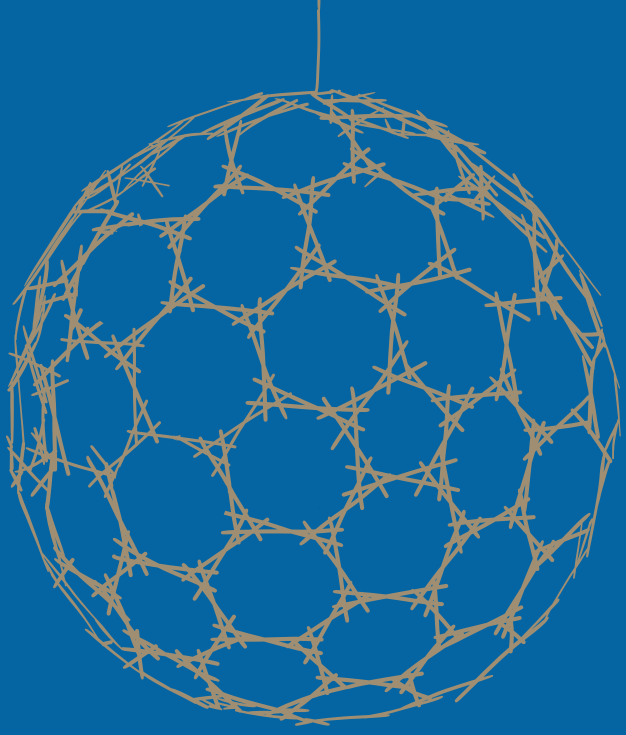
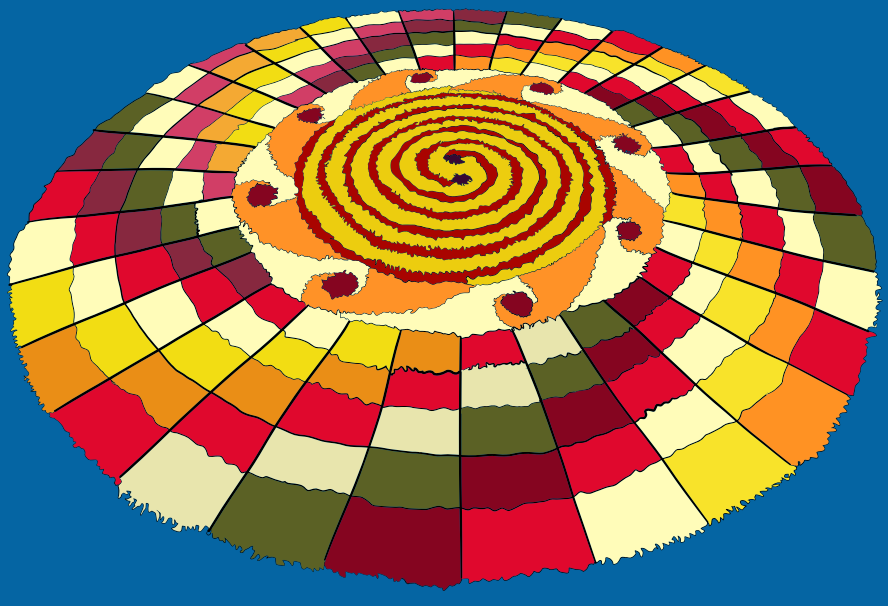


2022-2023 ICTS ACTIVITY REPORT



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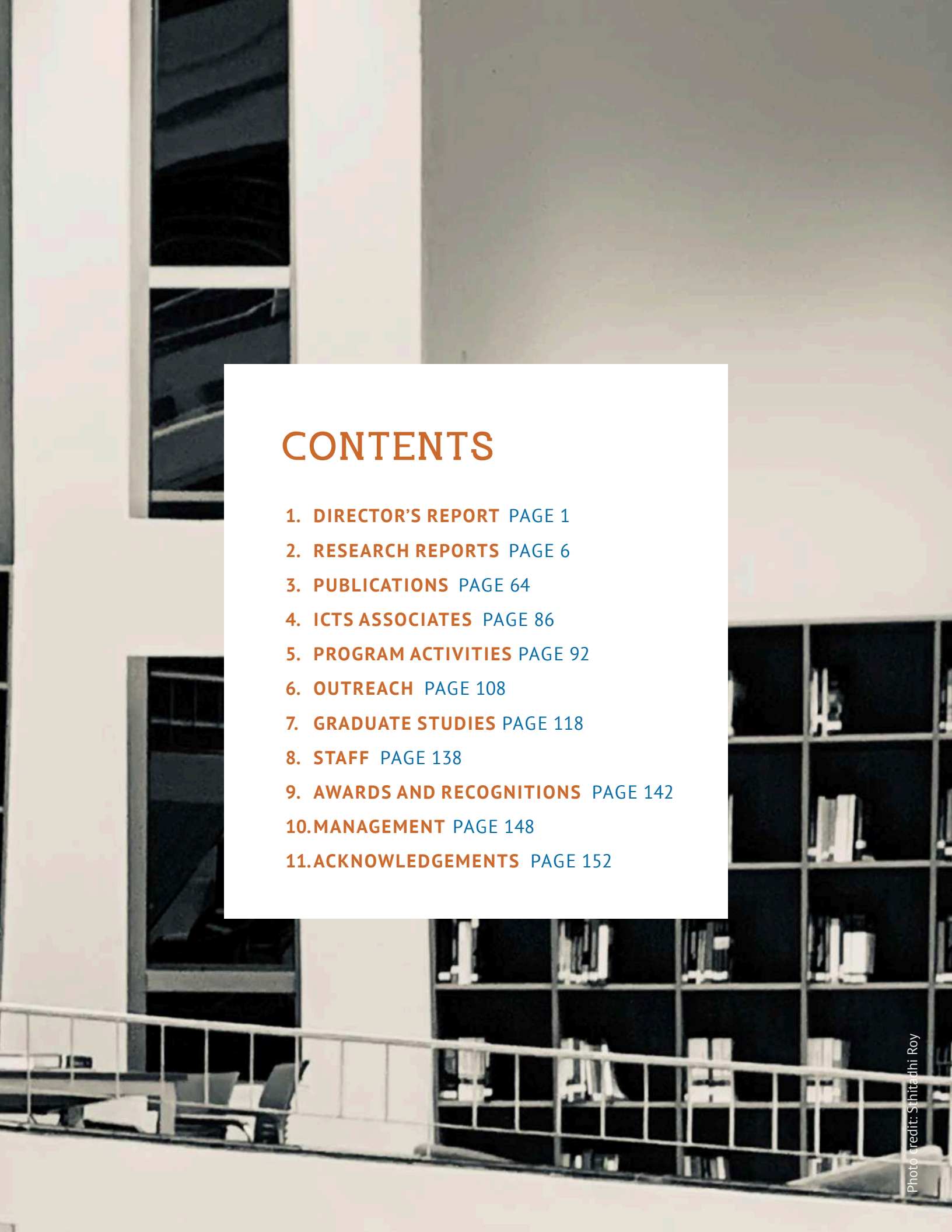


CONTENTS

Photo credit: Shitadhi Roy

DIRECTOR'S REPORT

The edifice of science is not raised like a dwelling, in which the foundations are first firmly laid and only then one proceeds to construct and to enlarge the rooms. Science prefers to secure as soon as possible comfortable spaces to wander around and only subsequently,..., it sets about supporting and fortifying them. This is not a weakness, but rather the right and healthy path of development.

David Hilbert

I very much like how Hilbert visualises science as creating "comfortable spaces to wander around". The wandering speaks to the forever restless and exploratory spirit which animates our research while the comfortable spaces are our provisional footholds on knowledge where we seek to pitch our tents as we scout the territory. Conversely, comfortable places to physically wander help create good science. In the ICTS campus, the architecture is designed to light the creative spark. Blackboards play an important role here - a theme I will let run through this report, giving a sense of the role it plays in the life at ICTS.

Blackboards are canvases where thoughts unspool from the mind, are reified and refined. Ideas incarnate as pictures, equations or "graphiti" as they attempt to leapfrog from one mind to another and trigger further neuronal cascades. From this ferment, a few ultimately survive, which then cohere into a scientific result or even more occasionally into the breakthroughs that change our conception of the world. We often get to know about the end product of this process but rarely about their fledgling beginnings.

When visitors come to ICTS, they are often struck by the profusion of blackboards on campus. Not just in offices and lecture halls (our Ramanujan auditorium has perhaps one of the longest blackboards in the world!) but in the public spaces, the "commons" if you wish. These boards, often green, also deep indigo (but never white), are in corridors, alcoves, in the garden (in Santiniketan spirit) and even the cafeteria. I observe their daily changing tableaux as I walk to my office or for lunch and to me it is a signifier of the health of the institution.

The health of ICTS, both literally and metaphorically, were important concerns as we began to emerge in early 2022 from the trauma of the covid years. Fortunately, activities at ICTS rebounded with a vengeance. Our programs had overwhelming response and the number of proposals also shot up. As a result, we have kept a blistering pace of 35-40 programs and discussion meetings per year in the last couple of years. As you will see in this report, we had a number of very innovative workshops charting new directions whether in quantum metrology, climate and data sciences, soft as well as active matter or astronomy and astrophysics. As part of these events, we had the privilege of hosting some brilliant minds for our named lecture series.

On the academic front, we have had a post-covid boom in our intake of Phd students. We had a record high of acceptances leading to thirty new students on campus this year. The number includes those in our new "Physics of Life" program jointly run with NCBS-TIFR. This is a program that will draw in students with undergrad degrees in science, maths and engineering into problems of biology creating a new generation of interdisciplinary researchers. We have had Akshit Goyal, microbial evolutionary biologist, join us from MIT as a Simons Young Researcher and will soon have Brato Chakrabarti, biophysical fluid dynamicist,

from the Flatiron Institute, soon joining us which will strengthen this program. I am very excited that we will have a new vibrant strand in the weave of ICTS.

Central to ICTS are the blackboards in the quadrangle, near our pantry. The coffee and the chalk are essential ingredients for the thrum of creativity. Here it is like music making in the park, with passersby listening in or daringly plunging into some heated discussion. The boards are an illegible scrum of scrawls and yet somehow everyone there is able to discern the different chords and chime in. Our continually changing set of program visitors also gravitate here and add their own tunes to the Antakshari. Magic happens. If there is such a thing as an institutional or collective mind in a place like ICTS, it is these spaces with their boards which bring it out and give expression to it.

A different kind of buzz is in the air whenever our campus fills with young minds (I mean ten to fifteen year olds) who have been thronging our outreach events. The last two years saw an amazing number of new outreach activities including a large number of hands-on science and maths events which you will read about - like PRISM, MathSpark, science kit exhibition. The outreach team has also started new activities like a blog in addition to continuing with our public lectures and the maths circles which are gaining strength. A high point was the collective fashioning of a geosphere under the guidance of folks from CCL, IIT-Gandhinagar, which is now a striking addition to our Chandrasekhar foyer.

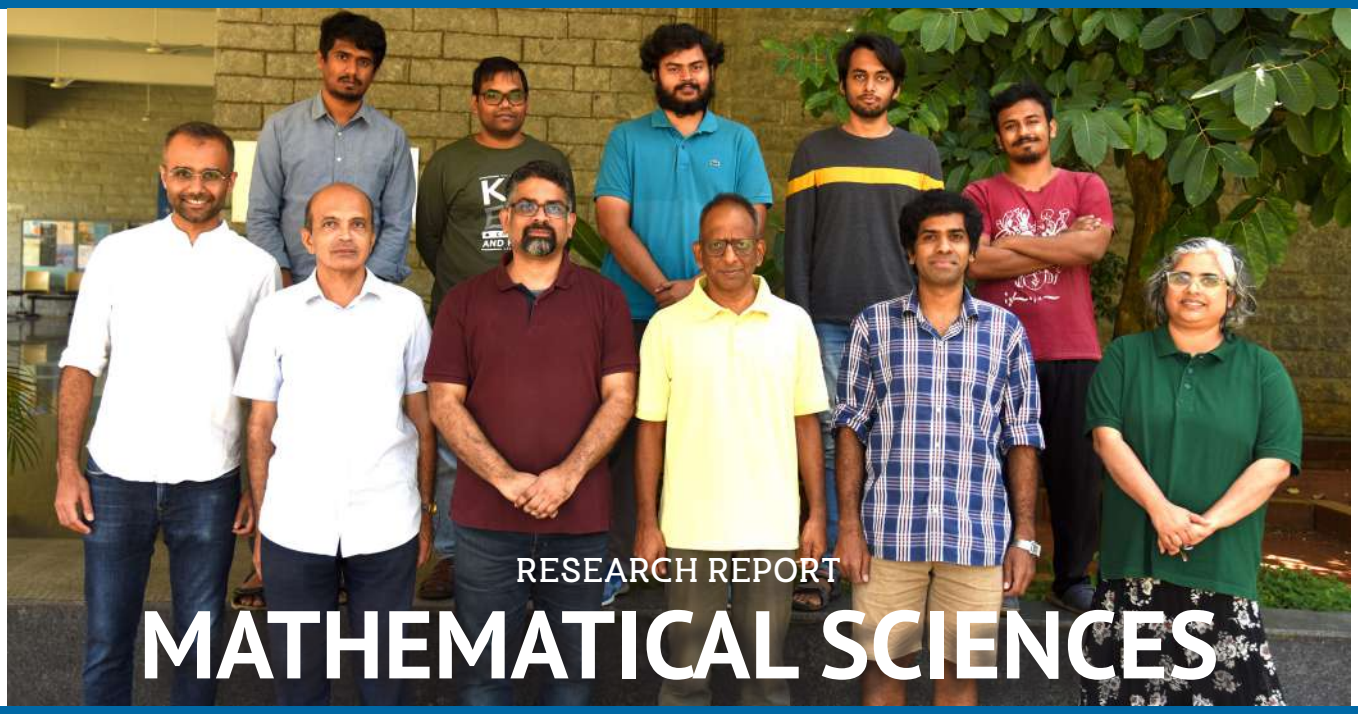
There is also whimsy in evidence, especially in the public areas, in the form of a slogan or a sketch splashed across a blackboard. Recently, ICTS has had its in-house Banksy, whose Manga style artwork materialises overnight. I find myself looking forward to spotting a new illustration as I enter the building each morning.

As ICTS grows and new activities sprout, our administrative and technical staff have given much more than duty demands. It is their selfless dedication to ICTS and sense of ownership in the institution that is such a source of strength to all of us. It is something to be watered at the roots so that it embeds into the institutional DNA. It has also been our privilege to have such a supportive advisory board. I would particularly like to acknowledge so many friends, far and near, who have supported the ICTS mission in ways both small and big. And a warm invite to all well-wishers to stop by our campus and see for yourself our blackboards and beyond.

Rajesh Gopakumar
January 2024

Photo credit: Juny K. Wilfred

RESEARCH @ICTS



RESEARCH REPORT

MATHEMATICAL SCIENCES

Applied and Computational Mathematics

FACULTY

Amit Apte ❖ Mythily Ramaswamy *(NASI Senior Scientist)* ❖ Vishal Vasan

POSTDOCTORAL FELLOWS

Sharath Jose

STUDENTS

Manisha Goyal ❖ Pinak Mandal ❖ Vishal Neeraje ❖ Shashank Kumar Roy

RESEARCH REPORT

Vishal VASAN

Vishal Vasan is interested in the theoretical and numerical analysis of partial differential equations as well as their applications. The application domains include large-scale atmospheric and ocean dynamics, Bose-Einstein condensates and cold atoms, coastal engineering, growth of biological systems amongst others. His research presently consists of two broad themes.

Dynamical Systems and Data

The broad aim of this research theme is to establish the data-driven viewpoint of dynamical systems from a theoretical perspective. Results that firmly establish inference principles for the state and parameters of a dynamical system from partial noisy observations are sought. The ultimate goal is to develop a theory of learning for dynamical systems. Continuing the work on observers and PDEs, Vasan showed convergence is guaranteed by tuning a rate-parameter related to the frequency of measurements. Moreover, the time-asymptotic state-error is a Lipschitz function model/measurement error. Building upon this work, Vasan seeks to establish guarantees on parameter estimations by adapting the observer framework. One of the motivating problems for the development of state-estimators for PDEs comes from atmospheric/ocean science where the eventual goal is to use satellite observations in combination with PDE models to infer meteorological variables, rapidly and efficiently. However, parameter estimation is far more widely applicable with areas of interest including epidemiology. ecology, material science, chemical engineering, etc.

Analysis and Computation

This theme is concerned with developing numerical algorithms and their analysis to establish guarantees on error, convergence and computational cost. The algorithms are strongly motivated by applications and influenced by the theoretical understanding of the mathematical models. Recently Vasan and collaborators developed a Runge-Kutta style explicit integrator for equations with memory terms, such as those found in fractional differential equations. They did this by introducing a notion of a spectral representation for a function. This representation readily suggests a Markovian embedding. This idea has been adapted to more physical systems including bouncing droplets on a liquid surface as well as the single-phase melting ice problem in 1-dimension. In ongoing work, they look for extensions to higher dimensions. The motivating problem here is the simulation of the motion of solid particles in a three-dimensional turbulent fluid flow.

Computer Science

FACULTY

Jaikumar Radhakrishnan

Geometry and Physical Mathematics

FACULTY

Rukmini Dey ❖ Pranav Pandit ❖ TN Venkataramana *(DAE- Raja Ramanna Chair)*

POSTDOCTORAL FELLOWS

Anantadulal Paul ❖ Sachchidanand Prasad ❖ Savita Rani

STUDENTS

Kohinoor Ghosh ❖ Mayank Kumar Bijay ❖ Srikanth B Pai ❖ Bhanu Kiran S

RESEARCH REPORT

Rukmini DEY

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

Dey and collaborators showed that a Berezin-type quantization can be achieved on a compact even dimensional manifold M2d by removing a skeleton Mo of lower dimension such that what remains is diffeomorphic to R2d which is identified with Cd and embed in CPd. A local Poisson structure and Berezin-type quantization were induced from CPd. This construction depends on the diffeomorphism. They studied the possibility of this construction to be extended to the whole of M2d. They had a similar construction where they considered an arbitrary complex manifold and used local coordinates to induce the quantization from CPd. They studied the possibility of defining a global Berezin quantization on compact complex manifolds. They gave a similar construction of Berezin-Toeplitz quantization. Finally, they gave a simple construction of pullback coherent states on compact smooth manifolds. The collaborator was Kohinoor Ghosh.

Dey is working on a Berezin-type and Odzijewicz-type quantization which can be achieved on any compact smooth manifold Md by embedding it in R2d by Whitney embedding or any other suitable embedding and then using pull back coherent states.

Dey and collaborators have finished a work on interpolation of two real analytic curves by maximal surfaces in Lorentz-Minkowski 3-space and minimal surface in Euclidean 3-space. This is a reformulation of the Plateau's problem and involves functional analysis techniques. The collaborator was Rahul Kumar Singh.

Dey and collaborators have studied and completed work on algebraicity and non algebraicity of constant mean curvature surfaces of revolution. In the process, they showed a deep connection between these surfaces and elliptic curves. The collaborators were Anantadulal Paul and Rahul Kumar Singh.

RESEARCH REPORT

Pranav PANDIT

The projects that Pranav Pandit has worked on lie at the interface between mathematical physics, higher category theory, and algebraic geometry.

One area of focus for Pandit's group has been the study of topological quantum field theories (TQFTs). This class of quantum field theories is amenable to a rigorous mathematical axiomatization using the language of higher categories. The cobordism hypothesis is a powerful theorem that gives a complete classification of TQFTs in all dimensions in terms of fully dualizable objects in higher categories. This leads to the problem of using this framework to give mathematically rigorous descriptions of well-known TQFTs that arise from heuristic considerations in theoretical physics.

Dijkgraaf-Witten theory is a gauge theory with a finite gauge group. It is an example of a TQFT. Many facts about the representation theory of finite groups can be conveniently encoded in terms of cutting and gluing of manifolds using this theory. Equations in algebra are strings of symbols written on a one-dimensional object (a line). Higher algebra deals with equations whose ``shapes'' are governed by higher dimensional spaces. For example, 2-dimensional algebra studies surfaces with regions labeled by symbols. These labeled surfaces are the analogues of strings of symbols in ordinary algebra. Higher groups are higher dimensional analogues of groups. In recent years, higher groups and higher categories have come to play an important role in theoretical physics, where they appear as generalized symmetries in quantum field theories. Pandit and his student Srikanth Pai have developed higher categorical foundations that will be used to give a mathematical description of Dijkgraaf-Witten theory for finite 2-groups. This is the first step in a project that aims to develop the representation theory of 2-groups using the framework of topological quantum field theory.

Rosansky-Witten theory is a 3d TQFT. It has important applications to the theory of knots, and also appears in the context of 3d mirror symmetry as one side of a duality relating two physical theories. The mathematics of 3d mirror symmetry is at a very early stage of development, and promises to have many applications in geometry and representation theory. An important problem in this subject is to give a description of the 2-category of boundary conditions of Rosansky-Witten theory. Kapustin, Rozansky and Saulina outlined a candidate for this 2-category. An important ingredient in their proposal is a deformation of a certain 2-category. Pandit and his student Bhanu Kiran have developed the foundations of the theory of deformations of n-categories, and are currently working on applying their results to the Kapustin-Rozansky-Saulina proposal. Algebraic varieties are spaces that arise as solutions to polynomial equations. One approach to classifying varieties in terms of their complexity is based on the theory of Ulrich bundles. These are a special class of vector bundles on a projective variety. Pandit and former ICTS postdoc Poornapushkala Narayanan have initiated a new approach to Ulrich bundles, based on categorical noncommutative geometry and ideas inspired by homological mirror symmetry.

Probability Theory

FACULTY

Siva Athreya ❖ Anirban Basak ❖ Riddhipratim Basu

POSTDOCTORAL FELLOWS

Akshay Goel

RESEARCH REPORT

Siva ATHREYA

Siva Athreya's primary field of interest has been in probability theory. Along with collaborators, he has been working with models that arise in either statistical physics or population biology. The specific topics included interacting particle systems, semi-linear partial differential equations, stochastic partial differential equations (SPDE), stochastic differential equations (SDE), diffusion and random graphs.

During the COVID-19 pandemic, he worked closely with the Technical Advisory Committee and Government of Karnataka to help design and implement various aspects of the public health response. One of Athreya's key contributions has been working on the two rounds of serological surveys for the state. Currently he is involved in disease surveillance modelling for the state for neglected tropical diseases.

Here is a summary of selected works:

Stochastic Reaction–Diffusion Equation Driven by Space-time White Noise

Athreya and collaborators studied the stochastic reaction–diffusion equation driven by space-time white noise and a generalised distributional drift [[Communications in Pure and Applied Mathematics]. They introduced a notion of a solution to this equation and obtained the existence and uniqueness of a strong solution when the drift belongs to a Besov space with an exponent at least -1.5. Their results extended the work of Bass and Chen (2001) to the framework of stochastic partial differential equations and generalized the results of Gyöngy and Pardoux (1993) to distributional drifts. To establish these results, they exploited the regularization effect of the white noise through a new strategy based on the stochastic sewing lemma introduced in Lê (2020). . The collaborators were (jointly with Oleg Butkovsky, Khoa Le and Leonid Mytnik)

Coupled Models of Genomic Surveillance and Evolving Pandemics with Applications for Timely Public Health Interventions

Disease surveillance systems provide early warnings of disease outbreaks before they become public health emergencies. However, pandemics containment would be challenging due to the complex immunity landscape created by multiple variants. Genomic surveillance is critical for detecting novel variants with diverse characteristics and importation/emergence times. formulated an integrated computational modeling framework to study a realistic course of action based on sequencing, analysis, and response. Athreya and collaborators studied the effects of the second variant's importation time, its infectiousness advantage and, its cross-infection on the novel variant's detection time, and the resulting intervention scenarios to contain epidemics driven by two-variants dynamics. Their results illustrated the limitation in the intervention's effectiveness due to

the variants' competing dynamics and provide the following insights: i) There is a set of importation times that yields the worst detection time for the second variant, which depends on the first variant's basic reproductive number; ii) when the second variant is imported relatively early with respect to the first variant, the cross-infection level does not impact the detection time of the second variant. They found that depending on the target metric, the best outcomes are attained under different interventions' regimes. Their results emphasize the importance of sustained enforcement of Non-Pharmaceutical Interventions on preventing epidemic resurgence due to importation/emergence of novel variants. [Proceedings of the National Academy of Sciences, USA]. The collaborators were Baltazar Espinoza, Aniruddha Adiga, Srinivasan Venkatramanan, Andrew Scott Warren, Jiangzhuo Chen, Bryan Leroy Lewis, Anil Vullikanti, Samarth Swarup, Sifat Moon, Christopher Louis Barrett, Siva Athreya, Rajesh Sundaresan, Vijay Chandru, Ramanan Laxminarayan, Benjamin Schaffer, H. Vincent Poor, Simon A. Levin, and Madhav V. Marathe.

RESEARCH REPORT

Anirban **BASAK**

Anirban Basak's research during the period of this report has primarily focused on large deviations in sparse random graphs and matrices, and on the study of statistical physics models on large locally tree-like graphs.

Large Deviations in Sparse Random Graphs and Matrices

Over the past few years there has been increasing interest in studying atypical behaviors of spectral observables in random graphs and matrices. In a recent work, Basak considered the upper tail large deviations of the spectral radius of $G(n,p)$, the Erdös-Rényi graph on n vertices with edge connectivity probability $p \in (0,1)$, for an intermediate range of sparsity. This work together with a couple other works in the area settles the problem of upper tail large deviations of the spectral radius of sparse $G(n,p)$. In another work, Basak with his co-author studied the upper tail large deviations of the largest eigenvalue of sparse supercritical Wigner matrices, where the entries on and above the diagonal of the symmetric matrices are independent and identically distributed and are products of sub-Gaussian random variables and $Ber(p)$ random variables with $\log n/n \ll p \ll 1$.

Potts and Random Cluster Measures on Locally Tree-like Graphs

Based on cavity methods, statistical physics predicts that for a wide class of ferromagnetic spin models on large locally tree-like graphs, the asymptotic free energy density should be given by the maximum of the Bethe free energy over all 'meaningful' fixed points of the belief propagation equations. Moreover, if the

Bethe free energy is maximized by a unique fixed point, commonly termed as a pure state, then in the large n limit the ferromagnetic spin model is believed to be governed by that pure state. On the other hand, if there are multiple maximizers the limit is to be determined by a mixture of such pure states. While these conjectures have been in the physics literature for quite some time, verifying them rigorously poses serious mathematical challenges, and has been verified in only a handful of cases. In a recent work, Basak with his co-authors established this conjecture for the ferromagnetic Potts and random cluster measures, with an external magnetic field, on locally tree-like graphs converging to the infinite regular tree.

RESEARCH REPORT

Riddhipratim BASU

During 2022-23, the main focus of Riddhipratim Basu's research was the space time correlations in the KPZ universality class.

In the zero temperature model of exponential LPP, Basu and collaborators determined the exponent governing the decay of correlation for the profile started from the flat initial condition. The collaborators were Ofer Busani and Patrick L. Ferrari.

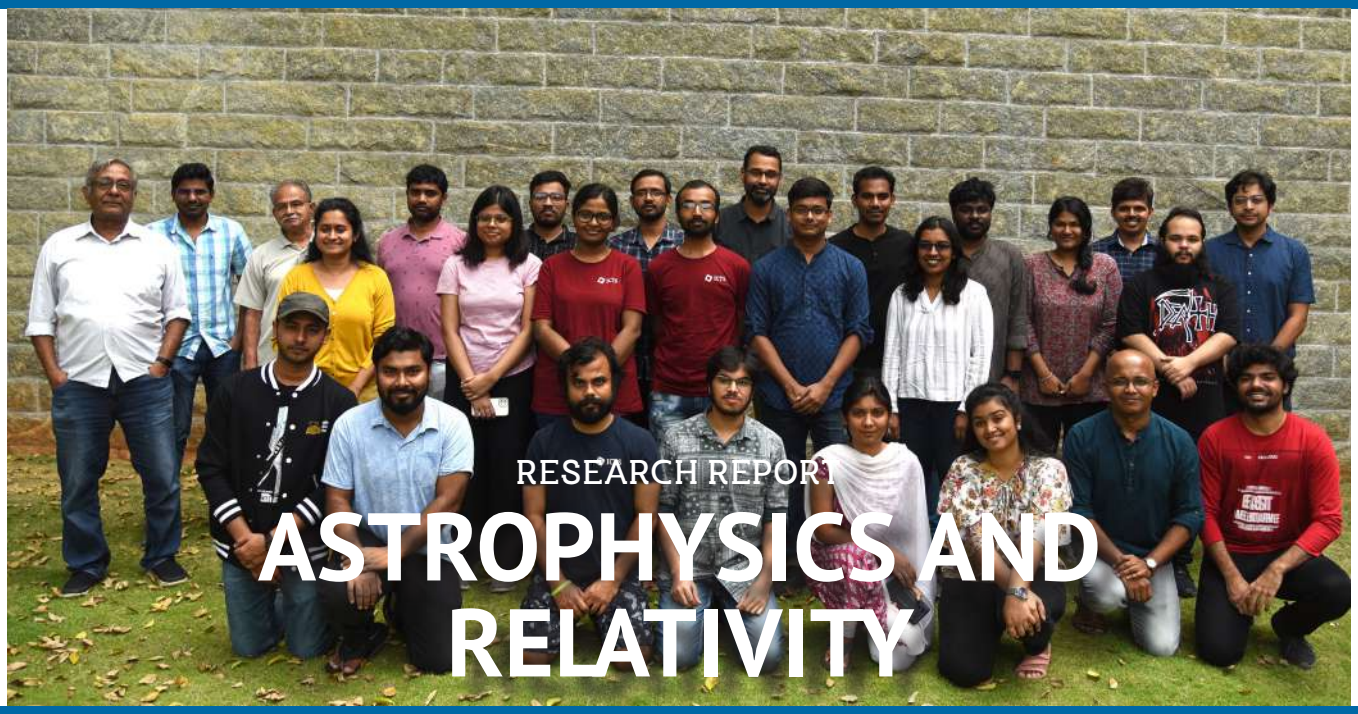
In another work on the same model, Basu and collaborators answered several questions regarding the behavior of geodesic trees. Considering the scaling limit of the exponential LPP model, the directed landscape, they studied pairs of mated geodesic trees and the space-filling Peano curve between them. The collaborators were Marton Balazs and Sudeshna Bhattacharya.

Basu and collaborators constructed this curve and studied several of its fractal properties. In a different line of work they considered a positive temperature model in the KPZ class, namely the log-Gamma polymer. The collaborator was Manan Bhatia.

Basu determined the exponents for temporal correlation decay in this model for the droplet initial condition, showing that the exponents are the same as in the zero temperature case. The collaborators were Timo Seppalainen and Xiao Shen.

In a follow up work with Xiao Shen, Basu determined the same exponents for a large class of random initial conditions, including the stationary initial condition. These results also applied to the zero temperature case and significantly strengthens the existing results there.

