Complex Networks

Yasir Iqbal
IIT Madras
Condensed Matter Physics

Bala Iyer *[From July 2025]*
ICTS-TIFR, Bengaluru
Gravitational-wave Physics, Analytical Relativity

Prashant Kumar *[From August 2025]*
IIT Bombay, Mumbai
Theoretical Quantum Condensed Matter Physics

Shasvath Kapadia *[Till October 2025]*
IUCAA, Pune
Gravitational-wave Astronomy, Astrophysics and Cosmology

Amala Mahadevan *[Till July 2024]*
The Woods Hole Oceanographic Institution
Physical Oceanography

Gautam Mandal *[Till January 2025]*
TIFR, Mumbai
Gauge Theory and String Theory

Govind Menon *[From April 2024]*
Brown University, USA
Partial Differential Equations, Probability Theory

Narayanan Menon
University of Massachusetts (UMass) Amherst, USA
Experimental Condensed Matter Physics, Statistical Mechanics

Adway Mitra *[Till November 2024]*
IIT Kharagpur
Machine Learning, Data Science, Complex System Modeling and Simulation, Climate Informatics

Subroto Mukerjee
IISc, Bengaluru
Theoretical Condensed Matter Physics

Gananpathy Murthy
University of Kentucky, USA
Condensed Matter Physics

Vidyanand Nanjundiah
Centre for Human Genetics, Bengaluru
Developmental Biology (Pattern Formation), Evolutionary Biology (Social Behaviour), Theoretical Biology

Shobhana Narasimhan *[From March 2025]*
JNCASR, Bengaluru
Condensed Matter Physics

Ashwin Nayak *[From June 2025]*
University of Waterloo, Canada
Theoretical Computer Science

Praneeth Netrapalli
Google Research India, Bengaluru
Computer Science

Rajaram Nityananda *[From July 2025]*
ICTS-TIFR, Bengaluru
Optical and Statistical Physics, Radio Astronomy

Onkar Parrikar *[From August 2024]*
TIFR, Mumbai
Quantum Gravity, AdS/CFT correspondence, Quantum Field Theory

Jahnavi Phalkey
Bangalore Science Gallery
History of Science

Jason Picardo *[From July 2024]*
IIT Bombay
Computational Flow Modelling (CFD), Fluid Mechanics and Stability, Heat and Mass Transfer

Jedediah H. Pixley *[From February 2025]*
Rutgers University, USA
Condensed Matter Physics

Thara Prabhakaran *[Till July 2024]*
Indian Institute of Tropical Meteorology, Pune
Fluid Dynamics

Shiroman Prakash
Dayalbagh Educational Institute, Agra
Gauge Theory and String Theory

Archak Purkayastha
IIT Hyderabad
Non-equilibrium Quantum Statistical Physics

Shankar R.
Institute of Mathematical Sciences, Chennai
Condensed Matter Physics, Glaciers and Climate

Srinivas Raghu *[From November 2024]*
Stanford University, USA
Condensed Matter Physics

Mythily Ramaswamy *[From March 2024]*
ICTS-TIFR, Bengaluru
Partial Differential Equations, Control Theory and Fluid flow problems

Sujatha Ramdorai
University of British Columbia, Canada
Algebraic Theory of Quadratic Forms, Arithmetic Geometry of Elliptic Curves, Study of Motives and Noncommutative Iwasawa Theory

Kabir Ramola *[Till February 2025]*
TIFR Hyderabad
Classical and Quantum Statistical Mechanics, Soft Matter Physics, Condensed Matter Theory, Computational Physics

V. Ravindran *[From November 2025]*
IMSc, Chennai
Perturbative Quantum Chromodynamics

Sanjib Sabhapandit
RRI, Bengaluru
Statistical Physics

Srikanth Sastry *[From October 2025]*
JNCASR, Bengaluru
Statistical Mechanics and Soft Matter Physics

BS Sathyaprakash
The Pennsylvania State University, USA
Gravitational-wave Physics and Astrophysics

Arnab Sen
Indian Association for the
Cultivation of Science (IACS), Kolkata
Strongly Correlated Systems and Statistical Mechanics

Suraj Shankar *[From April 2024]*
University of Michigan, USA
Condensed Matter, Statistical Mechanics, Complex Systems, Biology

Herbert Spohn
Technical University of Munich, Germany
Condensed Matter Physics

Mukund Thattai *[Till September 2025]*
NCBS-TIFR, Bengaluru
Computational Cell Biology

Dootika Vats *[From December 2024]*
IIT Kanpur
Statistics

Dario Vincenzi *[Till December 2024]*
CNRS, Université Côte d'Azur, France
Numerical Modeling and Fluid Dynamics

Raju Venugopalan *[From June 2025]*
Brookhaven National Laboratory, USA
QCD, Quantum Field Theory, Many-body physics, Collider physics

Mahendra Verma *[From October 2025]*
IIT Kanpur
Turbulence, Nonequilibrium Statistical Physics

PROGRAM ACTIVITIES @ICTS

PROGRAMS AND DISCUSSION MEETINGS

ICTS has successfully hosted 53 programs and 23 discussion meetings during the years 2024-2025.

List of programs

Hydrodynamics, Fluctuations, and Noise in Quantum and Classical Systems
Organizers: Jacopo De Nardis *(Cergy Paris University, France)*, Gautam Mandal *(ICTS-TIFR, Bengaluru)* and Tridib Sadhu *(TIFR, Mumbai)* ♦ 1-12 December 2025

Combinatorics, Geometry, and Representation Theory
Organizers: Vyjayanthi Chari *(University of California, Riverside, USA)*, Raghavan K.N. *(Krea Unviersity, Sricity)*, Venkatesh Rajendran *(IISc, Bengaluru)* and Milen Yakimov *(Northeastern University, USA)* ♦ 17-28 November 2025

Geometry, Mechanics and the Physics of Growth
Organizers: Joel Marthelot *(Aix-Marseille University, France)*, S Ganga Prasath *(IIT Madras, Chennai)* and Suraj Shankar *(University of Michigan, USA)* ♦ 3-14 November 2025

Women in Astrophysics: Voices, Equity, and Science (WAVES) - A Workshop on Gender Equity and Advances in Astrophysics
Organizers: Pallavi Bhat *(ICTS-TIFR, Bengaluru)*, Preeti Kharb *(NCRA-TIFR, Pune)* and Ruta Kale *(NCRA-TIFR, Pune)* ♦ 3-4 November 2025

FTSky: A program in the field of Fast Radio Transients
Organizers: Jayanta Roy *(NCRA-TIFR, Pune)*, J. Xavier Prochaska *(University of California-Santa Cruz, USA)*, Laura Spitler *(MPIFR, Germany)*, Manisha Caleb *(University of Sydney, Australia)*, Scott Ransom *(National Radio Astronomy Observatory, USA)*, Wesley Armour *(University of Oxford, UK)*, Bhaswati Bhattacharyya *(NCRA-TIFR, Pune)*, Resmi Lekshmi *(IIST, Kerala)*, Yogesh Maan *(NCRA-TIFR, Pune)* and Visweshwar Ram Marthi *(NCRA-TIFR, Pune)* ♦ 6-17 October, 2025

Dynamics and Evolution of RNA Functions
Organizers: Sandeep Eswarappa, Tanweer Hussain, Purusharth I. Rajyaguru and Umesh Varshney *(IISc, Bengaluru)* ♦ 22 September-3 October 2025

Bangalore School on Statistical Physics-XVI
Organizers: Abhishek Dhar *(ICTS-TIFR, Bengaluru)* and Sanjib Sabhapandit *(RRI, Bengaluru)* ♦ 3-19 September 2025

Geometry and Analysis of Minimal Surfaces
Organizers: Rukmini Dey *(ICTS-TIFR, Bengaluru)*, Rafe Mazzeo *(Stanford University, USA)*, Charles Ouyang *(Washington University, USA)* and Franz Pedit *(University of Massachusetts, Amherst, USA)* ♦ 18-29 August 2025

Data Science: Probabilistic and Optimization Methods II
Organizers: Jatin Batra *(TIFR, Mumbai)*, Vivek Borkar *(IIT Bombay, Mumbai)*, Sandeep Juneja *(Ashoka University, Sonepat)*, Praneeth Netrapalli *(Google DeepMind, Bengaluru)* and Devavrat Shah *(MIT, Cambridge, USA)* ♦ 4-15 August 2025

Unifying Theories in High-Dimensional Biophysics
Organizers: Marianne Bauer *(Delft University of Technology, Netherlands)*, Akshit Goyal *(ICTS-TIFR, Bengaluru)*, Sidhartha Goyal *(University of Toronto, Canada)* and Gautam Reddy *(Princeton University, USA)* ♦ 21 July-1 August 2025

Advanced Machine Learning for Earth System Modeling
Organizers: Roxy Mathew Koll *(IITM, Pune)*, Bipin Kumar *(IITM, Pune)*, Adway Mitra *(IIT Kharagpur)* and Shikha Singh *(IITM, Pune)* ♦ 7-18 July 2025

Summer School on Gravitational-Wave Astronomy
Organizers: Parameswaran Ajith *(ICTS-TIFR, Bengaluru)*, K.G. Arun *(CMI, Chennai)*, Bala R. Iyer *(ICTS-TIFR, Bengaluru)* and Prayush Kumar *(ICTS-TIFR, Bengaluru)* ♦ 7-18 July 2025

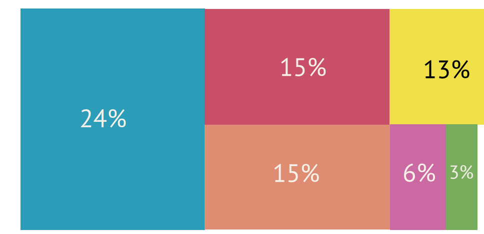
Summer School for Women in Physics 2025
Organizers: Ranjini Bandyopadhyay *(RRI, Bengaluru)*, Mahua Ghosh *(Mount Carmel College, Bengaluru)*, Kripa Gowrishankar *(APU, Bengaluru)*, Sushan Konar *(NCRA-TIFR, Pune)*, P.K. Mohanty *(IISER Kolkata)*, Rajaram Nityananda *(ICTS-TIFR, Bengaluru)*, Shirish Pathare *(HBCSE-TIFR, Mumbai)* and Sumathi Rao *(ICTS-TIFR, Bengaluru)* ♦ 16-27 June 2025

Summer School for Women in Mathematics and Statistics *Organizers:* Nikita Agarwal *(IISER Bhopal)*, Siva Athreya *(ICTS-TIFR, Bengaluru)*, Rhythm Grover *(IIT Guwahati)* and Dootika Vats *(IIT Kanpur)* ♦ 2-13 June 2025

Automorphic Forms and the Bloch–Kato Conjecture
Organizers: Ashay Burungale *(University of Texas, Austin, USA)*, Haruzo Hida *(University of California, Los Angeles, USA)*, Somnath Jha *(IIT Kanpur)* and Ye Tian *(MCM, Chinese Academy of Sciences, China)* ♦ 19-30 May 2025

SUBJECTS	NO OF EVENTS
Mathematics and Computer Science	24
Statistical Physics and Condensed Matter	15
Astrophysics and Cosmology	15
Quantitative Biology	13
Climate Sciences and Fluid Dynamics	6
High Energy Physics	3

Total Participation	**6608**
Total Participation days	**637**
Indian participation	5295
Foreign Participation	1313
SPEAKERS	
Indian	773
Foreign	801
GENDER	
Female	1939
Male	4666
Other	3
STUDENTS AND POSTDOCS	
Indian	3390
Foreign	613



Jan 2024 - Dec 2025	**76**
Discussion Meetings	23
Programs	53

ICTS Workshop on HDXs and Codes
Organizers: Irit Dinur *(Weizmann Institute of Science Rehovot, Israel)*, Venkat Guruswami *(University of California, Berkeley, USA)* and Prahladh Harsha *(TIFR, Mumbai)* ♦ 28 April-9 May 2025

Radio Cosmology and Continuum Observations in the SKA Era: A Synergic View
Organizers: Suman Majumdar *(IIT Indore)*, Abhirup Datta *(IIT Indore)*, Ilian T Iliev *(University of Sussex, UK)*, Mark T Sargent *(ISSI, Switzerland)*, Dharam Vir Lal *(NCRA-TIFR, Pune)*, Nirupam Roy *(IISc, Bengaluru)*, Tirthankar Roy Choudhury *(NCRA-TIFR, Pune)*, Girish Kulkarni *(TIFR, Mumbai)*, Narendra Nath Patra *(IIT Indore)* and Saurabh Singh *(RRI, Bengaluru)* ♦ 7-18 April 2025

Beyond the Horizon: Testing the Black Hole Paradigm
Organizers: Sumanta Chakraborty *(IACS, Kolkata)* and Sudipta Sarkar *(IIT Gandhinagar)* ♦ 24 March-4 April 2025

Decisions, Games, and Evolution
Organizers: Sagar Chakraborty *(IIT Kanpur)*, Vishwesha Guttal *(IISc, Bengaluru)*, Sandeep Krishna *(NCBS-TIFR, Bengaluru)* and Supratim Sengupta *(IISER Kolkata)* ♦ 10-21 March 2025

New Trends in Teichmüller Theory
Organizers: Krishnendu Gongopadhyay *(IISER Mohali)*, Subhojoy Gupta *(IISc, Bengaluru)*, Kenichi Ohshika *(Gakushuin University, Japan)* and Athanase Papadopoulos *(CNRS and University of Strasbourg, France)* ♦ 24 February-7 March 2025

Positive Geometry in Scattering Amplitudes and Cosmological Correlators
Organizers: Nima Arkani-Hamed *(IAS Princeton, USA)*, Johannes Henn *(MPI Physics, Germany)*, Suvrat Raju *(ICTS-TIFR, Bengaluru)* and Jaroslav Trnka *(University of California Davis, USA)* ♦ 10-21 February 2025

Quantum Trajectories
Organizers: Michel Bauer *(IPhT, CEA Saclay, France)*, Cedric Bernardin *(National Research University Higher School of Economics, Moscow, Russia)*, Raphael Chetrite *(Université Côte d'Azur, Nice, France)* and Abhishek Dhar *(ICTS-TIFR, Bengaluru)* ♦ 20 January-7 February 2025

ICTP-ICTS Winter School on Quantitative Systems Biology
Organizers: Stefano Allesina *(University of Chicago, USA)*, Akshit Goyal *(ICTS-TIFR, Bengaluru)*, Jacopo Grilli *(ICTP, Italy)* and Meghna Krishnadas *(NCBS-TIFR, Bengaluru)* ♦ 6-17 January 2025

Hearing Beyond the Standard Model with Cosmic Sources of Gravitational Waves
Organizers: Koushik Dutta *(IISER Kolkata)*, Tathagata Ghosh *(HRI, Allahabad)*, Anish Ghoshal *(University of Warsaw, Poland)* and Subhendra Mohanty *(IIT Kanpur)* ♦ 30 December 2024-10 January 2025

Indo-French Workshop on Classical and Quantum Dynamics in Out of Equilibrium Systems
Organizers: Abhishek Dhar *(ICTS-TIFR, Bengaluru)*, Manas Kulkarni *(ICTS-TIFR, Bengaluru)*, Satya N. Majumdar *(LPTMS, France)*, Gautam Mandal *(TIFR, Mumbai)*, Alberto Rosso *(LPTMS, France)* and Gregory Schehr *(LPTHE, France)* ♦ 16-20 December 2024