PHYSICAL AND NATURAL SCIENCES



RESEARCH REPORT

ASTROPHYSICS AND RELATIVITY

FACULTY

Parameswaran Ajith ❖ Pallavi Bhat ❖ Bala Iyer *(Simons Visiting Professor)* ❖ Prayush Kumar ❖ Rajaram Nityananda *(Simons Visiting Professor)*

POSTDOCTORAL FELLOWS

Shalabh Gautam ❖ Akash Kumar Mishra ❖ Tushar Mondal ❖ Krishnendu N V ❖ Vaishak Prasad ❖ Prasad R

STUDENTS

Ankur Barsode ❖ Soummyadip Basak ❖ Uddeepta Deka ❖ Srashti Goyal ❖ Alorika Kar ❖ Koustav Narayan Maity ❖ Souvik Jana ❖ Aditya Kumar Sharma ❖ Akash Maurya ❖ Mukesh Kumar Singh ❖ Aditya Vijaykumar

RESEARCH REPORT

Parameswaran AJITH

One major aspect of Parameswaran Ajith's current research is the gravitational lensing of gravitational waves (GWs). The first detection of lensed GWs is expected in the next few years. 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 work also explores how future lensing observations can be used as new probes of gravity, astrophysics and cosmology.

In the LIGO-Virgo-KAGRA Collaboration, the ICTS group [with A. Ganguly, S. Goyal and S. J. Kapadia] performed the first search for strongly lensed GWs in the LIGO-Virgo data from the third observing run. This was done using Bayesian Inference and Machine Learning methods that they developed earlier. From the non-observation of microlensing signatures in the observed GW signals, the ICTS group [with S. Basak] also produced constraints on the fraction of dark matter in the form of compact objects.

Ajith's recent work [with S. Jana, S. J. Kapadi and T. Venumadhav] showed how observations of strongly lensed GW signals can provide a powerful new tool for cosmography. The number of lensed GW events and the distribution of the time delay between lensed images depend on cosmological parameters, which can be extracted from the large number of lensed signals that the next-generation detectors will observe.

In collaboration with S. Basak, A. K. Sharma and S. J. Kapadia, Ajith investigated the prospects for observing continuous GWs from spinning neutron stars strongly lensed by the galactic supermassive black hole. They concluded that the next-generation detectors have a reasonable chance of detecting some lensed signals, which will open up new ways of probing the galactic supermassive black hole and its astrophysical environment.

His most recent work [in collaboration with U. Deka, S. Chakraborty (IACS), S. J. Kapadia, M. A Shaikh] explored how the properties of a black hole could be measured from the GWs that are microlensed by the black hole. As a first step, they showed how the charge (which could have electromagnetic or modified gravity origin) of a non-rotating black hole lens could be constrained from the microlensing distortions on the GW signal.

Ajith and collaborators also explored how future multi-messenger observations of gravitationally lensed compact binary mergers could offer new probes of astrophysics. In collaboration with M. K. Singh, S. J. Kapadia, S. Basak and S. P. Tendulkar (TIFR), his work showed how observations of lensed fast radio bursts

(FRBs) can be used to confidently test the hypothesis that FRBs are produced by compact binary coalescences. Work led by the IUCAA group [S Magare, S. J. Kapadia, A. More, A. N. Ramprakash] in collaboration with M. K. Singh and Ajith showed how such observations could provide early warning to telescopes, enabling the observation of precursors and prompt emission of electromagnetic radiation.

Ajith's work also covers other aspects of GW astrophysics: They explored the effect of higher harmonics of the gravitational radiation in improving the early warning of compact binary mergers [with M. K. Singh, Divyajyoti (IIT Madras), S. J. Kapadia and M. A. Shaikh]. At the same time, they showed that higher harmonics have a negligible effect on inferring the population properties of binary black holes [with M. K. Singh, S. J. Kapadia and A. Vijaykumar]. His work, in collaboration with A. Vijaykumar and S. J. Kapadia showed that GW signals from binary neutron stars in the vicinity of supermassive black holes (such as in the galactic centre) will enable an improved measurement of the post-merger signal through the gravitational redshift produced by the supermassive black hole. The line-of-sight acceleration of such a binary could also be measured from its imprint on the GW signal, shedding light on the astrophysical environment of the binary [with A. Vijaykumar, A. Tiwari (IUCAA), S. J. Kapadia, K. G. Arun (CMI)].

RESEARCH REPORT

Pallavi BHAT

The astrophysical fluids and plasmas group led by Pallavi Bhat has been working on varied research problems. Here is a summary.

Angular Momentum Transport and Large-scale Dynamo in a System Driven by Magnetorotational Instability (MRI) in Accretion Disks

Bhat and her collaborators developed a unified mean field model for MRI turbulence and using direct statistical simulations uncovered new dynamo effects called rotation-shear-current and rotation-shear-vorticity effects. This work establishes a foundation for developing sub-grid models for computationally demanding global simulations, holding potential to further our understanding of the data from the Event Horizon Telescope. The collaborator was Tushar Mondal.

Quasi-two-dimensional Nature of Decaying 3D Magnetohydrodynamic Turbulence

Recently it has been established that magnetically dominated decaying

turbulence can exhibit inverse transfer in energy, irrespective of whether the field is helical or nonhelical. The team used direct numerical simulations to show that the decay laws are interestingly the same in both 2D or 2.5D and 3D cases. Using Minkowski functional analysis they show that the 3D system has a certain degree of anisotropy which explains the quasi-2D behaviour. This will be applied to understand early universe evolution of magnetic fields. The collaborators were Shreya Dwivedi and Chandranathan A.

Fluctuation Dynamo in Collapsing Background

MHD equations involve extra terms and appearance of a scale factor when a collapsing background is considered. These can be transformed away neatly to recover the original form of the equations by using "supercomoving" variables. The team analytically explored the new effects in dynamo operation in such a scenario applicable to early stages of star and galaxy formation. The analytical exposition led to a super-exponential growth of magnetic fields. The collaborator was Muhammed Irshad.

Particle Acceleration Driven by Magnetic Reconnection Applied to Galaxy-clusters

They used WARPX, a particle-in-cell code, to set up numerical experiments involving tearing mode reconnection and quantified the energisation of particles in such a system. They observed that the kinetic energy of the particles increase by around two orders of magnitude. They also obtained the slope of the kinetic energy spectra to be around -1, which is consistent with the previous literature. This would be the first study to apply reconnection based energization to understand nonthermal emission in galaxy clusters. The collaborator was Subham Ghosh.

Exploration of Magnetic Reconnection in 3D

The phenomenon of reconnection studied extensively in 2D is largely unexplored in 3D. In their preliminary studies, the team found the 3D growth rates to be different from that in the 2D case. They are exploring these differences using direct numerical simulations and analytical calculation of linear stability analysis. The collaborator was Vinay Kumar.

Investigating Accretion-disk-jet Connections Using General Relativistic Magnetohydrodynamic (GRMHD) Simulations

Observations of γ-rays and spectral lines from AGNs and gamma ray burst (GRB) sources show a correlation between jet power and accretion-disk luminosity. The group is performing direct numerical simulations of disk-jet using the publicly available GRMHD code called Black-Hole Accretion Code (BHAC). They plan to compute the disk luminosity via energy budget considerations and jet power from Poynting flux and kinetic energy of the flow. The collaborators are Santhiya P S, Tushar Mondal and Prayush Kumar.

RESEARCH REPORT

Bala IYER

During the last two years, Bala Iyer has continued working with the LIGO-Virgo-KAGRA collaboration. Here is a summary of the work done.

The third observational run (O_3) of LIGO and Virgo was one of consolidation revealing newer varieties of compact binaries and leading to the GWTC-3 catalogue of ninety compact binary coalescences. Exceptional events included a second binary neutron star (GW190425), neutron star black hole binaries (GW200115, GW200105), an intermediate-mass black hole (GW190521), asymmetric binary black holes that can reveal higher multipoles of gravitational radiation (GW190412, GW190814), etc. In addition, these observations revealed the existence of compact objects that are in the traditional "mass gap regions", where the collaboration doesn't expect compact objects to exist due to astrophysical reasons.

The O_3 Gravitational Wave (GW) data was used to issue Open Alerts (to look for electromagnetic and neutrino counterparts of GW sources), search for exceptional events like those listed above, create a catalogue of GW transients together with their parameters, infer merger rates of compact binaries, their population properties and astrophysical formation mechanism, perform tests of gravity, constrain the cosmic expansion history, search for GW lensing signatures, search for GW from burst sources like core-collapse supernovae, gamma-ray bursts, magnetars and fast radio bursts and finally explore exotica like scalar boson clouds around spinning black holes and subsolar mass binaries. Different kinds of searches were performed for persistent GW emission from isolated neutron stars, known supernova remnants, 20 accreting millisecond X-ray pulsars, the low-mass x-ray binary Scorpius X-1,and unknown neutron stars in the Milky Way center. These analyses led to upper limits on the GW strain of continuous GW sources and on the quadrupole ellipticities of the involved neutron stars.

RESEARCH REPORT

Prayush KUMAR

Prayush Kumar's research during 2022-2023 has focussed on the following.

Eccentric Binaries

A common theme of the compact-binary merger events observed in the GW spectrum so far has been their orbital geometry. Binary orbits being quasi-circular is a powerful indicator of the astrophysical surroundings that these systems were born and evolved in. An alternate possibility is of binaries that are dynamically formed in dense stellar environments where multi-body encounters are likely, creating gravitationally bound binaries. The key signature of such binaries is their orbital eccentricity, which often remains measurably large when the gravitational-wave signals from them enter the sensitive frequency band of ground-based detectors. Population synthesis studies estimate that it is possible for up to 10% of all GW observations to be from eccentric binary mergers. Yet, they remain elusive and are yet to be observed. Much of Kumar's research over the past few years has been the quest to detect eccentric binaries and study them.

Kumar and his collaborators developed the first GR-based source modeling framework that captures the inspiral through merger of eccentric binary sources in 2017. Since then they have improved upon the framework using Numerical Relativity (NR) simulations and recent post-Newtonian (PN) theory calculations. Last year, they published an improved version of the Eccentric, Non-spinning, Inspiral-Gaussian-process Merger Approximant (ENIGMA) waveform model. A critical shortcoming of ENIGMA so far has been that it cannot capture the effects of black hole spins on the orbital dynamics. In the past two years, they completed a first version of an inspiral+merger+ringdown model describing black holes with aligned spins on eccentric orbits and their gravitational-wave emission including its higher harmonics. Fig. 1 shows a preliminary result from this ongoing work, comparing the prediction of ENIGMA with a numerical relativity simulation of a spinning eccentric binary. A manuscript describing the waveform model is under preparation.

Numerical Relativity

The current generation of NR codes have all come up against their inherent limitations, that are borne out of choices made to discretize GR and MHD equations, perform parallel computation that can leverage modern supercomputers, and other such technological choices. Therefore, with the Simulating eXtreme Spacetimes (SXS) collaboration, Kumar has been working on a paradigm changing new NR code called SpECTRE for the past six years. Over time h**e** has finalized the essential infrastructure and paradigm choices that this code will be based on. During the past years, he has worked on the following projects in numerical relativity, including contributions to SpECTRE:

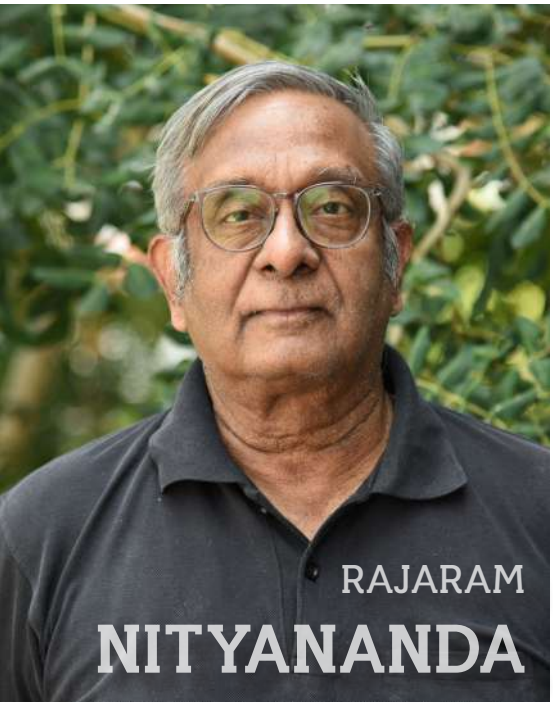
Kumar worked on a new approach to potentially reduce the computational cost of high mass-ratio binary simulations by replacing the smaller object with an analytical model approximating a tidally deformed black hole. This work is based on Dhesi et al (2021), and a toy model of a scalar charge in a fixed circular geodesic orbit around a Schwarzschild black hole was implemented in SpECTRE.

They implemented a technique in SpECTRE to evolve gravitational waves out to null infinity from the binary source, known as Cauchy-characteristic matching (CCM). This is important because it will remove ambiguities in the results of numerical relativity simulations that stem from various factors related to this extraction step. The method is free of approximations and can be applied to any physical system, and yields higher precision in waveforms and smaller violations of Bondi-gauge constraints.

Numerical-relativity surrogate models for both black-hole merger waveforms and remnants have emerged as important tools in gravitational-wave astronomy. While producing very accurate predictions, their applicability is limited to the region of the parameter space where numerical-relativity simulations are available and computationally feasible. Notably, this excludes extreme mass ratios. They developed a machine-learning approach to extend the validity of existing and future numerical-relativity surrogate models toward the test-particle limit, targeting in particular the mass and spin of post-merger black-hole remnants. Their model reaches an accuracy that is comparable to or higher than that of existing remnant models while providing robust predictions for arbitrary mass ratios.

In 3+1 numerical relativity, they typically do not have access to global concepts of horizons such as an event horizon. Instead one has to work with quasilocal notions of horizons such as apparent horizons, static horizons, and dynamical horizons. These are typically worldtube of outermost marginally trapped surfaces. Recent works, such as Prasad et al (2021), have shown that the dynamics of dynamical horizons can actually be correlated with the spacetime metric multipoles at null infinity. However, all such efforts work with completely gauge/coordinate dependent dynamical horizons, and therefore universality of these correlations can not be established. They took this a few steps further and used a covariant construction of dynamical horizon multipole moments to study the common horizon formed following the merger of two black holes. They choose an equal-mass, non spinning, quasicircular binary-black-hole system. They found a strong correlation between these multipole moments and the gravitational waveform. They also found that the multipole moments are well described by the fundamental quasinormal modes at sufficiently late times.

Modeling Compact Binary Merger Waveforms Beyond General Relativity
Massive black hole binaries, that form a majority of LIGO-Virgo black hole population, offer a unique opportunity to conduct tests of our theories of Gravity in their fully dynamical regime, which has never really been possible before. In order to maximize the science output of our tests of GR, one needs to validate recorded gravitational-wave (GW) data against both GR-based and beyond-GR signal models so as to uncover evidence of truly new Physics. Towards this end, Kumar and collaborators developed the following waveform model capable of capturing a range of beyond-GR effects within the parametrized post-Einsteinian (ppE) framework that modifies inspiral waveform models to incorporate effects beyond general relativity (GR). Kumar and collaborators extended the framework into the merger-ringdown regime. The additional modifications introduced add a single degree of freedom that corresponds to a change in the binary coalescence time. The ringdown spectrum is retained as predicted by GR. This is the first complete inspiral-merger-ringdown model capable of capturing beyond-GR effects in the gravitational-wave emission from compact-object binaries.



RESEARCH REPORT

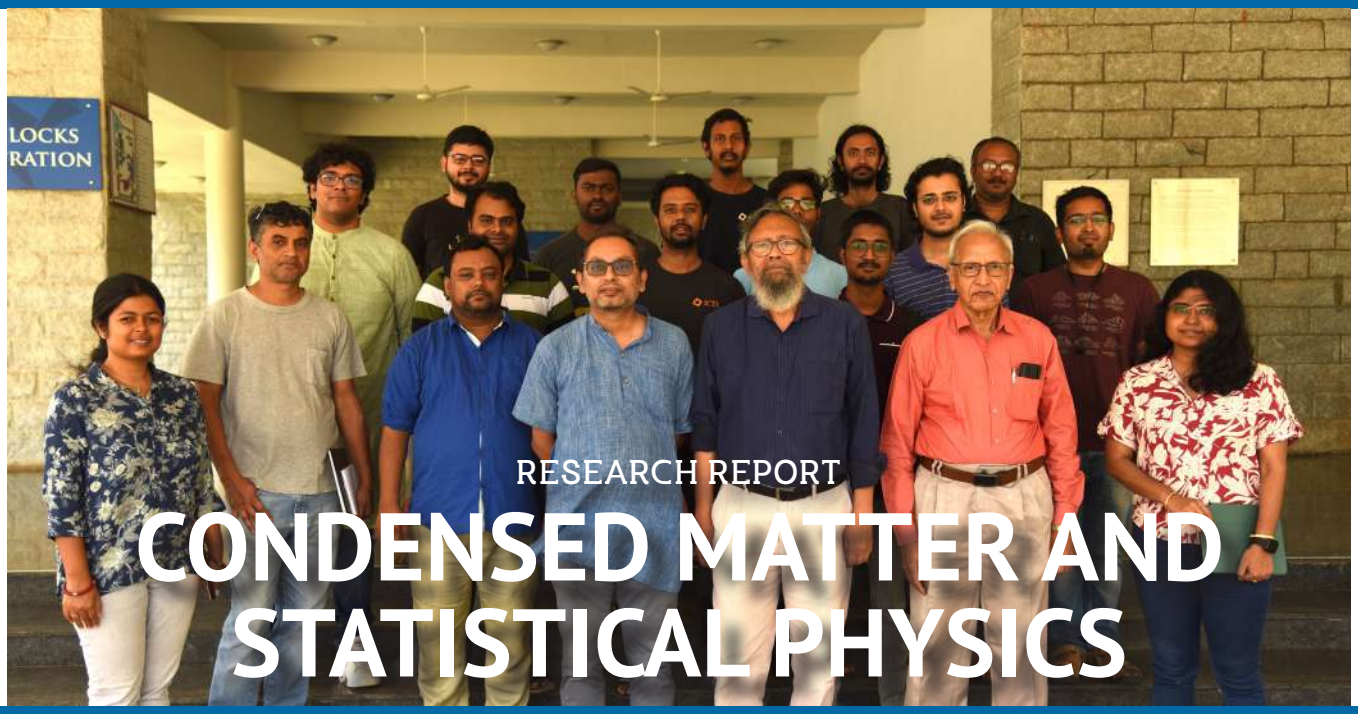
Rajaram **NITYANANDA**

Rajaram Nityananda has worked on the closure invariants in radio astronomy with Joseph Samuel. (Please see page 39). That collaboration led to subsequent research, the details of which are outlined below.

Practical Issues in Polarised Interferometric Radio Imaging with Closure Invariants

Earlier and ongoing work with Joseph Samuel and Nithyanandan Thyagarajan on polarised radio inteferometry brought out a complete set of functions made from products of correlation matrices around a closed loop, which are unaffected by changes in the complex, matrix valued 'gains' at each antenna. The problem of using these invariants (which are quite nonlinear in the Fourier transform of the polarised image) is being investigated. So far, their ability to distinguish a set of model parameters has been studied by simulation. The realistic problem with noisy data involves estimating a likelihood function in the image/parameter space - it was found to be non gaussian with long tails coming from situations where some of the matrices were close to singular, calling for a heavily computational approach. The collaborator was Vinay Kumar.

Photo Credit: Madhulika Singh



RESEARCH REPORT

CONDENSED MATTER AND STATISTICAL PHYSICS

FACULTY

Subhro Bhattacharjee ❖ Chandan Dasgupta *(Simons Visiting Professor)* ❖ Abhishek Dhar ❖ HR Krishnamurthy *(Simons Visiting Professor)* ❖ Manas Kulkarni ❖ Anupam Kundu ❖ Sthitadhi Roy ❖ Sumathi Rao *(ICTS Endowed Senior Professor)* ❖ Joseph Samuel *(Simons Visiting Professor)*

POSTDOCTORAL FELLOWS

Suman Dutta ❖ Soumi Ghosh ❖ Subhajit Paul ❖ Dipankar Roy ❖ Madhumita Saha

STUDENTS

Junaid Majeed Bhat ❖ Ankush Chaubey ❖ Varun Dubey ❖ Sparsh Gupta ❖ Jitendra Kethepalli ❖ Umesh Kumar ❖ Basudeb Mondal ❖ Saurav Pandey ❖ Mahaveer Prasad ❖ Tamoghna Ray ❖ Saikat Santra ❖ Sahil Kumar Singh

RESEARCH REPORT

Subhro BHATTACHARJEE

Subhro Bhattacharjee's research during the last two years is summarized below.

Quantum Spin Liquids

Bhattacharjee and collaborators explored the dynamical experimental signatures of the fractionalised excitations in Quantum Spin Liquids in context of concrete spin models (on honeycomb lattice) as well as candidate material (on pyrochlore lattice). In regard to the first issue, they studied [Phys. Rev. B 108, 035149 (2023)] the nature of anionic excitations in the QSL as realised in honeycomb Kitaev model as a function of [111] magnetic field and bond anisotropy. This built on their earlier work on studying the fate of the QSL as a function of anisotropy. In the above work, they showed that in different regimes of the magnetic field and bond anisotropy, the nature of the lowest energy anyonic excitation changes and eventually dictates the fate of the phase in the associated parameter regime. The nature of these anyons leave their characteristic signatures in the dynamic spin-spin correlations. Such experimental signatures are also present in other QSLs and in particular they probed the effect of the magnetic, electric charges and photons in the Raman scattering of phonons in a 3D U(1) QSL realised in pyrochlore magnets. Bhattacharjee and collaborators showed that such Raman signatures are sensitive to the symmetry fractionalisation (0-flux vs π-flux quantum spin ice) and are particularly strong in non-Kramers spin ice [Phys Rev B 106, 054507 (2022)]. In fact, they showed, in a separate work in collaboration with experimental results [Nature Physics 19, 92–98 (2023)] in the non-Kramers magnet $Pr_2Zr_2O_7$ where linear spin-phonon coupling can stabilise a correlated paramagnet at low temperature via dynamic magneto-elastic effects. Indeed, in other magnets such as bilayer kagome material $Ca_{10}Cr_7O_{28}$, they showed [Phys. Rev. B 108, L241103 (2023)] that Raman signatures can reveal important details about the nature of spin-lattice coupling that eventually seals the fate of the low temperature magnetic phase. Similarly such spin-lattice couplings can lead to experimental signatures for probing unconventional multipolar orders [npj quantum materials 8, 42 (2023)]. The collaborators were Shi Feng, Adhip Agarwala, Nandini Trivedi, Arnab Seth, Roderich Moessner, Nan Tang, Yulia Gritsenko, Kenta Kimura, Akito Sakai, Mingxuan Fu, Hikaru Takeda, Huiyuan Man, Kento Sugawara, Yosuke Matsumoto, Yasuyuki Shimura, Jiajia Wen, Collin Broholm, Hiroshi Sawa, Masashi Takigawa, Toshiro Sakakibara, Sergei Zherlitsyn, Joachim Wosnitza, Satoru Nakatsuji, Sreekar Voleti, Koushik Pradhan, Tanusri Saha-Dasgupta and Arun Paramekanti.

Spin-orbit Coupled (SOC) Semimetals

In regards to Spin-orbit coupled (SOC)systems, Bhattacharjee and collaborators investigated the non-trivial implementation of symmetries in J=3/2 SOC electrons on honeycomb lattice and showed that for d systems this can lead to SU(8) Dirac semimetal. The large emergent symmetry allows for systematic understanding of the phases proximate to the Dirac semimetal [Phys. Rev B 108, 245106 (2023)] which are dictated by the unconventional embedding of the UV symmetries on the IR theory. Following up on this work, they showed [Phys. Rev. Research 5, 043219 (2023)] that the SU(8) Dirac semimetal may provide a useful starting point for understanding associated materials. Associated issues were explored in other SOC materials to understand the interplay of symmetries and topology in $LaCuO_3$ / $SrIrO_3$ heterostructure [Appl. Phys. Lett. 122, 021602 (2023)]. The collaborators were Basudeb Mondal, Vijay B. Shenoy, Samir Rom, Santu Baidya, Tanusri Saha-Dasgupta.

Theories of Emergent Tensor Electromagnetism

Finally, in continuation of their work on applying theories of emergent tensor electromagnetism to understand the mechanical properties of granular assemblies, Bhattacharjee and collaborators extended their understanding to develop the theory of dynamics of these systems both in two and three dimensions (Phys. Rev. E 106, 065004 (2023)). The collaborators were Jishnu N. Nampoothiri, Michael D'Eon, Kabir Ramola and Bulbul Chakraborty.

RESEARCH REPORT

Chandan DASGUPTA

Chandan Dasgupta's research during the last two years focussed on the following:

Liquids Under Strong Confinement

Dasgupta's work on the conformational properties of a double-stranded DNA molecule confined in carbon nanotubes of different diameters showed a novel melting transition of the confined DNA in nanotubes with diameters below a critical value. Their study of water molecules flowing through a carbon nanotube under a pressure gradient showed that the flow induces an alignment of the dipole moments of the water molecules inside the nanotube.

Dense Active Matter

Dasgupta and collaborators' earlier study of the dynamics of dense active liquids, based on the random first-order transition theory, was extended to the high activity regime. This work improves the agreement between theoretical predictions and simulation results for large values of the active force and its persistence time.

Their work showed 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 threshold value. The jamming process exhibits intermittency and a strong dependence on the system size. Properties of the jammed state are found to depend strongly on the protocol used in its preparation.

Scalar Activity

In their study of the effects of scalar activity on the phase behavior of a system of soft spherocylinders, activity was modeled by placing half of the particles in contact with a heat bath with temperature higher than that of the heat bath in contact with the other half of the particles. The study showed that if the difference between the two temperatures is sufficiently large, then the system undergoes phase separation into hot and cold regions and the activity drives the cold particles through a phase transition to a more ordered state compared to the initial equilibrium state. Dasgupta and collaborators also found that scalar activity induces liquid-crystal phases that are not observed in equilibrium for certain values of the aspect ratio.

Two-dimensional Systems with Pinning Disorder

Their study of melting in a two-dimensional system of classical particles with Gaussian-core interactions and pinning disorder showed that a random distribution of pinning centres forces a hexatic-like low temperature phase that transits into a liquid at a single melting temperature. In contrast, 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. In a collaboration with experimentalists at TIFR, Mumbai, Dasgupta showed that in a thin-film superconductor, the interplay of pinning and intervortex interactions produces a very inhomogeneous vortex liquid state where some vortices remain static, whereas others move forming a percolating network. With increase in temperature or magnetic field, this network becomes denser, eventually encompassing all vortices.

RESEARCH REPORT

Abhishek DHAR

The main focus of Abhishek Dhar's research has been towards the application of the hydrodynamic approach to a broad class of physical systems with the view of understanding their macroscopic observed properties.

One class of systems are the so-called integrable Hamiltonian systems which refer to systems with a large number of conserved quantities. The specific examples of the hard rod gas and the Ishimori-Haldane chain were investigated and interesting features such as anomalous transport, thermalization (or its lack of) and ergodicity breaking were investigated. The case of quantum ideal gases in one dimension was studied as a simple example to illustrate how irreversibility arises in the evolution of a many-body isolated system. This was shown via construction of an appropriate Boltzmann entropy function whose time evolution during the process of free expansion was studied and shown to increase monotonically.

The second class of system studied was that of active matter which at the microscopic level consists of the motion of a collection of randomly moving self-driven objects, such as bacteria that interact with each other simply via exclusion. Several simple but nontrivial models of active matter have been studied and exact results on the form of hydrodynamic equations and steady state density profiles and correlation functions have been obtained. The main aim has been to obtain analytic results for the case with interactions and confinement.

Another study considered a model to describe light transmission across a one-dimensional channel of cavities which can be modelled as anharmonic oscillators. It was shown that the dynamics of this system admits two steady states, one of which is periodic and has high transmission while another is chaotic and has a low transmission. The stability of the steady states on addition of thermal noise was studied.

One of the simplest descriptions of an open quantum system is through the Lindblad equation which preserves complete positivity and trace, two basic physical requirements. In addition, it should preserve local conservation laws and show thermalization and these are typically difficult to implement in many-body systems. The ICTS group has established the necessary conditions on the Lindblad operators and shown that the problem of finding the appropriate Lindbladian can be cast into one of semidefinite programming. An algorithm to implement this for spin chains has been developed.

In a classic work related to understanding the physics of explosions, Taylor, von Neumann and Sedov (TvNS) showed that blasts are accurately described by self-similar solutions of the euler equations of fluid dynamics. The study at ICTS

examined the question of the effect of dissipation, namely the Navier-Stokes-Fourier corrections to the fluid dynamic equations. It was shown that the TvNS solution is accurate in the exterior region of the blast while there are significant corrections to the inner structure. A double-scaling structure which can be understood analytically has been shown to describe the blast.

As a simple model to understand the effect of continuous quantum measurements, a two-state system that is monitored continuously by a two-state detector was studied. The detector periodically gets entangled with the system and measurements on it then lead to a stochastic evolution of the system's state vector. It was shown that the system's effective evolution on the Bloch sphere consists of a deterministic drift and a stochastic resetting to a fixed state. Analytic results were obtained for the distribution of the number of detector events and the time-evolution of the probability distribution of the state vector.

RESEARCH REPORT

Manas KULKARNI

Here is a brief summary of Manas Kulkarni's research during the years 2022-2023.

Kulkarni worked extensively on theoretical methods in open quantum systems. He investigated fundamental limitations in Lindblad descriptions of systems weakly coupled to baths. He studied methods involving searching for Lindbladians that obey local conservation laws and show thermalization. Kulkarni worked on casting the problem of finding local Lindblad equations which can show thermalization into a semidefinite program. Kulkarni worked on transport in open systems. He studied universal subdiffusive behavior at band edges from transfer matrix exceptional points. This work unravelled a deep connection between parity-time symmetric optical systems and quantum transport in one-dimensional fermionic chains in a two-terminal open system setting. He also explored the highly non-trivial phenomena of superballistic scaling of conductance which was environment assisted. Kulkarni studied exceptional hypersurfaces of transfer matrices of finite-range lattice models and their consequences on quantum transport properties.Kulkarni worked on a family of classical confined power-law models and their various special cases. He studied gap statistics, edge fluctuations and third-order phase transition in such systems.He explored finite temperature equilibrium density profiles of integrable systems in confining potentials. Kulkarni investigated aspects of ergodicity, chaos, and thermalization for a one-dimensional classical gas of hard rods confined to an external quadratic or quartic trap, which breaks

microscopic integrability. The work shows that quadratically trapped hard rods are highly nonergodic and do not resemble a Gibbs state even at extremely long times, despite compelling evidence of chaos for four or more rods. In addition to powerlaw classical models and their various special limits, Kulkarni also considered several other classical systems. He studied aspects out-of-time-ordered correlator in the one-dimensional Kuramoto-Sivashinsky and discrete Kardar-Parisi-Zhang equations. He studied robustness of Kardar-Parisi-Zhang (KPZ) scaling in a classical integrable spin chain with broken integrability. His work showed that KPZ behavior prevails even when one considers integrability-breaking but spin-symmetry preserving terms, strongly indicating that spin symmetry plays a central role even in the nonperturbative regime.

Kulkarni worked on non-Hermitian systems and non-Hermitian random matrices. In particular, he explored spectral properties of disordered interacting non-Hermitian systems. His work attempts to analyze their chaotic behavior or lack of it through the lens of the recently introduced non-Hermitian analog of the spectral form factor and the complex spacing ratio. Kulkarni studied eigenvector correlations across the localisation transition in non-Hermitian power-law banded random matrices. Kulkarni explored the connections between dissipative quantum phase transitions and non-Hermitian random matrix theory. For this, he considered the framework of the dissipative Dicke model which is archetypal of symmetry-breaking phase transitions in open quantum systems. Kulkarni thoroughly investigated quantum dynamics when an empty lattice is locally injected with quantum particles.

Kulkarni worked on entanglement generation by quantum resetting. The work demonstrates that quantum resetting provides a simple and effective mechanism to enhance entanglement between two parts of an interacting quantum system. Kulkarni also investigated first detection probability in quantum resetting via random projective measurements. The work provides a general framework to compute the probability distribution of the first detection time of a state of interest in a closed quantum system subjected to random projective measurements.

RESEARCH REPORT

Anupam **KUNDU**

During the years 2022 and 2023, Anupam Kundu's research has mainly involved: non-local description of anomalous transport, hydrodynamic evolution of many particle integrable (or nearly integrable) systems, thermalisation, growth of Boltzmann entropy, equilibrium properties of long-range interacting systems, tracer dynamics in active medium and non-instantaneous stochastic resetting.

Non-local Description of Anomalous Transport

In low dimensional systems, the transport of energy on macroscopic scale does not obey Fourier's law and is often anomalous as manifested by emergence of superdiffusion. So far, anomalous transport has been observed in simulations of model systems and understood within the framework of nonlinear fluctuating hydrodynamics. Some of the important outstanding questions are (i) what equations replace Fourier's Law of heat conduction, (ii) how does one understand the crossover from diffusive to anomalous transport? In a recent study of transport in a one-dimensional lattice system with two conserved quantities ('volume' and energy), Kundu's research has demonstrated how the Fourier's law gets replaced by a non-local equation characterised by a kernel operator [SciPost Phys. 15, 038 (2023)]. This kernel operator was shown to be related to the space-time correlations of local hydrodynamic currents. In a sequel of this paper, Kundu has shown how one can compute the kernel operator from the correlation of the microscopic currents [arXiv:2212.06408].

Hydrodynamics in Low-dimensional Systems

In the last ten years, there has been a lot of interest and activity in the fields of hydrodynamics and generalized hydrodynamics (GHD) in low-dimensional systems because of some cutting-edge experiments done on systems of cold trapped atoms along with significant theoretical developments. Some of the important questions in these areas are - establishing the correct hydrodynamic equations for a given microscopic model, understanding the process of thermalisation and a characterisation of the stationary state from the form of static and dynamic space-time correlations. Kundu's recent research addressed: equilibrium properties of equilibrated integrable systems [Physical Review E 107 (4), 044101, (2023)], evolution of Boltzmann's entropy and thermalisation in classical and quantum (noninteracting) integrable systems [J. Phys. A: Math. Theor. 55 394002, (2022), arXiv:2303.12330], in non-integrable system [Journal of Statistical Physics 190 (4), 74 (2023)], thermalisation in an interacting integrable system (hard rods) [arXiv:2310.18684] and also role of chaos when these rods are trapped in a confining potential [arXiv:2306.11713]. The collaborators were Jitendra Kethepalli, Debarshee Bagchi, Abhishek Dhar, Manas Kulkarni, Subhadip Chakraborti, Sheldon Goldstein, Joel L. Lebowitz, Saurav Pandey, Junaid Majeed Bhat, David A. Huse, Sahil K. Singh, Herbert Spohn, and Vir B. Bulchandani.

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 studied the fluctuations of the particles at the edge of the density profile [Journal of Statistical Mechanics: Theory and Experiment 2022 (3), 033203], the fluctuations of the gaps in the bulk [Physical Review Letters 128 (17), 170603 (2022)] as well as the modification if the interaction range is made finite [arXiv:2308.12124].

Tracer Particle Diffusion in Active Systems

The motion of a tagged particle in one dimension gets hemmed 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 [arXiv:2307.09908], 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 can not be captured by an effective hydrodynamic description. The collaborators were Jitendra Kethepalli, Manas Kulkarni, Satya Majumdar, David Mukamel, Gregory Schehr, Saikat Santra, Sanaa Agarwal, Abhishek Dhar, Prashant Singh.

Non-instantaneous Stochastic Resetting

Most of the theoretical studies of stochastic resetting so far have focused on instantaneous resetting which is, however, a major impediment to practical realisation or experimental verification in the field. In recent work, Kundu has shown that Stochasticity in returns can expedite classical first passage under resetting [arXiv:2307.16294]. The collaborators were Arup Biswas, and Arnab Pal.

RESEARCH REPORT

Sthitadhi ROY

During the last two years, Sthitadhi Roy's research has focussed on understanding theoretically different aspects of certain novel dynamical phases of matter in many body systems.

Dynamics of Disordered Quantum Many-body Systems

The dynamical phase diagram of disordered quantum many-body systems has been a topic of enduring interest. A formulation of this problem is based on an exact mapping to a fictitious single particle hopping on the disordered, complex and correlated Fock/Hilbert-space graph. This formulation is particularly promising for analytical progress by harnessing the wealth of knowledge on Anderson localisation on high-dimensional graphs. However, explicit connections between real-space local observables which are of natural interest and might be accessible experimentally, and correlation functions on the Fock/Hilbert space are missing. This is the precise gap that Roy's research in this direction aims to fill. Some of the specific results in this direction were: Roy and collaborators derived an analytic relation between local spin autocorrelations and the return probability on the Hilbert space, the two simplest correlation functions in either space. They showed that the latter unambiguously encodes the dynamical structure of real-space autocorrelations and hence can detect the regime of the dynamical phase diagram that the system is in [Phys. Rev. B 108, L140201 (2023)]. Roy also showed that the specific four-point

correlations between eigenstate amplitudes on the Hilbert space encode their entanglement structure. As such these correlations can be used to characterise the many-body localisation transition as it is also an entanglement transition wherein eigenstates go from being volume-law entangled to area-law entangled [Phys. Rev. B 106, L140204 (2022)]. In a related work, it was shown how the dynamical version of these correlations can be used to understand the anomalous entanglement growth in the many-body localised phase. The collaborators were Bikram Pain and Kritika Khanwal.

Constrained Dynamics

Constrained dynamics were historically proposed as a model for glass forming systems at low temperatures. Roy and collaborators, however, asked the question: what is the effect of such constraints on the infinite temperature dynamics of classical many-body systems, in particular on many-body chaos? They found that such systems where the strength of the constraints can be tuned, host a novel dynamical phase transition where in the system transitions from a chaotic phase at weak constraints to one where the chaos is fully arrested at strong constraints [Phys. Rev. Lett. 129, 160601 (2022)]. In a follow up work, they showed that this dynamical phase transition is similar to an absorbing phase transition. Via a detailed scaling analysis, they showed that the transition is in fact in the directed percolation universality class [Phys. Rev. Lett. 129, 190601 (2022) (Editors' Suggestion)]. The collaborators were Aydin Deger, Achilleas Lazarides.

Eigenvector Correlations in Non-hermitian Random Matrices

This direction of research focussed on understanding localisation transitions in non-hermitian random matrices through the lens of eigenvector correlations. The motivation was that they stand as useful models in certain limits of open quantum systems. Using non-hermitian power law banded random matrices Roy and collaborators showed that the eigenvector correlations in the delocalised

RESEARCH REPORT

Sumathi Rao

Sumathi Rao's work focussed on quantum Hall effect in graphene, and on anyonic quasiparticles that occur in these materials as excitations, i.e., Majorana modes and their even more exotic cousins, parafermions.

Rao and collaborators considered a Josephson junction made of counter-propagating edge modes of two quantum Hall (QH) systems, proximitized by an s-wave superconductor. They showed that the difference between the lengths (which can be controlled by external gates) of the two counter-propagating

chiral edges at the Josephson junction, can act as a source of spontaneous phase bias. This allows for electrical control of the Majorana/parafermion zero modes in integer/fractional QH systems. They also studied the effect of edge reconstruction in QH systems on potential Majorana/parafermion zero modes. A smooth edge potential on a $\nu = 1$ QH system leads to a $\nu = 1/3$ side strip, which could yield both Majorana and parafermion zero modes at the domain wall of the superconductor and ferromagnet on the edge. However, constraints imposed by the $\nu = 1$ bulk allow only for a pair of Majoranas, leading to a Z2 × Z2 symmetric ground state. Signatures of both Majoranas appear in the 4π fractional Josephson current when the edge velocities are taken to be different.

Rao and collaborators also studied monolayer graphene at charge neutrality in a quantizing magnetic field. Due to the spin and valley (near) degeneracies, there are several possible ground states. Previous work, based on an ultra short-range assumption on the symmetry-allowed interactions, predicted a phase diagram with distinct regions of spin-polarized, canted antiferromagnetic, inter-valley coherent, and charge density wave order. While early experiments suggested that the system was in the canted antiferromagnetic phase at a perpendicular field, recent scanning tunneling studies found Kekulé bond order, and sometimes charge density wave order. Recently, it was found that relaxing the stringent assumption mentioned above, one could have co-existing phases. In their work, starting from the continuum limit appropriate for experiments, we presented the complete phase diagram of $\nu = 0$ graphene in the Hartree-Fock approximation, using generic symmetry-allowed interactions. Allowing for a sublattice potential (valley Zeeman coupling), they found numerous phases with different types of coexisting order. They concluded with a discussion of the physical signatures of the various states.

Rao also studied the two-channel Kondo problem in the context of two interacting helical liquids coupled to a spin-1/2 magnetic impurity. Using a multichannel Luttinger liquid formalism, she and her collaborators analyzed both the Toulouse limit, where an exact solution is available, and the weak coupling limit, which can be studied via a perturbative renormalization group approach. The observable consequences were then captured using linear response theory.

Finally, they investigated the effects of introducing a boost (a Zeeman field parallel to the spin quantization axis) at the proximitized helical edge of a two-dimensional quantum spin Hall insulator. Their self-consistent analysis found that a Fulde-Ferrell-Larkin-Ovchinnikov (FFLO) superconducting phase could emerge at the edge when the boost is larger than a critical value tied to the induced pairing gap. They contrasted their results with previous studies of such 1D models, which found that the FFLO phase either does not appear for any value of the boost (in non-self-consistent calculations), or that it self-consistently appears even for infinitesimal boost, but carries no current and magnetization.

RESEARCH REPORT

Joseph SAMUEL

During the last two years Joseph Samuel has worked on the following:

Closure Invariants in Radio Astronomy

The use of Wilson loops in astronomical imaging was explored in two papers published in PRL and PRD. This uses ideas from gauge theory and graph theory to extract the maximum uncorrupted information from noisy VLBI (Very Long Baseline Interferometry) measurements of astronomical images. One very relevant application is the imaging of the black hole in M87. One of the main new advances in this work was the use of advariants, which are the square roots of holonomies. This tool permits a complete solution of the problem and produces a complete and independent set of closure invariants. After these papers were published, the work was extended to the problem of incomplete graphs . This work further reveals that without the use of advariants, it is impossible to extract all of the uncorrupted information except in some very special cases. The collaborators were Nithyanandan Thyagarajan and Rajaram Nityananda.

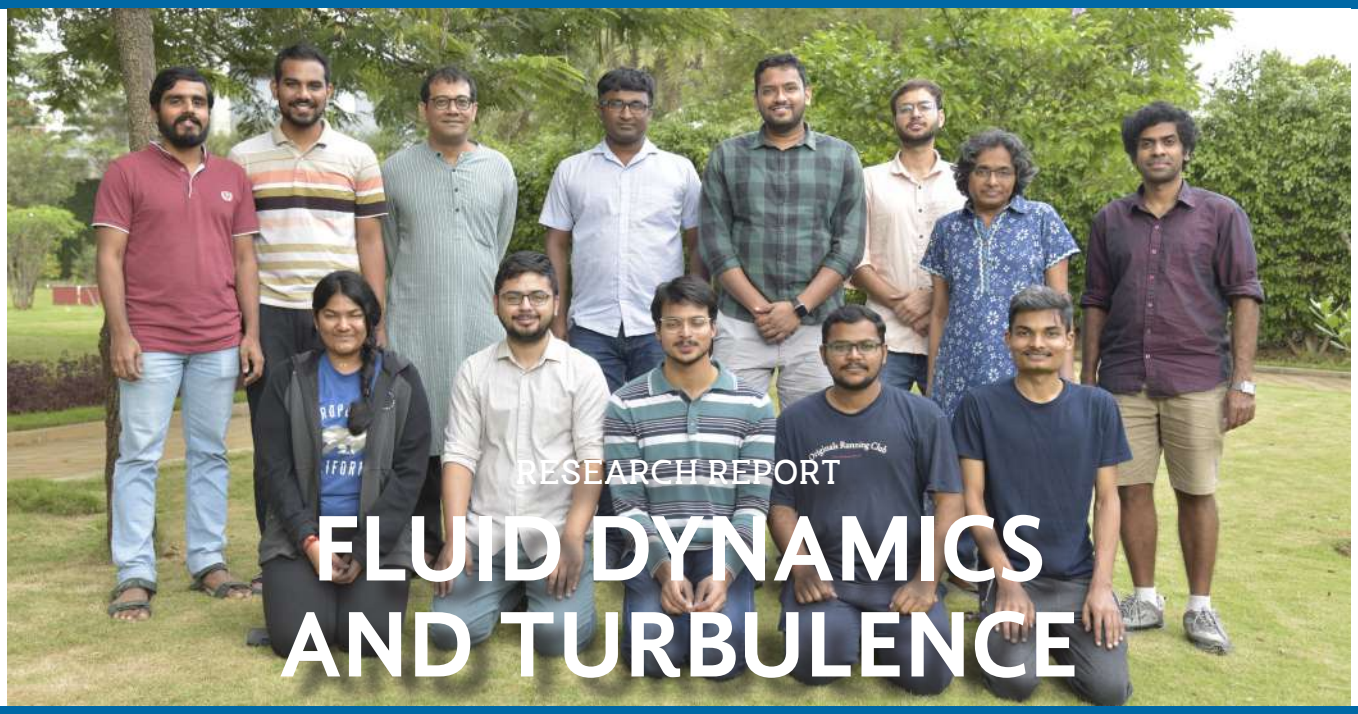
Space, Time and Heat

The problem of local conservation of energy in general relativity was addressed in a paper published in the International Journal of Modern Physics D. It was shown that a split of spacetime into time and space (somewhat different from the usual canonical approach) reveals thermodynamic aspects of general relativity in a regime far removed from black holes. This study also suggested that entropy in general relativity is at least as subtle a concept as energy.

Born-Oppenheimer and the Geometry of Ray Space: Application to Cold Atoms

Within the Born-Oppenheimer approximation of quantum theory, the back-reaction of the fast modes on the slow modes was explored. This results in synthetic electric and magnetic fields which affect the slow motion. These synthetic fields do not have to satisfy all the inhomogeneous Maxwell equations. As a result they evade the conditions of Earnshaw's theorem, which forbids stable electromagnetic trapping by very general arguments. These ideas were used to suggest methods for confining spinning neutral atoms, with a view to making smaller and better clocks. The synthetic fields can be used to construct wave guides and traps for manipulating cold atoms.


Photo credit: Roshni Samuel



RESEARCH REPORT

FLUID DYNAMICS AND TURBULENCE

FACULTY

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

POSTDOCTORAL FELLOWS

Prateek Anand ❖ Subham Ghosh ❖ Siddhartha Mukherjee ❖ Sibaram Ruidas ❖ Arun Kumar Varanasi

STUDENTS

Rajarshi Chattopadhyay ❖ Divya Jaganathan ❖ Harshit Joshi ❖ Saumav Kapoor ❖ Anup Kumar ❖ Sugan Durai Murugan ❖ Ritwik Mukherjee ❖ Mukesh Singh Raghav

RESEARCH REPORT

Rama GOVINDARAJAN

The past two years have seen Rama Govindarajan's group becoming stronger in terms of the numerical solvers now available to solve a variety of problems in particulate flows.

Small Drops and Particles in Flow

Particles and droplets in flow display clustering, which can be important in a variety of situations. Students Divya Jaganathan, Saumav Kapoor, Rajarshi Chattopadhyay, Anup Gupta and Harshit Joshi have been working on different aspects of this problem.

The dynamics of a small particle in unsteady Stokes flow is described by the Maxey-Riley-Gatignol equation, which contains a force called the Basset-Boussinesq history (BBH) force. Divya has made immense progress on particle simulations including the BBH force, in collaboration with Vishal Vasan. Numerical solutions of this problem are not easy since the expression contains a singularity at zero time, which means that one cannot write expansions in powers of the time-step. Second, the history term means that a particle does not obey a dynamical system. The group now has a powerful and new numerical solver for this hard problem correct to second-order in time.

Particles that are heavier than the fluid in which they are embedded are thought to always centrifuge out of vortical regions in the flow. Saumav and Divya have shown that this is not true in a simple system of a pair of co-rotating vortices. Particles can stay near the vortices for eternity, collecting in fixed points, limit cycles or chaotic attractors. Moreover, the neglect of BBH (this force is normally neglected) was shown to lead to serious underestimation of the regimes of attraction.

Anup showed how dusty channel flow can be very different from channel flow of clean fluid in its stability behaviour, and pinned it down by asymptotic analysis to the overlap of the particle-dense layer to the critical layer of the dominant perturbation.

Former student Rahul Chajwa, with help from Rajarshi and input from Sriram Ramaswamy, showed how active particles with no inertia can mimic inertial particles in a limited analogy, especially that they can form caustics.

Harshit wrote a boundary integral method code for the exact solution of Stokes flow for collections of arbitrary-shaped solids. He is also working with Samriddhi Sankar Ray and Govindarajan on the clustering of non-spherical particles in turbulence.

The collaboration with Anu Nath and Anubhab Roy of IIT Madras and

S Ravichandran of IIT Bombay continues.

Dynamics of Larger Ellipsoids in Fluid
Andrew Boyd (PhD student working with Prashant Valluri and others of the University of Edinburgh and Govindarajan) has developed a solver for potential flow around collections of ellipsoids moving in flow.

Atmospheric Waves

PhD student Mukesh Singh Raghav and postdoctoral fellow Sharath Jose, in collaboration with Amit Apte and Govindarajan, have shown that the system if equations describing atmospheric waves becomes nonnormal when Earth's curvature in taken into account, and find algebraic growth in atmospheric waves.

RESEARCH REPORT

Samriddhi Sankar RAY

Samriddhi Sankar Ray's research during the last two years has focussed on the following areas.

Active turbulence - seen most prominently in dense, bacterial suspensions - has gathered great traction recently as an intriguing class of emergent, complex flows, occurring in several living systems at the mesoscale, whose understanding lies at the interface of non-equilibrium physics and biology. However, are these low Reynolds number living flows really turbulent or just chaotic with structural similarities with high Reynolds number (classical) inanimate turbulence? Ray and his group have been looking at this question through the prism of classical turbulence and in particular looking for fingerprints - universality, chaos and intermittency - which distinguishes high Reynolds number flows in such living fluids.

The question of universality (and scale invariance) in active flows was raised recently by Bratanov, Jenko and Frey [PNAS (2015)], who showed that such systems are characterised by activity-dependent scaling exponents and hence lack the universality - the celebrated 5/3 law of Kolmogorov - associated with classical turbulence. Ray and collaborators showed [Nature Physics 19, 891 (2023)] that while this is true for mild activity, beyond a critical (experimentally realisable) activity, such suspensions reach an asymptotic state with a unique scaling exponent. Hence universality a la Kolmogorov emerges in bacterial flows beyond a critical activity. More strikingly, these living fluids show an emergent intermittency when pushed beyond this critical activity which also marks maximally chaotic states unlike the

case of inertial turbulence where measures of chaos - the Lyapunov exponent - grows with the Reynolds number and does not saturate. The collaborators were S. Mukherjee, R. K. Singh and M. James.

Ray also carried out extensive Lagrangian studies [Physical Review Fluids 7, 033101 (2022)] of such suspensions to establish how emergent, anomalous structures in the flow - streaks - aid in persistent motion of tracer trajectories. These show up in a variety of measurements: An ensemble of tracer trajectories show significant variation, from adopting highly persistent, directed motion to very knotted, diffusive paths and its obvious consequences for the first passage problem. Interestingly, this also leads to a true dynamical heterogeneity in highly active suspensions: the flow contains a few lucky regions that lead to trajectory bundles translating persistently to cover large distances, while other flow regions result in diffusive meandering. The collaborators were R. K. Singh, S. Mukherjee.

In the area of high Reynolds number turbulent transport, Ray and collaborators have studied the role of interactions - soft spheres - and anisotropy - filaments in the last two years. This led to the first theoretical observation of crystalline aggregates in turbulence [Physical Review E (Letters) 106, L062601 (2022)], for the former, and the nature of gravitational settling [Physical Review Fluids 7, 084502 (2022)], for the latter. The collaborators were M. Gupta, P. Chaudhuri, J. Bec,R. K. Singh, J. R. Picardo.

On more fundamental questions of turbulence, Ray showed just how spatially heterogeneous the multifractal nature of fully developed turbulence really is in a recent study [ArXiv: 2307.06074]. They believe that the ideas developed in this paper may have interesting connections to fundamental questions of anomalous dissipation and singularities. The collaborators were S. Mukherjee, S. D. Murugan, R. Mukherjee. This work adds to the corpus of work on multiscaling and multifractality that has been a central theme of their research, including, most recently, the nature of dynamic (multi)scaling in strongly rotating flows [Physical Review E (Letters) 105, L063102 (2022)]. The collaborators were S. K. Rathor, S. Chakraborty.

Finally, this period also led to the first real study of the onset of thermalisation in the three-dimensional, incompressible Euler equation [Physical Review Fluids 8, 084605 (2023)]. The relevance of this work lies in the fact that a numerical approach to predict finite-time blow-up through the analyticity strip width fails as small-scales thermalise. Moreover, dissipative solutions (Onsager's conjecture) are impossible to realise numerically. Thus, uncovering the mechanisms by which such the Euler equation thermalises would, one hopes, lead to strategies which prevents equipartition and hence allow a resolution of these outstanding questions. The collaborator was S. D. Murugan.

RESEARCH REPORT

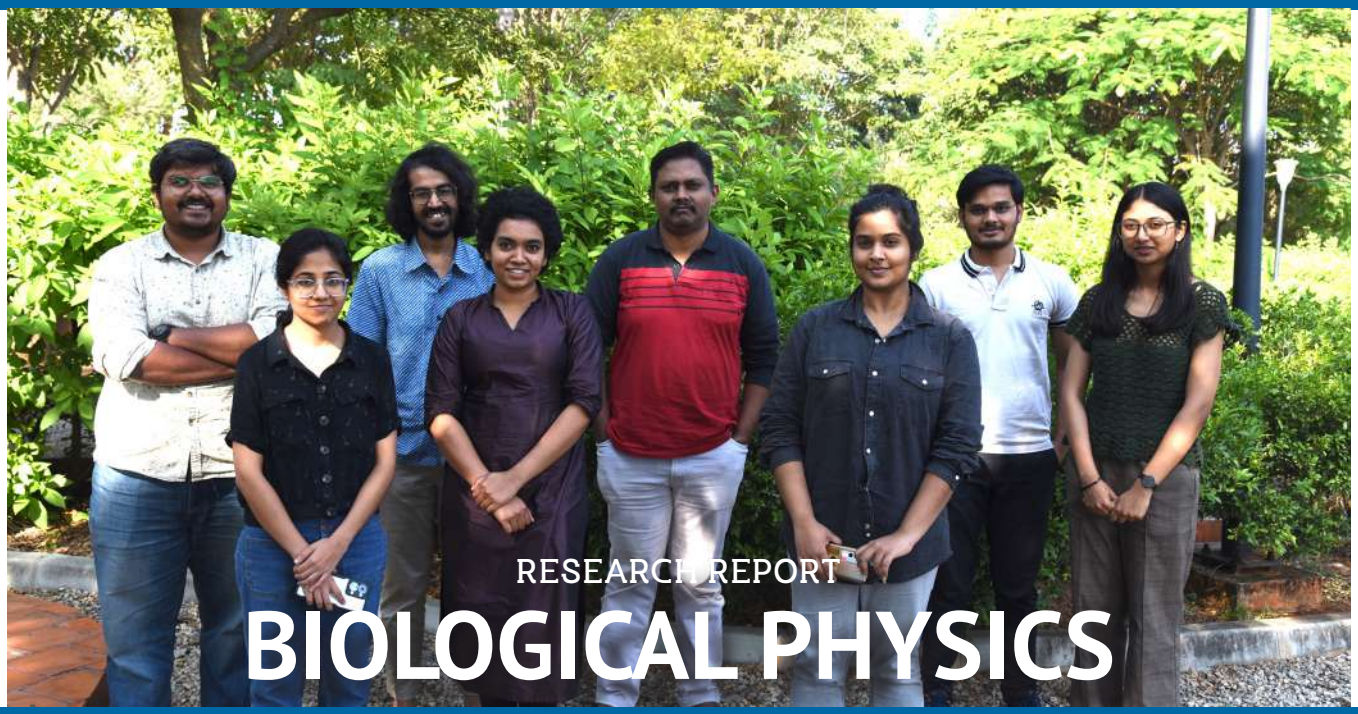
Jim THOMAS

Over the past two years, Jim Thomas has focused on three different areas in physical oceanography: submesoscale turbulence, tracer dispersion, and wave turbulence. The work in these three directions are explained below.

Submesoscales in the ocean refer to spatial scales below 10 kms and time scales of the order of a day or less. Submesoscale flows are generically seen to be dominant in oceanic observations and high resolution ocean models, and the oceanographic community is keen on understanding how submesoscale flows transfer energy across scales. Thomas' research in this direction is funded by the earth science division of SERB and he has been looking at features of submesoscale turbulence in the ocean with two-dimensional and three-dimensional models [Journal of Physical Oceanography 52 (11), 2609-2625]. This work is expected to continue for another three years. The collaborator is R. Vishnu.

Oceanic flows move around different kinds of tracers, such as oxygen and planktons for example, and understanding the details of these tracers' transport is crucial for predicting ocean states. Through several decades of dedicated efforts, the oceanographic community has acquired a detailed understanding of how large scale eddies in the ocean disperses tracers. However, it is still unclear how non-eddy fields, such as internal gravity waves in the ocean, affect tracer dispersion. Thomas' research in this direction has been to uncover how non-eddy fields affect tracer dispersion and so far their findings point out that the non-eddy components enhance tracer dispersion by an order of magnitude relative to eddy induced tracer dispersion. The results from these studies are being disseminated in two publications. The collaborators are Madhav Sirohi and C.P. Sanjay.

Oceanic flows are composed of different kinds of dispersive waves that transport energy from large scales, where the flow is forced by atmospheric winds and solar and lunar tides, to small viscous scales where the flow energy is dissipated. Due to the complexity of the system and the high dimensionality of the variables involved, the detailed mechanisms by which waves cascade their energy downscale remains an unresolved puzzle. Thomas has been working with multiple reduced mathematical models to understand the energy transfers between turbulent dispersive waves that helps them transfer energy downscale and thereby dissipate at small scales. Different kinds of physically motivated nonlinear partial differential equations that are hyperbolic and dispersive in nature are used for this study [J. Fluid Mech. 961, A2 (2023)] The collaborators were L.Ding, Aman Gupta and R. Rajpoot.



RESEARCH REPORT

BIOLOGICAL PHYSICS

FACULTY

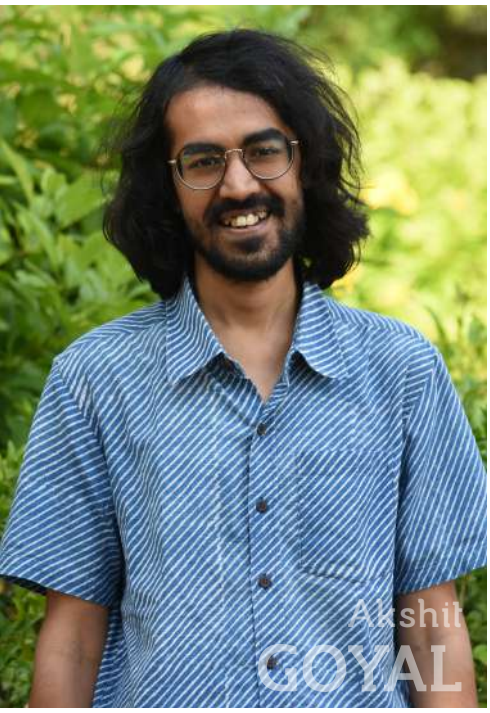
Akshit Goyal *(Simons Young Researcher & DBT-Ramalingaswami Re-entry Fellow)* ❖ Vijay Kumar Krishnamurthy ❖ Shashi Thutupalli *(Joint Faculty with NCBS-TIFR, Bengaluru)*

POSTDOCTORAL FELLOWS

Tuhin Chakrabortty

STUDENTS

Aditya Singh Rajput ❖ Jigyasa Watwani



RESEARCH REPORT

Akshit GOYAL

During the last two years, Akshit Goyal has been primarily studying evolution in complex ecosystems, as well as the stability of self-sustaining ecosystems.

Evolutionary Dynamics in Complex Communities

Using statistical analyses and modelling, Goyal and collaborators have disentangled the eco-evolutionary dynamics of a natural microbial community derived from pitcher plants [eLife (2022)]. This work demonstrated that several fine-scale strains of the same species could coexist with each other over long evolutionary timescales. Moreover, analysing their dynamics revealed that strains evolved to behave differently from each other, and that this difference arose due to them having evolved different ecological interactions with the rest of the community. The collaborators were Leonora S. Bittleston, Gabriel E. Leventhal, Lu Lu, Otto X. Cordero. Follow-up work showed that differences in metabolic strategies can quantitatively explain the observed strain diversity [PLoS Comp Biol (2023)]. This work has shown that strains can rapidly diversify in their ecological interactions and explain why fine-scale diversity is commonly observed in natural microbial communities. The collaborators were Yulia Fridman, Zihan Wang, Sergei Maslov.

Goyal and collaborators have also shown that community evolution can be controlled in the context of response to antibiotics [PNAS (2023)]. Current research on evolution in response to antibiotics has focused primarily on single-strain bacterial populations, with little attention given to diverse communities common in nature. In their work, Goyal's experimental collaborators evolved a simple two-strain community consisting of an antibiotic-resistant strain protecting a susceptible one. Surprisingly, susceptible populations evolved tolerance (lower death rates), not resistance (better growth rates at increased antibiotic concentrations). By developing a mathematical model of the interactions in the community, the dynamics of the antibiotics, and consumption of resources, they explained that tolerance was fitter than resistance in this community context. Further, their model predicted how to control when tolerance would evolve, which they experimentally confirmed. Goyal and collaborators showed that ecological interactions can significantly influence evolution in antibiotic contexts, urging the field to study them in greater depth. The collaborators were Sivan Pearl Mizrahi and Jeff Gore.

Self-organization in Closed Ecosystems

Life on earth relies on sunlight for energy, but this energy can only be exploited through the collective recycling of matter by communities of microbes, plants and animals. Yet we lack a framework for understanding how ecosystems can organize themselves to collectively capture the sun's energy by running cycles

of matter subject to thermodynamic constraints. In recent work, Goyal and collaborators have advanced a new theoretical framework to study the collective properties of nutrient-cycling ecosystems (Goyal et al, PNAS (2023)). Surprisingly, they found that even though biological species "greedily" extract energy from the environment, sufficiently diverse communities of species almost always manage to sustain themselves by extracting enough energy. Further, the amount of energy extracted by these communities is close to the maximum possible, and much greater (100x) than extracted by random collections of species. The collaborators were Avi I. Flamholz, Alexander P. Petroff, and Arvind Murugan.