Combinatorial Methods in Enumerative Algebra
Organizers: Angela Carnevale *(University of Galway, Ireland)*, Uri Onn *(Australian National University, Australia)*, Amritanshu Prasad *(IMSc, Chennai)*, Pooja Singla *(IIT Kanpur)* and Christopher Voll *(Bielefeld University, Germany)* ♦ 2-13 December 2024

Moist Convective Dynamics of Monsoons
Organizers: Gilles Bellon *(CNRM Toulouse, France)*, Vishal Dixit *(IIT Bombay, Mumbai)*, Bishakhdatta Gayen *(IISc, Bengaluru)* and Jim Thomas *(ICTS-TIFR & TIFR-CAM, Bengaluru)* ♦ 18-29 November 2024

Circle Method and Related Topics
Organizers: Mallesham Kummari *(IIT Bombay, Mumbai)*, Ritabrata Munshi *(Indian Statistical Institute [ISI] Kolkata)* and Saurabh Kumar Singh *(IIT Kanpur)* ♦ 28 October-8 November 2024

Discrete Integrable Systems: Difference Equations, Cluster Algebras and Probabilistic Models
Organizers: Arvind Ayyer *(IISc, Bengaluru)*, Rei Inoue *(Chiba University, Japan)*, Rinat Kedem *(UIUC, USA)*, Sanjay Ramassamy *(CNRS, France)* and Ralph Willox *(University of Tokyo, Japan)* ♦ 21 October-1 November 2024

3rd IAGRG School on Gravitation and Cosmology
Organizers: Parameswaran Ajith *(ICTS-TIFR, Bengaluru)*, Sudipta Das *(Visva-Bharati, Santiniketan)*, Archana Pai *(IIT Bombay, Mumbai)*, Sudipta Sarkar *(IIT Gandhinagar)*, Anjan Ananda Sen *(JMI New Delhi)* and Amitabh Virmani *(CMI, Chennai)* ♦ 14-25 October 2024

Deterministic and Stochastic Analysis of Euler and Navier-Stokes Equations
Organizers: Ujjwal Koley and Debayan Maity *(TIFR-CAM Bengaluru)* ♦ 23 September-4 October 2024

Interdisciplinary Aspects of Chromatin Organization and Gene Regulation
Organizers: Mithun Kumar Mitra *(IIT Bombay, Mumbai)*, Dimple Notani *(NCBS-TIFR, Bengaluru)* and Ranjith Padinhateeri *(IIT Bombay, Mumbai)* ♦ 9-20 September 2024

Bangalore School on Statistical Physics XV
Organizers: Abhishek Dhar *(ICTS-TIFR, Bengaluru)* and Sanjib Sabhapandit *(RRI, Bengaluru)* ♦ 4-20 September 2024

Quantum Information, Quantum Field Theory and Gravity
Organizers: Vijay Balasubramanian *(University of Pennsylvania, USA)*, Pawel Caputa *(University of Warsaw, Poland)*, Johanna Erdmenger *(Julius Maximilian University of Würzburg (JMU), Germany)*, Onkar Parrikar *(TIFR, Mumbai)*, Suvrat Raju *(ICTS-TIFR, Bengaluru)*, Tadashi Takayanagi *(Yukawa Institute for Theoretical Physics (YITP), Japan)* and Sandip Trivedi *(TIFR, Mumbai)* ♦ 12 August-6 September 2024

Geometry in Groups
Organizers: Radhika Gupta *(TIFR, Mumbai)* and Suraj Krishna M.S. *(Technion-Israel Institute of Technology, Haifa, Israel)* ♦ 29 July-9 August 2024

Engineered 2D Quantum Materials
Organizers: Arindam Ghosh *(IISc, Bengaluru)*, Priya Mahadevan *(SNBNCBS, Kolkata)*, Srimanta Middey *(IISc, Bengaluru)*, Arun Paramekanti *(University of Toronto, Canada)* and Chandni U *(IISc, Bengaluru)* ♦ 15-26 July 2024

Emerging Infectious Diseases: Ecology and Evolution
Organizers: Uma Ramakrishnan *(NCBS-TIFR, Bengaluru)*, Farah Ishtiaq *(Tata Institute of Genetics and Society, Bengaluru)* and Ansil BR *(NCBS-TIFR, Bengaluru)* ♦ 1-12 July 2024

Summer School on Gravitational-Wave Astronomy
Organizers: Parameswaran Ajith *(ICTS-TIFR, Bengaluru)*, K.G. Arun *(CMI, Chennai)*, Bala R. Iyer *(ICTS-TIFR, Bengaluru)* and Prayush Kumar *(ICTS-TIFR, Bengaluru)* ♦ 1-12 July 2024

Summer School for Women in Mathematics and Statistics *Organizers:* Siva Athreya *(ICTS-TIFR and ISI, Bengaluru)*, Rhythm Grover *(IIT Guwahati)* and Dootika Vats *(IIT Kanpur)* ♦ 17-28 June 2024

Summer School for Women in Physics 2024
Organizers: S. Annapoorni *(Delhi University)*, Ranjini Bandyopadhyay *(RRI, Bengaluru)*, Dipankar Bhattacharya *(Ashoka University, Sonepat)*, Mahua Ghosh *(Mount Carmel College, Bengaluru)*, Kripa Gowrishankar *(Azim Premji University, Bengaluru)*, Sushan Konar *(NCRA-TIFR, Pune)*, Rajaram Nityananda *(ICTS-TIFR, Bengaluru)*, Shirish Pathare *(HBCSE-TIFR, Mumbai)*, Sumathi Rao *(ICTS-TIFR, Bengaluru)*, Joseph Samuel *(ICTS-TIFR, Bengaluru)*, T. R. Seshadri *(Delhi University)* and Supurna Sinha *(RRI, Bengaluru)* ♦ 3-14 June 2024

Theoretical and Practical Perspectives in Geophysical Fluid Dynamics
Organizers: Manita Chouksey *(Institut für Ostseeforschung Warnemünde, Germany)*, Hossein Amini Kafiabad *(Durham University, UK)*, Han Wang *(University of Edinburgh, UK)* and Jim Thomas *(ICTS-TIFR and TIFR-CAM, Bengaluru)* ♦ 20-31 May 2024

Theoretical and Empirical Approaches to Understand Polygenic Adaptation
Organizers: Kavita Jain *(JNCASR, Bengaluru)*, Christian Schlötterer *(Vetmeduni Vienna, Austria)* and Sam Yeaman *(University of Calgary, Canada)* ♦ 6-17 May 2024

Workshop on Data Assimilation in Weather and Climate Models
Organizers: Govindan Kutty *(Indian Institute of Space Science and Technology, Valiamala)*, A. Chandrasekar *(Indian Institute of Space Science and Technology, Valiamala)* and Amit P Kesarkar *(National Atmospheric Research Laboratory, Gadanki)* ♦ 6-17 May 2024

Understanding the Universe Through Neutrinos
Organizers: Amol Dighe *(TIFR, Mumbai)*, Srubabati Goswami *(PRL, Ahmedabad)*, Alex Himmel *(Fermilab, Chicago, USA)*, Rukmani Mohanta *(University of Hyderabad)* and Sanjay Kumar Swain *(NISER Bhubaneswar)* ♦ 22 April-3 May 2024

School for Advanced Topics in Particle Physics (SATPP): Selected Topics in Effective Field Theories
Organizers: Rick Sandeepan Gupta *(TIFR, Mumbai)*, Tuhin S. Roy *(TIFR, Mumbai)* and Sudhir Vempati *(IISc, Bengaluru)* ♦ 8-19 April 2024

Theoretical Approaches in Cancer Progression and Treatment
Organizers: Helen Byrne *(Oxford University, UK)*, Shaon Chakrabarti *(NCBS-TIFR, Bengaluru)*, Mohit Kumar Jolly *(IISc, Bengaluru)* and Franziska Michor *(Harvard University, USA)* ♦ 11-22 March 2024

Future Roadmap Vision 2047 - Chintan Shivir
Organizers: Heads of Aided Institutes of DAE ♦ 5-9 March 2024

Predictability in General Relativity
Organizers: Shalabh Gautam *(ICTS-TIFR, Bengaluru)*, Prayush Kumar *(ICTS-TIFR, Bengaluru)*, Kartik Prabhu *(RRI, Bengaluru)* and Sumati Surya *(RRI, Bengaluru & IAGRG, Kalapakkam)* ♦ 28-29 February 2024

Recent Advances on Control Theory of PDE Systems
Organizers: Shirshendu Chowdhury *(IISER Kolkata)*, Debayan Maity *(TIFR-CAM, Bengaluru)* and Debanjana Mitra *(IIT Bombay, Mumbai)* ♦ 12-23 February 2024

Sixth Bangalore School on Population Genetics and Evolution
Organizers: Deepa Agashe *(NCBS-TIFR, Bengaluru)* and Kavita Jain *(JNCASR, Bengaluru)* ♦ 12-23 February 2024

International School and Workshop on Probing Hadron Structure at the Electron-Ion Collider
Organizers: Abhay Deshpande *(CFNS, Stony Brook University and Brookhaven National Laboratory, USA)*, Bedangadas Mohanty *(NISER Bhubaneswar)*, Asmita Mukherjee *(IIT Bombay, Mumbai)* and Marco Radici *(INFN Pavia, Italy)* ♦ 29 January-9 February 2024

Stability of Quantum Matter in and out of Equilibrium at Various Scales
Organizers: Arnab Das *(IACS, Kolkata)*, Roderich Moessner

(Max Planck Institute for the Physics of Complex Systems, Dresden, Germany)*, Anatoli Polkovnikov *(Boston University, USA)*, Tomaz Prosen *(University of Ljubljana, Slovenia)* and Dibyendu Roy *(RRI, Bengaluru)* ♦ 15-26 January 2024

Zariski Dense Subgroups, Number Theory and Geometric Applications
Organizers: Gopal Prasad *(University of Michigan, USA)*, Andrei Rapinchuk *(University of Virginia, USA)*, B Sury *(ISI, Bengaluru)* and Aleksy Tralle *(University of Warmia and Mazury, Poland)* ♦ 1-12 January 2024

DISCUSSION MEETINGS

Women at the Intersection of Mathematics and Theoretical Physics
Organizers: Sylvie Paycha *(University of Potsdam, Germany)*, Sujatha Ramdorai *(University of British Columbia, Canada)*, Kasia Rejzner *(University of York, UK)* and Sumati Surya *(RRI, Bengaluru)* ♦ 29 December-2 January 2025

Frontiers in Quantum Condensed Matter Physics
Organizers: Sumilan Banerjee *(IISc, Bengaluru)*, Ravindra N. Bhatt *(Princeton University, USA)*, Subhro Bhattacharjee *(ICTS-TIFR, Bengaluru)*, Arindam Ghosh *(IISc, Bengaluru)*, H. R. Krishnamurthy *(IISc & ICTS-TIFR, Bengaluru)*, Mohit Randeria *(Ohio State University, USA)*, Subir Sachdev *(Harvard University, USA)* and Nandini Trivedi *(Ohio State University, USA)* ♦ 15-19 December 2025

The Future of Gravitational-Wave Astronomy
Organizers: Parameswaran Ajith *(ICTS-TIFR, Bengaluru)*, K G Arun *(CMI, Chennai)*, Sumanta Chakraborty *(IACS, Kolkata)*, Bala Iyer *(ICTS-TIFR, Bengaluru)*, Prayush Kumar *(ICTS-TIFR, Bengaluru)*, Surhud More *(IUCAA, Pune)*, Archana Pai *(IIT Bombay, Mumbai)* and Sudipta Sarkar *(IIT Gandhinagar)* ♦ 27-31 October 2025

Spatial Organization of Biological Functions
Organizers: Sankar Adhya *(National Cancer Institute [NCI], USA)*, Anjana Badrinarayanan *(NCBS-TIFR, Bengaluru)*, Vijaykumar Krishnamurthy *(ICTS-TIFR, Bengaluru)*, Melike Lakadamyali *(University of Pennsylvania, USA)*, Satyajit Mayor *(NCBS-TIFR, Bengaluru & University of Warwick, UK)* and Jie Xiao *(Johns Hopkins School of Medicine, USA)* ♦ 21-24 October 2025

AI and Fundamental Sciences Workshop
Organizers: Jatin Batra *(TIFR, Mumbai)*, Sarthak Chandra *(ICTS-TIFR, Bengaluru)*, Rajesh Gopakumar *(ICTS-TIFR, Bengaluru)*, Manish Gupta *(Google DeepMind)*, Prateek Jain *(Google DeepMind)*, Ameena Khaleel *(Google, India)*, Prayush Kumar *(ICTS-TIFR Bengaluru)*, Vinothkumar Kutti Ragunath *(NCBS-TIFR, Bengaluru)*, Suvrat Raju *(ICTS-TIFR Bengaluru)*, Ashwani Sharma *(Google, India)*, LS Shashidhara *(NCBS-TIFR, Bengaluru)* and Shruthi Viswanath *(NCBS-TIFR, Bengaluru)* ♦ 7 October 2025

Discussion Meeting on Fractionalized Quantum Matter
Organizers: Subhro Bhattacharjee, Rajesh Gopakumar, Sumathi Rao and Sthitadhi Roy *(ICTS-TIFR, Bengaluru)* and Arindam Ghosh *(IISc, Bengaluru)* ♦ 28-29 July 2025

Harmonic Maass Forms, Mock Modular Forms and Their Applications
Organizers: Ajit Bhand and Karam Deo Shankhadhar *(IISER Bhopal)* ♦ 30 June-4 July 2025

Geometry, Probability, and Algorithms
Organizers: Akash Kumar *(IIT Bombay, Mumbai)*, Anand Louis *(IISc, Bengaluru)* and Piyush Srivastava *(TIFR, Mumbai)* ♦ 12-16 May 2025

Gravitational Wave Open Data Workshop 2025
Organizers: Parameswaran Ajith *(ICTS-TIFR, Bengaluru)*, Ankur Barsode *(ICTS-TIFR, Bengaluru)*, Bala Iyer *(ICTS-TIFR, Bengaluru)*, Alorika Kar *(ICTS-TIFR, Bengaluru)*, Prayush Kumar *(ICTS-TIFR, Bengaluru),* Akash Maurya *(ICTS-TIFR, Bengaluru)* and Koustav Narayan Maity *(ICTS-TIFR, Bengaluru)* ♦ 12-14 May 2025

Lean for the Curious Mathematician
Organizers: Siddhartha Gadgil *(IISc, Bengaluru)*, Ashvni Narayanan *(University of Sydney, Australia)* and T. V. H. Prathamesh *(Krea University, Andhra Pradesh)* ♦ 24-26 April 2025

10th Indian Statistical Physics Community Meeting
Organizers: Ranjini Bandyopadhyay *(RRI, Bengaluru)*, Abhishek Dhar *(ICTS-TIFR, Bengaluru)*, Kavita Jain *(JNCASR, Bengaluru)*, Rahul Pandit *(IISc, Bengaluru)*, Sanjib Sabhapandit *(RRI, Bengaluru)* and Samriddhi Sankar Ray *(ICTS-TIFR, Bengaluru)* ♦ 23-25 April 2025

[Clockwise from top left) Participants of the Workshop on Data Assimilation in Weather and Climate Models (May 2024); Bangalore School of Statistical Physics (September 2025); Women at the Intersection of Mathematics and Physics (December 2025); A Hundred Years of Quantum Mechanics (January 2025); and Discussion Meeting on Neuroscience, Data Science and Dynamics (April 2025). ♦ **Photo credit: AS Sumukh.**

Discussion Meeting on Neuroscience, Data Science and Dynamics
Organizers: Amit Apte *(IISER Pune)*, Neelima Gupte *(IIT Madras, Chennai)* and Ramakrishna Ramaswamy *(IIT Delhi)* ♦ 21-23 April 2025

A Hundred Years of Quantum Mechanics
Organizers: Abhishek Dhar and Rajesh Gopakumar *(ICTS-TIFR Bengaluru)* | 13-17 January 2025

Quantum Many-Body Physics in the Age of Quantum Information
Organizers: Subhro Bhattacharjee *(ICTS-TIFR, Bengaluru)*, Manas Kulkarni *(ICTS-TIFR, Bengaluru)*, Subroto Mukerjee *(IISc, Bengaluru)* and Sthitadhi Roy *(ICTS-TIFR, Bengaluru)* ♦ 25-29 November 2024

Climate Dynamics and Networks
Organizers: Neelima Gupte *(IIT Madras, Chennai)*, Ramakrishna Ramaswamy *(IIT Delhi)* and Rupali Sonone ♦ 11-15 November 2024

Zero Mean Curvature Surfaces
Organizers: Rukmini Dey *(ICTS-TIFR, Bengaluru)* and Pradip Kumar *(Shiv Nadar University, Noida)* ♦ 2-6 September 2024

Kagome Off-scale
Organizers: Yasir Iqbal *(IIT Madras, Chennai)* and Ronny Thomale *(Julius Maximilians University of Wurzburg, Germany)* ♦ 12-16 August 2024

Cosmic Revelations: A Joint DESI and eROSITA Symposium *Organizers:* Shadab Alam and Subha Majumdar *(TIFR, Mumbai)* ♦ 22 May 2024

Gravitational Wave Open Data Workshop
Organizers: Parameswaran Ajith, Ankur Barsode, Bala Iyer, Prayush Kumar and Akash Maurya *(ICTS-TIFR, Bengaluru)* ♦ 18-20 April 2024

9th Indian Statistical Physics Community Meeting
Organizers: Ranjini Bandyopadhyay *(RRI, Bengaluru)*, Abhishek Dhar *(ICTS-TIFR, Bengaluru)*, Kavita Jain *(JNCASR, Bengaluru)*, Rahul Pandit *(IISc, Bengaluru)*, Samriddhi Sankar Ray *(ICTS-TIFR, Bengaluru)*, Sanjib Sabhapandit *(RRI, Bengaluru)* and Prerna Sharma *(IISc, Bengaluru)* ♦ 3-5 April 2024

Grothendieck Teichmüller Theory
Organizers: Pierre Lochak *(CNRS and IMJ-PRG, Paris, France)* and Devendra Tiwari *(Bhaskaracharya Pratishthana, Pune)* ♦ 26 February-1 March 2024

Turbulence and Vortex Dynamics in 2D Quantum Fluids
Organizers: Dario Ballarini *(CNR NANOTEC, Italy)*, Iacopo Carusotto *(CNR-INO, BEC Center, Trento)*, Alessandra S. Lanotte *(CNR NANOTEC and INFN, Lecce, Italy)*, Samriddhi Sankar Ray *(ICTS-TIFR, Bengaluru)* and Daniele Sanvitto *(CNR NANOTEC, Italy)* ♦ 26 February-1 March 2024

ICTS-NETWORKS Workshop "Challenges in Networks"
Organizers: Siva Athreya *(ISI, Bengaluru and ICTS-TIFR, Bengaluru)*, Arijit Chakraborty *(ISI Kolkata)*, Rajat Subhra Hazra *(Universiteit Leiden, Netherlands)* and Frank den Hollander *(Universiteit Leiden, Netherlands)* ♦ 29 January-2 February 2024

[Clockwise from top left] Participants of Geometry and Analysis of Minimal Surfaces (August 2025); Dynamics and Evolution of RNA Functions (September 2025); and the Summer School for Women in Mathematics and Statistics (June 2025). ♦ **Photo credit: A.S. Sumukh.**

PROGRAM ACTIVITIES

LECTURE SERIES

INFOSYS-ICTS CHANDRASEKHAR LECTURES

Topology of Electronic Materials and their Linear and Nonlinear Responses
Joel Moore *(University of California Berkeley and Lawrence Berkeley National Laboratory, Berkeley, USA)* ♦ 26-28 November 2024

Entanglement and Emergence of Gravitational Spacetime
Tadashi Takayanagi *(Yukawa Institute for Theoretical Physics, Japan)* ♦ 13, 14, 16 August 2024

INFOSYS-ICTS RAMANUJAN LECTURES

Applied l-adic Cohomology
Philippe Michel *(Ecole Polytechnique Fédérale de Lausanne, Lausanne, Switzerland)* ♦ 29 October-2 November 2024

The Onsager Theorem and Beyond
Camillo De Lellis *(Institute for Advanced Study, Princeton, USA)* ♦ 26 September-3 October 2024

INFOSYS-ICTS TURING LECTURES

The Mathematics of Large Machine Learning Models
Andrea Montanari *(Stanford University, USA)* ♦ 11 August 2025

Dynamical Systems and Artificial Intelligence Applied to Data Modelling in Biological Problems
Gabriel Mindlin *(University of Buenos Aires, Argentina)* ♦ 21 April 2025

DISTINGUISHED LECTURES

Gravitational Wave Stochastic Backgrounds and Pulsar Timing Arrays
Bruce Allen *(Max Planck Institute for Gravitational Physics, Hannover, Germany)* ♦ 30 October 2025

A Strange New Universe: Where Bizarre Quantum Particles Rule
Jainendra Jain *(Pennsylvania State University, USA)* ♦ 11 July 2025

Are We Living in the Matrix? What Quantum Experiments Reveal About the World and Our Powers in it, and What the Future May Hold
Howard Wiseman *(Griffith University, Brisbane, Australia)* ♦ 27 January 2025

Dissipation and Mixing: From Turbulent Flows to Weak Solutions
László Székelyhidi *(Max Planck Institute for Mathematics in the Sciences, Germany)* ♦ 23 September 2024

Arithmetic Topological Quantum Field Theory
Minhyong Kim *(University of Edinburgh, UK)* ♦ 2 September 2024

Why We Explore?
Robert Myers *(Perimeter Institute for Theoretical Physics, Canada)* ♦ 28 August 2024

The Atiyah Singer Index Theorem - An Overview
Madabusi Raghunathan *(Distinguished Professor, UM-DAE Centre for Excellence in Basic Sciences & Honorary Fellow, TIFR, Mumbai)* ♦ 22 July 2024

Principles of Evolutionary Overdesign and Underperformance
Michael Lynch *(Center for Mechanisms of Evolution, Arizona State University, USA)* ♦ 10 May 2024

The Evolutionary Enigma of Sex
Sarah Otto *(University of British Columbia, Canada)* ♦ 16 February 2024

FOUNDATION DAY LECTURES

A Tale of Two Symmetries
Chandrashekhar Khare *(University of California, Los Angeles, USA)* ♦ 9 December 2025

During the 2025 Foundation Day celebrations, two other events were held. Sundararaman Ramanan gifted a collection of his gifts to ICTS-TIFR, which will now be a part of the ICTS Library. Prof. Ramanan is a distinguished mathematician known for his fundamental contributions to algebraic geometry and differential geometry, in particular, for his study of the moduli spaces of vector bundles on curves which has received wide application in mathematics and theoretical physics.

Then, Chandrashekhar Khare discussed his book *Chasing a Conjecture: Inside the Mind of a Mathematician* with Centre Director Rajesh Gopakumar. The book is a personal and insightful memoir that captures the intellectual and emotional journey behind mathematical discovery. Through the story of pursuing deep problems in number theory, Prof. Khare reflects on mentorship, collaboration, setbacks and breakthroughs, offering a rare look into how a mathematician thinks and what it takes to arrive at a profound result.

Two Paradoxes in the Theory of Games
Deepak Dhar *(ICTS-TIFR, Bengaluru)* ♦ 27 December 2024

VISHVESHWARA LECTURES

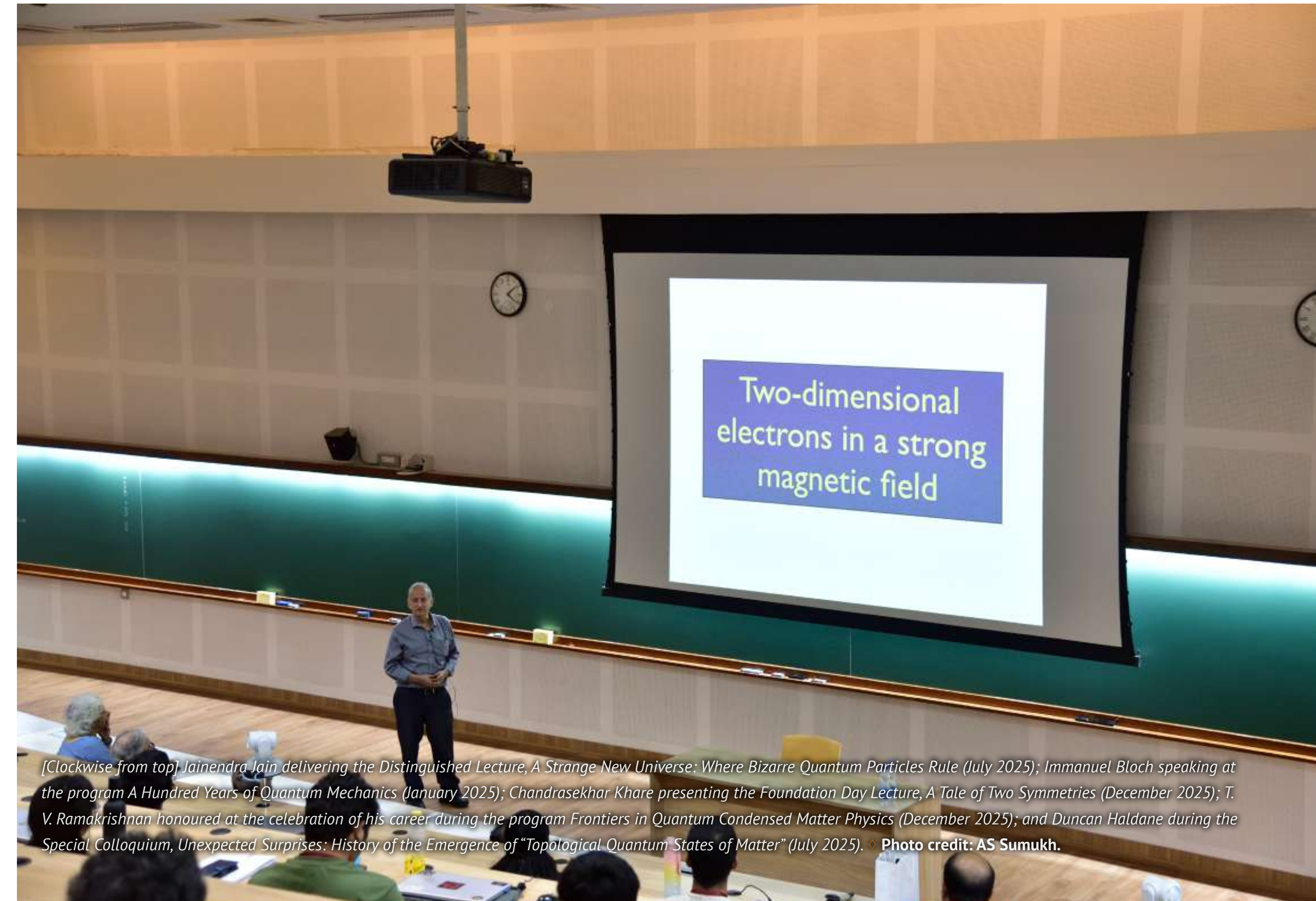
Quantum Astrophysics
Roger Blandford *(Stanford University, USA)* ♦ 18 January 2025

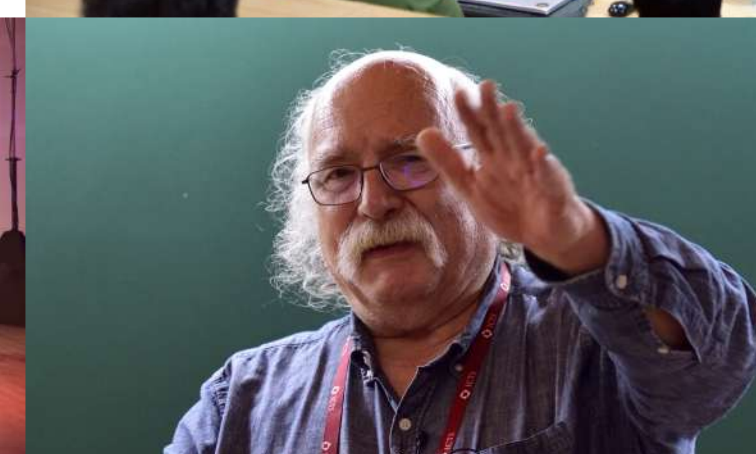
Gravitational-wave Astronomy: New Discoveries, Puzzles & Prospects
B.S. Sathyaprakash *(Penn State University, USA & Cardiff University, UK)* ♦ 3 January 2024

MADHAVA LECTURES

'Assaying' the Eight Metals of Antiquity: Archaeometallurgical Perspectives on Indian Heritage
Sharada Srinivasan *(National Institute of Advanced Studies, Bengaluru)* ♦ 12-14 March 2024


[Top] Dancers from Nrityagram performing at the Subrahmanyan Chandrasekhar auditorium at ICTS-TIFR (May 2025) [Below] Members around the vibrant pookalam they designed in celebration of Onam (September 2025)
Photo credit: AS Sumukh.







[Clockwise from top] Jainendra Jain delivering the Distinguished Lecture, A Strange New Universe: Where Bizarre Quantum Particles Rule (July 2025); Immanuel Bloch speaking at the program A Hundred Years of Quantum Mechanics (January 2025); Chandrasekhar Khare presenting the Foundation Day Lecture, A Tale of Two Symmetries (December 2025); T. V. Ramakrishnan honoured at the celebration of his career during the program Frontiers in Quantum Condensed Matter Physics (December 2025); and Duncan Haldane during the Special Colloquium, Unexpected Surprises: History of the Emergence of "Topological Quantum States of Matter" (July 2025). ♦ **Photo credit: AS Sumukh.**

OUTREACH

@ICTS

OUTREACH

The mission of connecting science with the general public is at the heart of ICTS's vision. It believes that sharing the wonder of discovery is as vital as discovery itself, and is deeply committed to bringing science closer to every curious mind.

Over the past two years, ICTS hosted its regular outreach initiatives, including the **Public Lectures**, **Vigyan Adda**, **Einstein Lectures**, and the monthly **Kaapi With Kuriosity** series. It has continued to organise the in-person **ICTS-RRI Maths Circle** sessions in collaboration with Raman Research Institute for Bengaluru students. During 2024-2025, there were 35 ICTS-RRI Maths Circle sessions held. ICTS is also successfully spearheading **Maths Circle India**, a pan-TIFR initiative for talented middle-school students across India. Between January 2024 and December 2025, ICTS conducted 42 online Maths Circle India sessions as part of this nationwide effort. In addition, special **Mathspark** sessions were also organised.

As part of the **school outreach initiative**, the ICTS Outreach team visited St. Anne's School in Hesaraghatta on 3 July 2025, and conducted a workshop on Commensurables and Irrationals for 47 students of Class 10. Through hands-on activities using paper strips and string as measuring tools, students explored the idea that all positive rational numbers are commensurable with each other. They were also introduced to the technique of proof by contradiction. During the session, two students observed that the set of even numbers and the set of natural numbers can be put in one-to-one correspondence. The ICTS Outreach team also visited HSLN Global Smart School in Hesaraghatta on 1 July 2025, and conducted a short workshop for 26 students from classes 8-10. The session focussed on understanding the number pi (π). Through hands-on activities and visual aids, students gained insight into how pi was estimated in ancient times using geometry.