RESEARCH REPORT

Vijay Kumar KRISHNAMURTHY

Vijay Kumar Krishnamurthy's research in the last two years has focussed on the following areas.

Collections of persistently moving active particles are an example of a nonequilibrium heat bath. One way to study the nature of nonequilibrium fluctuations in such systems is to follow the dynamics of an embedded probe particle. With this aim, Krishnamurthy and his collaborators studied the dynamics of an anisotropic inclusion embedded in a bath of active particles. By studying various statistical correlation functions of the dynamics, they showed that the emergent motility of this inclusion depends on its shape as well as the properties of the active bath. They demonstrated that both the decorrelation time of the net force on the inclusion and the dwell time of bath particles in a geometrical trap on the inclusion have a non-monotonic dependence on its shape. They also found that the motility of the inclusion is optimal when the volume fraction of the active bath is close to the value for the onset of motility induced phase separation. The collaborators were Pritha Dolai and Aditya Singh Rajput. [arXiv:2312.06997]

The unfolding and displacement of the germband during Drosophila germband retraction (GBR) accomplish the straightening of the embryonic anterior-posterior axis. The failure of GBR reduces embryonic viability and results in the mispositioning of the embryonic segments and the gastrointestinal tract. Despite its importance, the cellular, molecular and physical mechanisms that govern the unfolding of the germband and ensure the accurate positioning of cell fields within it remain poorly understood. Here, Krishnamurthy and collaborators uncovered the requirement of planar polarized, supracellular, tensile actomyosin cables for entraining cellular morphodynamics, cell field positioning and

retraction kinematics. Circumferential, non-constricting cables that form during early retraction ensure the coherence of 'placode-like' cell cohorts, pattern medio-lateral gradients in cell shape and sidedness within it, and dampen retraction speed. Linear, constricting cables that power displacement at the end of retraction enable sequential, multi-tissue, collective T1 transitions to reposition medial cell fields to more posterior locations. Together, their results revealed how the spatiotemporally regulated deployment of actomyosin structures, functioning either as barricades or as purse strings, modulate the speed of tissue unfolding and enable cell field positioning by influencing the morphodynamic and mechanical properties of cell cohorts during morphogenesis. The collaborators were Sudeepa Nandi, Aanchal Balse, Mandar M. Inamdar and Maithreyi Narasimha. [bioRxiv: 10.1101/2022.09.23.509113v1, under review in eLife]

A self-propelled particle is a basic ingredient of active matter. Any handle on its noise characteristics is thus of both fundamental and applied interest. In this paper, Krishnamurthy and collaborators showed that geometric constraints are a route to affect the emergent noise properties of a single active particle, thus demonstrating that seemingly different active particle classes are equivalent to each other. Specifically, they found that the chiral active Brownian motion of a self-propelled particle seen in two-dimensions switches to a run-and-tumble like motion when confined to a quasi-one-dimensional channel. Their analysis of this switching behavior connects the resulting active stochastic dynamics to that of a two-state molecular motor. The emergent tuning of active noise characteristics by unbiased external driving, as we demonstrate here, is illustrative of generic mechanisms of active noise control in other systems. The collaborators were Aniruddh Murali, Pritha Dolai, Ashwini Krishna and Shashi Thutupalli. [Phys Rev Res, 4, 013136 (2022)]

RESEARCH REPORT

Shashi THUTUPALLI

A recent highlight from Shashi Thutupalli's research activities was the identification of a new class of entropically driven molecular motors that play a key role in vesicle trafficking inside cells [Nature Physics, 1-8 (2023)] – this was the work of Thutupalli's first PhD student Anupam Singh in collaboration with the groups of Marino Zerial and Stephan Grill at the MPI in Dresden.

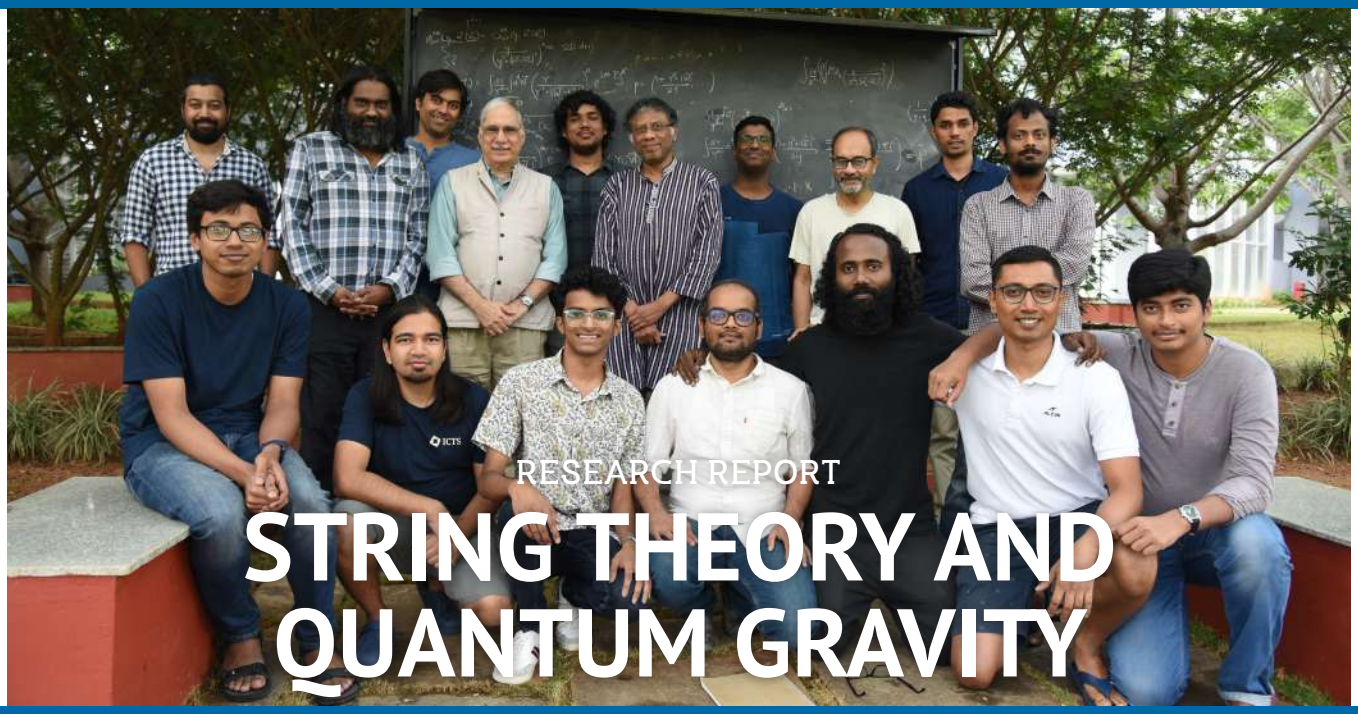
Thutupalli had an HFSP grant - together with Geert van den Bogaart (Netherlands) and Stefano Sacanna (USA) - to investigate the role of particle shape in the process of cellular phagocytocis. This grant drew to a close in 2023, resulting in three publications [Biophysical Reports, 2 (3), 100069 (2022), Frontiers in immunology 11, 607945 (2021), Soft Matter 18 (9), 1757-1766 (2022)] overall, in addition to exchange research visits for the postdocs working on this

project.

Thutupalli's work reporting pre-biotic chemistries within the confines of complex coacervates, involving a postdoc Sandeep Ameta, in his group, and Yoshiya Matsubara, a joint postdoc with Sandeep Krishna, has resulted in a publication [Communications Chemistry 6 (1), 91 (2023)]. Thutupalli's collaboration on this research area with Sandeep Krishna [Life 11 (4), 308 (2021)], continues with more results in the pipeline.

Together with a postdoc Jeffrey Phillipson in his group and a Simons-NCBS Fellow, Richard Morris Thutupalli studied the evolutionary outcome of population growth following a bottleneck event, uncovering some hitherto unrecognised effects [Physical Review Research, 5 (1), 013093 (2023)]. The collaborations with the groups of Madan Rao and Vijay Krishnamurthy on topics in active matter physics have produced new results on the emergence of non-reciprocal interaction between active particles as the outcome of a dynamical phase transition [Nature Communications, 13 (1), 4533 (2022)] and the geometric control of the dynamics of an active particle [Physical Review Research, 4 (1), 013136 (2022)]. In addition, there is a nascent collaboration with the groups of Akash Gulyani and Sunil Laxman on the interplay of intracellular mechanics and bioenergetics in cells [Proc. Nat. Acad. Sci. (2023)].

In terms of personnel, the group has some happy news: Anupam Singh, the first PhD student in the group, has moved on to do his postdoc at the MPI, Dresden. Sandeep Ameta, a Simons postdoc in the group has started an independent faculty position at the Ashoka University. Yoshiya Matsubara, a joint Simons postdoc, has started a new postdoctoral position at the University of Chicago with Arvind Murugan and Jack Szostak.



RESEARCH REPORT

STRING THEORY AND QUANTUM GRAVITY

FACULTY

Rajesh Gopakumar ❖ R. Loganayagam ❖ Suvrat Raju ❖ Ashoke Sen *(Infosys-ICTS Madhava Chair Professor)* ❖ Spenta R. Wadia *(Infosys Homi Bhabha Chair Professor)*

POSTDOCTORAL FELLOWS

Anupam A H ❖ Asrat Demise ❖ Victor Godet ❖ Navaneeth Krishna Gaddam ❖ Anurag Kaushal ❖ Amiya Mishra ❖ Athira P V ❖ Naveen Prabhakar

STUDENTS

Tuneer Chakraborty ❖ Chandramouli Choudhary ❖ Sarthak Duary ❖ Ashik H ❖ Pronobesh Maity ❖ Godwin Martin ❖ Priyadarshi Paul ❖ Shivam Sharma ❖ Omkar Shetye ❖ Kaustubh Singhi ❖ Shridhar Vinayak ❖ Sarthak Duary

RESEARCH REPORT

Rajesh GOPAKUMAR

The broad direction of Rajesh Gopakumar's research has been a program of deriving gauge-string duality starting from weakly interacting large N gauge theories or equivalently around the tensionless limit of the dual string theory. He pursues this in the context of specific examples which have ranged from toy models of matrix integrals, through two dimensional CFTs to four dimensional Yang-Mills theories. Another area of focus has been on the conformal bootstrap, specifically developing the so-called Polyakov-Mellin bootstrap.

Deriving Gauge-String Duality

Matrix Models: The particular case of matrix models captures some of the essence of gauge-string duality in a very simple and controlled setting. Thus one can consider a single hermitian matrix integral, in the conventional 't Hooft large N limit. In the first of a series of three papers, an explicit correspondence with a (mirror) pair of closed topological string theories was proposed and verified. These duals were arrived at through a process dubbed as "open-closed-open triality". This is the notion that two open string descriptions ought to exist for the same closed string theory depending on how closed strings manifest themselves from open string modes. Exploiting this enables one to establish the equality of correlators, to all genus, between single trace operators in the original matrix model and those of the dual closed strings. This simplest of dualities can also be fruitfully viewed in terms of an embedding into the full AdS/CFT correspondence. The collaborator was Edward A. Mazenc.

2d CFTs: One of the examples where this general approach of deriving gauge string duality was explicitly illustrated is that of the so-called AdS_3/CFT_2 correspondence between string theories on AdS3 and a special class of two dimensional CFTs known as free symmetric orbifolds. In recent work, this has been extended to the interacting case where one goes away from the tensionless limit. A hidden integrability in the theory was also exhibited when one considers large operators. It provides a pathway for extending the derivation of gauge-string duality to interacting theories. The collaborators were Matthias Gaberdiel and Beat Nairz.

4d Yang-Mills: The most non-trivial case of gauge-string duality is that of the duality of the (supersymmetric) Yang-Mills theory to string theory on AdS5. A proposal was made for a worldsheet description that obtained the spectrum of the dual free Yang-Mills theory (with M. Gaberdiel). A generalisation was made of earlier observations in AdS_3/CFT_2 on connecting the gauge theory Feynman diagrams with covering maps from a worldsheet to spacetime. The area associated with the natural Strebel differential on the worldsheet gave

rise to the free Feynman propagators. This supported the picture of Feynman diagrams organising themselves into string amplitudes. The collaborators were Faizan Bhat, Pronobesh Maity, Bharathkumar Radhakrishnan.

RESEARCH REPORT

R. LOGANAYAGAM

During the period 2022-2023, R. Loganayagam's work has mainly revolved around the construction of open quantum field theories(QFTs), QFTs coupled to environments, using strongly coupled field theories as environments. This is done through holography or AdS/CFT. Such open field theories can come in two versions: one version in which the environment evolves very fast (Markovian), and another version in which some part of the environment evolves slowly (non-Markovian). Another related theme is to construct the open system that describes an observer in an expanding universe.

In a series of works [arXiv:2202.04079, arXiv:2205.03415], Loganayagam, Temple He, Mukund Rangamani, Akhil Sivakumar and Julio Virrueta constructed a series of new examples of open quantum field theories through holography. In all these cases, we have a fluid/plasma of a field theory as the environment. One intricate example is the non-Markovian case where the slow mode in the environment is the sound mode of a fluid. The physical challenge is to understand how the sound mode propagates and attenuates in the plasma, as well as the nature of long-lived fluctuations in this mode. In holography, this question turns into one of understanding the scalar sector of gravitational waves, their dissipation into a black hole, and their Hawking fluctuations. The technical complexity here can be traced back to interlinked Gauss constraints in this sector which are challenging to solve for. Loganayagam and collaborators showed how this can be done and for the first time, constructed the Hawking modes in this sector which describe acoustic fluctuations.

In a couple of publications [arXiv:2202.04079, arXiv:2205.03415] with Mukund Rangamani and Julio Virrueta, Loganayagam constructed a variety of toy models of open quantum field theories using holography. Their main focus was on the analytic structure of finite temperature correlators in these models. They analyzed the tree-level contact and exchange diagrams in the black hole backgrounds, including the effects of Hawking radiation, to understand the pole structures of correlations in these models. In the second work, they showed how certain subtle contributions arise due to near-horizon physics in models with derivative interactions.

In a recent work [arXiv:2309.07290] with Omkar Shetye, Loganayagam gave a new prescription for describing the physics of an observer in an expanding universe. Consider one such observer coupled to the ambient fields, e.g., one might imagine a charged particle producing electromagnetic fields. Once we integrate out this field, one gets an effective description of the observer as an open system that loses/gains energy from the field. Such an 'integrating out' process has its subtleties due to the divergences that plague these computations. In the above-mentioned work, Loganayagam showed how to circumvent these difficulties by a systematic counterterm procedure inspired by similar prescriptions in AdS/CFT. They mainly illustrated the procedure with scalar models but, in the future, they hope to generalize it to more realistic fields like electromagnetism and gravity.

RESEARCH REPORT

Suvrat RAJU

In 2022-23, Suvrat Raju continued work on the unusual localization of information in gravity— a phenomenon that is called the "holography of information." This involved the study of massive particles in asymptotically flat space, and a separate study of quantum gravity in asymptotically de Sitter space. These are described below followed by a separate project, where Raju studied the fluctuations of branes in AdS and found a version of Jackiw-Teitelboim gravity.

Massive Particles at Spatial Infinity

Raju and collaborators set up a new formalism to study massive fields in flat space. Conventionally, the behavior of these fields simplifies in the far future and the far past or, more formally, near the blowup of future infinity or the blowup of past infinity. They explored the alternative possibility that one could understand these fields by studying them at large spatial distances from a chosen origin.

More precisely, they studied massive fields at the blowup of spatial infinity. This is a geometric construction that has been previously explored in the gravitational literature. In the conventional Penrose diagram, spatial infinity is a point but upon blowing it up, one obtains a copy of three-dimensional de Sitter space. The exponentially suppressed tails of massive particles in Minkowski space induce a family of free fields on this boundary de Sitter space. This construction is mathematically quite intricate and Raju explored many of its properties.

The objective of performing this construction was to extend the principle of holography of information in asymptotically flat space to include massive particles coupled to gravity in asymptotically flat space. Their previous results in this direction pertained to null infinity, which is a useful home for massless particles but not for massive particles. However, the results obtained so far pertain purely to quantum field theory. They hope to generalize these results to gravitational theories in forthcoming work.

The collaborators were Alok Laddha, Siddharth Prabhu and Pushkal Shrivastava.

The Hilbert Space and Holography of Information in de Sitter Quantum Gravity

Raju and collaborators studied how the principle of holography of information could be generalized to de Sitter space. De Sitter space presents several unique features that are absent in both asymptotically flat space and asymptotically anti-de Sitter space. Notable among them is the absence of a nongravitational boundary that provides an external clock and can be used to define gauge-invariant observables.

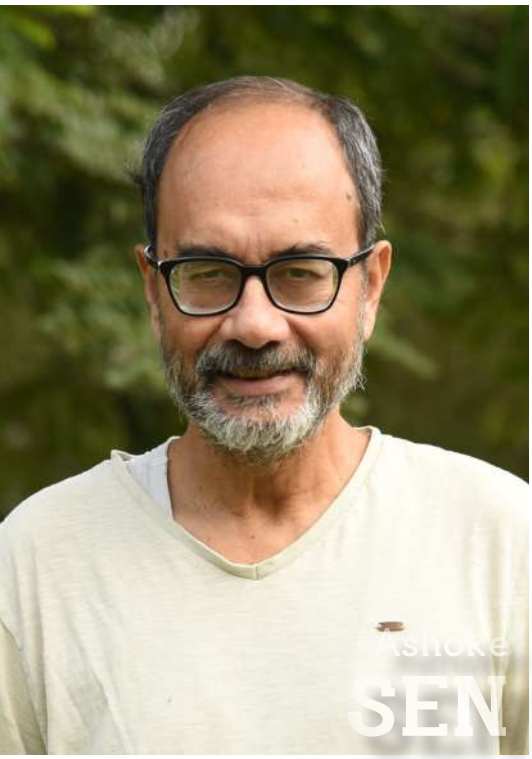
In their work, Raju noted that the volume of Cauchy slices provides a useful clock in the late-time limit of asymptotically de Sitter space. They then obtained a complete basis of solutions to the constraints of gravity in the large-volume limit. The addition of a natural norm-structure on this basis of solutions led them to a novel proposal for the Hilbert space for quantum gravity in de Sitter space.

This Hilbert space is different from the space that one would obtain by naively quantizing quantum fields on a de Sitter background. In fact, in the limit where the gravitational coupling becomes weak, their answer matches a proposal made earlier by Higuchi using very different methods.

The collaborators were Tuneer Chakraborty, Priyadarshi Paul, Joydeep Chakravarty and Victor Godet.

Jackiw-Teitelboim Gravity from the Karch-Randall Braneworld

In a separate project, Raju studied the fluctuations of a system with two Karch-Randall branes in an ambient three-dimensional anti-de Sitter spacetime. Raju and collaborators had earlier studied the same system in higher-dimensional anti-de Sitter space. Their objective, at that time, was to understand evaporating black holes coupled to a gravitational bath. In this setup, one of the branes acts as a bath. They had found that these baths behave quite differently from the nongravitating baths that had been studied previously in the literature.



RESEARCH REPORT

Ashoke SEN

Ashoke Sen's work during the last two years has been mainly on the analysis of D-instanton contribution to string amplitudes but also on some aspects of classical soft theorems and black holes

Sen and collaborators computed D-instanton corrections to minimal string theories and compared them with the predictions of the dual matrix model, finding perfect agreement in every case studied. This established that the duality between the two descriptions holds at the non-perturbative level. Earlier work had established this duality at the level of perturbation expansion. They also resolved an earlier puzzle involving D-instanton corrections in two dimensional string theory. In view of this result, they now have perfect agreement between the results of direct D-instanton computation and predictions from dual descriptions, whenever such a comparison is possible. The collaborators were Dan Stefan Eniceicu, Raghu Mahajan, Chitraang Murdia and Pronobesh Maity.

Sen computed D-instanton corrections to the superpotential in N=1 supersymmetric string compactification. The knowledge of such superpotentials is essential for the study of string compactification leading to semi-realistic models of our universe. The collaborators were Sergei Alexandrov, Atakan Hilmi Firat, Manki Kim and Bogdan Stefanski.

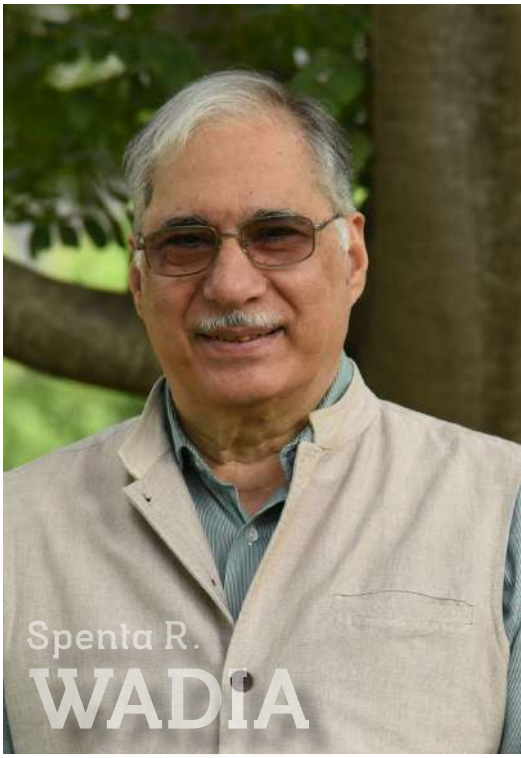
Sen computed the normalization of D-instanton correction to amplitudes in type 0B string theory and showed that the result agrees with the prediction of a dual matrix model. He also described how one can compute infrared nite semi-inclusive scattering cross section in these theories. The collaborator was Joydeep Chakravarty.

Sen and collaborators computed D-instanton corrections to the sine-Liouville theory. Wherever the results were known from the dual matrix model computation, they found perfect agreement. However, since the earlier methods used for the analysis of the matrix model left some ambiguities, they used a new approach to the matrix model computation that is free from ambiguities. With this new approach they found perfect agreement between the results from the two sides. The collaborators were Sergei Alexandrov and Raghu Mahajan.

Sen also showed how one can rewrite subsubleading classical soft theorem in a way so that the result becomes independent of the momenta carried by final state massless particles. This is useful in the study of gravitation waves where computing the detailed spectrum of gravitational waves emitted during a process involves detailed numerical computation. The collaborator was Biswajit Sahoo.

Sen generalized the result of Dabholkar, Murthy and Zagier (DMZ) on the connection between single centered black hole index and mock modular forms to the case of CHL models. They found, however, that not all single centered black hole indices are given by Fourier coefficients of Mock modular forms, even for the case originally studied by DMZ. The collaborators were Ajit Bhand and Ranveer Singh.

Few years ago, Iliesiu, Kologlu and Turiaci showed how one can use gravitational path integral to compute supersymmetric index of black holes. Sen and collaborators applied this procedure to compute logarithmic correction to the index of supersymmetric black holes in four dimensions and found perfect agreement with earlier results based on the analysis of the near horizon geometry, as well as the results of microscopic counting. The collaborators were A.H. Anupam, P.V. Athira and Chandramouli Chowdhury. With Anupam and Chowdhury, he later generalized this analysis to five dimensional black holes.



RESEARCH REPORT

Spenta R. WADIA

During the last two years Spenta R. Wadia has worked on the following.

A Dynamical Theory of Black Hole Evaporation in 1+1 Dimensional Quantum Gravity

This work focused on non-equilibrium dynamics of a low temperature 2-dim black hole coupled to an external bath, using the dual Sachdev-Ye- Kitaev model. Tracing over the bath degrees of freedom, in the Schwinger-Keldysh formalism, led to solving non-local stochastic differential equations for the BH degrees of freedom. The combination of SYK operators enable complete evaporation of the Black Hole, and the fluctuations that characterise the end point of the evaporation process. The collaborators were Anurag Kaushal (ICTS-TIFR), Gautam Mandal (TIFR Mumbai) and Adwait Gaikwad (Tel-Aviv University).

Meson Spectrum of SU(2) QCD1+1 with Quarks in Large Representations

Wadia and collaborators considered SU(2) quantum chromodynamics in 1+1 dimensions with a single quark in the spin J representation of the gauge group and studied the theory in the large J limit with λ=g2J2 fixed. They worked with a Dirac spinor field for arbitrary J, and with a Majorana spinor for integer J since the integer spin representations of SU(2) are real. The theory is reformulated in terms of global color non-singlet fermion bilocal operators which satisfy a W∞ ×U (2J+1) algebra. In the large J limit, the dynamics of the bilocal fields is captured by fluctuations along a particular coadjoint orbit

of the W∞ algebra. They showed that the global colour-singlet sector of the bilocal field fluctuations satisfy the same integral equation for meson wavefunctions that appears in the 't Hooft model. For Majorana spinors in the integer spin J representation, the Majorana condition projects out half of the meson spectrum, as a result of which the linear spacing of the asymptotic meson spectrum for Majorana fermions is double that of Dirac fermions. The Majorana condition also projects out the zero mass bound state that is present for the Dirac quark at zero quark mass. They also considered the formulation of the model in terms of local charge densities and computed the quark spectral function in the large J limit: one sees evidence for the absence of a pole in the quark propagator. The collaborators were Anurag Kaushal (ICTS-TIFR) and Naveen Prabhakar (ICTS-TIFR).

Faculty members and group photos credit: S. Shantaraj/AS Sumukh

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RESEARCH REPORT

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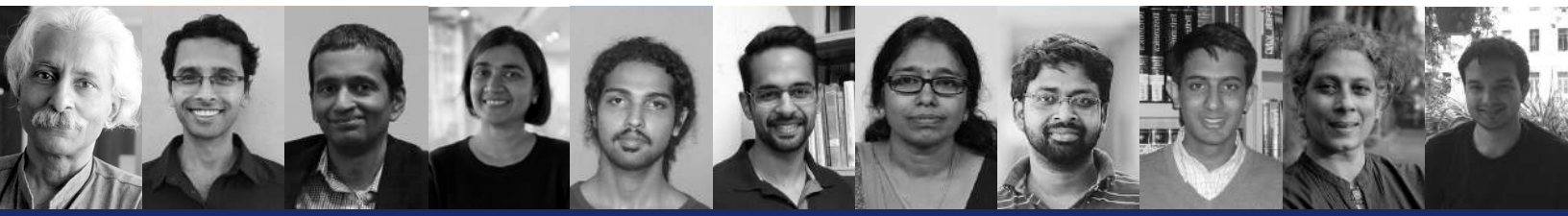
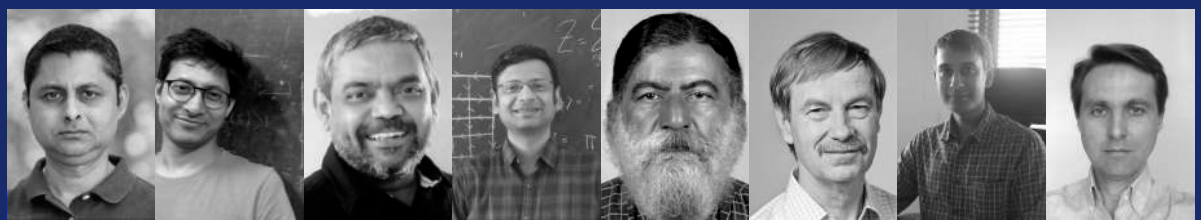


RESEARCH

ICTS ASSOCIATES



ICTS ASSOCIATES

The active engagement of numerous distinguished, world-renowned scientists has significantl empowered ICTS, contributing to various activities within the Centre. Together, they constitute the expansive cohort of ICTS Associates.

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PROGRAM ACTIVITIES

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PROGRAM ACTIVITIES

PROGRAMS AND DISCUSSION MEETINGS

ICTS has successfully hosted 43 programs and 29 discussion meetings during the years 2022-2023. After the Covid-19 restrictions were fully lifted in early 2022, all programs were hosted at their usual venues on the ICTS-TIFR campus. Here are details of a few important programs and discussion meetings.

PROGRAMS

Soft and Living Matter: From Fundamental Concepts to New Material Design ♦ 7-25 August 2023

From the food we eat to the shampoo and lotion we use for personal care or a collection of bacteria swimming in constrained environments, soft materials and complex fluids are ubiquitous in our daily life. Despite occupying a myriad of unrelated systems and settings, they share several overlapping properties and behavior. This diversity renders Soft Matter Physics fantastically interdisciplinary, for it borrows tools from various branches of physics, e.g. Dynamical Systems, Fluid Dynamics, Condensed Matter & Statistical Physics etc. and applies them to systems and problems far afield, including but not limited to, Biology, Earth & Atmospheric Science, Engineering, and Food & Cosmetics industry among many others.

The SLM2023 School and Workshop on Soft and Living Matter hosted global experts who delivered pedagogical lectures on a subset of this broad field to students and young researchers. The topics were representative of the breadth of this field, such as Geometry & Mechanics, Collective Phenomena, Suspensions & Particulate Systems, Liquid Crystals, Biological Matter and Non-equilibrium Physics.

Machine Learning for Health and Disease ♦ 24 July-4 August 2023

This program brought together machine learning experts, statisticians, clinicians, and public health experts to discuss how to harness modern mathematical and computational techniques to better understand health-related data across multiple domains. Basics of various machine learning techniques, including logistic regression, tree-based methods, support vector machines, Bayesian methods, and deep networks were covered with examples of their applicability in biomedicine and health. Applications included predicting outcomes for individual patients from clinical and lifestyle parameters, analysing patient data such as X-rays, ultrasound images and ECG measurements, genomic variant analysis, and inferring patterns in heterogeneous large-scale data. Speakers from both computational/ statistical and clinical backgrounds participated.

It was partly supported by the IMSc Centre for Disease Modelling, The Institute of Mathematical Sciences, Chennai.

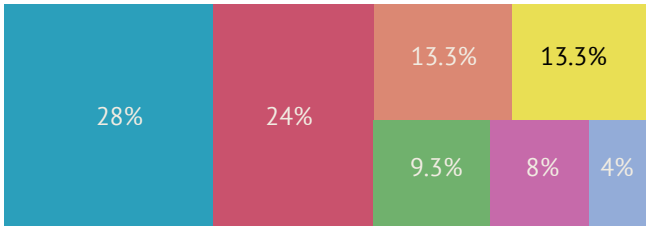
Introduction to Precision Measurements and Quantum Metrology ♦ 10-21 July 2023

Quantum physics has come a long way since its inception 120 years ago to the application of quantum effects in day-to-day life in the form of quantum technologies that are emerging rapidly across multiple fields. This school aimed at building knowledge and awareness on precision measurements and quantum metrology among young students who will be the future researchers in this area and be part of the National Quantum Mission in India. The lectures in this school covered the theory of precision measurements, theory of estimation, classical and quantum metrology, atomic & optical physics techniques used for quantum metrology and precision measurements, precision measurements using atoms/ ions/ molecules, photons, NV-centers.