Through the **science education program,** a science and mathematics teachers' training workshop, a one-day, in-person workshop designed for science and mathematics educators teaching classes 8-10 was held on 6 September 2024. The program featured sessions by educator Sita Ayyar and H.R. Madhusudan (JN Planetarium, Bengaluru) focusing on reflective teaching practices, innovative pedagogical strategies, and interactive hands-on activities. Also, as part of the JNP-ICTS Science Education Program, an experienced team of teachers from Jawaharlal Nehru Planetarium conducts training sessions for teachers from rural districts of Kerala. The team brings simple activities and demonstrations to the classroom to illuminate basic ideas and concepts of science and mathematics. ICTS provides organizational support and the zoom platform for the online sessions. There have been six sessions held during the period of the report.

David Gross interacting with budding scientists after his Public Lecture *Frontiers of Science* (August 2025). ◊ **Photo credit: AS Sumukh**

There was a **special movie screening** of *Galois. Story of a Revolutionary Mathematician*, a cinematic journey through the short yet extraordinary life of Évariste Galois—mathematical genius, political radical, and romantic hero on 30 July 2025.

There was an afternoon that brought science and art together through a **book reading** from *Two Revolutions: Einstein's Relativity and Quantum Physics*, jointly authored by the late black hole physicist C. V. Vishveshwara and his daughter, theoretical physicist Smitha Vishveshwara. The book explores the twin revolutions of Einstein's relativity and quantum physics, woven through personal reflections and imaginative storytelling. The event featured artists and physicists sharing science, dramatised dialogues spanning themes from the quantum to cosmic, and a dance performance interpreting the story of the Universe and the rhythm of scientific discovery through movement.

The ICTS Astro Club organised **Sky Watch at ICTS** on 27 January 2025 to view a rare parade of six planets.

Open Day 2025 was held on 8 March 2025, welcoming the public to an engaging Science Festival on campus. Students and faculty showcased their research through interactive exhibits, offering visitors a glimpse into the institute's diverse scientific work.

As part of the **Sci560 exhibition** organized by Science Gallery from 24 August 2024 to 28 February 2025, ICTS-TIFR had three unique exhibits that bridged the gap between cutting-edge scientific research and interactive public engagement. These exhibits showcased the synergy between theoretical physics, experimental analogies, and natural phenomena, inviting visitors to explore complex concepts through visually compelling and hands-on experiences.

An event titled **Beyond Boundaries: A Day of Interdisciplinary Exploration**, featuring programs specifically curated for high school and undergraduate students, was held on 19 December 2024. The fascinating patterns of nature and mathematics were explored while celebrating the birth anniversary of Srinivasa Ramanujan. Participants included JBNSTS students from Kolkata and students from various colleges in Bengaluru. The event concluded with a creative and interactive session, blending science and origami to tackle "The Ein-stein Problem."

As part of the **Connect India Art Residency** program, the Swiss artist, Lou Masduraud and the Indian artist, Shailesh BR spent a three-week residency at ICTS-TIFR. They received support from the curatorial teams from Arts at CERN and ICTS to explore new forms of artistic expression and transform these explorations into art productions.

ICTS can be found across multiple social media platforms. **Synapse at ICTS** showcases articles, interviews and journal events. In addition to LinkedIn, Twitter, Facebook and Instagram accounts, ICTS also has a WhatsApp channel with over 1,000 followers.

LIST OF PUBLIC LECTURES

Frontiers of Science
David Gross (*Kavli Institute for Theoretical Physics, University of California, Santa Barbara, USA*) ♦ 4 August 2025

Peering Into the Darkness – Imaging Black Hole Horizons
Feryal Özel *(Georgia Institute of Technology, USA)* ♦ 27 March 2025 ♦ Science Gallery Bengaluru

What Happens at Shorter Distances?
Nathan Seiberg *(Institute for Advanced Study, Princeton, USA)* ♦ 14 February 2025

The Many-Body Physics of Computation
Vedika Khemani *(Stanford University, USA)* ♦ 15 January 2025

On Rational and Irrational Numbers, Strings and Harmony
Uri Onn *(Mathematical Sciences Institute, ANU)* with Shubhadeep Chakraborty (Guitar), Michelle Simons (Cello) and Sayantan Mandal (Piano) ♦ 6 December 2024

The Dynamic Universe
Shri Kulkarni *(California Institute of Technology, USA)* ♦ 28 July 2024

Evolution of Women Over the Last 50 Years
Sudha Murty *(Founder of Infosys Foundation, Author, Philanthropist, Chairperson of Murty Trust and Rajya Sabha MP)* ♦ 18 June 2024

The Forever War Against Cancer
Herbert Levine *(Northeastern University, USA)* ♦ 11 March 2024 ♦ Chandrasekhar Auditorium, ICTS-TIFR, Bengaluru

LIST OF KAAPI WITH KURIOSITY LECTURES

New Frontiers for Statistical Physics
Rahul Nandkishore *(University of Colorado Boulder, USA)* ♦ 14 December 2025

Flexible Solutions: Lessons from Nature's Rubber Proteins
Namrata Gundiah *(IISc, Bengaluru)* ♦ 23 November 2025

Neutron Stars: Natural Laboratories for the Universe's Smallest and Largest Scales
Sukanta Bose *(Washington State University, Pullman, USA)* ♦ 26 October 2025

Why Strings?
Rajesh Gopakumar *(ICTS-TIFR, Bengaluru)* ♦ 28 September 2025

The Mathematics of Soap Bubbles
Franz Pedit (University of Massachusetts, Amherst, USA) ♦ 24 August 2025

How to Read a Genome
Michael Desai (Harvard University, USA) ♦ 27 July 2025

What's in your DNA? Tales from the Human Genome
Shweta Ramdas (Centre for Brain Research, IISc, Bengaluru) ♦ 22 June 2025

Coding Theory: Error-Resilience via Judicious Redundancy
Venkatesan Guruswami (University of California, Berkeley, USA) ♦ 10 May 2025

Three Puzzles from the First Billion Years
Girish Kulkarni *(TIFR, Mumbai)* ♦ 13 April 2025

Curation as Misinformation
Cailin O'Connor and **James Owen Weatherall** *(University of California, Irvine, USA)* ♦ 22 March 2025 ♦ *Online*

A History of Time
Spenta R. Wadia *(ICTS-TIFR, Bengaluru)* ♦ 23 February 2025

Quantum Mechanics: The Wild World of Atoms
Klaus Mølmer *(Niels Bohr Institute, Copenhagen, Denmark)* ♦ 25 January 2025

Numbers: Are They Normal?
Malabika Pramanik *(University of British Columbia, Canada)* ♦ 19 December 2024

Understanding Animal Societies
T.N.C. Vidya *(JNCASR, Bengaluru)* ♦ 3 November 2024

Dusty Flows in Nature (and Why Clouds Don't Fall from the Sky)
Rama Govindarajan *(ICTS-TIFR, Bengaluru)* ♦ 19 October 2024

The ABC Mysteries
Minhyong Kim *(International Centre for Mathematical Sciences, Edinburgh)* ♦ 8 September 2024

Magnetic Reconnection: The Engine Behind Solar Flares and Aurorae
Pallavi Bhat *(ICTS-TIFR, Bengaluru)* ♦ 25 August 2024

Hyperbolicity
Indira Chatterji *(Université Côte d'Azur à Nice, France)* ♦ 28 July 2024

Secrets of the Indian Savanna
Abi T Vanak *(Ashoka Trust for Research in Ecology and the Environment (ATREE), Bengaluru)* ♦ 30 June 2024

The Accelerating Expanding Universe: Dark Matter, Dark Energy, and Einstein's Cosmological Constant
Bharat Ratra *(Kansas State University, USA)* ♦ 26 May 2024

When Big Meets Small: The Connection Between Particle Physics and Cosmology
Yvonne Wong *(University of New South Wales, Australia)* ♦ 28 April 2024

What Does Not Kill Cancer Can Make it Stronger: Investigating Cancer as a Complex System
Mohit Kumar Jolly *(IISc, Bengaluru)* ♦ 17 March 2024

Fitness Landscapes and the Predictability of Evolution
Claudia Bank *(Institute of Ecology and Evolution, University of Bern, Switzerland)* ♦ 25 February 2024

Understanding the Glue - the "Super-God Particle" - That Binds Us All
Abhay Deshpande *(Stony Brook University, USA)* ♦ 28 January 2024

LIST OF EINSTEIN LECTURES

Nature's Symmetries and Textures
Sidney R. Nagel *(University of Chicago, USA)* ♦ 6 December 2025

How Natural Structures Shape Themselves: Growth, Geometry, and Frustration
Efi Efrati *(Weizmann Institute of Science, Israel)* ♦ 11 November 2025

Einstein's Ears: The Astronomy of Gravitational Waves
Scott Hughes *(Massachusetts Institute of Technology, Cambridge, USA)* ♦ 7 November 2025

Why are Turbulent Flows so Fascinating?
Samriddhi Sankar Ray *(ICTS-TIFR, Bengaluru)* ♦ 27 February 2025

The Six Faces of Subrahmanyan Chandrasekhar
Rajaram Nityananda *(ICTS-TIFR, Bengaluru)* ♦ 29 October 2024

The Plasma Universe
Pallavi Bhat *(ICTS-TIFR, Bengaluru)* ♦ 27 February 2024 ♦ Maharani Lakshmi Ammanni College For Women Autonomous, Bengaluru

LIST OF VISVESHWARA LECTURES

Quantum Astrophysics
Roger Blandford *(Stanford University, USA)* ♦ 18 January 2025

Gravitational-wave Astronomy: New Discoveries, Puzzles & Prospects
B.S. Sathyaprakash *(Penn State, USA & Cardiff University, UK)* ♦ 3 January 2024

MADHAVA LECTURES

'Assaying' the Eight Metals of Antiquity: Archaeometallurgical Perspectives on Indian Heritage
Sharada Srinivasan *(National Institute of Advanced Studies, Bengaluru)* ♦ 12-14 March 2024

LIST OF VIGYAN ADDA LECTURES

Experimental Evolution
Christian Schlötterer (Institute of Population Genetics, Vienna) ♦ 30 May 2024 ♦ *Online*

LIST OF MATHSPARK SPECIAL EVENTS

MathSpark 2025
Conducted by: **Kaushik Basu** (University of California, Berkeley, USA) ♦ Interactive session: 8 August 2025

How Many Digits Does the Repeating Decimal Expansion of 1/1729 Have?
Conducted by: **Apoorva Khare** (IISc, Bengaluru) ♦ Interactive session: 8 May 2025

Tales of Pyramids and Spheres: Speaking Volumes of Cavalieri - MathSpark 2024
Conducted by: **Kaushik Basu** *(University of California, Berkeley, USA)* ♦ Interactive Session: 21 December 2024

LIST OF PRISM SESSIONS

PRISM 8: Think, Play, Prove: Hands-On Explorations in Maths
Shweta Naik *(Homi Bhabha Centre for Science Education (HBCSE)-TIFR)* ♦ 30 November 2025

PRISM 7: Exploring Newton's Laws with Tug-of-war and Drag Forces with Dropped Cones
Kaushik Basu *(University of California, Berkeley, USA)* ♦ 3 August 2024

PRISM 6: Magnifying Science in Field Settings
Rahul Chajwa *(Stanford University, USA)* ♦ 2 May 2024

OTHER EVENTS

Women of Mathematics from around the World

29 December 2025 to 02 January 2026, Chandrasekhar Auditorium, ICTS-TIFR

Women of Mathematics from around the World is a photography exhibition featuring portraits of 20 women mathematicians and theoretical physicists from across the globe. The photographs are by Noel Tovia Matoff.

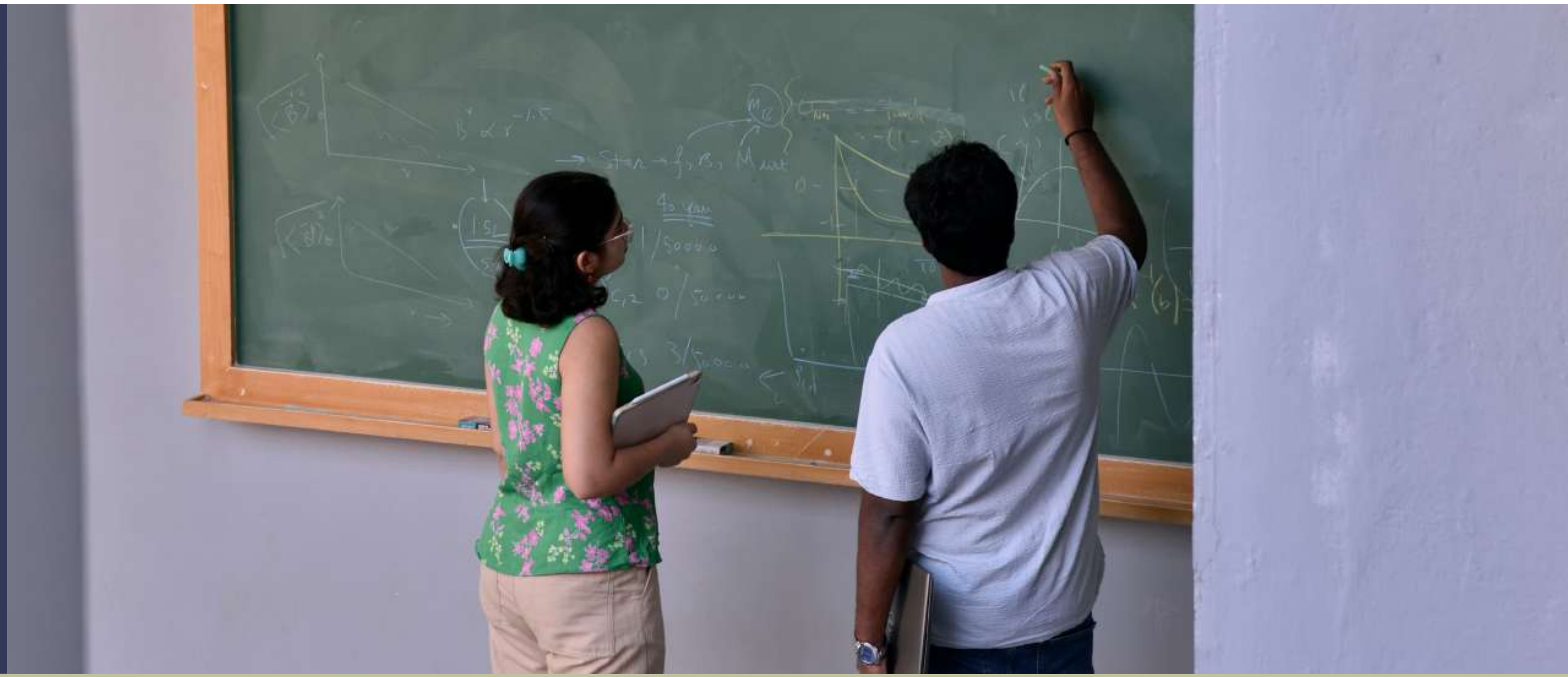
Presented during the Women at the Intersection of Mathematics and Theoretical Physics discussion meeting at ICTS, the exhibition and its accompanying catalogue bring together scientific work and personal narratives. Through excerpts of interviews and visual material, the women reflect on their career paths, the challenges they faced, and the support systems that shaped their journeys.

First launched at the 7th European Congress of Mathematics in Berlin in 2016, the exhibition has since been shown at over 150 venues worldwide, including universities, research institutes, schools, and cultural centres. Its aim is to encourage young women to pursue careers in mathematics and theoretical physics, fields in which women remain underrepresented globally.

The exhibition at ICTS is organised in collaboration with Raman Research Institute, Science Gallery Bengaluru and the Consulate General of the Federal Republic of Germany. Printing and exhibition setup were carried out by Arc Earth, Bengaluru.

[Clockwise from top] Vedika Khemani delivering her Public Lecture on The Many-Body Physics of Computation (January 2025); Kaushik Basu conducting a special Mathspark session (December 2024); Students sharing their ideas at a special Mathspark session (December 2024); Photographs at the exhibition Women in Mathematics from around the world (December 2025); and Uri Ohn during his Public Lecture, On Rational and Irrational Numbers, Strings and Harmony (December 2024). ◊ **Photo credit: AS Sumukh, Rohit Chavan**

GRADUATE PROGRAMS AND TRAINING @ICTS

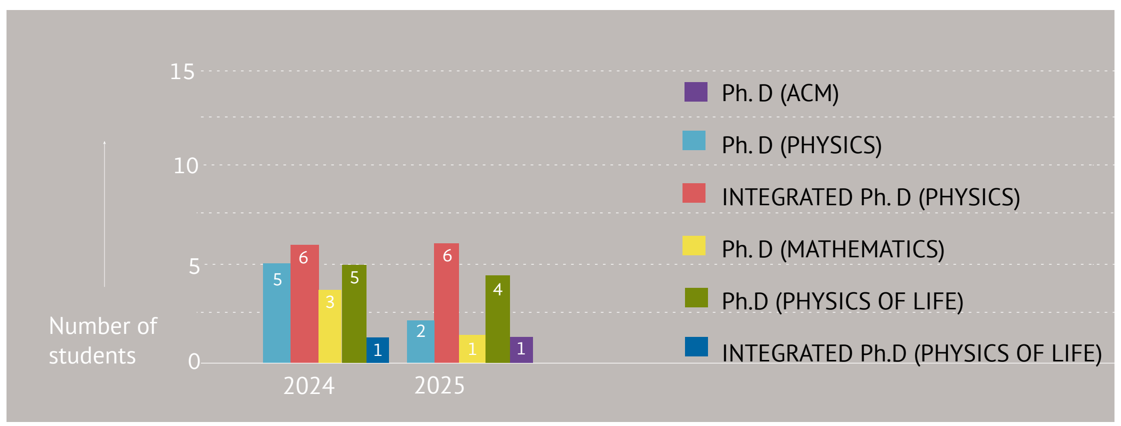


GRADUATE PROGRAMS

The ICTS graduate program offers rigorous training to aspiring graduate students, preparing them extensively for future research endeavors. During 2024-2025, 34 students joined the ICTS graduate program – 7 in physics, 12 in integrated physics, 4 in mathematics, and 9 in the newly introduced physics of life program. 30 postdoctoral fellows joined ICTS during 2024-2025.

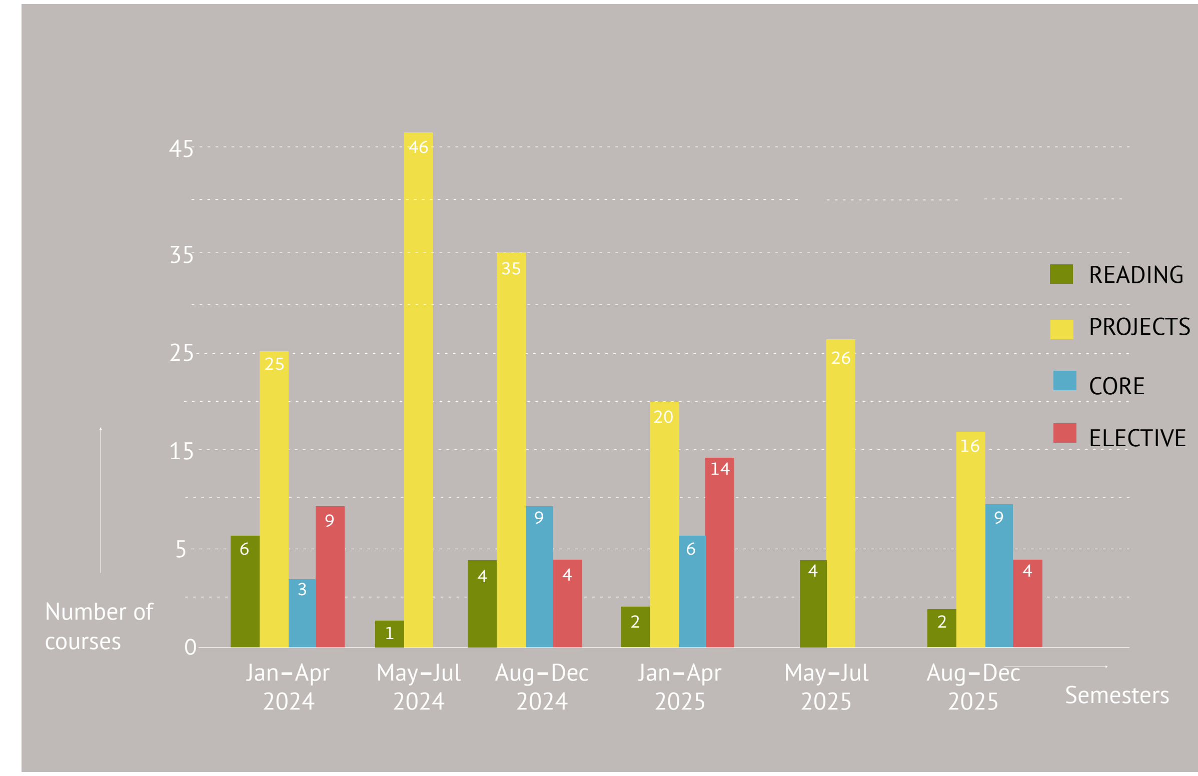
NUMBER OF STUDENTS JOINED PER YEAR

YEAR	PHYSICS		ACM	MATHS	PHYSICS OF LIFE		TOTAL
	Ph.D.	Integrated Ph.D.	Ph.D.	Ph.D.	Ph.D.	Integrated Ph.D.	
2024	5	6	-	3	5	1	20
2025	2	6	1	1	4	-	14
	7	12	1	4	9	1	34



CORE AND ELECTIVE COURSE

SEMESTER	CORE	ELECTIVE	TOTAL
Jan-Apr 2024	3	9	12
May – Jul 2024	-	-	0
Aug-Dec 2024	9	4	13
Jan – Apr 2025	6	14	20
May – Jul 2025	-	-	0
Aug-Dec 2025	9	4	13
			58



READING AND PROJECT COURSE

SEMESTER	READING	PROJECTS	TOTAL
Jan–Apr 2024	6	25	31
May–Jul 2024	1	46	47
Aug–Dec 2024	4	35	39
Jan–Apr 2025	2	20	22
May–Jul 2025	4	26	30
Aug–Dec 2025	2	16	18
TOTAL	19	168	187

SUMMER COURSE

YEAR	NUMBER OF COURSES	NUMBER OF OFFLINE PARTICIPANTS	NUMBER OF ONLINE PARTICIPANTS	TOTAL
2024	1	28	185	213

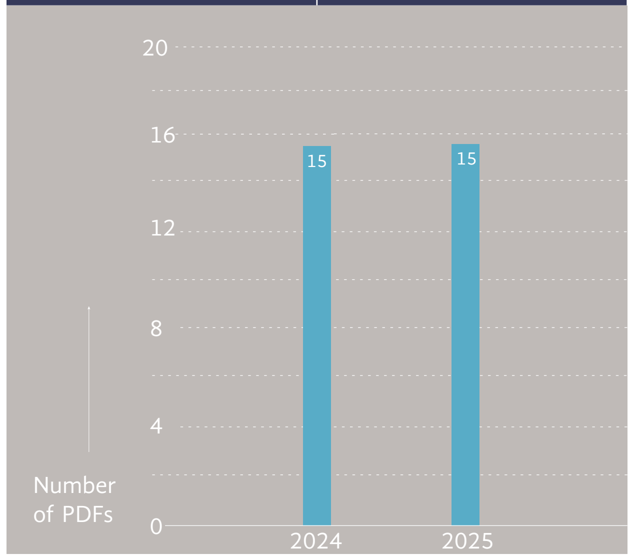
In 2025 summer course was not held.

LONG TERM VISITING PROGRAM (LTVSP)

YEAR	STUDENTS
2024	12
2025	13
TOTAL	25

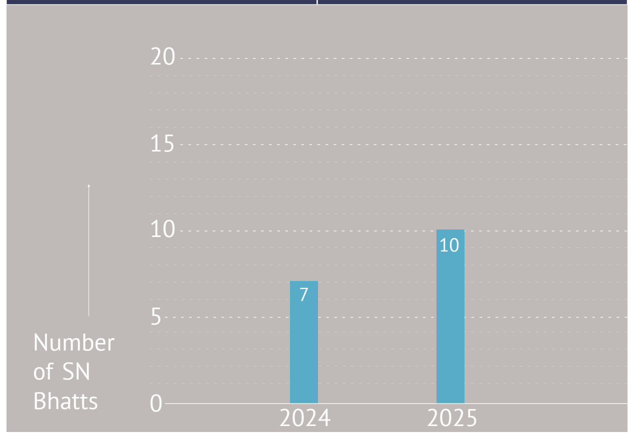
POST DOCTORAL FELLOWS

YEAR	PDFs
2024	15
2025	15
TOTAL	30



S. N. BHATT MEMORIAL FELLOWSHIP

YEAR	STUDENTS
2024	10
2025	7
TOTAL	17



List of Academic Lectures

Equivariant Localization in Supergravity
Jerome Peter Gauntlett *(Imperial College, London, UK)*
♦ 18-21 November 2025

The Count of Instantons
Nikita Nekrasov *(Stony Brook University, USA)*
♦ 18 September-2 December 2025

Interacting Particle Systems on Random Graphs
Frank den Hollander *(Leiden University, The Netherlands and Faculty Associate of ICTS)*
♦ 15-19 September 2025

A Short Course on Reinforcement Learning
Hugo Touchette *(Stellenbosch University, South Africa)*
♦ 1-5 November 2024

Arithmetic Geometry and Quantum Field Theory
Minhyong Kim *(University of Edinburgh, UK)*
♦ 3-5 September 2024

A Short Course on the Atiyah-Singer Index Theorem
Madabusi Raghunathan *(Distinguished Professor, UM-DAE Centre for Excellence in Basic Sciences and Honorary Fellow, TIFR)*
♦ 24 July-2 August 2024

Mini Course on Arakelov Geometry and Modular Forms
Anna-Maria Pippich *(University of Konstanz, Germany)*, **Jurg Kramer** *(Humboldt University, Germany)* and **Anilatmaja Aryasomayajula** *(IISER Tirupati)*
♦ 13-15 March 2024

Compact Lie Groups
T N Venkataramana *(ICTS-TIFR, Bengaluru)*
♦ 15 January 2024


Photo credit: Tamoghna Ray

SEMINARS

The following is the complete list of seminars and colloquia held on the ICTS campus during 2024-2025.

Semi-universality of CFT_d at Large Spin
Sridip Pal *(Institut des Hautes Études Scientifiques, France)* ♦ 24 December 2025

Influence of Particle Geometry on Hydrodynamic and Electrostatic Interactions
Harshit Joshi *(ICTS-TIFR, Bengaluru)* ♦ 19 December 2025

Twisted D-branes and TQFTs valued in Calabi-Yau categories
Surya Raghavendran *(Yale University, USA)* ♦ 18 December 2025

The Role of r-modes in Pulsar Spin-down, Pulsar Timing, and Gravitational Waves
Sree Ram Valluri *(University of Western Ontario, Canada)* ♦ 18 December 2025

Localization of Strings on Group Manifolds
Sameer Murthy *(King's College, London, UK)* ♦ 15 December 2025

Genetic Algorithm-Based Training of a Smart Triangular Swimmer
Ruma Maity *(Technische Universität Wien, Austria)* ♦ 12 December 2025

Intermittency, Multifractality and Chaos in Turbulence
Ritwik Mukherjee *(ICTS-TIFR, Bengaluru)* ♦ 11 December 2025

Lensing of Gravitational Waves by Globular Clusters and Dark Matter
Sreekanth Harikumar *(Nicolaus Copernicus Astronomical Center, Poland)* ♦ 11 December 2025

The Disordered Quantum Ising Model with Periodic and Quasiperiodic Driving
Felix von Oppen *(Freie Universität Berlin, Germany)* ♦ 5 December 2025

Cubic String Field Theory Using Auxiliary Fields
Harold Erbin *(Institute of Theoretical Physics, France)* ♦ 5 December 2025

Microlensing of Gravitational Waves as a New Tool for Astrophysics
Uddeepta Deka *(ICTS-TIFR, Bengaluru)* ♦ 5 December 2025

Model-Agnostic Identification of Compact-Binary Morphologies with Phenomenological Waveforms
Shrobana Ghosh *(Max Planck Institute for Gravitational Physics, Germany)* ♦ 4 December 2025

SU(2) Representations from Geometry
Pranav Pandit *(ICTS-TIFR, Bengaluru)* ♦ 2 December 2025

Close But No Cigar: A Brief Review of Pulsar Glitches and Some New Perspectives
Anantharaman S.V. *(Ashoka University, Sonepat)* ♦ 28 November 2025

Modeling Mixing in Turbulence – Non-Markovianity is Essential
Prateek Gupta *(IIT Delhi)* ♦ 28 November 2025

Holographic Fluctuations at Finite Density
Shivam Kumar Sharma *(ICTS-TIFR, Bengaluru)* ♦ 28 November 2025

New Constraints On Renormalization Group Flows
Ken Kikuchi *(ICTS-TIFR, Bengaluru)* ♦ 27 November 2025

On the Heaviest and Largest Components in Critical Inhomogeneous Random Graphs
Sourish Maniyar *(IISc, Bangalore)* ♦ 27 November 2025

Multiplex Random Graphs
Shaibal Karmakar *(ICTS-TIFR, Bengaluru)* ♦ 27 November 2025

The Triangle Friendship Paradox
Pradeeptha Jain *(ICTS-TIFR, Bengaluru)* ♦ 27 November 2025

High-Energy Pion Scattering in Holographic QCD
Bartosz Pyszkowski *(Yukawa Institute for Theoretical Physics, Japan)* ♦ 26 November 2025

Computation of Monodromy Hypergeometric Case
T. N. Venkataramana *(ICTS-TIFR, Bengaluru)* ♦ 4, 11, 18 and 25 November 2025

Entanglement Inequalities, Black Holes And The Architecture Of Typical States
Ayan Mukhopadhyay *(Pontificia Universidad Catolica de Valparaiso, Chile)* ♦ 24 November 2025

Probing Horizon Scale Magnetic Fields and Strong-field Gravity with Polarized EHT Observations of M87*
Saurabh K. *(Max Planck Institute for Radio Astronomy, Germany)* ♦ 20 November 2025

Interpreting Biological Complexity with Systems Approaches (Online)
Lokanand Koduru *(Genome Institute of Singapore, Singapore)* ♦ 17 November 2025

Beyond Propagation of Chaos: A Stochastic Algorithm for Mean Field Optimization
Dheeraj Nagaraj *(Google DeepMind, Bengaluru)* ♦ 14 November 2025

Emergent Photons vs Confinement: the Roles of Vortices and Monopoles
Mendel Nguyen *(Durham University, United Kingdom)* ♦ 13 November 2025