Largest Cosmological Surveys and Big Data Science ♦ 1-12 May 2023

The tremendous success of Cosmic Microwave Background (CMB) observations, by WMAP and Planck, have heralded an era in precision cosmology. This program aimed to expose young researchers to the forefront of cosmology research in the areas that are poised to dominate the field in the next decade and initiate, strengthen and extend collaborations between active early career scientists with the researchers from the top-most CMB and LSS research groups. The program was unique by its very different focus and methods. It brought expert knowledge, through hands-on short projects, to early career researchers who are poised to grasp complex details of multi-messenger cosmology. The key idea was to provide the very valuable "insider insight" which is crucial when working with large

SUBJECTS	NO OF EVENTS
Mathematics and Computer Science	21
Condensed Matter and Statistical Physics	18
Astrophysics and Cosmology	10
Quantitative Biology	10
High Energy Physics	7
Climate Sciences and Fluid Dynamics	6
Others	3



Total Participation	**6959**
Total Participation days	**56817**
Indian participation	5355
Foreign Participation	1604
SPEAKERS	
Indian	800
Foreign	727
GENDER	
Female	1724
Male	5235
STUDENTS AND POSTDOCS	
Indian	3390
Foreign	613

Jan 2022 - Dec 2023	**75**
Discussion Meetings	27
Programs	37
Online	11

survey data. There was a strong focus on presenting complex ideas effectively by various talks students will have to give during the two weeks period.

Topics in High Dimensional Probability ♦ 2-13 January 2023

The focus of this program was on several interconnected themes in modern probability theory, which can broadly be brought under the umbrella of high dimensional probability. The particular themes covered included (i) random matrices and random operators, (ii) geometric functional analysis and high dimensional convex geometry, (iii) point processes and interacting particle systems, and (iv) spin glasses and Gaussian free fields.

The program also featured two mini-courses by Subhroshekhar Ghosh and Mark Rudelson. An Infosys-ICTS Ramanujan Lecture Series (five one-hour lectures) was delivered by Hugo Duminil-Copin and a Distinguished Lecture by Ofer Zeitouni.

DISCUSSION MEETINGS

Data Science: Probabilistic and Optimization Methods ♦ 3-7 July 2023

This workshop was focused on the analytic and algorithmic side of data science. The current boom in data science, in reality an umbrella term for diverse but loosely connected activity, has been brought about by rapid advances in techniques for collection, storage

and dissemination of data, along with increased computational abilities to process it. It is on the scale of the industrial revolution except that it is now the abstract symbols rather than energy and material that is being generated, stored and distributed. This is affecting the older sciences as well where pure model-based approaches are being combined with purely data driven ones, to get the best of both worlds. The major action, however, is on a different front - that of fast processing tools for the enormous data that is being generated, sometimes at a high speed.

This workshop opened a window to some of the leading themes in this sphere and exposed the participants to both their underpinnings and to the new directions they are headed for, with a focus on probabilistic and optimization techniques.

As part of the program, Michael I. Jordan (Pehong Chen Distinguished Professor, UC Berkeley) delivered the Infosys-ICTS Turing Lectures.

Mathematical Modeling of Climate, Ocean, and Atmosphere Processes ♦ 26-30 June 2023

This pedagogical program discussed fluid dynamics of the atmosphere and the ocean and its impact on climate scale processes. The topics discussed included turbulent dynamics and convection in the ocean, monsoon dynamics, dynamical systems approach to climate models, and machine learning techniques for atmosphere-ocean processes.

Inaugural Meeting of Asian-Oceanian Women in Mathematics ♦ 24-28 April 2023

This was the first hybrid meeting of the Asian-Oceanian Women in Mathematics (AOWM). AOWM was formed online in August, 2022, with the support of the CWM members of the IMU, in order to facilitate interactions among women mathematicians in these regions. AOWM hopes to provide an empathetic platform to women mathematicians to share their concerns, and to highlight and bring to the forefront their achievements. One of the primary goals of this meeting was to decide the future course of academic activities in these regions. A number of distinguished as well as young promising women mathematicians delivered lectures. There were interactive sessions in hybrid mode with women students and postdocs from all over the world to enlighten them on various career opportunities in research, and the means and support systems available to overcome any challenges they might meet in their pursuits.

Lunar Gravitational-Wave Detection ♦ 17-20 April 2023

Lunar exploration has become a strategic objective of space agencies worldwide. These programs offer extraordinary opportunities for science as well. The goal of this meeting was to discuss mission concepts for lunar GW detection, payload technologies, GW science, as well as lunar geophysics, which plays a crucial role in the planning of these missions. This meeting also included scientists who are working on other mission concepts for decihertz GW detection to facilitate a meaningful exchange of ideas and techniques. Another aim of this meeting was to help to step up the Indian presence in the international efforts to prepare a science white paper on decihertz GW astronomy.

List of programs

ICTP-ICTS Winter School on Quantitative Systems Biology
4-15 December 2023 ♦ *Organizers* - Vijaykumar Krishnamurthy *(ICTS-TIFR, Bengaluru)*, Daniel Needleman *(Harvard University, USA)*, Simone Pigolotti *(OIST, Japan)* and Shashi Thutupalli *(ICTS/ NCBS- TIFR, India)*

Algebraic and Combinatorial Methods in Representation Theory
13 - 24 November 2023 ♦ *Organizers* - B Ravinder *(IIT Tirupati)*, R Venkatesh *(IISc, Bengaluru)* and S Viswanath *(IMSc, Chennai)*

Active Matter in Complex Environments
23 October- 3 November 2023 ♦ *Organizers* - Tapomoy Bhattacharjee *(NCBS-TIFR, Bengaluru)*, Christina Kurzthaler *(Max Planck Institute for the Physics of Complex Systems, Germany)* and Sumantra Sarkar *(IISc. Bengaluru)*

IAGRG School on Gravitation and Cosmology
9-20 October 2023 ♦ *Organizers* - Amitabh Virmani *(CMI, Chennai)*, Anjan Ananda Sen *(CTP, Jamia Millia Islamia, New Delhi)*, Archana Pai *(IIT Bombay, Mumbai)*, Sudipta Das *(VBU, Santiniketan)*, Sudipta Sarkar *(IIT Gandhinagar)* and Parameswaran Ajith *(ICTS-TIFR, Bengaluru)*

Condensed Matter meets Quantum Information
25 September-6 October 2023 ♦ *Organizers* - Yuval Gefen *(Weizmann Institute, Israel)*, Ganpathy Murthy *(University of Kentucky, USA)* and Sumathi Rao *(ICTS-TIFR, Bengaluru)*

Rational Points on Modular Curves
11-22 September 2023 ♦ *Organizers* - Chandrakant Aribam *(IISER Mohali)*, Shaunak Deo *(IISc, Bengaluru)*, Narasimha Kumar (*IIT Hyderabad)* and Pierre Parent *(Institute Mathematics De Bordeaux, France)*

Bangalore School on Statistical Physics - XIV
11-22 September 2023 ♦ *Organizers* - Abhishek Dhar *(ICTS-TIFR, Bengaluru)* and Sanjib Sabhapandit *(RRI, Bengaluru)*

Statistical Methods and Machine Learning in High Energy Physics
28 August- 8 September 2023 ♦ *Organizers* - Sunanda Banerjee *(University of Wisconsin, USA)*, Satyaki Bhattacharya *(SINP, Kolkata)*, Indumathi D *(IMSc. Chennai)*, Bhawna Gomber *(University of Hyderabad)*, Partha Konar *(PRL, Ahmedabad)*, Aruna Kumar Nayak *(IOPB, Bhubaneshwar)* and Ritesh Kumar Singh *(IISER, Kolkata)*

Soft and Living Matter: from Fundamental Concepts to New Material Design
7-25 August 2023 ♦ *Organizers* - Mahesh M Bandi *(Okinawa Institute of Science and Technology, Japan)* and Ranjini Bandyopadhyay *(RRI, Bengaluru)*

Machine Learning for Health and Disease
24 July-4 August 2023 ♦ *Organizers* - Gautam Menon *(Ashoka University, Sonepat)*, Leelavati Narlikar *(IISER Pune)*, Uma Ram *(Seethapathy Clinic & Hospital, Chennai)*, Ponnusamy Saravanan *(University of Warwick, UK)* and Rahul Siddharthan *(IMSc, Chennai)*

Summer School on Gravitational-Wave Astronomy
24 July-4 August 2023 ♦ *Organizers* - Parameswaran Ajith *(ICTS-TIFR, Bengaluru)*, K. G. Arun *(CMI, Chennai)*, Bala R. Iyer *(ICTS-TIFR, Bengaluru)* and Prayush Kumar *(ICTS-TIFR, Bengaluru)*

Introduction to Precision Measurements and Quantum Metrology
10-21 July 2023 ♦ *Organizers* - Subhadeep De *(IUCAA, Pune)*, Saikat Ghosh *(IIT Kanpur)*, Arup Kumar Raychaudhuri *(CGCRI, Kolkata)*, Kasturi Saha *(IIT Bombay, Mumbai)*, Bijaya Kumar Sahoo *(PRL, Ahmedabad)* and Anil Shaji *(IISER, Thiruvananthapuram)*

Modern trends in Harmonic Analysis
26 June – 7 July 2023 ♦ *Organizers* - Jotsaroop Kaur *(IISER Mohali)* and Saurabh Shrivastava *(IISER Bhopal)*

Periodically and Quasi-Periodically Driven Complex Systems
12-23 June 2023 ♦ *Organizers* - Jonathan Keeling *(University of St Andrews, UK)*, Manas Kulkarni *(ICTS-TIFR, Bengaluru)* and Aditi Mitra *(New York University, USA)*

Summer School for Women in Physics
29 May-9 June 2023 ♦ *Organizers* - Mahua Ghosh *(Mount Carmel College, Bengaluru)*, Kripa

Gowrishankar *(Azim Premji University, Bengaluru)*, Sushan Konar *(NCRA-TIFR, Pune)*, Rajaram Nityananda *(ICTS-TIFR, Bengaluru)*, Sumathi Rao *(ICTS-TIFR, Bengaluru)*, Joseph Samuel *(ICTS-TIFR, Bengaluru)* and Supurna Sinha *(RRI, Bengaluru)*

Summer School for Women in Mathematics and Statistics
29 May-9 June 2023 ♦ *Organizers* - Siva Athreya *(ICTS-TIFR & ISI Bengaluru)*, Rhythm Grover *(IIT Guwahati)* and Dootika Vats *(IIT Kanpur)*

Dualities in Topology and Algebra
15-26 May 2023 ♦ *Organizers* - Samik Basu *(ISI Kolkata)*, Anita Naolekar *(ISI Bengaluru)* and Rekha Santhanam *(IIT Bombay, Mumbai)*

Largest Cosmological Surveys and Big Data Science 1-12 May 2023 ♦ *Organizers* - Shadab Alam *(TIFR, Mumbai)*, Girish Kulkarni *(TIFR, Mumbai)*, Subha Majumdar *(TIFR, Mumbai)*, Surhud More *(IUCAA, Pune)*, Aseem Paranjape *(IUCAA, Pune)* and Tirthankar Roy Choudhury *(NCRA-TIFR, Pune)*

Less Travelled Path to the Dark Universe
13-24 March 2023 ♦ *Organizers* - Arka Banerjee *(IISER Pune*), Subinoy Das *(IIA, Bengaluru)*, Koushik Dutta *(IISER, Kolkata)*, Raghavan Rangarajan *(Ahmedabad University)*, Vikram Rentala *(IIT Bombay, Mumbai)*

Probabilistic Methods in Negative Curvature
27 February -10 March 2023 ♦ *Organizers* - Riddhipratim Basu *(ICTS-TIFR, Bengaluru)*, Anish Ghosh *(TIFR, Mumbai)*, Subhajit Goswami *(TIFR, Mumbai)*, Mahan MJ *(TIFR, Mumbai)*

Vortex Moduli
6-17 February 2023 ♦ *Organizers* - Nuno Romão *(University of Augsburg, Germany)*, Sushmita Venugopalan *(IMSc, Chennai)*

Turbulence: Problems at the Interface of Mathematics and Physics
16-27 January 2023 ♦ *Organizers* - Uriel Frisch *(Observatoire de la Côte d'Azur and CNRS, France)*, Konstantin Khanin *(University of Toronto, Canada)*, Rahul Pandit (*IISc, Bengaluru)*

Topics in High Dimensional Probability
2-13 January 2023 ♦ *Organizers* - Anirban Basak *(ICTS-TIFR, Bengaluru)*, Riddhipratim Basu *(ICTS-TIFR, Bengaluru)*

Ergodic Theory and Dynamical Systems (Hybrid)
5-16 December 2022 ♦ *Organizers* - C. S. Aravinda *(TIFR-CAM, Bengaluru)*, Anish Ghosh *(TIFR, Mumbai)* and Riddhi Shah *(JNU, Delhi)*

ICTP-ICTS Winter School on Quantitative Systems Biology (Hybrid)
5-16 December 2022 ♦ *Organizers* - Vijay Balasubramanian *(University of Pennsylvania, USA)*, Antonio Celani *(ICTP, Trieste, Italy)*, Pratik Chaudhari *(University of Pennsylvania, USA)*, Matteo Marsili *(ICTP, Trieste, Italy)* and Guido Sanguinetti (SISSA, *Trieste*, Italy)

Horizons in Accelerators, Particle/Nuclear Physics and Laboratory-based Quantum Sensors for HEP/NP (Hybrid)
14-17 November 2022 ♦ *Organizers* - Swapan Chattopadhyay *(FNAL, USA & IISc, Bengaluru)* and Rohini Godbole (*IISc, Bengaluru)*

Statistical Biological Physics: From Single Molecule to Cell
11-22 October 2022 ♦ *Organizers* - Debashish Chowdhury *(IIT Kanpur)*, Ambarish Kunwar *(IIT Bombay, Mumbai)* and Prabal K. Maiti (*IISc, Bengaluru)*

Tipping Points in Complex Systems (Hybrid)
19-30 September 2022 ♦ *Organizers* - Partha Sharathi Dutta *(IIT Ropar)*, Vishwesha Guttal (*IISc, Bengaluru)*, Mohit Kumar Jolly (*IISc, Bengaluru)* and Sudipta Kumar Sinha *(IIT Ropar)*

Frustrated Metals and Insulators (Hybrid)
5-16 September 2022 ♦ *Organizers* - Federico Becca *(University of Trieste, Italy)*, Subhro Bhattacharjee *(ICTS-TIFR, Bengaluru)*, Yasir Iqbal *(IIT Madras, Chennai)*, Bella Lake *(Helmholtz-Zentrum Berlin für Materialien und Energie, Germany)*, Yogesh Singh *(IISER Mohali)* and Ronny Thomale *(Julius-Maximilians-Universität at Würzburg, Germany)*

Nonperturbative and Numerical Approaches to Quantum Gravity, String Theory and Holography (Hybrid)
22 August- 2 September 2022 ♦ *Organizers* - David Berenstein *(University of California, Santa Barbara, USA)*, Simon Catterall *(Syracuse University,*

(Clockwise from top left) Participants of the program Asia Oceania Women in Mathematics ◊ Gagandeep Kang (Director in the Division of Global Health at the Bill and Melinda Gates Foundation) during the program Machine Learning for Health and Disease ◊ Participants of the program Soft and Living Matter ◊ Participants at the Summer School for Women in Physics ◊ Participants of the program Fascinating World of Flows ◊ Photo credit: S. Shantaraj

USA), Masanori Hanada *(University of Surrey, UK)*, Anosh Joseph *(IISER Mohali)*, Jun Nishimura *(KEK Japan)*, David Schaich *(University of Liverpool, UK)*, Toby Wiseman *(Imperial College London, UK)*

Elliptic Curves and the Special Values of L-Functions (Hybrid)
8-19 August 2022 ♦ *Organizers* - Ashay Burungale *(CalTech/UT Austin, USA)*, Haruzo Hida *(UCLA, USA)*, Somnath Jha *(IIT Kanpur)*, Ye Tian *(MCM, CAS)*

First-Passage Percolation and Related Models (Hybrid)
11-29 July 2022 ♦ *Organizers* - Riddhipratim Basu *(ICTS-TIFR, Bengaluru)*, Jack Hanson *(City University of New York, USA)*, Arjun Krishnan *(University of Rochester, USA)*

Bangalore School on Statistical Physics – XIII (Hybrid)
11-22 July 2022 ♦ *Organizers* - Abhishek Dhar *(ICTS-TIFR, Bengaluru)*, Sanjib Sabhapandit *(RRI, Bengaluru)*

Combinatorial Algebraic Geometry: Tropical and Real (Hybrid)
27 June-8 July 2022 ♦ *Organizers* - Arvind Ayyer *(IISc, Bengaluru)*, Madhusudan Manjunath *(IIT Bombay, Mumbai)*, Pranav Pandit *(ICTS-TIFR, Bengaluru)*

Summer School for Women in Mathematics and Statistics
13-24 June 2022 ♦ *Organizers* - Siva Athreya *(ISI Bengaluru)*, Anita Naolekar *(ISI Bengaluru)*, Senthil Raani K.S *(IISER-Berhampur)*, Dootika Vats *(IIT Kanpur)*

ICTS Summer School on Gravitational-Wave Astronomy (Hybrid)
30 May-10 June 2022 ♦ *Organizers* - Parameswaran Ajith *(ICTS-TIFR, Bengaluru)*, K. G. Arun *(CMI, Chennai)*, Bala R. Iyer *(ICTS-TIFR, Bengaluru)*, Prayush Kumar *(ICTS-TIFR, Bengaluru)*

Physics with Trapped Atoms, Molecules and Ions (Hybrid)
9-13 May 2022 ♦ *Organizers* - Bimalendu Deb *(IACS, Kolkata)*, Sourav Dutta *(TIFR, Mumbai)*, Saikat Ghosh *(IIT Kanpur)*

Future Flavours: Prospects for Beauty, Charm and Tau Physics
25 April- 6 May 2022 ♦ *Organizers* - B. Ananthanarayan *(IISc, Bengaluru)*, Thomas Browder *(University of Hawaii, U.S.A)*, Amol Dighe *(TIFR, Mumbai)*, Jim Libby *(IIT Madras, Chennai)*, Namit Mahajan *(PRL, Ahmedabad)*, Gagan Mohanty *(TIFR, Mumbai)*, Soumitra Nandi *(IIT Guwahati)*, Nita Sinha *(IMSc, Chennai)*, Sanjay Kumar Swain *(NISER Bhubaneswar)*, Guy Wilkinson *(University of Oxford, England)*

Classical and Quantum Transport Processes: Current State and Future Directions
17-28 January 2022 ♦ *Organizers* - Alberto Imparato *(University of Aarhus, Denmark)*, Anupam Kundu *(ICTS-TIFR, Bengaluru)*, Carlos Mejia-Monasterio *(Technical University of Madrid, Spain)*, Lamberto Rondoni *(Polytechnical University of Turin, Italy)*

Fifth Bangalore School on Population Genetics and Evolution
17-28 January 2022 ♦ *Organizers* - Deepa Agashe *(NCBS-TIFR, Bengaluru)*, Kavita Jain *(JNCASR, Bengaluru)*

Kavli Asian Winter School (KAWS) on Strings, Particles and Cosmology
10-23 January 2022 ♦ *Organizers* - Francesco Benini *(SISSA, Italy)*, Bartek Czech *(Tsinghua University, China)*, Dongmin Gang *(Seoul National University, South Korea)*, Sungjay Lee *(Korea Institute for Advanced Study, South Korea)*, Cheng Peng *(KITS-UCAS, China)*, Pavel Putrov *(ICTP, Trieste, Italy)*, Loganayagam R *(ICTS-TIFR, Bengaluru)*, Aninda Sinha *(IISc, Bengaluru)*, Tadashi Takayanagi *(YITP, Kyoto University, Japan)*, Masahito Yamazaki *(Kavli IPMU, The University of Tokyo, Japan)*

Physics of the Early Universe (Hybrid)
3-12 January 2022 ♦ *Organizers* - Robert Brandenberger *(McGill University, Canada)*, Jerome Martin *(IAP, France)*, Subodh Patil *(Leiden University, Netherlands)*, L. Sriramkumar *(IIT Madras, Chennai)*

List of Discussion Meetings

Field Theory and Turbulence
18 - 22 December 2023 ♦ *Organizers* - Katepalli R. Sreenivasan *(New York University, USA)*, Loganayagam Ramalingam *(ICTS-TIFR, Bengaluru)*, Luca Moriconi *(UFRJ, Rio de Janeiro, Brazil)* and Mahendra K. Verma *(IIT Kanpur)*

(Clockwise from top-left) Bala Iyer, Shankar V. Nakhe *(DIrector RRCAT),* Patrick Brady *(LSC Spokesperson)* and Ajit Mohanty *(Secretary DAE)* during a panel discussion on LIGO ♦ Jan Wonk of Lieden University during the program Rational Points on Modular Curves ♦ Participants discussing during the Summer School for Women in Mathematics and Statistics ♦ Photo Credit: S. Shantaraj

Lectures on Probability and Stochastic Processes
17- 21 November 2023 ♦ *Organizers* - Siva Athreya *(ICTS-TIFR & ISI Bengaluru)* and Koushik Ramachandran *(TIFR-CAM, Bengaluru)*

Active Matter and Beyond
6 - 10 November 2023 ♦ *Organizers* - Jean-François Joanny *(Collège de France)*, Vijaykumar Krishnamurthy *(ICTS-TIFR, Bengaluru*), Cristina Marchetti *(University of California, Santa Barbara, USA)*, Gautam Menon *(Ashoka University, Sonipat and IMSc. Chennai)*, Shraddha Mishra *(IIT Varanasi (BHU)*, Madan Rao *(NCBS-TIFR, Bengaluru)* and Prerna Sharma *(IISc, Bengaluru)*

LIGO Science Workshop
27 - 28 October 2023 ♦ *Organizers* - Parameswaran Ajith *(ICTS-TIFR, Bengaluru)*, K. G. Arun *(CMI, Chennai)*, Bala Iyer *(ICTS-TIFR, Bengaluru)*, Shasvath Kapadia *(IUCAA, Pune)*, Sanjit Mitra *(IUCAA, Pune)*, Archana Pai *(IIT Bombay, Mumbai)* and Sendhil Raja *(RRCAT, Indore)*

Data Science: Probabilistic and Optimization Methods
3-7 July 2023 ♦ *Organizers* - Vivek Borkar *(IIT Bombay, Mumbai)*, Sandeep Juneja *(TIFR, Mumbai)*, Praneeth Netrapalli *(Google Research, Bengaluru)* and Devavrat Shah *(MIT, USA)*

Mathematical Modeling of Climate, Ocean, and Atmosphere Processes
26-30 June 2023 ♦ *Organizers* - Jim Thomas *(ICTS-TIFR, Bengaluru)*, Ashwin K Seshadri *(IISc, Bengaluru)* and Aman Gupta *(Stanford University, USA)*

Gravitational-Wave Open Data Workshop
16-17 May 2023 ♦ *Organizers* - Bala Iyer *(ICTS-TIFR, Bengaluru)*, Mukesh Kumar Singh *(ICTS-TIFR, Bengaluru)*, Prayush Kumar *(ICTS-TIFR, Bengaluru)*, Uddeepta Deka *(ICTS-TIFR, Bengaluru)* and Parameswaran Ajith *(ICTS-TIFR, Bengaluru)*

Inaugural meeting of Asian-Oceanian Women in Mathematics
24-28 April 2023 ♦ *Organizers* - Rukmini Dey *(ICTS-TIFR, Bengaluru)*, Sanoli Gun *(IMSc Chennai)*, Purvi Gupta *(IISc, Bengaluru)*, Hyang-Sook Lee *(Ewha Womans University, South Korea)*, Polly Sy *(University of the Philippines Diliman, Philippines)*, Melissa Tacy *(University of Auckland, New Zealand)*

Lunar Gravitational-Wave Detection
17-20 April 2023 ♦ *Organizers* - Parameswaran Ajith *(ICTS-TIFR, Bengaluru)*, Jan Harms *(Gran Sasso Science Institute, Italy)*, Andrea Maselli *(Gran Sasso Science Institute, Italy)*, Rajesh Nayak *(IISER Kolkata)*, P. Sreekumar *(ISRO / MAHE, Bengaluru)*

Topics in Hodge Theory
20-25 February 2023 ♦ *Organizers* - Indranil Biswas *(TIFR, Mumbai)*, Mahan Mj *(TIFR, Mumbai)*

Second Preparatory School on Population Genetics and Evolution
20-24 February 2023 ♦ *Organizers* - Deepa Agashe *(NCBS-TIFR, Bengaluru)*, Kavita Jain *(JNCASR, Bengaluru)*

8th Indian Statistical Physics Community Meeting
1-3 February 2023 ♦ *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)*, Prerna Sharma *(IISc, Bengaluru)*

Physics Teachers Training Program – Quantum Mechanics
9-13 January 2023 ♦ *Organizers* - Raghavan Rangarajan *(Ahmedabad University)*, SVM Satyanarayana *(Pondicherry University)*, M Sivakumar *(University of Hyderabad)*

Statistical Physics of Complex Systems
19-23 December 2022 ♦ *Organizers* - Sumedha *(NISER,Bhubaneswar)*, Abhishek Dhar *(ICTS-TIFR, Bengaluru)*, Satya Majumdar *(University of Paris-Saclay, France)*, R. Rajesh *(IMSc, Chennai)*, Sanjib Sabhapandit *(RRI, Bengaluru)* and Tridib Sadhu *(TIFR, Mumbai)*

Structured Light and Spin-Orbit Photonics
29 November-2 December 2022 ♦ *Organizers* - Bimalendu Deb *(IACS Kolkata)*, Tarak Nath Dey *(IIT Guwahati)*, Subhasish Dutta Gupta *(UOH, TIFR*

Hyderabad) and Nirmalya Ghosh *(IISER Kolkata)*

Bangalore Quantum Technology Initiative
29 November 2022 ♦ *Organizers* - Subhro Bhattacharjee *(ICTS-TIFR, Bengaluru)* and Arindam Ghosh *(IISc, Bengaluru)*

Particle Physics: Phenomena, Puzzles, Promises
21-23 November 2022 ♦ *Organizers* - Amol Dighe *(TIFR, Mumbai)*, Rick S Gupta *(TIFR, Mumbai)*, Sreerup Raychaudhuri *(TIFR, Mumbai)* and Tuhin S Roy *(TIFR, Mumbai)*

Mathematics Teachers Training Camp at ICTS
4-7 November 2022 ♦ *Organizers* - Prithwijit De *(HBCSE-TIFR, Mumbai)* and Pranav Pandit *(ICTS-TIFR, Bengaluru)*

The Future of Indian Astronomy (Hybrid)
31 October-2 November 2022 ♦ *Organizers* - Parameswaran Ajith *(ICTS-TIFR, Bengaluru)*, G. C. Anupama *(IIA Bengaluru)*, Dipankar Banerjee *(ARIES Nainital & IIAP Bengaluru)*, Varun Bhalerao *(IIT Bombay, Mumbai)*, Poonam Chandra *(NCRA-TIFR, Pune)* and Divya Oberoi *(NCRA - TIFR Pune)*

Targeted Questions in Condensed Matter (Online)
22 September 2022 ♦ *Organizers* - Subhro Bhattacharjee *(ICTS-TIFR, Bengaluru)*, Arun Paramekanti *(University of Toronto, Canada)* and Nandini Trivedi *(Ohio State University, USA)*

L-functions, Circle-Method and Applications (Hybrid)
27 June-1 July 2022 ♦ *Organizers* - Soumya Das *(IISc Bengaluru)*, Ritabrata Munshi *(ISI Kolkata)*, Saurabh Kumar Singh *(IIT Kanpur)*

Stochastic Thermodynamics: Recent Developments (Online)
14-17 June 2022 ♦ *Organizers* - Shamik Gupta *(TIFR, Mumbai)*, Sourabh Lahiri *(BIT, Mesra)*, Arnab Saha *(University of Calcutta)*

LIGO-Virgo Open Data Workshop
25-26 May 2022 ♦ *Organizers* - Parameswaran Ajith *(ICTS-TIFR, Bengaluru)*, Soummyadip Basak *(ICTS-TIFR, Bengaluru)*, Srashti Goyal *(ICTS-TIFR, Bengaluru)*, Aditya Vijaykumar *(ICTS-TIFR, Bengaluru)*

Laboratory for Interdisciplinary Breakthrough Science (Hybrid)
25 May 2022 ♦ *Organizer* - Shravan Hanasoge *(TIFR, Mumbai)*

Waves, Instabilities and Mixing in Rotating and Stratified Flows
4-8 April 2022 ♦ *Organizers* - Thierry Dauxois *(CNRS & ENS de Lyon, France)*, Sylvain Joubaud *(ENS de Lyon, France)*, Manikandan Mathur *(IIT Madras, Chennai)*, Philippe Odier *(ENS de Lyon, France)*, Anubhab Roy *(IIT Madras, Chennai)*

APS Satellite Meeting at ICTS (Hybrid)
15-18 March 2022 ♦ *Organizers* - Ranjini Bandyopadhyay *(RRI, Bengaluru)*, Subhro Bhattacharjee *(ICTS-TIFR, Bengaluru)*, Arindam Ghosh *(IISc, Bengaluru)*, Shobhana Narasimhan *(JNCASR, Bengaluru)*, Sumantra Sarkar *(IISc, Bengaluru)*

Complex Lagrangian Problems of Particles in Flows
14-18 March 2022 ♦ *Organizers* - Massimo Cencini *(Istituto dei Sistemi Complessi)*, Kristian Gustafsson *(University of Gothenburg)*, Filippo De Lillo *(University of Turin & INFN)*, Samriddhi Sankar Ray *(ICTS-TIFR, Bengaluru)*

Workshop on Climate Studies (Hybrid)
1-3 March 2022 ♦ *Organizers* - Rama Govindarajan *(ICTS-TIFR, Bengaluru)*, Sandeep Juneja *(TIFR, Mumbai)*, Ramalingam Saravanan *(Texas A&M University, USA)*, Sandip Trivedi *(TIFR, Mumbai)*

Statistical Physics: Recent advances and Future directions
14-15 February 2022 ♦ *Organizers* - Sakuntala Chatterjee *(S. N. Bose National Centre for Basic Sciences, Kolkata)*, Kavita Jain *(JNCASR, Bengaluru)*, Tridib Sadhu *(TIFR, Mumbai)*

Neuroscience, Data Science and Dynamics
7-10 February 2022 ♦ *Organizers* - Amit Apte *(ICTS-TIFR, Bengaluru)*, Neelima Gupte *(IIT Madras, Chennai)*, Ramakrishna Ramaswamy *(IIT Delhi)*

PROGRAM ACTIVITIES

LECTURE SERIES

DD KOSAMBI LECTURES

Ancient Mural Paintings of India
Benoy K Behl *(Adjunct Professor at National Institute of Advanced Studies)* ♦ 11 August 2022

INFOSYS-ICTS TURING LECTURES

An Alternative View on AI: Collaborative Learning, Incentives, Social Welfare, and Dynamics
Michael I. Jordan *(University of California, Berkeley, USA)* ♦ 4 July 2023

How Stable is the Earth's Climate
J. Srinivasan *(Divecha Centre for Climate Change, Indian Institute of Science, Bengaluru)* ♦ 1-3 March 2022

INFOSYS-ICTS CHANDRASEKHAR LECTURES

The Allure of Active Matter
Sriram Ramaswamy *(IISc, Bengaluru)* ♦ 6-8 November 2023

How Materials Can Learn by Themselves
Andrea J Liu *(University of Pennsylvania, Philadelphia, USA)* ♦ 21-23 August 2023

The Future of Cosmology
Joseph Silk *(The Institut d'Astrophysique de Paris, France and Johns Hopkins University, USA)* ♦ 1-2 May 2023

Multiple Phase Transitions in a System of Hard Core Rotors on a Lattice
Deepak Dhar *(IISER Pune)* ♦ 19-21 December 2022 |

Looking Into the Future of High-Energy Particle Physics
Gian Giudice *(CERN, Switzerland)* ♦ 21-23 November 2022

INFOSYS-ICTS RAMANUJAN LECTURES

Critical Phenomena Through the Lens of the Ising Model
Hugo Duminil-Copin *(Institut des Hautes Études Scientifiques, France & University of Geneva, Switzerland)* ♦ 9-13 January 2023

INFOSYS-ICTS STRING THEORY LECTURES

Symmetries in QFT and Their Relationship With Category Theory
Lakshya Bhardwaj *(Mathematical Institute, University of Oxford)* ♦ 10-12 October 2022

Supersymmetric Black Holes, the Superconformal Index, and Phases of AdS/CFT
Sameer Murthy *(King's College, London, UK)* ♦ 2-5 August 2022

DISTINGUISHED LECTURES

Exact Solution Of Decaying Turbulence
Alexander Migdal *(New York University, Abu Dhabi, UAE)* ♦ 19 December 2023

Duality in Condensed Matter Physics and Field Theory
Eduardo H Fradkin *(University of Illinois at Urbana-Champaign, USA)* ♦ 27 September 2023

Statistical Mechanics of Mutilated Sheets and Shells
David R. Nelson *(Harvard University, USA)* ♦ 18 August 2023

A Century after Heisenberg: Discovering the World of Simultaneous Measurements of Noncommuting Observables
Carlton M. Caves *(University of New Mexico, USA)* ♦ 19 July 2023

The History of Gravitational Lensing in Cosmology
Nick Kaiser *(Département de Physique, ENS Paris)* ♦ 10 May 2023

The Ubiquity of Logarithmically Correlated Fields and Their Extremes
Ofer Zeitouni *(Weizmann Institute of Science, Israel & New York University, USA)* ♦ 5 January 2023

Maxwell's Demon Goes Optical!
Swapan Chattopadhyay *(FNAL, USA & IISc, Bengaluru)* ♦ 15 November 2022

Controlling Activation of G Protein-Coupled Receptors for New Drugs to Relieve Pain, Give Pleasure, and Modulate Nerve Transmission
William A. Goddard III *(California Institute of Technology, USA)* ♦ 11 October 2022

A Material Quest: Building Technology with Atomic Layers (An Infosys Prize Lecture)
Arindam Ghosh *(IISc, Bengaluru)* ♦ 28 September 2022

FOUNDATION DAY LECTURE

Dimensions: 1,2,3,4...
Mahan Mj *(TIFR, Mumbai)* ♦ 13 December 2023 ♦ Chandrasekhar auditorium, ICTS-TIFR

The Edge of a Cell: A Living Fabric
Satyajit Mayor *(NCBS-TIFR, Bengaluru)* ♦ 13 December 2022 ♦ Chandrasekhar auditorium, ICTS-TIFR

ABDUS SALAM MEMORIAL LECTURES

The Future of the Indian Space Programme
S. Kiran Kumar *(Vikram Sarabhai Professor at ISRO and Member of the Space Commission, Govt of India)* ♦ 18 April 2023

TMC DISTINGUISHED LECTURES

On the Tensor Product of Representations of Classical Groups
Speaker - Dipendra Prasad *(IIT, Bombay)* ♦ Video release:3 August 2022 ♦ Interactive session: 3 August 2022

Asymmetry in Dynamics
Speaker - Amie Wilkinson *(University of Chicago, USA)* ♦ Video release: 21 June 2022 ♦ Interactive session: 14 July 2022

Finite Quotients of 3-Manifold Groups
Speaker - Melanie Matchett Wood *(Harvard University, USA)* ♦ Video release: 30 March 2022 ♦ Interactive session: 20 April 2022

CENTENNIAL TRIBUTE TO AMAL RAYCHAUDHURI

This is a special lecture series conducted as a centennial tribute to Amal Kumar Raychaudhuri. The lecture series provides a brief overview of topics relevant to current research on General Relativity.
Advanced General Relativity: A Centennial Tribute to Amal Kumar Raychaudhuri
Sunil Mukhi (Adjunct Professor, ICTS- TIFR, Bengaluru)
24, 27, 31 March, 3, 7, 10, 15, 17, 21, 24, 28 April 2023

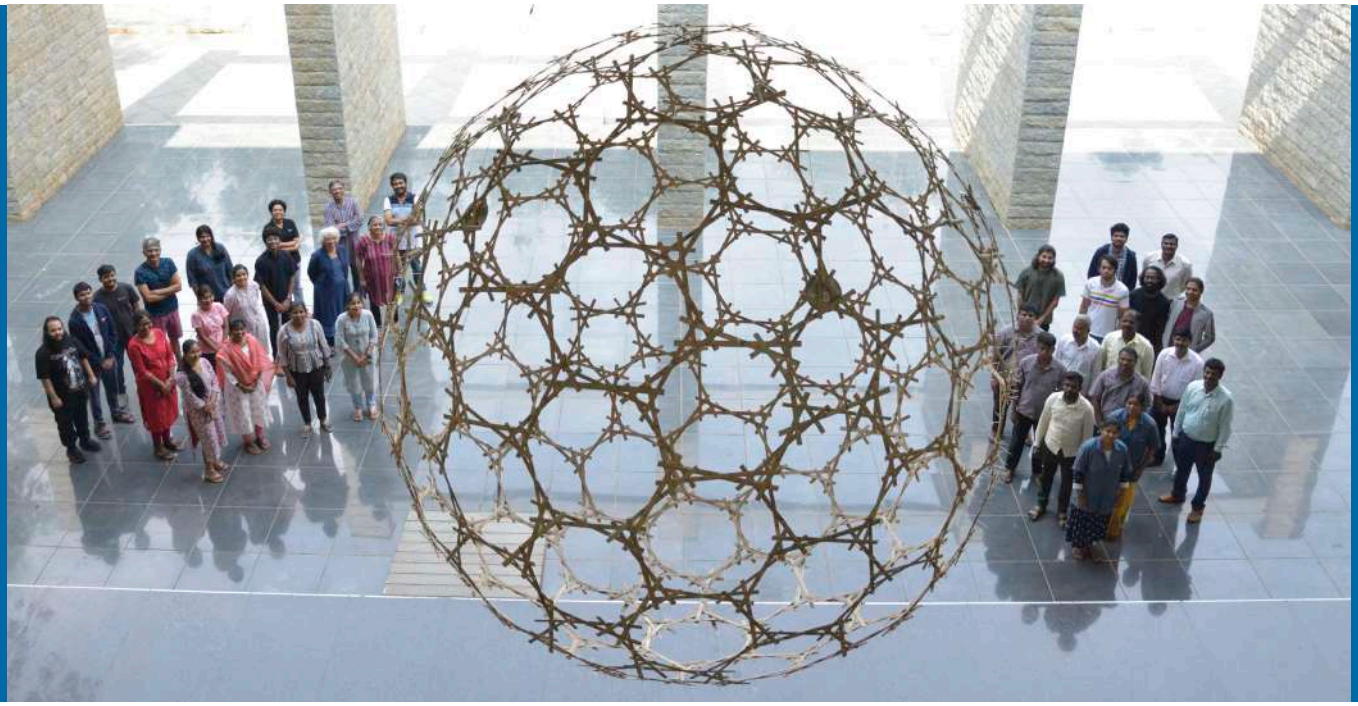
SPECIAL ICTS KOLMOGOROV SYMPOSIUM

On the occasion of A.N. Kolmogorov's 120th birth anniversary, a symposium was held on 25 April 2023. The symposium featured online talks by leading researchers in the fields where Kolmogorov had an impact in its early stages.
The speakers were Hao Wu (Tsinghua University), Samriddhi Sankar Ray (ICTS-TIFR), Prahladh Harsha (TIFR, Mumbai), Amit Apte (ICTS-TIFR, on lien at IISER Pune), Alison Etheridge (Oxford University), Riddhipratim Basu (ICTS-TIFR) and S.R.S. Varadhan (Courant Institute of Mathematical Sciences, NYU) and K.R. Parthasarathy (Indian Statistical Institute).

(Clockwise from top) Spenta Wadia, Joe Silk and Rajesh Gopakumar share a light moment. Silk delivered a Infosys-ICTS Chandrasekhar Lecture ◊ Andrea J. Liu during her Infosys-ICTS Chandrasekhar Lecture ◊ Mahan Mj delivers the ICTS Foundation Day Lecture ◊ Nick Kaiser during his Distinguished Lecture ◊ Michael I. Jordan delivers his Infosys-ICTS Turing Lecture ◊ Photo credit: S. Shantaraj

OUT REACH

@ICTS



OUTREACH

Science outreach plays a crucial role in bridging the gap between the scientific community and the general public. ICTS invests considerable time and resources in this engagement between scientific research and the broader community.

During the last two years, ICTS has continued to host the regular **Public Lectures**, **Vigyan Adda**, **Einstein Lectures** and the monthly **Kaapi With Kuriosity**. In early 2022, the in-person **ICTS-RRI Maths Circle** sessions, in collaboration with the Raman Research Institute, were started. These sessions will be conducted once every two weeks for Bengaluru students studying in grades 6-10. ICTS is also leading the pan-TIFR effort to seed Maths Circles for talented middle school students across the country. ICTS has conducted 41 online **Maths Circle India** sessions during January 2022 - December 2023.

The **School Outreach** initiative by ICTS aims to foster a scientific temper within children. The following programs are part of school outreach. The **JNP-ICTS Science Education Program** was introduced where an experienced team of teachers from Jawaharlal Nehru Planetarium conducts training sessions for teachers from rural districts of Karnataka. 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. The first interactive session was held on March 16, 2022, and there have been three sessions held during the duration of this report. **PRISM (Promise in Science and Mathematics)**, as part of the DAE iconic week to celebrate the Azadi ka Amrit Mahotsav, was organised. ICTS invited 75 students from government middle schools in north Bengaluru, along with 25 teachers. The event had two sessions - a hands-on maths circle session and a virtual tour of the astrophysical phenomena observed in large length scales. The session was held in Kannada. PRISM has been planned as an annual event of ICTS Outreach. During PRISM events, school students are invited to ICTS for various hands-on science and math demonstrations and lectures. Science kits were distributed to 47 government schools. Library kits have been distributed to 20 schools. There have been two teacher training sessions about science demonstrations using these kits. There is a plan to follow up on the usage of science kits and conduct a school-level competition

ICTS members during a school visit in Bengaluru. ◊ Photo credit: Roshini George

for students to come up with interesting science experiments and demonstrations.

A team from Centre for Creative Learning, IIT Gandhinagar, led an event of making a **Geodesic Dome** at ICTS, followed by talks on Enigma machines and other related science toys and machines on December 4, 2023.

A **science drawing competition** was held on campus during 2-10 November, 2023.

The **Connect India Residency**, an international program intended to foster experimentation in the arts in connection with fundamental science across the world, began at ICTS from April 16, 2023. Two selected artists, Elisa Storelli and Rohini Devashar, spent four weeks at ICTS, followed by three weeks at CERN. The Connect India Residency hopes to expose the artists to two unique scientific organisations and the fundamental research conducted there.

An exhibition, titled **Climate Chaos: We're Just Warming Up** was displayed at the J.N. Tata Planetarium in collaboration with Science Gallery Bangalore on March 11, 2023. The exhibition showed an informed, starkly visual impression of what the climate crisis will mean for our lives in urban Indian megacities like Bangalore, Mumbai, Delhi, Chennai and Kolkata. The exhibition featured interactive demonstrations and videos, like showing the link between carbon dioxide emissions and sea-level rise, the increase in frequency of extreme climate events due to a shifting global mean and a live demonstration of the discomfort of humid heat vs dry heat (a particularly coastal problem). The exhibition also featured AI-generated speculative imagery of future scenarios of Indian cities, with and without climate intervention. Finally, the exhibition ended with "The Hope", demarcating steps and pointers for individuals, to build up consciousness about the effects of the climate crisis on every aspect of our lives and livelihoods.

On January 24, 2023, science writer Ananyo Bhattacharya spoke about some of John von Neumann's incredible mathematical ideas, demonstrating why his legacy is omnipresent in our lives today. Bhattacharya is the author of the book *The Man from the Future: The Visionary Ideas of John von Neumann*. The talk and interaction was part of the **Meet the Author** series.

Kōlam, a Western Perspective, was organised on February 13, 2023. The event consisted of a photography exhibition, an introductory talk by Claudia Silva (a professional photographer and videographer), about kōlam from various points of view: audiovisual, anthropological, educational, ephemeral art, women's traditions and ethno-mathematical aspects. There was a live performance by Jayanthi Murugesh, a kōlam artist from South India, and a kōlam workshop.

On the occasion of Independence Day and as part of the Har Ghar Tiranga programme, a special event called **Quiz Time** for the TIFR community in Bengaluru was held on August 15, 2022 at NCBS Bengaluru. The ICTS Outreach team was part of the organization team.

The film "**Secrets of the Surface: The Mathematical Vision of Maryam Mirzakhani**" was screened at ICTS on March 9, 2022, on the occasion of International Women's Day. The TIFR Committee on Gender Harmony screened the film across all TIFR Centres, throughout the week starting from March 7.

An online panel discussion titled, **Bengaluru: The Astronomy City**, was organised with premier astronomy organisations in Bengaluru on February 27, 2022.

ICTS can be found across social media platforms. The **ICTS Blog** on the website has regular features on the latest scientific developments. In addition to LinkedIn, Twitter, Facebook, and Instagram accounts, ICTS now has a WhatsApp channel with close to 1,000 followers.

PUBLIC LECTURES

On Quarks and Turbulence
David Tong *(University of Cambridge, UK)* ♦ 20 December 2023 ♦ Chandrasekhar Auditorium, ICTS, Bengaluru

VIGYAN ADDA LECTURES

Some Tales of Universality from the World of Probability
Riddhipratim Basu *(ICTS-TIFR, Bengaluru)* ♦ 13 July 2023 ♦ Online talk

Dynamics of Quantum Entanglement
Sthitadhi Roy *(ICTS-TIFR, Bengaluru)* ♦ 02 February 2023 ♦ Online talk

Branching Random Walks: Two Conjectures and a Theorem
Parthanil Roy *(ISI, Bengaluru)* ♦ 5 June 2022 ♦ Online talk

KAAPI WITH KURIOSITY LECTURES

Marine Living Resources: A Blue Future
Sherine Sonia Cubelio *(Centre for Marine Living Resources & Ecology, Kochi)* ♦ 10 December 2023 ♦ J.N. Planetarium, Bengaluru

High Fidelity Sound Reproduction: Practical Aspects for the DIYer
Reji Philip *(Raman Research Institute, Bengaluru)* ♦ 9 November 2023 ♦ J.N. Planetarium, Bengaluru

The Extreme Physics of Zombie Stars
Nils Andersson *(University of Southampton, UK)* ♦ 08 October 2023 ♦ J.N. Planetarium, Bengaluru

The Imaging Story: Black Holes to MRI
Rajaram Nityananda *(ICTS-TIFR, Bengaluru)* ♦ 17 September 2023 ♦ J.N. Planetarium, Bengaluru

The Odyssey of Liquid Crystals, From Carrot to Flat Screen
Michel Mitov *(French National Centre for Scientific Research)* ♦ 13 August 2023 ♦ J.N. Planetarium, Bengaluru

Conway's Tangles
Michael Lacey *(Georgia Institute of Technology, USA)* ♦ 2 July 2023 ♦ J.N. Planetarium, Bengaluru

Is Clay a Solid or a Liquid?
Ranjini Bandyopadhyay *(Raman Research Institute, Bengaluru)* ♦ 17 June 2023 ♦ J.N. Planetarium, Bengaluru

What's the Matter with Primordial Black Holes?
Ravi K. Sheth *(University of Pennsylvania, USA)* ♦ 14 May 2023 ♦ J.N. Planetarium, Bengaluru

Opportunities for Breakthrough Science With Lunar Exploration
Jan Harms *(Gran Sasso Science Institute, Italy)* ♦ 16 April 2023 ♦ J.N. Planetarium, Bengaluru

What is Natural Selection (And Why it is Not 'Survival of the Fittest')?
Amitabh Joshi *(JNCASR, Bengaluru)* ♦ 26 March 2023 ♦ J.N. Planetarium, Bengaluru

Ways of Computing
Jaikumar Radhakrishnan (*ICTS-TIFR, Bengaluru)* ♦ 26 February 2023 ♦ J.N. Planetarium, Bengaluru

Black Holes, Quantum Mechanics and the Reversibility of Time
Suvrat Raju *(ICTS-TIFR, Bengaluru)* ♦ 14 January 2023 ♦ J.N. Planetarium, Bengaluru

Chance and Chaos: How to Predict the Unpredictable
Jens Marklof *(University of Bristol, UK)* ♦ 11 December 2022 ♦ J.N. Planetarium

Beaming into Matter and Life with Particles and Light
Swapan Chattopadhyay *(Fermi National Accelerator Laboratory, USA)* ♦ 27 November 2022 ♦ J.N. Planetarium

History of Walking Robots
Shishir N.Y. Kolathaya *(IISc, Bengaluru)* ♦ 30 October 2022 ♦ J.N. Planetarium

Finding Our Place Among Stars
Sarita Vig *(Indian Institute of Space Science and Technology, Thiruvananthapuram)* ♦ 11 September 2022 ♦ J.N. Planetarium

Simulations: Why, What and How?

Parthanil Roy *(ISI, Bengaluru)* ♦ 28 August 2022 ♦ JN Tata Planetarium

Novel Phases of Matter Near Absolute Zero Temperature
Sanjukta Roy *(Raman Research Institute, Bengaluru)* ♦ 31 July 2022 ♦ JN Tata Planetarium

Greening of Bangalore
Vijay Thiruvady *(Bangalore Environment Trust)* ♦ 26 June 2022 ♦ JN Tata Planetarium

Coping with Salt and Drought: How Crop Plants Survive
M.K. Mathew *(NCBS, Bengaluru)* ♦ 8 May 2022 ♦ JN Tata Planetarium

Perspectives in Math and Art
Supurna Sinha *(Raman Research Institute, Bengaluru)* ♦ 24 April 2022 ♦ JN Tata Planetarium

Tilings
Mahuya Datta *(Indian Statistical Institute, Kolkata)* ♦ 27 March 2022

Taming the Transient Sky
Varun Bhalerao *(IIT Bombay)* ♦ 28 February 2022

The Story of Climate Change
R Shankar *(The Institute of Mathematical Sciences, Chennai)* ♦ 9 January 2022

EINSTEIN LECTURES

The Map of a Cat and Feynman's Other Intersections with Biology: Their Relevance for Today
Shashi Thutupalli *(ICTS and NCBS, Bengaluru)* ♦ 26 November 2023 ♦ Kiru Rangamandira, Mysore

Astronomy's New Frontiers
Ajith Parameswaran *(ICTS-TIFR, Bengaluru)* ♦ 6 October 2022 ♦ St Mary's Convent Girls HSS, Ernakulam

In Search of Brain Plasticity
Kshipra Gurunandan *(University of Cambridge, UK)* ♦ 5 September 2022 ♦ School of Sciences, Jain University, Bengaluru

DD KOSAMBI LECTURES

Ancient Mural Paintings of India
Benoy K Behl *(Adjunct Professor at National Institute of Advanced Studies)* ♦ **11 August 2022**

MATHS CIRCLE INDIA SESSIONS

Session 47
Conducted by: Mainak Ghosh, Chetan Balwe ♦ **Interactive session**: 3 November 2023

Session 46
Conducted by: Mainak Ghosh, Vaibhav Vaish, Chetan Balwe ♦ **Interactive session**: 20 October 2023

Session 45
Conducted by: Vaibhav Vaish, Jotsaroop Kaur, Mainak Ghosh, Chetan Balwe ♦ **Interactive session**: 6 October 2023

Session 44
Conducted by: Vaibhav Vaish, Jotsaroop Kaur, Mainak Ghosh, Chetan Balwe ♦ **Interactive session**: 22 September 2023

Session 43
Conducted by: Arghya Chakraborty, Malhar Managoli, Eeshan Modak, Hariharan Narayanan, Piyush Srivastava ♦ **Interactive session**: 8 September 2023

Session 42
Conducted by: Ashutosh Shankar, Arghya Chakraborty, Malhar Managoli, Eeshan Modak, Hariharan Narayanan, Piyush Srivastava ♦ **Interactive session**: 25 August 2023

Session 41
Conducted by: Arghya Chakraborty, Malhar Managoli, Eeshan Modak, Hariharan Narayanan, Piyush Srivastava ♦ **Interactive session**: 11 August 2023

Session 40
Conducted by: Arghya Chakraborty, Malhar Managoli, Eeshan Modak, Hariharan Narayanan, Piyush Srivastava ♦ **Interactive session**: 21 July 2023

Session 39
Conducted by: Ajit Bhand ♦ **Interactive session**:7 July 2023

Session 38
Conducted by: Pankaj Kapari, Surjeet Singh Choudhary, Atreyee Bhattacharya, Ajit Bhand ♦ **Interactive session**: 23 June 2023

Session 37
Conducted by: Pankaj Kapari, Surjeet Singh Choudhary, Atreyee Bhattacharya, Ajit Bhand ♦ **Interactive session**: 10 June 2023

Session 36
Conducted by: Krishna Menon, Sadhanandha B, Writika Sarkar, Priyavrat Deshpande ♦ **Interactive session**: 19 May 2023

Session 35
Conducted by: Krishna Menon, Sadhanandha B, Writika Sarkar, Priyavrat Deshpande ♦ **Interactive session**: 5 May 2023

Session 34
Conducted by: Krishna Menon, Sadhanandha B, Writika Sarkar, Aditya Karnataki, Priyavrat Deshpande ♦ **Interactive session**: 21 April 2023

Session 33
Conducted by: Krishna Menon, Sadhanandha B, Writika Sarkar, Priyavrat Deshpande ♦ **Interactive session**: 7 April 2023

Session 32
Conducted by: Krishanu Maulik, Mridul Nandi, Mrinal Kanti Das, Parthanil Roy ♦ **Interactive session**: 10 March 2023

Session 31
Conducted by: Krishanu Maulik, Mridul Nandi, Mrinal Kanti Das, Parthanil Roy ♦ **Interactive session**: 17 February 2023

Session 30
Conducted by: Krishanu Maulik, Mridul Nandi, Mrinal Kanti Das, Parthanil Roy ♦ **Interactive session**: 3 February 2023

Session 29
Conducted by: Krishanu Maulik, Mridul Nandi, Mrinal Kanti Das, Parthanil Roy ♦ **Interactive session**: 13 January 2023

Session 28
Conducted by: Divyansh Agrawal, Arnab Chowdhury, Aditya Thorat, Aadi Bhure, Viswanathan S, Joseph Samuel, Atul Shekhar ♦ **Interactive session**: 09 December 2022

Session 27
Conducted by: Divyansh Agrawal, Arnab Chowdhury, Aditya Thorat, Aadi Bhure, Joseph Samuel, Atul Shekhar ♦ **Interactive session**: 25 November 2022

Session 26
Conducted by: Divyansh Agrawal, Arnab Chowdhury, Aditya Thorat, Joseph Samuel, Atul Shekhar ♦ **Interactive session**: 11 November 2022

Session 25
Conducted by: Divyansh Agrawal, Arnab Chowdhury, Aditya Thorat, Joseph Samuel, Atul Shekhar ♦ I**nteractive session**: 28 October 2022

Session 24
Conducted by: Kedar S Damle, Amol Dighe, Vikram Tripathi, Dibya Sankar Chattopadhyay, Vineeth Krishna Talasila, Md Zahid Ansari, Nisheeta Desai ♦ **Interactive session**: 14 October 2022

Session 23
Conducted by: Kedar S Damle, Amol Dighe, Vikram Tripathi, Dibya Sankar Chattopadhyay, Vineeth Krishna Talasila, Md Zahid Ansari, Nisheeta Desai ♦ **Interactive session**: 30 September 2022

Session 22
Conducted by: Kedar S Damle, Amol Dighe, Vikram Tripathi, Dibya Sankar Chattopadhyay, Vineeth Krishna Talasila, Md Zahid Ansari, Nisheeta Desai ♦ **Interactive session**: 16 September 2022

Session 21
Conducted by: Kedar S Damle, Amol Dighe, Vikram Tripathi, Dibya Sankar Chattopadhyay, Vineeth Krishna Talasila, Md Zahid Ansari, Nisheeta Desai ♦ **Interactive session**: 2 September 2022

Session 20
Conducted by: Prahlad Vaidyanathan, Kartick Adhikary, Rahul Garg, Sannidhi A. S., Monika, Pankaj Kapdi, Ajit Bhand ♦ **Interactive Session**: 19 August 2022

Session 19
Conducted by: Prahlad Vaidyanathan, Kartick Adhikary, Rahul Garg, Sannidhi A. S., Monika, Pankaj Kapdi, Ajit Bhand ♦ **Interactive Session:** 5 August 2022

Session 18
Conducted by: Prahlad Vaidyanathan, Kartick Adhikary, Rahul Garg, Sannidhi A. S., Monika, Pankaj Kapdi, Ajit Bhand ♦ **Interactive Session:** 22 July 2022

Session 17
Conducted by: Prahlad Vaidyanathan, Kartick Adhikary, Rahul Garg, Sannidhi A. S., Monika, Pankaj Kapdi, Ajit Bhand ♦ **Interactive Session:** 8 July 2022

Session 16
Conducted by: Eeshan Modak, Varun Narayanan, Varun Ramanathan, Kedar Damle, Piyush Srivastava ♦ **Interactive Session:** 24 June 2022

Session 15
Conducted by: Sushant Vijayan, Neha, Ashutosh Shankar, Sayantan Chakraborty, Piyush Srivastava ♦ **Interactive Session:** 3 June 2022

Session 14
Conducted by: Shubhada Agrawal, Neha, Pranshu Gaba, Agniv Bandyopadhyay, Varun Ramanathan, Pranoy Varma, Ashutosh Shankar, Sayantan Chakraborty, Piyush Srivastava ♦ **Interactive Session:** 20 May 2022

Session 13
Conducted by: Shubhada Agrawal, Soumyajit Pyne, Eeshan Modak, Varun Ramanathan, Pranoy Varma, Ashutosh Shankar, Sayantan Chakraborty, Piyush Srivastava ♦ **Interactive Session:** 29 April 2022

Session 12
Conducted by: Eeshan vikram Modak, Sayantan Chakraborty, Neha Sangwan, Soumyajit Pyne, Vidya Sagar, Piyush Srivastava ♦ **Interactive session**: 15 April 2022

Session 11
Conducted by: Shane D'Mello, Jotsaroop Kaur, Vaibhav Vaish, Bishwadeep Karmakar ♦ **Interactive session**: 25 March 2022

Session 10
Conducted by: Shane D'Mello, Chetan Balwe, Jotsaroop Kaur, Vaibhav Vaish, Bishwadeep Karmakar ♦ **Interactive session**: 4 March 2022

Session 9
Conducted by: Vaibhav Vaish, Jotsaroop Kaur, Chetan Balwe, Shane D'mello, Neeraja Sahasrabudhe ♦ **Interactive session**: 18 February 2022

Session 8
Conducted by: Jotsaroop Kaur, Chetan Balwe, Vaibhav Vaish, Neeraja Sahasrabudhe ♦ **Interactive session**: 4 February 2022

Session 7
Conducted by: Ashutosh Roy Choudhury, Jaimin Patel, Roktim Mascharak, Amitava Bhattacharya ♦ **Interactive session**: 21 January 2022

Session 6
Conducted by: Ashutosh Roy Choudhury, Arnab Roy, Jaimin Patel, Amitava Bhattacharya ♦ **Interactive session**: 7 January 2022

MATHS CIRCLE INDIA SPECIAL EVENT

MCI Special talk: Divisibility tests and recurring decimals
Conducted by: Apoorva Khare (Indian Institute of Science, Bengaluru) ♦ **Interactive session**: 17 November 2023 ♦ Online

MathSpark
Conducfed by: Kaushik Basu, Joseph Samuel ♦ **Interactive session**: 22 July 2023 ♦ Foyer area of Chandrasekhar Auditorium, ICTS-TIFR

ICTS-RRI MATHS CIRCLE

Session 19
Conducted by: Divakaran D ♦ **Interactive session:** 16 December 2023 ♦ Raman Research Institute, Bengaluru

Session 18
Conducted by: Apoorva, Khushi, Nishanth, Manu, Aditya and Kshitij ♦ **Interactive session:** 25 November 2023 ♦ Raman Research Institute, Bengaluru

Session 17
Conducted by: Supurna Sinha, Joseph Samuel ♦ **Interactive session: 28 October 2023** ♦ Raman Research Institute, Bengaluru

Session 16
Conducted by: Aditya Subramanian, Nishanth Shetty,

Apoorva Dinesh Singh, Manu M Bhat, Parthanil Roy ♦ **Interactive session:** 14 October 2023 ♦ ICTS

Session 15
Conducted by: Kiran Estake, Kshitij Sharma, Parthanil Roy ♦ **Interactive session:** 09 September 2023 ♦ Raman Research Institute, Bengaluru

Session 14
Conducted by: Kiran Estake, Kshitij Sharma, Sachchidanand Prasad, Supurna Sinha, Joseph Samuel, Parthanil Roy ♦ **Interactive session:** 26 August 2023 ♦ Raman Research Institute, Bengaluru

Session 13
Conducted by: Kiran Estake, Kshitij Sharma, Sachchidanand Prasad, Supurna Sinha, Joseph Samuel, Parthanil Roy ♦ **Interactive session:** 12 August 2023 ♦ Raman Research Institute, Bengaluru

Session 11
Conducted by: Ajit Bhand ♦ **Interactive session:** 7 July 2023 ♦ Raman Research Institute, Bengaluru

Session 10
Conducted by: Kshitij Vijay, Kiran Estake, Harshitha K S, Kshitij Gajjar, Jaikumar Radhakrishnan, Supurna Sinha, Joseph Samuel ♦ **Interactive session:** 24 June 2023 ♦ Raman Research Institute, Bengaluru

Session 9
Conducted by: Kiran Estake, Kshitij Vijay, Supurna Sinha, Joseph Samuel ♦ **Interactive session:** 10 June 2023 ♦ Raman Research Institute, Bengaluru

Session 8
Conducted by: Supurna Sinha, Joseph Samuel ♦ **Interactive session:** 27 May 2023 ♦ Raman Research Institute, Bengaluru

Session 7
Conducted by: Kiran Estake, Parthanil Roy, Supurna Sinha, Joseph Samuel, Sachchidanand Prasad ♦ **Interactive session:** 13 May 2023 ♦ Raman Research Institute, Bengaluru

Session 6
Conducted by: Kiran Estake, Kshitij Sharma, Sachchidanand Prasad, Supurna Sinha, Joseph Samuel ♦ **Interactive session:** 8 April 2023 ♦ Raman Research Institute, Bengaluru

Session 5
Conducted by: Kiran Estake, Kshitij Sharma, Sachchidanand Prasad, Supurna Sinha, Parthanil Roy, Joseph Samuel ♦ **Interactive session:** 25 March 2023 ♦ Raman Research Institute, Bengaluru

Session 4
Conducted by: Kiran Estake, Kshitij Sharma, Sachchidanand Prasad, Lakshya Nahar, Supurna Sinha, Joseph Samuel ♦ **Interactive session:** 11 March 2023 ♦ Raman Research Institute, Bengaluru

Session 3
Conducted by: Kiran Estake, Kshitij Sharma, Supurna Sinha, Joseph Samuel ♦ **Interactive session:** 25 February 2023 ♦ Raman Research Institute, Bengaluru

Session 2
Conducted by: Kiran Estake, Kshitij Sharma, Muhammed Irshad, Manish Jain, Joseph Samuel ♦ **Interactive session:** 11 February 2023 ♦ Raman Research Institute, Bengaluru

Session 1
Conducted by: Kiran Estake, Kshitij Sharma, Jitendra Kethepalli, Sachchidanand Prasad, Joseph Samuel ♦ **Interactive session:** 28 January 2023 ♦ Raman Research Institute, Bengaluru

PRISM SESSIONS

PRISM 5: A Mathematics Adventure for Young Minds: Srinivasa Ramanujan's Birthday Anniversary ♦ Kaushik Basu *(University of California (Berkeley)* ♦ 22 December 2023 ♦ ICTS-TIFR, Bengaluru

PRISM 4: Magical STEM ♦ Manish Jain, Jyothi Krishnan and Ashutosh Bhakuni *(Centre for Creative Learning, IIT Gandhinagar)* ♦ 2 December 2023 ♦ ICTS-TIFR, Bengaluru

PRISM 3: Playground Science - the Physics of Soft Materials ♦ Shubha Tewari *(University of Massachusetts Amherst, USA)* ♦ 10 August 2023 ♦ ICTS-TIFR, Bengaluru

PRISM 2: A Hands-on Exploration of Everyday Physical Phenomena ♦ Kaushik Basu *(University of California, Berkeley, USA)* ♦ 15 December 2022 ♦ ICTS-TIFR, Bengaluru

PRISM 1: Srikanth Pai and Pallavi Bhat *(ICTS-TIFR, Bengaluru)* ♦ 26 August 2022 ♦ ICTS-TIFR, Bengaluru

(Clockwise from top) David Tong during his Public Lecture ◊ An ICTS-RRI Maths Circle session held at RRI, Bengaluru ◊ ICTS members during a school visit ◊ Ravi K. Sheth delivers his Kaapi with Kuriosity lecture ◊ Another ICTS-RRI Maths Circle session ◊ Photo credit: S. Shantaraj/AS Sumukh/Roshini George/Anupam Ghosh

GRADUATE PROGRAMS AND TRAINING

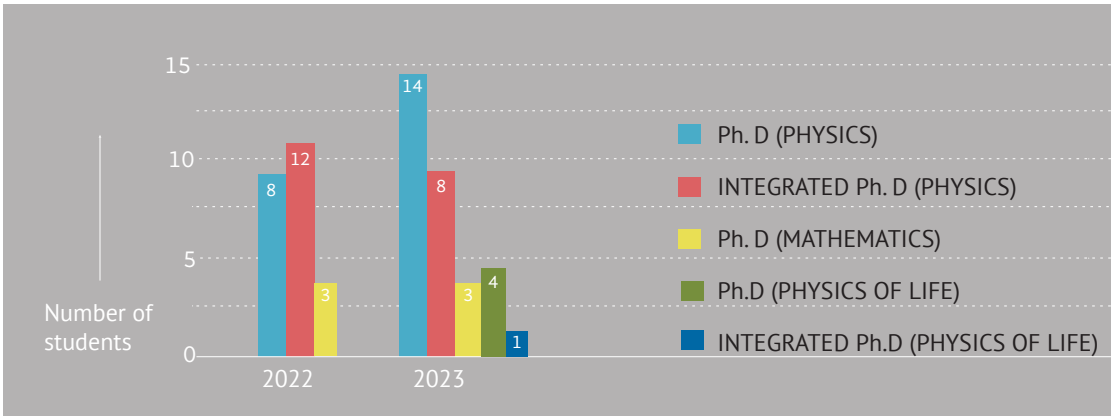
@ICTS

GRADUATE PROGRAMS

The ICTS graduate program offers rigorous training to aspiring graduate students, preparing them extensively for future research endeavors. During 2022-2023, 53 students joined the ICTS graduate program – 22 in physics, 20 in integrated physics, 6 in mathematics, and 5 in the newly introduced physics of life program. 17 postdoctoral fellows joined ICTS during 2022-2023.