Unveiling Statistical Properties of Galactic Synchrotron Emission
Aniket Nath *(ICTS-TIFR, Bengaluru)* ♦ 13 November 2025

Lattice Bosonization of Matrix Quantum Mechanics and c = 1
Ajay Mohan *(TIFR, Mumbai)* ♦ 12 November 2025

Channel Flow Stability: Influence of Dust Particles and Geometry
Anup Kumar *(ICTS-TIFR, Bengaluru)* ♦ 11 November 2025

Exquisite Clutter in the Circumgalactic Plasmas: Crosstalk Between Macro and Microphysics (Online)
Prakriti Palchoudhury *(University of Oxford, UK)* ♦ 10 November 2025

The Role of Synoptic Circulations in Lower-tropospheric Dry Static Energy Variability Over a South Asian Heatwave Hotspot
Hardik Shah *(IISER Pune)* ♦ 7 November 2025

Moments of the Hurwitz Zeta Function with Irrational Shifts
Anurag Sahay *(Purdue University, USA)* ♦ 7 November 2025

Stellar Dynamics and Astrophysical Transients in Centers of Galaxies
Karamveer Kaur *(Technion - Israel Institute of Technology, Israel)* ♦ 6 November 2025

Tensor Manipulation with Mathematica and xAct/xTensor
Guillaume Faye *(Paris Institute of Astrophysics, France)* ♦ 6 November 2025

Tensor Categories and Their Applications to Vertex Operator Algebras
Harshit Yadav *(University of Alberta, Canada)* ♦ 6 November 2025

Topological Photonics: From Exciton-Polariton Devices to On-chip Photonic Terahertz Communications
Rimi Banerjee *(Nanyang Technological University, Singapore)* ♦ 5 November 2025

Geometry of Random Walks and Random Interlacements
Subhajit Goswami *(TIFR, Mumbai)* ♦ 4 November 2025

A Re-look at "What is Life"?
Vidyanand Nanjundiah *(Centre for Human Genetics, Bengaluru)* ♦ 3 November 2025

Entangling Light Without Uncertainties: From Quantum Differential Geometry Towards Quantum Optical Computation
Aniruddha Bhattacharya *(Georgia Institute of Technology, USA)* ♦ 3 November 2025

Algebro-Geometric Algorithms for Program Synthesis and Verification
Harshit Jitendra Motwani *(Max Planck Institute for Software Systems, Germany)* ♦ 31 October 2025

Spatial Decomposition of Operators in 2d CFT
Manish Ramchander *(Institute of Mathematical Sciences, Chennai)* ♦ 30 October 2025

Instance-optimality in Universal Prediction
Alankrita Bhatt *(Granica Computing Inc., USA)* ♦ 30 October 2025

Exact Solutions of Matrix Models and String Theories
João Carlos Rodrigues *(Instituto Superior Tecnico, Portugal)* ♦ 29 October 2025

Approximation Barriers for Big Data Problems
Karthik C. S. *(Rutgers University, USA)* ♦ 28 October 2025

Gravitational Waves Passing Through Matter
Nigel Tempest Bishop *(Rhodes University, South Africa)* ♦ 24 October 2025

Tidal Responses of Black Holes and their Imprints in Gravitational Waves Emitted by their Binaries
Sukanta Bose *(Washington State University, USA)* ♦ 24 October 2025

Deciphering Enigmatic Neutron Stars: Where Ultra-dense Matter Meets Strong-field Gravity
Arunava Mukherjee *(Saha Institute of Nuclear Physics, Kolkata)* ♦ 23 October 2025

To Love or Not to Love
Sumanta Chakraborty *(Indian Association for the Cultivation of Science [IACS], Kolkata)* ♦ 16 October 2025

State Dependence and its Discontents
Suvrat Raju *(ICTS-TIFR, Bengaluru)* ♦ 15 & 16 October 2025

A Gentle Introduction to Bruhat-Tits Theory
Radhika Ganapathy *(IISc, Bengaluru)* ♦ 14 October 2025

Are Moduli Vacuum Expectation Values or Parameters?
Ashoke Sen *(ICTS-TIFR, Bengaluru)* ♦ 8 October 2025

Universality and Scaling in the Proximity of Jamming: A Perspective on the Rheology of Dense Suspensions
Bulbul Chakraborty *(Brandeis University, USA)* ♦ 8 October 2025

Mautner's Theorem on Decomposing a Unitary Representation into Irreducible Ones
M.S. Raghunathan *(Centre for Excellence in Basic Sciences, Mumbai)* ♦ 8 October 2025

Reflections of Topology in Magnetoconductivity of Nodal-point Semimetals
Ipsita Mandal *(Shiv Nadar University, Noida)* ♦ 8 October 2025

Integral Formulations and Numerical Methods for a Class of Half-space Interface Problems
Manas Rachh *(IIT Bombay, Mumbai)* ♦ 7 October 2025

The Wheeler-DeWitt Equation in Asymptotically Flat Spaces
Marc Henneaux *(Université Libre de Bruxelles and International Solvay Institutes, Belgium)* ♦ 6 October 2025

Local Tests of Global Properties
Jaikumar Radhakrishnan *(ICTS-TIFR, Bengaluru)* ♦ 30 September 2025

Seeing Through the Confinement Screen: DGLAP/ BFKL Mixing and Light-ray Matching in QCD
David Simmons-Duffin *(California Institute of Technology, USA)* ♦ 29 September 2025

The Role of Earth's Mantle Convection in Planetary Habitability
Jyotirmoy Paul *(University of Oslo, Norway)* ♦ 25 September 2025

The Efficient Primality Testing Algorithm of Agrawal, Kayal and Saxena
Jaikumar Radhakrishnan *(ICTS-TIFR, Bengaluru)* ♦ 23 September 2025

String Field Theory, Graph Homology and the Transition from Φ^3 to Gauge Theory Amplitudes
Roji Pius *(Institute of Mathematical Sciences, Chennai)* ♦ 22 September 2025

A Grothendieckian Taming of the Special Function Zoo. Part 1: The Loga Paradigm
Godwin Martin *(ICTS-TIFR, Bengaluru)* ♦ 17 September 2025

Probabilistic Facets of Virasoro Conformal Blocks
Promit Ghosal *(University of Chicago, USA)* ♦ 17 September 2025

Word Maps and their Images on Finite Groups
Shrinit Singh *(ICTS-TIFR, Bengaluru)* ♦ 16 September 2025

Self-Reinforced Preferential Attachment
Frank den Hollander *(Leiden University, The Netherlands)* ♦ 15 September 2025

Covariant Phase Space and L_∞ Algebras
Atakan Hilmi Firat *(University of California, Davis, USA)* ♦ 15 September 2025

Interplay of Microscopic Symmetries and Entanglement in Effective Theories of Correlated Quantum Matter
Ankush Chaubey *(ICTS-TIFR, Bengaluru)* ♦ 12 September 2025

Search for Dark Matter Over a Wide Mass Range: Using JWST and Neutrino Telescopes to Search for Non-gravitational Signatures of Dark Matter
Ranjan Laha *(IISc, Bengaluru)* ♦ 11 September 2025

Control of Tissue Flows and Embryo Geometry in Avian Gastrulation
Mattia Serra *(University of California, San Diego, USA)* ♦ 11 September 2025

Some Applications of Representation Theory to Classical Number Theory
B. Sury *(ICTS-TIFR, Bengaluru)* ♦ 3 and 10 September 2025

A Localising AdS_3 Sigma Model
Lorenz Eberhardt *(University of Amsterdam, The Netherlands)* ♦ 8 September 2025

From Microscopics to Hydrodynamics
Sahil Kumar Singh *(ICTS-TIFR, Bengaluru)* ♦ 2 September 2025

Symmetric Tensor Scars with Tunable Entanglement from Volume to Area Law
Bhaskar Mukherjee *(S.N. Bose National Centre for Basic Sciences, Kolkata)* ♦ 26 August 2025

The Howe-Moore Ergodicity Theorem
T. N. Venkataramana *(ICTS-TIFR, Bengaluru)* ♦ 26 August 2025

Lensing, Not Luck! Forecasting the Efficiency of Gravitational-wave Strong Lensing Search
Ankur Barsode *(ICTS-TIFR, Bengaluru)* ♦ 21 August 2025

Scarring and Quantum-classical Correspondence for Quantum Channels
Arul Lakshminarayan *(IIT Madras, Chennai)* ♦ 20 August 2025

Computing Infrared Observables in Scattering
Kartik Prabhu *(Raman Research Institute, Bengaluru)* ♦ 20 August 2025

A Catalogue and a Warning: The Great Nicobar Betrayal
Pankaj Sekhsaria *(Centre for Technology Alternatives for Rural Areas, IIT Bombay)* ♦ 18 August 2025

Probing Gravity using Black Hole Ringdown
Pratik Wagle *(Max Planck Institute for Gravitational Physics, Germany)* ♦ 18 August 2025

Open Quantum Mechanics for Cosmological Observers
Omkar Sanjay Shetye *(ICTS-TIFR, Bengaluru)* ♦ 18 August 2025

Renormalons as Saddle Points
Arindam Bhattacharya *(Harvard University, USA)* ♦ 18 August 2025

A "Dictionary" to Test GR with GW: From Observations to Theory
Suvendu Giri *(Perimeter Institute, Canada)* ♦ 14 August 2025

Loops in Cosmological Correlators
Supritha Bhowmick *(IISER Pune)* ♦ 13 August 2025

Dirichlet's Theorem, Continued
T. N. Venkataramana *(ICTS-TIFR, Bengaluru)* ♦ 12 August 2025

Solitons on Vaidya Spacetime and Hypersurfaces in Pseudo-Euclidean Space
Savita Rani *(ICTS-TIFR, Bengaluru)* ♦ 11 August 2025

Inhomogeneous Phases and Glasses - A Many-body Perspective
Zohar Nussinov *(Washington University in Saint Louis, USA)* ♦ 8 August 2025

Taming Eccentricity in Binary Black Hole Mergers
Tousif Islam *(Kavli Institute for Theoretical Physics, UCSB, USA)* ♦ 8 August 2025

Defining Eccentricity for Spin-precessing Binaries
Md Arif Shaikh *(Vivekananda Satavarshiki Mahavidyalaya, Jhargram)* ♦ 7 August 2025

Möbius Randomness in the Hartle-Hawking State
Victor Godet *(Sorbonne University, France)* ♦ 6 August 2025

Dirichlet's Theorem on the Infinitude of Primes
T. N. Venkataramana *(ICTS-TIFR, Bengaluru)* ♦ 5 August 2025

Autocatalytic Reaction Networks in Ecology, Evolutionary Biology, and Economics
Praful Gagrani *(The University of Tokyo, Japan)* ♦ 4 August 2025

Magnetized Bounds for Conformal Field Theories
Biswajit Sahoo *(King's College, London, UK)* ♦ 1 August 2025

The Host Environments of Compact Binaries
Aditya Vijaykumar *(Canadian Institute for Theoretical Astrophysics, Canada)* ♦ 31 July 2025

Dynamic Multiscaling in Turbulent Flows with Polymer Additives: A Shell Model Study
Swapan Limbu *(ICTS-TIFR, Bengaluru)* ♦ 30 July 2025

Random Walks, Bethe Ansatz and Riemann's Zeros
Giuseppe Mussardo *(Scuola Internazionale Superiore di Studi Avanzati (SISSA), Italy)* ♦ 30 July 2025

Neutron Stars and Gravitational Waves: Decoding Dense Matter Systems
Ritam Mallick *(IISER Bhopal)* ♦ 25 July 2025

Beyond Einstein: Search for New Gravitational Physics
Sudipta Sarkar *(IIT Gandhinagar)* ♦ 24 July 2025

Literature Review of Collision-coalescence Models in Clouds
Rajarshi Chattopadhyay *(ICTS-TIFR, Bengaluru)* ♦ 24 July 2025

Revisiting the Gelman-Rubin Diagnostic in MCMC
Dootika Vats *(IIT Kanpur)* ♦ 24 July 2025

Bifurcating Vortex Reconnections: A Departure from Anti-parallel Reconnection
Saumav Kapoor *(ICTS-TIFR, Bengaluru)* ♦ 23 July 2025

Quantum Covariant Bit Threads
Sreeman Reddy Kasi Reddy *(Weizmann Institute of Science, Israel)* ♦ 23 July 2025

Data-Driven Identification and Output Regulation Using Partially Observed Actuated Trajectories: A Koopman Bilinear Approach
Debdipta Goswami *(Ohio State University, USA)* ♦ 17 July 2025

Quasi-characters Revisited
Sunil Mukhi *(IISER Pune)* ♦ 16 July 2025

Spectral Form Factor in Generic Many-body Quantum Chaotic Systems Across all Dyson Symmetry Classes
Dibyendu Roy *(Raman Research Institute, Bengaluru)* ♦ 16 July 2025

When Waves Meet Vortices: A Topological Twist in Water
Mahesh Bandi *(Okinawa Institute of Science and Technology, Japan)* ♦ 16 July 2025

Prospects of Observing Gravitational Lensing of Continuous Gravitational Waves
Aditya Kumar Sharma (ICTS-TIFR, Bengaluru) ♦ 15 July 2025

MacDonald Indices of 4d N=2 SCFTs from Hilbert Series of Arc Spaces
Ranveer Kumar Singh *(Rutgers University, USA)* ♦ 10 July 2025

A Principled Approach to Randomized Selection under Uncertainty: Applications to Peer Review and Grant Funding
Nihar B Shah *(Carnegie Mellon University, USA)* ♦ 8 July 2025

Physics of Cytokinesis
Aditya Singh Rajput *(ICTS-TIFR, Bengaluru)* ♦ 4 July 2025

Echo Mapping Black Holes with Light
Prashant Kocherlakota *(Harvard University, USA)* ♦ 30 June 2025

Superconductors are Topological Phases Protected by Generalized Symmetries
Ashvin Vishwanath *(Harvard University, USA)* ♦ 30 June 2025

Soft Matter Quasicrystals: Minimal Recipes and New Tools to Analyse Them
Priya Subramanian *(The University of Auckland, New Zealand)* ♦ 25 June 2025

Understanding Organ Size Determination: A Focus on Rate of Deceleration
Carmen Coelho *(Centre for Human Genetics, Bengaluru)* ♦ 23 June 2025

Stability of Sedimenting Spheres Using an Idealized Two-Phase Continuum Model
Dylan James Reynolds *(ICTS-TIFR, Bengaluru)* ♦ 20 June 2025

Thermalization and Hydrodynamics in Integrable Systems
Saurav Pandey *(ICTS-TIFR, Bengaluru)* ♦ 16 June 2025

When is the CFT Attached to a Target Space Variety Rational?
Abhiram Kidambi *(Max Planck Institute for Mathematics in the Sciences, Germany)* ♦ 11 June 2025

Exceptional Times when Bigeodesics Exist in Dynamical Last Passage Percolation
Manan Bhatia *(Massachusetts Institute of Technology, USA)* ♦ 11 June 2025

Intersections of Random Walks
Trishen Gunaratnam *(TIFR, Mumbai)* ♦ 11 June 2025

Strong Lensing of Gravitational Waves: A New Probe of Cosmology and the Nature of Dark Matter
Souvik Jana *(ICTS-TIFR, Bengaluru)* ♦ 4 June 2025

The Characteristics of the Z-boson in Chern-Simons-matter Theory
Amiya Mishra *(Yau Center of Southeast University, China)* ♦ 2 June 2025

Tensionless Strings: Closed and Open
Priyadarshini Pandit *(IIT Kanpur)* ♦ 28 May 2025