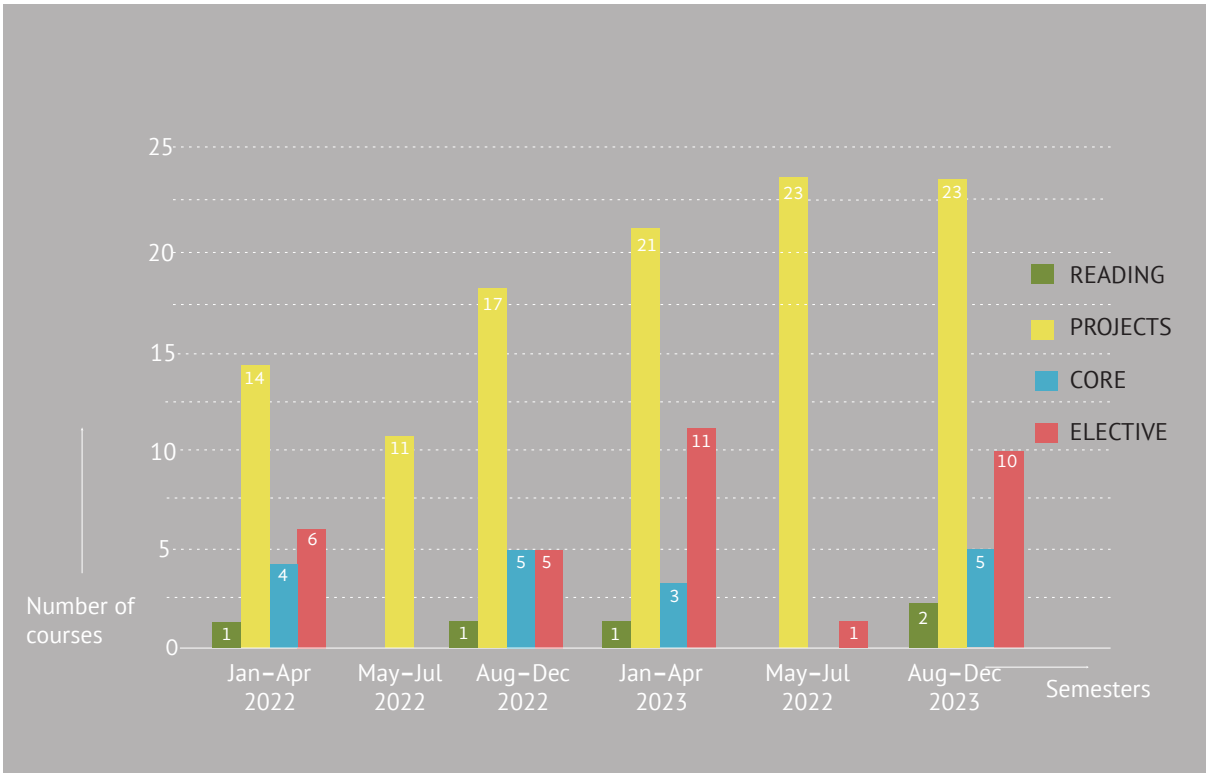
NUMBER OF STUDENTS JOINED PER YEAR

YEAR	PHYSICS		MATHS	PHYSICS OF LIFE		TOTAL
	Ph.D.	Integrated Ph.D.	Ph.D.	Ph.D.	Integrated Ph.D.	
2022	8	12	3	-	-	23
2023	14	8	3	4	1	30
	22	20	6	4	1	53



CORE AND ELECTIVE COURSE

SEMESTER	CORE	ELECTIVE	TOTAL
Jan-Apr 2022	4	6	10
May – Jul 2022	-	-	0
Aug-Dec 2022	5	5	10
Jan – Apr 2023	3	11	14
May – Jul 2023	-	1	1
Aug-Dec 2023	5	10	15
			50

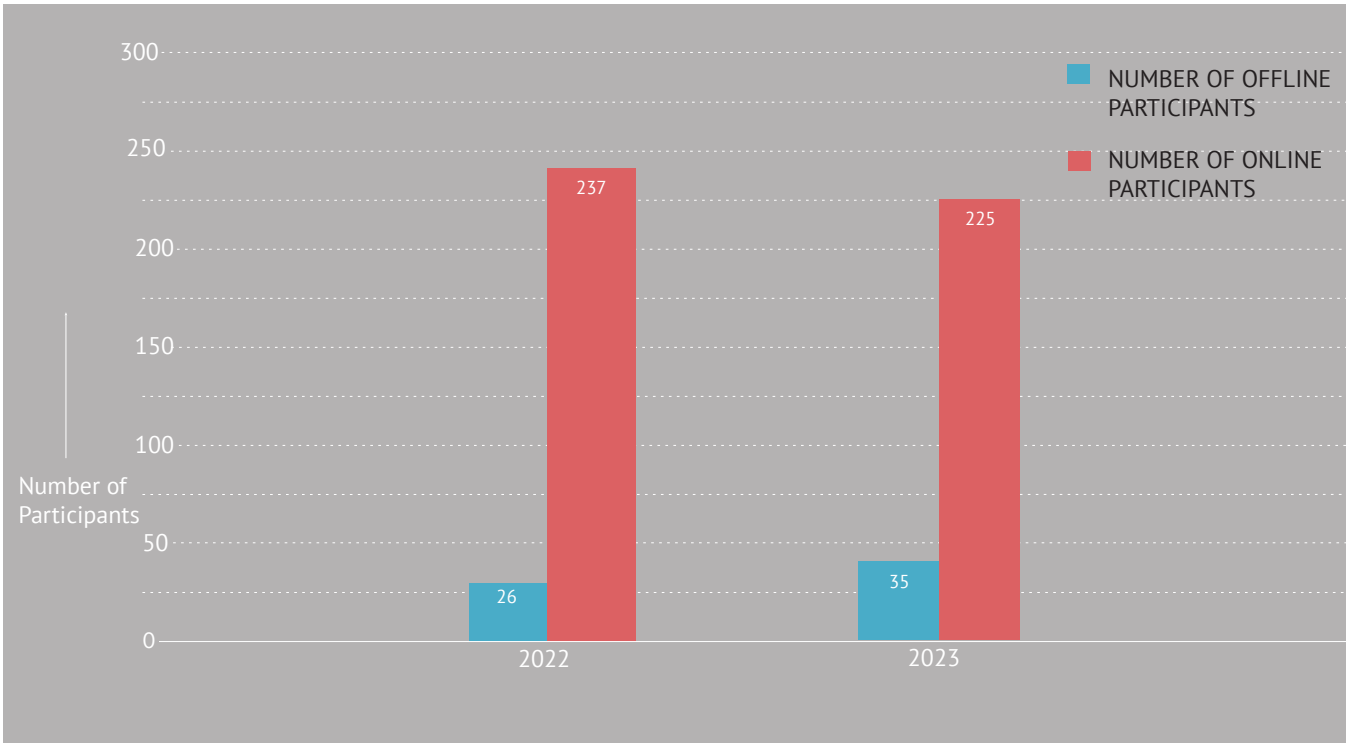


READING AND PROJECT COURSE

SEMESTER	READING	PROJECTS	TOTAL
Jan–Apr 2022	1	14	15
May–Jul 2022	-	11	11
Aug–Dec 2022	1	17	18
Jan–Apr 2023	1	21	22
May–Jul 2023	-	23	23
Aug–Dec 2023	2	23	25
TOTAL	5	109	114

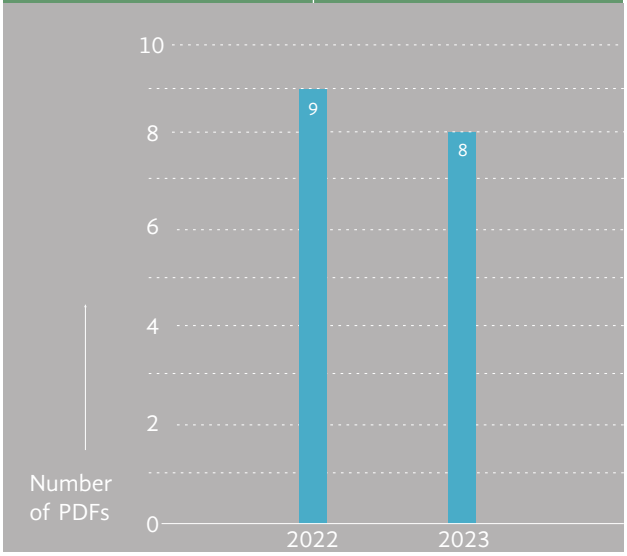
SUMMER COURSE

YEAR	NUMBER OF COURSES	NUMBER OF OFFLINE PARTICIPANTS	NUMBER OF ONLINE PARTICIPANTS	TOTAL
2022	1	26	237	263
2023	1	35	225	260
TOTAL	1	61	462	523



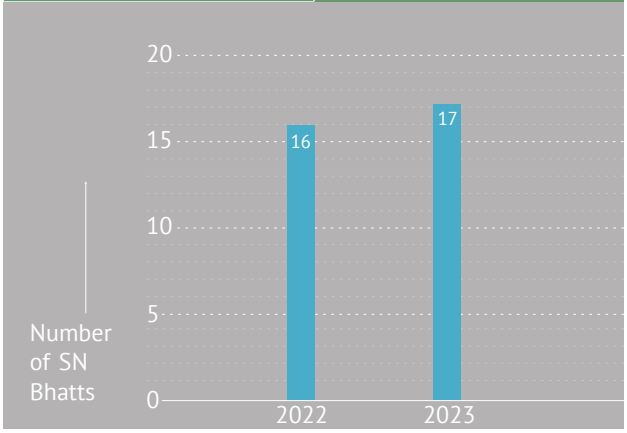
POST DOCTORAL FELLOWS

YEAR	PDFs
2022	9
2023	8
TOTAL	17



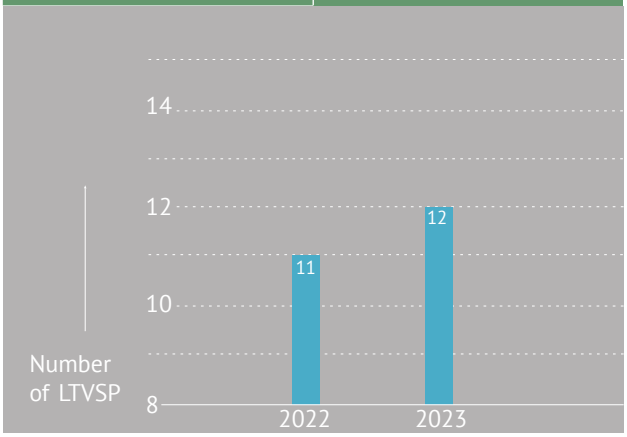
S. N. BHATT MEMORIAL FELLOWSHIP

YEAR	PDFs
2022	16
2023	17
TOTAL	33



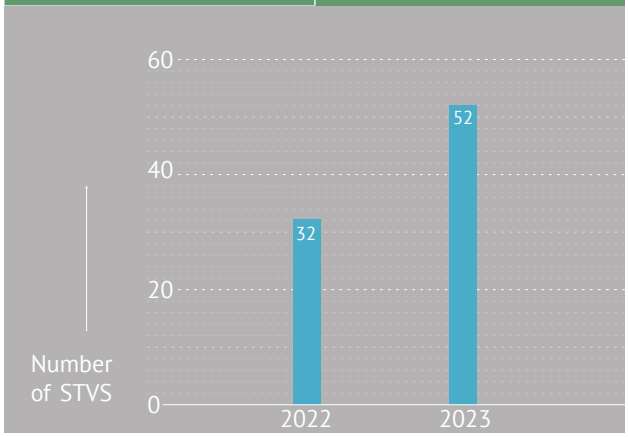
LONG TERM VISITING PROGRAM (LTVSP)

YEAR	PDFs
2022	11
2023	12
TOTAL	23



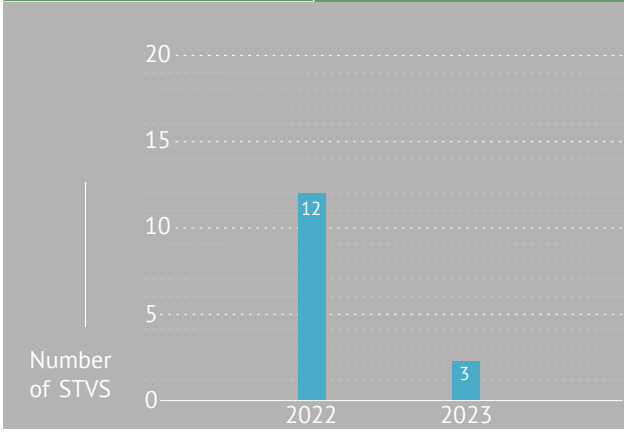
SHORT TERM VISITING STUDENTS (STVS)

YEAR	PDFs
2022	32
2023	52
TOTAL	84



LONG TERM VISITING STUDENTS (LTVS)

YEAR	PDFs
2022	12
2023	3
TOTAL	15



SEMINARS AND COLLOQUIA

The following is the complete list of seminars and colloquia held on the ICTS campus, online, and in the hybrid mode during 2022-2023.

Tricritical Phenomena in the Blume-Capel Model.
Trishen Gunaratnam *(University of Geneva)* ♦ 4 December 2023

Interface Evolution of Fluids at Nanoscale: Zooming in on Droplets
Sreehari Perumanath *(University of Warwick, UK)* ♦ 1 December 2023

The Dynamics of High-diversity Ecosystems: Insights from a Complex Systems' Approach
Thibaut Arnoulx de Pirey *(Technion, Israel)* ♦ 30 November 2023

Breakdown of Einstein's Gravity
Puskar Mondal *(Harvard University, USA)* ♦ 30 November 2023

Tauberian Theorems and High Energy Modular Bootstrap
Sridip Pal *(Caltech, USA)* ♦ 29 November 2023

On Some Aspects of Dijkgraaf-Witten Theory for Finite 2-groups
Srikanth Pai B *(ICTS-TIFR, Bengaluru)* ♦ 29 November 2023

It's About Time (Domain)! - The landscape of Stellar and Compact-Object Mergers Through a Time-Domain Lens
Viraj Karambelkar *(Caltech, USA)* ♦ 29 November 2023

Resource-efficient Computational Models for Code-switched Speech and Text
Preethi Jyothi *(IIT Bombay, Mumbai)* ♦ 28 November 2023

Testing Theories of Gravity with Gravitational Wave Observations
Akash Kumar Mishra *(ICTS-TIFR, Bengaluru)* ♦ 28 November 2023

D=2 strings, α'-corrections, and the Black Hole Singularity
Barton Zwiebach *(Massachusetts Institute of Technology, USA)* ♦ 22 November 2023

Quantum Sensing and Cooling in the Modern Era: Towards Resolving Quantized Energy Exchanges at the Level of a Single Graviton
Sreenath Kizhakkumpurath Manikandan *(Stockholm University and KTH Royal Institute of Technology, Sweden)* ♦ 17 November 2023

Implications of Inviscid Hydrodynamics and its Variants for Turbulence and Statistical Physics
Sugan Durai Murugan *(ICTS-TIFR, Bengaluru)* ♦ 17 November 2023

Controlling Quantum Systems and Building Quantum Computers
C. M. Chandrasekhar *(Indian Institute of Science, Bengaluru)* ♦ 16 November 2023

Rethinking Recombination: Primordial Magnetic Fields and their Implications for the Hubble Tension
Jonathan Schiff *(University of California, Santa Barbara , USA)* ♦ 9 November 2023

Electrically Tunable Magnetism in Van der Waals Heterostructures
Shubhayu Chatterjee *(Carnegie Mellon University, USA)* ♦ 8 November 2023

Fast Radio Burst Localisation and Followup with CHIME/FRB and uGMRT
Arvind Balasubramanian *(TIFR, Mumbai)* ♦ 3 November 2023

The Relaxation of Collision-less and Weakly Collisional Many-body Systems with Long Range Interactions
Uddipan Banik *(Princeton University, USA)* ♦ 2 November 2023

QCD Worldsheet Axion and S-matrix Bootstrap
Adwait Gaikwad *(Tel-Aviv University, Israel)* ♦ 1 November 2023

Doubly Regularized Entropic Wasserstein Barycenters
Lénaïc Chizat *(École Polytechnique Fédérale de Lausanne)* ♦ 31 October 2023

Emanant Symmetries
Nathan Seiberg *(IAS, Princeton, USA)* ♦ 30 October 2023

Persistence of Heavy-tailed Sample Averages
Ayan Bhattacharya *(IIT Bombay, Mumbai)* ♦ 30 October 2023

Compactified Hyperboloidal Evolution in Numerical Relativity
Shalabh Gautam *(ICTS-TIFR, Bengaluru)* ♦ 30 October 2023

Almost Sharp Lower Bound for the Nodal Volume of Harmonic Functions
Lakshmi Priya M.E. *(Tel Aviv University, Israel)* ♦ 30 October 2023

Frictionless Flow with Magnetic Confinement: When Fluids and Magnetism Join Hands
Arvind Arun Dev *(Cornell University, USA)* ♦ 20 October 2023

On Gauge-String Dualities and String Amplitudes
Pronobesh Maity *(ICTS-TIFR, Bengaluru)* ♦ 19 October 2023

Traffic Rules in Neurons
Sandhya Koushika *(DBS-TIFR, Mumbai)* ♦ 19 October 2023

Petz Recovery from Subsystems in Conformal Field Theory
Shreya Vardhan *(Stanford University, USA)* ♦ 18 October 2023

The Origin for WNL Stars: Impact on Ionizing Photon Budgets
Arpita Roy *(Scuola Normale Superiore, Italy)* | 12 October 2023

Constructing a Local AdS Holographic Dual from the ERG of a CFT
Pavan Dharanipragada *(The Institute of Mathematical Sciences, Chennai)* ♦ 11 October 2023

Effective General Relativistic Description of Jamming in Granular Matter
Parthasarathi Majumdar *(Indian Association for the Cultivation of Science, Kolkata)* ♦ 11 October 2023

Strong Lensing of Gravitational Waves and the Tests of General Relativity
Srashti Goyal *(ICTS-TIFR, Bengaluru)* ♦ 11 October 2023

Plane Rational Curves with an M-Fold Point
Anantadulal Paul *(ICTS-TIFR, Bengaluru)* ♦ 9 October 2023

Magnetic Instabilities and Dynamics in Compact Stars
Prasanta Bera *(Open University of Israel)* ♦ 5 October 2023

Quantum Pseudoentanglement
Soumik Ghosh *(University of Chicago, USA)* ♦ 5 October 2023

Shallow-water Wave Models and Ocean-Depth Measurement
Manisha Goyal *(ICTS-TIFR, Bengaluru)* ♦ 5 October 2023

Thermal One-point Functions in Holography and Large N-Models
Justin David *(Indian Institute of Science, Bengaluru)* ♦ 4 October 2023

Deconvolving Discrimination to Degender Physics Practice:The Way Forward & the Need for an Intersectional Lens
Prajval Shastri *(RRI, Bengaluru)* ♦ 27 September 2023

The Free Energy of the Large-N Fermionic Chern–Simons Theory in the "Temporal" Gauge
Vatsal *(IIT Bombay, Mumbai)* ♦ 27 September 2023

Munching to be Seen: Different Angles on Accreting Supermassive Black Holes
Prajval Shastri *(RRI, Bengaluru)* ♦ 27 September, 2023

Near Optimal Heteroscedastic Regression with Symbiotic Learning
Praneeth Netrapalli *(Google Research India, Bengaluru)* ♦ 26 September 2023

On Multivariate Quantiles
Sreekar Vadlamani *(TIFR-CAM, Bengaluru)* ♦ 25 September 2023

Log-Concavity in 1-d Coulomb Gas Ensembles
B.S. Jnaneshwar *(Indian Institute of Science, Bengaluru)* ♦ 25 September 2023

Coherent Fluctuations in the Monsoon Atmosphere and Ocean
Debasis Sengupta *(ICTS-TIFR, Bengaluru)* ♦ 22 September 2023

Pathways to Planetesimal Formation: New Insights from Turbulent Clustering
Vishnu Prasath Thulasiraman *(ICTS- TIFR, Bengaluru)* ♦ 22 September 2023

Disordered QFTs and Parisi-Sourlas Supersymmetry
Apratim Kaviraj *(DESY, Germany)* ♦ 22 September 2023

Workshop on Well-Being in Science
Brandon Vaidyanathan *(The Catholic University of America, USA)* ♦ 21 September 2023

Motion Planning for 1D Parabolic PDEs
Vivek Natarajan *(IIT Bombay, Mumbai)* ♦ 21 September 2023

BMS Symmetry of Gravity from Hamiltonian Formulation(s)
Sucheta Majumdar *(ENS de Lyon, France)* ♦ 20 September 2023

Beauty and the Beast Part 2: Apprehending the Missing Supercurrent
Raneer Kumar Singh *(Rutgers University, USA)* ♦ 18 September 2023

Some Aspects of Black Hole Microstate Counting
Shanmugapriya Prakashan *(Chennai Mathematical Institute)* ♦ 13 September 2023

Deconfined Pseudocriticality in a Model Spin-1 Quantum Antiferromagnet
Nisheeta Desai *(TIFR, Mumbai)* ♦ 13 September 2023

The Heating Conundrum in Driven Critical Systems
R. Chitra *(ETH Zurich, Switzerland)* ♦ 11 September 2023

Exploring Mechanisms Driving Chromosome Structural Features Across the Tree of Life
Sumitabha Brahmachari *(Rice University, USA)* ♦ 6 September 2023

Emergent Encoding of Dispersal Network Topologies in Spatial Metapopulation Models
Prajwal Padmanabha *(University of Padova, Italy)* ♦ 1 September 2023

Compactified Hyperboloidal Evolution in Numerical Relativity
Shalabh Gautam *(ICTS-TIFR, Bengaluru)* ♦ 1 September 2023

Understanding Climate Variability with Statistical Machine Learning and Artificial Intelligence
Bedartha Goswami *(University of Tübingen, Germany)* ♦ 29 August 2023

New Black Hole Mergers From a Search Pipeline for Gravitational Waves with Higher-Order Harmonics
Digvijay Wadekar *(Institute for Advanced Study, USA)* ♦ 24 August 2023

Krylov Complexity for Quantum Floquet Dynamics
Amin A. Nizami *(Ashoka University)* ♦ 23 August 2023

Nonequilibrium Green's Function Formalism for Topological Materials and Some Applications
Junaid Majeed Bhat *(ICTS-TIFR, Bengaluru)* ♦ 22 August 2023

Revisiting Logarithmic Corrections to BPS Black Entropy in Four and Five Dimensions
Anupam A H *(ICTS-TIFR, Bengaluru)* ♦ 18 August 2023

Insights from GRBs for Optical Follow-Up of Gravitational-Wave Counterparts
Kruthi Krishna *(Radboud University, The Netherlands)* ♦ 18 August 2023

Standard-Siren Cosmology: Overview of Current Results, Challenges, and Prospects
Archisman Ghosh *(Ghent University, Belgium)* ♦ 17 August 2023

Quantum Corrections to Near-Extremal Black Hole Thermodynamics
Muktajyoti Saha *(IISER, Bhopal)* ♦ 16 August 2023

Gravitational-Wave Microlensing as a Probe of Compact Dark Matter
Soummyadip Basak *(ICTS-TIFR, Bengaluru)* ♦ 16 August 2023

Theory Dependence of Black Hole Interior Reconstruction and Improved Strong Subadditivity
Roji Pius *(The Institute of Mathematical Sciences, Chennai)* ♦ 14 August 2023

Inradius of Random Lemniscates
Koushik Ramachandran *(TIFR Center for Applicable Mathematics, Bengaluru)* ♦ 14 August 2023

Almost-Optimal Best Restless Markov Arm Identification with Fixed Confidence
P. N. Karthik *(National University of Singapore)* ♦ 14 August 2023

A Gravitational-Wave Remedy for the Hubble Problem
Ish Mohan Gupta *(Pennsylvania State University, USA)* ♦ 10 August 2023

Emergence of Structure in Cortical Circuits Through Bottom-up Dynamical Principles
Sarthak Chandra *(Massachusetts Institute of Technology, USA)* ♦ 10 August 2023

On Production of Excited Kaluza-Klein States in Large Radius Compactification Scenario
Jnanadeva Maharana *(IOP, Bhubaneswar)* ♦ 9 August 2023

Geostrophic Turbulence and the Formation of Large Scale Structure
Edgar Knobloch *(University of California, Berkeley, USA)* ♦ 3 August 2023

Unconventional Symmetries in Quantum Many-Body Physics
Sanjay Moudgalya *(Caltech, USA)* ♦ 1 August 2023

Heavy Element Nucleosynthesis & Energetic Neutrinos from Highly Magnetized Outflows
Mukul Bhattacharya *(Pennsylvania State University, USA)* ♦ 1 August 2023

On Gauge-String Dualities and String Amplitudes
Pronobesh Maity *(ICTS-TIFR, Bengaluru)* ♦ 27 July 2023

Critical Phenomena in Gravitational Collapse
Thomas Baumgarte *(Bowdoin College, USA)* ♦ 26 July 2023

Pseudo-Goldstone Modes and Order-by-Disorder
Jeffrey Rau (*University of Windsor, Canada)* ♦ 21 July 2023

Nonlinear Interactions Between Fluid Flows and Evolving Boundaries
Srikanth Toppaladoddi *(University of Leeds, UK)* ♦ 21 July 2023

Applied Nonrelativistic Conformal Field Theory: Scattering-Length and Effective-Range Corrections to Nuclear Physics
Ruchira Mishra *(University of Chicago, USA)* ♦ 20 July 2023

On Some Aspects of Dijkgraaf-Witten Theory for Finite 2-Groups
Srikanth Pai B *(ICTS-TIFR, Bengaluru)* ♦ 20 July 2023

Stability Studies on the Shallow Water Equations
Mukesh Singh Raghav *(ICTS-TIFR, Bengaluru)* ♦ 19 July 2023

Quantum Condensate Shells: From Ground-Based Lattices to Space
Smitha Vishveshwara *(University of Illinois, USA)* ♦ 18 July 2023

Numerical Filter Stability, Fokker Planck Equations and Infinite Dimensional Optimization with Deep Learning
Pinak Mandal *(ICTS-TIFR, Bengaluru)* ♦ 14 July 2023

A Study of Dynamical Instabilities and Filter Stability Using Ensemble Kalman Filters
Shashank Kumar Roy *(ICTS-TIFR, Bengaluru)* ♦ 13 July 2023

A Unified Treatment of Mean-Field Dynamo and Angular-Momentum Transport in Magnetorotational Instability-Driven Turbulence
Tushar Mondal *(ICTS-TIFR, Bengaluru)* ♦ 11 July 2023

Approximate Models for Water Waves and an Algorithm for Detection of Bottom Boundary
Manisha Goyal *(ICTS-TIFR, Bengaluru)* ♦ 7 July 2023

Deriving the Simplest Gauge-String Duality
Edward Mazenc *(University of Chicago, USA)* ♦ 5 July 2023

Reconstructing Gauge Group from Extended Operators
Rajath Radhakrishnan *(ICTP, Trieste, Italy)* ♦ 30 June 2023

Steady State Flow in Dense Colloidal Suspensions
Alan Ranjit Jacob *(IIT Hyderabad)* ♦ 23 June 2023