Unitary Rigid Supersymmetry for the Chiral Graviton and Chiral Gravitino in de Sitter Spacetime
Vasileios Letsios *(University of Mons, Belgium)* ♦ 21 May 2025

Spectral and Dynamical Observables in Disordered Open Quantum Systems
Sparsh Gupta *(ICTS-TIFR, Bengaluru)* ♦ 20 May 2025

New Theoretical Insights into Black Hole Coronae
Navin Sridhar *(Stanford University, USA)* ♦ 15 May 2025

Many-Body Localization in Bond-Disordered Spin-1/2 Chains
Adith Sai Aramthottil *(Jagiellonian University, Poland)* ♦ 14 May 2025

Universality of the Microcanonical Entropy at Large Spin in Non-rational 2D CFTs
Sridip Pal *(California Institute of Technology, USA)* ♦ 12 May 2025

Search for Evaporating Exoplanets and Protoplanetary Discs
Joe P. Ninan *(TIFR, Mumbai)* ♦ 9 May 2025

Amplitudes for Hawking Radiation
Donal O'Connell *(The University of Edinburgh, UK)* ♦ 8 May 2025

Looking at Bulk Points in General Geometries
Joydeep Chakravarty *(McGill University, Canada)* ♦ 7 May 2025

Molecular Simulations of Nucleic Acid Packaging: Physical Virology and Beyond
Kush Coshic *(Max Planck Institute of Biophysics, Germany)* ♦ 1 May 2025

Holography for Flat Spacetimes - A Carrollian Adventure
Arjun Bagchi *(IIT Kanpur)* ♦ 30 April 2025

Monomer-Dimer-Tensor-Network (MDTN) Basis for Lattice Gauge Theories
Shailesh Chandrasekharan *(Duke University, USA)* ♦ 29 April 2025

Impact of the Basset History Force on Inertial Particle Dynamics in a Taylor-Green Vortex Flow
Shasvat Venkata Vudumula *(ICTS-TIFR, Bengaluru)* ♦ 29 April 2025

Stability Studies of Inviscid Shallow Water Flows on a Sphere
Mukesh Singh Raghav *(ICTS-TIFR, Bengaluru)* ♦ 25 April 2025

Cosmological Correlators in Gravitationally-constrained de Sitter States
Suvrat Raju *(ICTS-TIFR, Bengaluru)* ♦ 23 April 2025

Gauging Non-invertible Symmetries in 2+1d
Rajath Radhakrishnan *(International Centre for Theoretical Physics, Italy)* ♦ 16 April 2025

Influence of Particle Geometry on Hydrodynamic and Electrostatic Interactions
Harshit Joshi *(ICTS-TIFR, Bengaluru)* ♦ 16 April 2025

Ordering Transition of the Three-dimensional Four-state Random-field Potts Model
Manoj Kumar (National Institute of Science Education and Research, Bhubaneswar) ♦ 16 April 2025

Microlensing of Gravitational Waves as a New Tool for Astrophysics
Uddeepta Deka *(ICTS-TIFR, Bengaluru)* ♦ 9 April 2025

An Inflationary Cosmology from (AdS) Wormholes
Panos Betzios *(Ghent University, Belgium)* ♦ 7 April 2025

Co-evolving Vertex and Edge Dynamics in Dense Graphs
Siva Athreya *(ICTS-TIFR, Bengaluru)* ♦ 7 April 2025

The Supercritical Phase of the ϕ4 Model is Well-behaved
Trishen Gunaratnam *(TIFR-Mumbai and ICTS-TIFR, Bengaluru)* ♦ 7 April 2025

HL Cone, Foams, and Graph Coloring
Amit Kumar *(Louisiana State University, USA)* ♦ 3 April 2025

The Sound of Black Holes
Vitor Cardoso *(Niels Bohr Institute, Denmark)* ♦ 3 April 2025

Some Model <<anticommuting>> Quantum Spin Liquids with Residual Ground State Entropy
Sumiran Pujari *(IIT Bombay, Mumbai)* ♦ 2 April 2025

Open Quantum Mechanics for Cosmological Observers
Omkar Sanjay Shetye *(ICTS-TIFR, Bengaluru)* ♦ 27 March 2025

Strings from Feynman Diagrams: A Picture Scrapbook
Rajesh Gopakumar *(ICTS-TIFR, Bengaluru)* ♦ 27 March 2025

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Angchuk Dorje *(Indian Institute of Astrophysics, Bengaluru)* ♦ 14 March 2024

Stretched Horizon, Replica Trick, and Off-shell Winding Condensate, and All That
Indranil Halder *(Harvard University, USA)* ♦ 13 March 2024

Mean Field Dynamo: Beyond MHD
Vinod Krishan *(Indian Institute of Astrophysics, Bengaluru)* ♦ 13 March 2024

Lava Flows: Defending Lives and Housing by Theory, Experiments and Field Data
Herbert Huppert *(University of Cambridge, UK)* ♦ 12 March 2024

Cosmology Without Assuming a Cosmology
Luca Amendola *(University of Heidelberg, Germany)* ♦ 12 March 2024

Constraining the Abundance of Galactic Compact Objects with Continuous Gravitational Waves
Gopal Prabhu *(IUCAA, Pune)* ♦ 12 March 2024

Constraining Exotic Matter in Neutron Stars
Swarnim Shirke *(IUCAA, Pune)* ♦ 11 March 2024

Escape in Open Dynamical Systems
Nikita Agarwal *(IISER Bhopal)* ♦ 11 March 2024

Online Bin Packing under Random Order Model
Arindam Khan *(IISc, Bengaluru)* ♦ 11 March 2024

A Spinor Proof of the Positivity of the Quasi-local Energy in (Semi-)Riemannian Geometry
Puskar Mondal *(Harvard University, USA)* ♦ 6 March 2024

Looking for Non-Abelian Braiding in Quantum Hall Systems
Kirill Shtengel *(University of California, Riverside, USA)* ♦ 6 March 2024

Tales of Cells Sensors: Through a Cellular-biophysics Lens
Swadhin Chandra Jana *(NCBS-TIFR, Bengaluru)* ♦ 5 March 2024

Computational Study of Fingering Instability due to an Instantaneous Chemical Reaction in a Porous Medium
Priya Verma *(IISc, Bengaluru)* ♦ 1 March 2024

Stability and Dynamics of Convection in Dry Salt Lakes
Lucas Goehring *(Nottingham Trent University, UK)* ♦ 29 February 2024

Manifold Learning via Sparse Self-regularised Transport
Gilles Mordant *(Georg-August-University of Goettingen, Germany)* ♦ 27 February 2024

The Prospect of Unravelling the Physics of High-density Matter: An Astrophysical Perspective
Ritam Mallick *(IISER Bhopal)* ♦ 23 February 2024

Quantum Games
Diptiman Sen *(IISc, Bengaluru)* ♦ 22 February 2024

Hearing the Universe Hum with Gravitational Waves at Pulsar Timing Array: Astrophysical, Cosmological and Particle Physics Interpretations
Anish Ghoshal *(University of Warsaw, Poland)* ♦ 22 February 2024

On the Role of Particle-flow Interactions in Cloud Microphysics
Anubhab Roy *(IIT Madras, Chennai)* ♦ 22 February 2024

Page Curve Entanglement Dynamics of Free Fermions: Results from Numerics and Hydrodynamics
Abhishek Dhar *(ICTS-TIFR, Bengaluru)* ♦ 21 February 2024

The Conundrum of Tidal Love Number
Sumanta Chakraborty *(Indian Association for the Cultivation of Science, Kolkata)* ♦ 20 February 2024

Gamma-Ray Bursts (GRBs) as Electromagnetic (EM) Counterparts of Gravitational Wave (GW) Sources with Fermi GBM
Suman Bala *(USRA, Huntsville, USA)* ♦ 20 February 2024

A New Characterization of Small-scale Dynamics in Turbulent Flows
Rishita Das *(IISc, Bengaluru)* ♦ 16 February 2024

The S-matrix and Boundary Correlators in Flat Space
Diksha Jain *(TIFR, Mumbai)* ♦ 14 February 2024

Mass Lysis of Bacterial Predators Drives the Enrichment of Antibiotic Resistance in Soil Microbial Communities
Samay Pande *(IISc, Bengaluru)* ♦ 14 February 2024

A Fresh Look at the Large N Limit of Matrix Models and Proposal for a New Continuum Description
Gautam Mandal *(TIFR, Mumbai)* ♦ 13 February 2024

Exploring Gravity, Astrophysics, and Cosmology with Gravitational Waves
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The 2d Sinh and Sine Gordon Models on the Infinite Cylinder
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Universal Features of 2 → N Scattering in QCD and Gravity from Shockwave Collisions
Raju Venugopalan *(Brookhaven National Lab, USA)* ♦ 7 February 2024

Solving 4D Planar Gauge Theory with Integrability and Conformal Bootstrap
Nika Sokolova *(King's College London, UK)* ♦ 6 February 2024

X-ray Flaring Event in AGN: Multi-wavelength Investigation and Interpretation of Physical Processes
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Impact Phenomena in Liquid Interfacial Systems Across Spatiotemporal Scales
Durbar Roy *(IISc, Bengaluru)* ♦ 2 February 2024

Gauge Orbit Space and Yang-Mills in 3d and 4d
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Unraveling the Secrets of Particle Acceleration in Collisionless Shocks
Siddhartha Gupta *(Princeton University, USA)* ♦ 30 January 2024

Hydrodynamic Transport in Active Cellular Aggregates
Subhadip Chakraborti *(Friedrich-Alexander Universität Erlangen-Nürnberg, Germany)* ♦ 29 January 2024

Parity Breaking in Classical and Quantum Fluids
Dylan Reynolds *(City College of New York, USA)* ♦ 24 January 2024

Overview of 21cm Experiments Probing the Epoch of Reionisation and Updates on the Square Kilometre Array
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Quantum Simulation Using Fermionic Atoms in Optical Lattices with Tunable Geometry
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Information-theoretic Aspects of Scrambling and Chaos
Namit Anand *(NASA Quantum AI Lab, USA)* ♦ 8 January 2024

Probing Dissipative Effects in Neutron Stars Using Gravitational Waves
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A Brief Introduction to Quantum Key Distribution
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Scattering Amplitudes and Holography
Akshay Yelleshpur Srikant *(University of Oxford, UK)* ♦ 3 January 2024

COLLOQUIA

Quantum Bounds to Chaos and Fluctuation - Dissipation Equality
Jorge Kurchan *(LPENS, École Normale Supérieure, Paris)* ♦ 10 December 2025

Dipole Induced Topological Transition in Three-dimensional Amorphous Solids
Itamar Procaccia *(Weizmann Institute of Science, Israel)* ♦ 8 December 2025

High Precision Waveforms with the Small Mass Ratio Limit and the Future of Gravitational-wave Source Modeling
Scott A. Hughes *(Massachusetts Institute of Technology, USA)* ♦ 11 November 2025

Morphing Without Muscles: Hydraulic Actuation in Nature
Joel Marthelot *(Aix-Marseille University, France)* ♦ 4 November 2025

From LLMs to LRMs: The Rise of Reasoning Models
Anil Ananthaswamy *(NCBS-TIFR, Bengaluru and IIT Madras, Chennai)* ♦ 14 October 2025

Neutron Stars as Cosmic Laboratories: Probing QCD, Dark Matter and Axions in the Multi-Messenger Era
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Motif Estimation, Polynomial Chaos, and the Ising Model
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Using Mathematical Modelling to Understand Collective Cell Motion
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Dark Energy Dynamics, Spatial Curvature, Neither, or Both?
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Breaking Thermalization in Quantum Many-Body Systems: Scars, Fragmentation, and Novel Symmetries
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Hugo Touchette *(Stellenbosch University, South Africa)* ♦ 24 October 2024

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Philippe Di Francesco *(Institut de Physique Theorique, Universite Paris-Saclay and University of Illinois at Urbana-Champaign)* ♦ 22 October 2024

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Shyama Narendranath *(Indian Space Research Organisation [ISRO], Bengaluru)* ♦ 17 September 2024

Fractons: A Novel Paradigm for Broken Ergodicity
Abhishodh Prakash *(University of Oxford, UK)* ♦ 10 September 2024

Deciphering Cosmic Dawn: A Conquest of the Final Frontier
Hamsa Padmanabhan *(Universite de Geneve, Switzerland)* ♦ 9 July 2024

Some Inverse Problems in Active Matter
L. Mahadevan *(Harvard University, USA)* ♦ 13 June 2024

Exploring Equitable and Climate Compatible Futures
Tejal Kanitkar *(National Institute of Advanced Studies, Bengaluru)* ♦ 4 June 2024

A Global Experiment to Characterize Oceanic Internal Wave Climates
James Girton *(University of Washington, USA)* ♦ 28 May 2024

Cosmic Revelation: Quest for Dark Energy
Shadab Alam *(TIFR, Mumbai)* ♦ 22 May 2024

Holomorphic Curves and their Applications in Symplectic Topology
Mohan Swaminathan *(Stanford University, California, USA)* ♦ 14 May 2024

Mechano-genomics of Cell-state Transitions
G.V. Shivashankar *(ETH Zurich & Paul Scherrer Institute, Switzerland)* ♦ 7 May 2024

Neutrinos in Cosmology: A Match Made in the Heavens
Yvonne Wong *(The University of New South Wales, Australia)* ♦ 23 April 2024

Human-Level AI by 2030?
Jared Kaplan *(Anthropic and Johns Hopkins University, USA)* ♦ 23 April 2024

Encoding Memory in Flowing Solids
Vinutha H.A. *(Georgetown University)* ♦ 25 March 2024

Emergence of Structure in Cortical Circuits Through Bottom-up Dynamical Principles
Sarthak Chandra *(Massachusetts Institute of Technology, USA)* ♦ 21 March 2024

Are There Bounds on the Superconducting Transition Temperature?
Mohit Randeria *(The Ohio State University)* ♦ 19 March 2024

Achieving Net-zero and Relevance of Nuclear Power
K.N. Vyas *(Former Secretary, DAE, and Chairman, AEC Govt. of India)* ♦ 14 March 2024

Recent Progress in Non-linear Geometric PDEs
Puskar Mondal *(Harvard University, USA)* ♦ 5 March 2024

Percolation and the Critical Behaviour of ϕ4 and Blume-Capel Models
Trishen Gunaratnam *(University of Geneva, Switzerland)* ♦ 8 February 2024

Chern-Simons Field Theory Invariants
Pichai Ramadevi *(IIT Bombay, Mumbai)* ♦ 16 January 2024

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STAFF

@ICTS

STAFF

The administrative, scientific, and technical teams at ICTS are exceptional, efficient and always responsive. They support faculty, postdoctoral fellows, students and visitors. They help to orchestrate programs, lectures, and seminars with ease. Their work quietly powers the institute, sustaining an environment where research can truly thrive.

ADMINISTRATION

Kavya Anand
Clerk Trainee (Stores)

Jenny Burtan
Clerk (Establishment)

Paramesha BS
Project Supervisor (Hospitality & Hostel facilities)

Dhananjayan C P
Project Clerk (Program Office)

Abhijit De
Administrative Officer D (Head Administration and Finance)

Anitha Dominic
Project Supervisor (Guest House & Campus Residential Facilities)

Vinay Bharadwaj DS
Project Clerk (Academic Office)

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Centre Director, ICTS-TIFR

Kavyashree H A
Project Administrative Executive (Program Office)

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Clerk Trainee (Program Office)

Manu M
Administrative Assistant B (Accounts)

Ramya M (Till September 2025)
Project Accounts Assistant

Jeeva M
Administrative Assistant C (Section Head - Academic Office)

Aruna Mahendarkar
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Raju Ram Mali
Project Assistant (Program Office)

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Clerk Trainee (Purchase)

Gayatri N
Administrative Assistant C (Program Office)

Jeyakumar N (Joined December 2025)
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Clerk Trainee (Program Office)

Manjunath P
Administrative Assistant B (Accounts and Finance)

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Clerk *(Accounts)*

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Project Manager (Services and Health Promotion Centre)

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Dean, Administration

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Clerk Trainee (Accounts)

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Administrative Assistant (Accounts)

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Harshitha S N
Clerk Trainee (Stores)

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Administrative Officer C (Section Head - Accounts and Finance)

Rajalakshmi Swaminathan
Administrative Assistant C (Purchase)

B S Vishnu Vishal
Administrative Assistant 'B' (Academic Office)

SCIENTIFIC AND TECHNICAL

Anugraha A (Till October 2025)
Project Scientific Coordinator (Outreach)

Sumukh A S
Technical Trainee (AV)

Ikbal Ahmed
Scientific Assistant C (Labs)

Harshith B S
Project Scientific Assistant (Web)

Gaayatri Chandrasekharan
Project Scientific Assistant B (Outreach)

Rohit Chavan
Tradesman B (AV)

Rakesh D S
Technical Trainee (Web)

Ananya Dasgupta
Consultant

Hemanta Kumar G (From June 2025)
Scientific Officer 'D' (Section Head- IT & HPC)

Mohan G
Engineer (Civil)

Roshini George
Project Scientific Assistant B (Outreach)

Vivek Gowda V
Technical Trainee (IT)

Abdul Hakki
Technical Trainee (Laboratory)

Mohammad Irshad
Scientific Assistant C (IT/AV)

Veena Iyer
Consultant (Program Office)

Dhananjay J
Tradesman B (HVAC Mechanical)

Vignesh J
Project Junior Engineer B (Electrical)

Harish K B
Project Technical Officer - C (Section Head - Electrical)

Disha Kuzhively
Project Scientific Coordinator (Outreach)

Naveen Kumar L C
Scientific Assistant (AV)

Puneeth M
Project Junior Engineer B (Civil)

Gobinath M
Technical Assistant (AV)

Deanish M A
Project *Scientific Officer C (Web)*

Rifat Naaz
Scientific Officer C

Naveena P
Tradesman B (Electrical)

Devanath P R
Scientific Assistant B (Library/ SIRC)

Basavaraj S Patil
Work Assistant

Sai Prakash Poldas
Library Trainee

B N R Prasanna
Consultant (Infrastructure and Construction)

Srinivasa R (Till June 2025)
Scientific Officer - In-charge - IT

Sarovar R
Technical Trainee (AV)

Shantaraj S
Scientific Assistant (AV)

Roshni Samuel
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Scientific Officer E (Resource Development and Societal Engagement Wing)

Renu Singh
Project Scientific Officer and Executive Assistant to Centre Director

Manjit Kumar Singh
Project Junior Engineer B (HVAC-Mechanical)

Prashanth Kumar V (Till August 2025)
Scientific Assistant (IT)

Nivrutti Vishe
Tradesman B (Civil Plumbing)

Kunal Waghmare
Project Scientific Assistant B (IT)

Nidhi Yadav
Project Scientific Assistant B (Academic & Faculty Secretariat Office)

Photo credit: Madhulika Singh

AWARDS AND RECOGNITIONS

Faculty Members

Parameswaran Ajith

- Elected as Fellow of the Indian Academy of Sciences (IASc).
- Elected as an Associate Fellow of the Indian National Science Academy (INSA).
- Awarded Simons Associateship by the International Centre for Theoretical Physics (ICTP), Trieste.
- Awarded a joint Indo-Italian research grant under the international bilateral science & technology program of the Department of Science and Technology (DST), with Prayush Kumar and in collaboration with Italian partners at Gran Sasso Science Institute in L'Aquila, Jan Harms and Andrea Maselli.

Siva Athreya

- Awarded the 2025 INSA Distinguished Lecture Fellowship.

Anirban Basak

- Selected as Member of the National Academy of Sciences, India (NASI).
- Awarded the ARG MATRICS grant (2025-2030) by the Anusandhan National Research Foundation (ANRF)

Riddhipratim Basu

- Joined the Editorial Board of the Electronic Journal of Probability (EJP)
- Elected as Fellow of Indian Academy of Sciences (IASc).

Subhro Bhattacharjee

- Received a joint Indo-Swedish International Mobility Grant, with Sergej Moroz (Karlstad University).

Vivek Borkar

- Awarded the National Science Chair of the Anusandhan National Research Foundation (ANRF).

Brato Chakrabarti

- Received a Scientific High Level Visiting Fellowship from the French Institute in India, with Anke Lindner (ESPCI-Paris). As part of the fellowship, they aim to study fluid- structure interaction phenomena in biophysics.
- Awarded the ANRF PM Early Career Research Grant.

Rajesh Gopakumar

- Awarded the INSA Distinguished Lecture Fellowship.

Rama Govindarajan

- Elected as Fellow of The World Academy of Sciences (TWAS).
- Awarded J. C. Bose Grant by ANRF of the DST, Government of India.
- Received the Vaibhav Collaborative Fellowship from DST, Government of India, with collaborator Prashant Valluri (University of Edinburgh).
- Joined the Editorial Committee of the Annual Review of Fluid Mechanics.
- Received the Outstanding Referee Award of the American Physical Society (APS).

Akshit Goyal

- Awarded an Associateship of the Indian Academy of Sciences.
- Awarded Simons Associateship by the International Centre for Theoretical Physics (ICTP), Trieste
- Received the Ramanujan Fellowship from DST, Government of India.
- Received a grant from DBT on climate-resilient agriculture, with Amey Redkar (NCBS) and Veena Anil (University of Agricultural Sciences (UAS), GKVK).

Vijaykumar Krishnamurthy

- Awarded the TAA B. M. Udgaonkar Excellence in Teaching Commendation for 2025 for biology.

Manas Kulkarni

- Named the Institute of Physics CNRS Guest Researcher for 2024.
- Joined the Editorial Board of the Journal of Statistical Mechanics.
- Awarded the CEFIPRA (Indo-French Centre for the Promotion of Advanced Research) grant, with Gregory Schehr for their project titled '*Classical and Quantum Dynamics in Out of Equilibrium Systems*'.
- Awarded an Indo-Japan grant under the India-Japan Circulation of Talented Youths in Science Programme (LOTUS Programme), with postdoctoral fellow Rekha Kumari and Tomoki Ozawa from Tohoku University (Japan).

Prayush Kumar

- Selected member of the National Academy of Sciences, India (NASI).
- Awarded a joint Indo-Italian research grant under the international bilateral science & technology program of the DST, with Parameswaran Ajith and in collaboration with Italian partners at Gran Sasso Science Institute in L'Aquila Jan Harms and Andrea Maselli.

Anupam Kundu

- Received IPA N. S. Satya Murthy Memorial Award.
- Awarded the ARG MATRICS grant (2025-2030) by the Anusandhan National Research Foundation (ANRF)

Gautam Mandal

- Awarded the DAE Raja Ramanna Chair.

Jaikumar Radhakrishnan

- Awarded the 2025 INSA Distinguished Lecture Fellowship.

Suvrat Raju

- Elected as Fellow of the Indian Academy of Sciences (IASc).

Sriram Ramaswamy

- Elected to the National Academy of Sciences (NAS) of the USA as an International Member.
- Awarded the National Science Chair of the ANRF.

Mythily Ramaswamy

- Elected as Fellow of the Indian National Science Academy (INSA).

Sumathi Rao

- Elected as Fellow of The World Academy of Sciences (TWAS).

Sthitadhi Roy

- Awarded the 2025 ICTP Prize.
- Selected as Associate of the Indian Academy of Sciences (IASc).
- Awarded an Advanced Research Grant (ARG) of the ANRF, with Sumilan Banerjee (IISc).

Ashoke Sen

- Received the 2024 ICBS Frontiers of Science Award.
- Awarded the 2025 INSA Distinguished Lecture Fellowship for distinguished contributions to string theory and gravity.

Jim Thomas

- Awarded a major research grant from the Naval Research Board (NRB) of the Defence Research and Development Organisation (DRDO) for his project titled "*Turbulent Dynamics and Energy Cascades of Internal Gravity Waves*."

Spenta Wadia

- Elected to the American Academy of Arts and Sciences (AAA&S) as an International Honorary Member.

Postdoctoral Fellows

Venkata Sai Saketh Muddu

- Selected for National Postdoctoral Fellowship (NPDF).

Siddhartha Mukherjee (Former fellow)

- Awarded the Saraswathi Cowsik Medal for 2025.

Indrajit Sau

- Selected for National Postdoctoral Fellowship (NPDF).

Farman Ullah

- Selected for the National Postdoctoral Fellowship (NPDF).

Students

Prateek Anand (Former student)

- Awarded the best poster award at the annual CompFlu 2024 event held at IIT-Hyderabad.

Souvik Jana

- Received an Honorable Mention in the Young Astronomer Award for the Best Publication by the Astronomical Society of India.
- Awarded the pan-TIFR Sarojini Damodaran International Student Travel Fellowship.

Ritwik Mukherjee

- Received the pan-TIFR Sarojini Damodaran International Student Travel Fellowship.
- Selected for the visiting doctoral student program of the Academy of Complex Systems of Universite Cote d'Azur.

Sugan Durai Murugan (Former student)

- Received an "Honorable Mention" in the Best Thesis Commendations of TIFR in physics for "*Implications of Inviscid Hydrodynamics and its Variants for Turbulence and Statistical Physics*"was completed under the supervision of Prof. Samriddhi Sankar Ray

Bikram Pain

- Awarded the NORDITA visiting PhD fellowship.

Nitesh Kumar Patro

- Topped Utkal University master's program in physics and received a gold medal from the President of India.

Mrinal Jyoti Powdel

- Awarded the best poster award at the annual CompFlu 2025 event held at IISc, Bengaluru.

Aditya Singh Rajput

- Awarded the pan-TIFR Sarojini Damodaran International Student Travel Fellowship.

P.S. Santhiya

- Selected for the spring term of the predoctoral program at the Center for Computational Astrophysics (CCA) at the Flatiron Institute, Simons Foundation, USA.

Aditya Vijaykumar (Former student)

- Received the 2024 Justice Oak Award for Outstanding Thesis in Astronomy by the Astronomical Society of India.
- Received the 2024 V. V. Narlikar Best Thesis Award by the Indian Association for General Relativity and Gravitation.

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String Theory

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Condensed Matter Physics

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String Theory

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Systems Biology

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MIT, USA
Condensed Matter Physics

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Courant Institute, New York University, USA
Mathematics

Spenta R. Wadia
ICTS-TIFR, Bengaluru
String Theory, Quantum Gravity, Statistical Mechanics

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University of Innsbruck, and Institute for Quantum Optics and Quantum Information, Innsbruck, Austria
Quantum Optics and Quantum Information

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IIT Bombay, Mumbai

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ICTS - TIFR, Bengaluru

Rama Govindarajan *[Till May 2025]*
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ICTS-TIFR & IISc., Bengaluru

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CNRS, LPTMS, Universite Paris-Sud

Mahan Mj
TIFR, Mumbai

Shiraz N. Minwalla
TIFR, Mumbai

Jaikumar Radhakrishnan *[From June 2025]*
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K. VijayRaghavan
NCBS-TIFR, Bengaluru

Spenta R. Wadia
ICTS - TIFR, Bengaluru

Registrar, TIFR [Rajeev Anand since March 2023]
Joint Secretary (R&D), DAE
Joint Secretary (Finance), DAE

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ICTS-TIFR, Bengaluru
Gravitational-Wave Physics and Astrophysics

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Electrical Engineering, Computer Science

Abhishek Dhar
ICTS-TIFR, Bengaluru
Non-equilibrium Statistical Mechanics

Rajesh Gopakumar
ICTS-TIFR, Bengaluru
Quantum Field Theory and String Theory

Srubabati Goswami
PRL, Ahmedabad
High Energy Physics, Astroparticle Physics, Neutrino Physics

Mahesh Kakde *[From 1 August 2025]*
IISc., Bengaluru
Mathematics

Meena Mahajan
IMSc., Chennai
Computer Science

Gautam I Menon
Ashoka University, Sonepat
Biophysics

Mahan Mj, Chair *[From 1 August 2023]*
TIFR, Mumbai
Mathematics

Jaikumar Radhakrishnan
ICTS- TIFR, Bengaluru
Computer Science

Mythily Ramaswamy
TIFR-CAM & ICTS- TIFR, Bengaluru
Mathematics

Sriram Ramaswamy *[From 1 August 2025]*
IISc. & ICTS-TIFR, Bengaluru
Statistical and Condensed Matter Physics, Active Matter

Debasis Sengupta *[From 1 August 2025]*
IISc. & ICTS-TIFR, Bengaluru
Oceanography, Monsoon variability

Prateek Sharma
IISc., Bengaluru
Theoretical Astrophysics

Vijay Shenoy *[From 1 August 2025]*
IISc., Bengaluru
Condensed Matter Physics

Spenta R. Wadia
ICTS-TIFR, Bengaluru
String Theory, Quantum Gravity, Statistical Mechanics

Former members [Till July 2025]

Kedar Damle
TIFR, Mumbai
Condensed Matter Physics

Chandan Dasgupta
IISc. & ICTS-TIFR, Bengaluru
Condensed Matter Physics and Statistical Mechanics

Manjunath Krishnapur
IISc., Bengaluru
Mathematics

Gautam Mandal
TIFR, Mumbai
String Theory, Black Holes, Gravity, Quantum Field Theory

Dipendra Prasad
IIT Bombay, Mumbai
Number Theory

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- Outreach Committee
- Postdoctoral Committee
- Program Cell
- SIRC Committee
- Visiting Students Committee

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- Cafeteria and Canteen Committee
- Cell for Prevention and Resolution of Sexual Harassment of Women at Workplace (CPRSHWW)
- Childcare Cell
- Cultural Committee
- Engineering Services Committee
- General administration and HR Planning & Management Committee
- Housing Cell
- ICTS Asset Verification Committee
- ICTS Building and Works committee
- ICTS Internal Building and Works Committee
- ICTS Internal Grievance Cell
- ICTS Purchase committee
- ICTS Standing Tender Committee
- ICTS Student Grievance Redressal Committee (SGRC)
- ICTS Student Support Cell (ISSC)
- Local Purchase Committee
- Medical Committee
- Official Language Implementation Committee (OLIC)
- Resource Development and Societal Engagement Wing
- RTI Cell
- Sports and Recreation Committee
- Student Grievance Redressal Committee (SGRC)
- Tender Opening Committee
- Transport and Security Committee

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ICTS was able to strengthen its research and outreach ecosystem through a series of generous endowments and partnerships. [Top left] In December 2025, the Centre marked the Sachdev Family Endowment with a plaque unveiling ceremony, honouring the memory of Mrs Usha Sachdev and Mr Dharmendra Kumar Sachdev, supporting students, postdoctoral researchers, and outreach initiatives. [Top right] ICTS also partnered with the National Centre for Biological Sciences to establish CALIBRE through philanthropic support from Mr Vishal Gupta and Major Deepshikha Gupta. [Bottom] In December 2024, ICTS signed a Memorandum of Understanding (MoU) with Tatineni Prem Kumar and Sujata Kumar to set up a travel grant fund. ICTS also launched the Pushkala & Ramani Travel Fellowship, expanding global academic engagement and support for women researchers. ◦ **Photo credit: AS Sumukh**

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