Principle of Holography of Information and Asymptotic Symmetries
Chandramouli Chowdhury *(ICTS-TIFR, Bengaluru)* ♦ 23 June 2023

Lessons from the Quotient Structure of Spacetime: Flat Space Cosmology Edition
Victoria Martin *(University of Iceland)* ♦ 21 June 2023

Unconventional Phases and Phase Transitions in Frustrated Magnets
Animesh Nanda *(ICTS-TIFR, Bengaluru)* ♦ 20 June 2023

Boundary Integral Method for Stokes Flow
Harshit Joshi *(ICTS-TIFR, Bengaluru)* ♦ 16 June 2023

GW_Eccentricity: A Python Package to Measure Orbital Eccentricity from Gravitational Waveforms
Md Arif Shaikh *(Seoul National University, Korea)* ♦ 15 June 2023

Role of Heterogeneous Ecosystems in Modulating Surface-Atmosphere Transport
Sreenath Paleri *(University of Wisconsin-Madison, USA)* ♦ 9 June 2023

Utility of the DBI Counter-Term
Dileep Jatkar *(Harish-Chandra Research Institute, Allahabad)* ♦ 1 June 2023

Towards Classification of Probe Measures of Multipartite Entanglement
Abhijit Gadde *(TIFR, Mumbai)* ♦ 31 May 2023

Power Laws in Spacetime: Real and Complex Exponents, Self-Organized Criticality and Griffiths Phase, Ising Type Transitions
Prashant M. Gade *(RTM Nagpur University)* ♦ 31 May 2023

Deep Latent Variable Models for Generating High-Dimensional Objects
Sunita Sarawagi *(Indian Institute of Technology, Mumbai)* ♦ 30 May 2023

Tensor t-str and w-str on the Derived Category of the Scheme
Umesh Dubey *(Harish-Chandra Research Institute, Allahabad)* ♦ 29 May 2023

The Future of Heatwaves Over India
Krishna AchutaRao (*Indian Institute of Technology, New Delhi)* ♦ 25 May 2023

Mahakala: A Python-Based Modular Ray-Tracing and Radiative Transfer Algorithm for Curved Spacetimes
Aniket Sharma *(IISER, Mohali)* ♦ 25 May 2023

Some Results in Double Scaled SYK
Prithvi Narayan *(Indian Institute of Technology, Palakkad)* ♦ 25 May 2023

The Matter with TT-bar + Lambda_2
Eva Silverstein *(Stanford University, USA)* ♦ 24 May 2023

Searching for Pulsars with the MeerKAT Radio Telescope
Prajwal Voraganti Padmanabh *(Max Planck Institute for Gravitational Physics, Hannover, Germany)* ♦ 24 May 2023

The Endpoint of the Kerr-AdS Super-Radiant Instability
Shiraz Minwalla (*TIFR Mumbai)* ♦ 19 May 2023

From Avatars of Associahedron to S-matrix of Scalar Field Theories
Alok Laddha *(Chennai Mathematical Institute)* ♦ 18 May 2023

Lie Algebras from Counting of Dyonic Degeneracies
Suresh Govindarajan *(Indian Institute of Technology Madras, Chennai)* ♦ 17 May 2023

Direct and Indirect Measurements in Quantum Mechanics |
Varun Dubey *(ICTS-TIFR, Bengaluru)* ♦ 17 May 2023

Exploring Turbulence Through Particles: Statistical Properties of Spheroids in Turbulent Flows
Enrico Calzavarini *(University of Lille, France)* ♦ 16 May 2023

Spectral and Eigenstate Correlations in Non-Hermitian Systems
Soumi Ghosh *(ICTS-TIFR, Bengaluru)* ♦ 16 May 2023

Cloud Radar Observations Showing the Turbulence-Triggered Onset of Warm Rain
Madhu Chandra R. Kalapureddy *(Indian Institute of Tropical Meteorology, Pune)* ♦ 15 May 2023

Pushing LIGO's Quantum Limits
Dhruva Ganapathy *(MIT Kavli Institute, USA)* ♦ 15 May 2023

Learning More About the Magic of Wilson's Renormalization Group
Shailesh Chandrasekharan *(Duke University, USA)* ♦ 11 May 2023

Wheeler-DeWitt States of Black Hole and Cosmological Interiors
Sean Hartnoll *(University of Cambridge, UK)* ♦ 10 May 2023

Dynamics and Rheology of Glassy Active Matter
Rituparno Mandal *(University of Chicago, USA)* ♦ 9 May 2023

Nonequilibrium Green's Function Formalism for Topological Materials and Some Applications
Junaid Majeed Bhat *(ICTS-TIFR, Bengaluru)* ♦ 4 May 2023

Microscopic Origin of the Entropy of Black Holes in General Relativity
Vijay Balasubramaniam *(University of Pennsylvania, USA)* ♦ 3 May 2023

Imagining Space
Vijay Balasubramanian *(University of Pennsylvania, USA)* ♦ 2 May 2023

Connections Between Number Theory and Physics
Abhiram Kidambi *(IPMU Japan)* ♦ 1 May 2023

Uncovering Hidden Orders
Arun Paramekanti *(University of Toronto, Canada)* ♦ 27 April 2023

Letting the Samples Speak: A New Approach Towards Efficient Importance Sampling for Tail Events
Kartyek Murthy *(Singapore University of Design and Technology)* ♦ 25 April 2023

Are Classical Information-Theoretic Model Selection Criteria Any Good in High-Dimensional Statistics?
Soumendu Sundar Mukherjee *(Indian Statistical Institute, Kolkata)* ♦ 25 April 2023

Fuzzballs and Random Matrices
Chethan Krishnan *(Indian Institute of Science, Bengaluru)* ♦ 19 April 2023

Extended Minimal Theories of Massive Gravity
Masroor C Pookkillath *(Mahidol University, Thailand)* ♦ 13 April 2023

On the Quantum Mechanics of Near Extremal Black Holes
Luca Iliesiu *(Stanford University, USA)* ♦ 12 April 2023

Bootstrapping Closed String Field Theory
Atakan Hilmi Farat *(MIT, USA)* ♦ 5 April 2023

Canonical Purification, Bulk Reconstruction and the Quantum Extremal Shock
Onkar Parikkar *(TIFR, Mumbai)* ♦ 29 March 2023

Submesoscale Ocean Dynamics: Theory and Progress from Recent Observational Campaigns
Alex Kinsella *(Woods Hole Oceanographic Institution, USA)* ♦ 29 March 2023

Sampling with Mollified Interaction Energy Descent |
Anna Korba *(ENSAE/CREST, Paris)* ♦ 28 March 2023

Learning Operators
Siddhartha Mishra *(ETH Zurich, Switzerland)* ♦ 28 March 2023

Equations of State in the Curved Space-time of Compact Degenerate Stars
Susobhan Mandal *(IISER Kolkata)* ♦ 23 March 2023

A Chern-Simons Theory for the Indian Ocean
David Tong *(DAMTP, University of Cambridge, UK)* ♦ 22 March 2023

Flow-Driven Instabilities in Coastal Wetlands
Amala Mahadevan *(Woods Hole Oceanographic Institution, USA)* ♦ 20 March 2023

Bond Percolation Games on Rooted Regular Trees and Ergodicity of Related Stochastic Tree Automata
Moumanti Podder *(IISER Pune)* ♦ 20 March 2023

Extremes of Stable Random Fields: An Overview
Parthanil Roy *(Indian Statistical Institute, Bengaluru)* ♦ 20 March 2023

Joint Statistics of Cosmological Constant and SUSY Breaking Scale in Flux Vacua with Nilpotent Goldstino
Kajal Singh *(Harish-Chandra Research Institute, Allahabad)* ♦ 14 March 2023

Breakdown of Hydrodynamics Below Four Dimensions in a Dipole-Conserving Fluid
Sahil Kumar Singh *(ICTS-TIFR, Bengaluru)* ♦ 14 March 2023

Modular Flow in Holographic Theories of Gravity
Pratik Rath *(UC, Santa Barbara, USA)* ♦ 13 March 2023

A Dynamical Model of Black Hole Evaporation in 2-Dim Gravity
Spenta R. Wadia *(ICTS-TIFR, Bengaluru)* ♦ 7 March 2023

Berezin Quantization of Even-Dimensional Compact Manifolds and Pullback Coherent States
Kohinoor Ghosh *(ICTS-TIFR, Bengaluru)* ♦ 3 March 2023

Aspects of the Generalized Second Law and the Covariant Entropy Bound
Vaibhav Kalvakota *(Turito Institute, Hyderabad)* ♦ 1 March 2023

Tidal Effects in Classical General Relativity and Beyond
Sumanta Chakraborty *(Indian Association for the Cultivation of Science, Kolkata)* ♦ 28 February 2023

Optimal Transport, Statistics, and PDE: A Fruitful Interaction
Soumik Pal *(University of Washington, Seattle, USA)* ♦ 28 February 2023

A Gentle Introduction to Optimal Transport
Soumik Pal *(University of Washington, Seattle, USA)* ♦ 28 February 2023

The 21-cm Cosmology
Rajesh Mondal *(Stockholm University, Sweden)* ♦ 27 February 2023

On Some Canonical Metrics on Holomorphic Vector Bundles over Kähler Manifolds
Kartick Ghosh *(IISc Bengaluru)* ♦ 27 February 2023

Robustness of the Kardar-Parisi-Zhang Scaling in a Classical Spin Chain with Broken Integrability |
Dipankar Roy *(ICTS-TIFR, Bengaluru)* ♦ 27 February 2023

Implications of Inviscid Hydrodynamics and its Variants for Turbulence and Statistical Physics
Sugan Durai Murugan *(ICTS-TIFR, Bengaluru)* ♦ 24 February 2023

Galactic Bubbles and Winds
Kartick Sarkar *(Tel Aviv University, Israel)* ♦ 23 February 2023

Disordered Electronic Systems: From Single Particle Localization to Many-body Localization
Ravindra N Bhatt *(Princeton University, USA)* ♦ 30 January, 1, 6, 8, 14, 16, 21, 23 February 2023
(This was a series of eight lectures covering several aspects of electronic properties of disordered quantum matter)

Emergent Non-Fermi Liquid in the Excitations of the Half-Filled Landau Level
Prashant Kumar *(Princeton University, USA)* ♦ 22 February 2023

Algebras and States in JT Gravity
Geoffrey Penington *(UC, Berkeley, USA)* ♦ 22 February 2023

What is a Random Translation Surface?
Jayadev Athreya *(University of Washington, Seattle, USA)* ♦ 20 February 2023

(1+1)D QCD with Heavy Adjoint Quarks
Meseret Asrat *(ICTS-TIFR, Bengaluru)* ♦ 15 February 2023

Numerical Experiments on Coefficients of Instanton Partition Functions
Aradhita Chattopadhyaya *(Dublin Institute for Advanced Studies, Ireland)* ♦ 8 February 2023

Networks, Forces and Transitions: A Synthetic Approach to Understand Axial Emergence in Multicellular Systems
Vikas Trivedi *(EMBL Barcelona, Spain)* ♦ 2 February 2023

A Top-Down Dictionary for Double Holography
Andreas Karch *(University of Texas, Austin, USA)* ♦ 1 February 2023

Supersymmetric Black Holes and T\bar{T} Deformation
Swapnamay Mondal *(Trinity College, Dublin)* ♦ 31 January 2023

The Second Law of Black Hole Mechanics in Effective Field Theory
Harvey Reall *(University of Cambridge, UK)* ♦ 25 January 2023

Quantum Chaos and Operator Growth in 2d CFTs
Surbhi Khetrapal *(University of Hyderabad)* ♦ 24 January 2023

ICM & Gaseous Halos: Cooling Clouds, Heating and Transport Mechanisms
Prakriti Pal Choudhury *(University of Cambridge, UK)* ♦ 19 January 2023

Rational Conformal Field Theories With A Single Critical Exponent, and Their Classification
Sunil Mukhi *(IISER Pune)* ♦ 18 January 2023

Scale Invariant Effective Field Theories in AdS/CFT
Mrityunjay Verma *(University of Southampton, UK)* ♦ 17 January 2023

Majorana Zero Modes and Topological Quantum Computation: What, Why, How, When?
Sankar Das Sarma *(University of Maryland)* ♦ 13 January 2023

Tracing the Birth of the Solar Wind
Lakshmi Pradeep Chitta *(Max Planck Institute for Solar System Research, Germany)* ♦ 12 January 2023

Developing a Hybrid-PIC Code with FLASH to Understand Magnetic Field Growth in Collision-Less Plasma
Radhika Achikanath Chirakkara *(Australian National University)* ♦ 10 January 2023

Hamiltonian Theory of Composite Fermions
Ganpathy Murthy *(University of Kentucky, USA)* ♦ 3, 6 January 2023

Entanglement Dualities in Supersymmetry
Krishanu Roy Chowdhury *(Saha Institute of Nuclear Physics, Kolkata)* ♦ 5 January 2023

Dynamical Fluctuations in the Riesz Gas
Rahul Dandekar *(Institut de Physique Theorique, CEA, CNRS, France)* ♦ 4 January 2023

Blast and Splash in a 1D Infinite System of Cold Gas
Subhadip Chakraborti *(Friedrich-Alexander Universität Erlangen-Nürnberg, Germany)* ♦ 3 January 2023

Causal Representation Learning in the Context of Cell State Transitions
Caroline Uhler *(Massachusetts Institute of Technology, USA)* ♦ 2 January 2023

ZZ Instanton Amplitudes in Minimal String Theory
Raghu Mahajan *(Stanford University, USA)* ♦ 21 December 2022

Josephson Junction of Nodal Superconductors
Ranjani Seshadri *(Ben-Gurion University, Israel)* ♦ 20 December 2022

On-Shell Supersymmetry and Higher-Spin Amplitudes
Arnab Rudra *(IISER Bhopal)* ♦ 16 December 2022

Waltzing Binaries: Probing Line-of-Sight Acceleration of Merging Compact Objects with Gravitational Waves
Avinash Tiwari *(IUCAA Pune)* ♦ 15 December 2022

The Importance of Using Amplitudes and Phases in Ringdown to Test GR
Swetha Bhagwat *(University of Birmingham, UK)* ♦ 14 December 2022

Pair Density Wave Superconductivity from Electron Repulsion
Srinivas Raghu *(Stanford University, USA)* ♦ 14 December 2022

A Continuum Theory for Cytoplasmic Streaming in the Drosophila Oocyte
Brato Chakrabarti *(Flatiron Institute, Simons Foundation, USA)* ♦ 14 December 2022

ESnet: Role of Networking In Enabling Computational Science
Inder Monga *(Lawrence Berkeley National Laboratory, USA)* ♦ 13 December 2022

Quantum Hall Ferromagnetism in Monolayer Graphene
Ganpathy Murthy *(University of Kentucky, USA)* ♦ 13 December 2022

Symmetry, Exceptional Points, and Phase Transitions
Ipsita Mandal *(The Henryk Niewodniczanski Institute of Nuclear Physics (IFJ PAN), Poland)* ♦ 8 December 2022

Testing the Sagittarius A* Spacetime Metric with the 2017 EHT Observations
Prashant Kocherlakota *(Harvard University, USA)* ♦ 7 December 2022

Triplet Pairing Mechanisms from Hund's-Kondo Models - Applications to Heavy Fermion Superconductors
Tamaghna Hazra *(Rutgers University, USA)* ♦ 6 December 2022

Defining Eccentricity for Gravitational Wave Astronomy
Md Arif Shaikh *(Seoul National University, Korea)* ♦ 1 December 2022

Anyons and Bosonization in 3d: Mapping Slightly Broken Higher Spin (SBHS) Theory Correlator to Free Theory Correlator
Sachin Jain *(IISER Pune)* ♦ 24 November 2022

Coronal Mass Ejections: From Observations to Simulations
Anshu Kumari *(University of Helsinki, Finland)* ♦ 24 November 2022

Dynamical Stability of Triple-Star Systems
Pavan Vynatheya *(Max Planck Institute for Astrophysics, Germany)* ♦ 17 November 2022

Black Hole Microstate Models, Quantum Weak Measurement and Black Hole Complementarity
Ayan Mukhopadhyay *(Indian Institute of Technology Madras, Chennai)* ♦ 16 November 2022

Statistical Properties of Single and Multiple Active Particles
Prashant Singh *(ICTS-TIFR, Bengaluru)* ♦ 14 November 2022

Lessons from Holography for Open Quantum Systems
Mukund Rangamani *(UC Davis, USA)* ♦ 10 November 2022

Partial Deconfinement
Jack Holden *(University of Southampton, UK)* ♦ 9 November 2022

Mesoscale Modelling of Multiphase Flow and Wetting
Thejas Hulikal Chakrapani *(University of Twente, Netherlands)* ♦ 4 November 2022

Full Classification of Transport on an Equilibrated \nu=5/2 Edge
Sourav Manna *(Weizmann Institute of Science and Tel Aviv University, Israel)* ♦ 1 November 2022

The Standard Model of Wave Interference - A Slight Detour Along the Journey
Joseph Ivin *(NIAS, Bangalore)* ♦ 28 October 2022

Curiosities in Crossing
Aninda Sinha *(Indian Institute of Science, Bengaluru)* ♦ 26 October 2022

Fractionalisation in Spin-Orbit Coupled Magnetic Insulators
Arnab Seth *(ICTS-TIFR, Bengaluru)* ♦ 26 October 2022

Liquid-State Properties and Jamming Dynamics of Persistent Athermal Active Matter
Suman Dutta *(ICTS-TIFR, Bengaluru)* ♦ 25 October 2022

Thermalized Fluids – Solutions to Truncated Ideal Hydrodynamical Equations
Sugan Durai Murugan *(ICTS-TIFR, Bengaluru)* ♦ 20 October 2022

At the Boundary of the Swampland
Irene Valenzuela *(CERN, Switzerland)* ♦ 19 October 2022

Quantum Entanglement in String Theory
Atish Dabholkar *(ICTP Trieste)* ♦ 14 October 2022

Simulating Turbulent Mixing Caused by Local Instability of Internal Gravity Waves
Yohei Onuki *(COAR, Kyushu University, Japan)* ♦ 14 October 2022

Constraint-Induced Arrested Classical Many-Body Chaos and Directed Percolation
Sthitadhi Roy *(ICTS-TIFR, Bengaluru)* ♦ 13 October 2022

Cool Core Cycles - Cold-Mode AGN Feedback in Galaxies, Groups and Clusters
Deovrat Prasad *(Michigan State University, US)* ♦ 13 October 2022

What Goes into the Images Made by the Event Horizon Telescope?
Rajaram Nityananda *(ICTS-TIFR, Bengaluru)* ♦ 12 October 2022

Universality, Dynamical Scaling and Surface Growth in Quantum Critical Systems
Devendra Singh Bhakuni *(Ben-Gurion University of the Negev, Beersheva, Israel)* ♦ 11 October 2022

Berezin Quantization of Even-Dimensional Compact Manifolds and Pullback Coherent States
Kohinoor Ghosh *(ICTS-TIFR, Bengaluru)* ♦ 7 October 2022

Crossing Symmetry in Matter Chern Simons Theories at Finite N and k
Shiraz Minwalla *(TIFR, Mumbai)* ♦ 7 October 2022

Perturbative Corrections to Infrared Physics in Presence of Small Cosmological Constant
Sayali Bhatka *(TIFR, Mumbai)* ♦ 28 September 2022

High Performance Computing Using Rudra Cluster
Siddharth Krithivasan *(JNCASR Bengaluru)* ♦ 28 September 2022

Demonstrating Wormholes as Black Hole Mimickers: A Perturbation Analysis
Poulami Dutta Roy *(Indian Institute of Technology, Kharagpur)* ♦ 27 September 2022

Looking for Logic in Social Practices
R.Ramanujam *(The Institute of Mathematical Sciences, Chennai)* ♦ 23 September 2022

The Waves Within Us: Problems on Dynamics of Passive and Active Filaments
Brato Chakrabarti *(Flatiron Institute, New York)* ♦ 20 September 2022

Effective Theory of Fluctuating Hydrodynamics from Holography
Akhil Sivakumar *(ICTS-TIFR, Bengaluru)* ♦ 15 September 2022

6d (2,0) Bootstrap with Soft-Actor-Critic
Vasilis Niarchos *(University of Crete, Greece)* ♦ 14 September 2022

Parameter Inference from Gravitational Wave Signals Emitted by Compact Binary Mergers
Tejaswi Venumadhav Nerella *(University of California Santa Barbara, USA)* ♦ 14 September 2022

Phase Transitions in a Gas of Hard Rods on Lattices
R. Rajesh *(The Institute of Mathematical Sciences, Chennai)* ♦ 13 September 2022

Thermalization, Chaos and Hydrodynamics in Classical Hamiltonian Systems
Santhosh Ganapa *(ICTS-TIFR, Bengaluru)* ♦ 13 September 2022

Quantum Aspects of Black Holes: The Bags of Gold and Monogamy Paradoxes
Joydeep Chakravarty *(ICTS-TIFR, Bengaluru)* ♦ 12 September 2022

Part-II: Recent Developments in the Information Paradox
Suvrat Raju *(ICTS-TIFR, Bengaluru)* ♦ 7 September 2022

The Phase Puzzle of $\nu = 0$ (charge neutrality) Graphene
Ankur Das *(Weizmann Institute of Science, Israel)* ♦ 2 September 2022

Cut Locus of Submanifolds: A Geometric and Topological Viewpoint
Sachchidanand Prasad *(IISER Kolkata)* ♦ 29 August 2022

Higher Derivative Action Using Dilaton Weyl Multiplet in Four-Dimensional N=2 Supergravity
Madhu Mishra *(IISER Trivandrum)* ♦ 24 August 2022

Bootstrability for 1d Defect CFT
Julius Julius *(King's College, London, UK)* ♦ 23 August 2022

The Black Hole Interior From Non-Isometric Codes and Complexity
Daniel Harlow *(Massachusetts Institute of Technology, USA)* ♦ 17 August 2022

Systematic Bias on the Inspiral-Merger-Ringdown Consistency Test Due to Neglect of Orbital Eccentricity
Sajad Bhat *(Chennai Mathematical Institute)* ♦ 17 August 2022

Aspects of N=3 Chern-Simons Quiver Gauge Theories with ADE Classification
Moumita Patra *(NISER Bhubaneswar)* ♦ 16 August 2022

Uncovering Distinct Contributions to the Stress Relaxation in Dense Packings of Soft Spheres
Vinutha H A *(Institute for Soft Matter Synthesis and Metrology Georgetown University, USA)* ♦ 10 August 2022

Is "Active Turbulence" Turbulence? A Tale with Plots and Subplots
Siddhartha Mukherjee *(ICTS-TIFR, Bengaluru)* ♦ 10 August 2022

Measuring the Distribution of Binary Black Hole Spins
Javier Roulet *(UC Santa Barbara, USA)* ♦ 10 August 2022

Fluctuating Hydrodynamics for a Driven Tracer
Rahul Dandekar *(Institut de Physique Theorique, CEA, France)* ♦ 8 August 2022

Ulrich Bundles - An Existence Problem
Poornapushkala Narayanan *(ICTS-TIFR, Bengaluru)* ♦ 8 August 2022

Supersymmetric Black Holes, the Superconformal Index, and Phases of AdS/CFT
Sameer Murthy *(King's College, London)* ♦ 2, 3, 5 August 2022

Resurgence and Partial Theta Series
David Sauzin *(Institute of Celestial Mechanics and Computation of the Ephemerides, Paris)* ♦ 5 August 2022

Recent Developments in the Information Paradox
Suvrat Raju *(ICTS-TIFR, Bengaluru)* ♦ 4 August 2022

Symplectic Eigenvalues: An Introduction and Recent Results
Tanvi Jain *(Indian Statistical Institute, New Delhi)* ♦ 4 August 2022

An Introductory Mini-Course on Resurgence Theory: Generalised Borel-Laplace Summation, "Alien Calculus", and Applications
David Sauzin *(Institute of Celestial Mechanics and Computation of the Ephemerides, Paris)* ♦ 25, 26 July, 1 August 2022

Symplectic Geometry of SU(2) Character Varieties and Lattice Gauge Theory
T. R. Ramadas *(Chennai Mathematical Institute)* ♦ 28 July 2022

Unconventional Phases and Phase Transitions in Frustrated Magnets
Animesh Nanda *(ICTS-TIFR, Bengaluru)* ♦ 18 July 2022

Extending Taubes' Gromov Invariant to Calabi-Yau 3-Folds
Mohan Swaminathan *(Princeton University, USA)* ♦ 14 July 2022

Aspects of Eigenstate Thermalization: Entanglement Entropy, Bounds on Chaos, and Non-Abelian ETH
Chaitanya Murthy *(Stanford University, USA)* ♦ 12 July 2022

Understanding Collective Phenomena from the Underlying Interaction Networks
Danny Raj M *(Department of Chemical Engineering, Indian Institute of Science, Bangalore)* ♦ 8 July 2022

Understanding Flow Around a Black Hole with GRMHD Simulation
Indu Kalpa Dihingia *(IIT Indore)* ♦ 24 June 2022

Spectral Properties of Random Perturbations of Non-Self-Adjoint Operators
Anirban Basak *(ICTS-TIFR, Bengaluru)* ♦ 23 June 2022

Geometric Obstructions to Scale Separation
Cumrun Vafa *(Harvard University)* ♦ 22 June 2022

Anomalous Transport in Integrable 1d Quantum Systems
Utkarsh Agrawal *(University of Massachusetts, Amherst, USA)* ♦ 21 June 2022

Meromorphic Connections on the Projective Line with Specified Local Behaviour
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Members of the ICTS Creche. Photo credit: Spenta R. Wadia

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Parameswaran Ajith

- Selected member of the National Academy of Sciences, India (NASI).
- Publication (in collaboration with Souvik Jana, Shasvath J. Kapadia, Tejaswi Venumadhav) titled, *Cosmology Using Strongly Lensed Gravitational Waves from Binary Black Holes*, highlighted as Editors' Suggestion in Physical Review Letters.

Riddhipratim Basu

- SERB MATRICS Grant, awarded by the Science and Engineering Research Board, Department of Science and Technology, Government of India.

Junaid Majeed Bhat

- Awarded the inaugural pan-TIFR Prof. S. Naranan Memorial Research Award.

Subhro Bhattacharjee

- Received the Indian Physics Association's Buti Foundation Award for Excellence in Theoretical Physics, Astrophysics and Biophysics 2022.
- Received a five-year associateship at the International Centre for Theoretical Physics (ICTP), Trieste, for six years (2023-28).
- Selected as a member of the National Academy of Sciences, India (NASI).
- Received the Indian National Science Academy (INSA) Medal for Young Scientists 2022.
- Received Indo-Swedish Initiation grant for collaboration with Sergej Moroz of Karlstadt University.
- Publication (in collaboration with Jishnu N. Nampoothiri, Michael D'Eon, Kabir Ramola and Bulbul Chakraborty), titled *Tensor Electromagnetism and Emergent Elasticity in Jammed Solids*, highlighted as Editors' Suggestion in Physical Review E.

Abhishek Dhar

- Selected for the prestigious J. C. Bose National Fellowship of the Science and Engineering Research Board (SERB), Department of Science & Technology, Government of India.
- Awarded the pan-TIFR TAA BM Udgaonkar: Excellence in Teaching Award for 2022 in Physics.

Rama Govindarajan

- Received the IIT Delhi Distinguished Alumni Award.
- Received Archana Sharma Memorial Lecture Award 2022 by the National

Academy of Sciences, India (NASI).

- Publication (in collaboration with Sumithra Reddy Yerasi and Dario Vincenzi of the Université Côte d'Azur, CNRS), titled *Spirographic Motion in a Vortex* was highlighted as Editor's Suggestion in Physics Review Fluids.
- Selected for the prestigious Kirk Distinguished Fellowship of the Isaac Newton Institute, Cambridge.

Rajesh Gopakumar

- Received the 2023 ICBS Frontiers of Science Award for his publication (in collaboration with Lorenz Eberhardt and Matthias Gaberdiel) titled, *The Worldsheet Dual of the Symmetric Product CFT*. The award was announced at the inaugural International Congress of Basic Sciences in Beijing.
- Recognised as an 'Outstanding Referee' by the American Physical Society.

Akshit Goyal

- Awarded DBT- Ramalingaswami Re-entry Fellowship.

Bhanu Kiran

- Selected for an Institut Henri Poincaré (IHP)-Centre International de Mathématiques Pures et Appliquées (CIMPA) fellowship.

Manas Kulkarni

- Received the Indian National Science Academy (INSA) Medal for Young Scientists 2022.
- Featured in the book *75 Under 50: Scientists Shaping Today's India*, published by the Department of Science and Technology, Government of India.

Prayush Kumar

- Received the NASI Young Scientist Platinum Jubilee Award for 2022.

Anupam Kundu

- Received the SERB-Core Research Grant (SERB-CRG).

R. Loganayagam

- Received the Indian Physics Association's N.S. Satya Murthy Memorial Award in Physics for 2022.

Pronobesh Maity

- Selected for the prestigious KITP Graduate Fellowship Program.

Samriddhi Sankar Ray

- Awarded the CEFIPRA (Indo-French) grant.
- Elected member of the National Academy of Sciences, India (NASI).
- Received the SERB-Core Research Grant (SERB-CRG).

Suvrat Raju

- Awarded the 10th Nishina Asia Award 2022 by the Nishina Memorial Foundation.

Sthitadhi Roy

- Awarded a Max Planck Partner Group.
- Publication (in collaboration with Aydin Deger and Achilles Lazarides from Loughborough University), titled *Constrained Dynamics and Directed Percolation*, was highlighted as Editors' Suggestion in Physics Review Letters.
- Publication (in collaboration with Max McGinley and S.A. Parameswaran) titled, *Absolutely Stable Spatiotemporal Order in Noisy Quantum Systems*, was highlighted as Editors' Suggestion in the journal Physical Review Letters.

Mythily Ramaswamy

- Awarded the prestigious P.C. Mahalanobis Medal of the Indian National Science Academy (INSA) in 2021. This medal is a lifetime achievement award given in recognition of her many contributions to mathematics.

Ashoke Sen

- Awarded the prestigious Atul Chandra Gupta Distinguished Alumnus Award of the Presidency University Association.

Prashant Singh

- Publication (in collaboration with Anupam Kundu) titled, *Local Time for Run and Tumble Particle*, was selected for the Top Cited Paper Awards India 2022 in the mathematical sciences category by IOP Publishing.

Sahil Kumar Singh

- Received the best poster award for his work (in collaboration with Abhishek Dhar, Herbert Spohn, and Anupam Kundu) titled *Thermalization and Hydrodynamics in an Interacting Integrable*

System: The Case of Hard Rods, presented at School/Workshop on Wave dynamics: Turbulent vs Integrable Effects at ICTP, Trieste.

Jim Thomas

- Awarded the SERB-Early Career Research Grant.
- Received a grant under the Deep Ocean Mission of the Ministry of Earth Sciences for his project titled, *Internal Gravity Waves and Deep Ocean Diffusivity.*
- Publication titled, *Upscale Transfer of Waves in One-Dimensional Rotating Shallow Water*, was selected as a featured publication by the Journal of Fluid Mechanics. An article about the paper was published in the Focus on Fluids section of the journal.

TN Venkataramana

- Awarded DAE- Raja Ramanna Chair.

Aditya Vijaykumar

- Selected for Fulbright-Nehru Doctoral Research Fellowship by the United States-India Educational Foundation.

(Clockwise from top) Nrityagram dance ensemble performs at ICTS-TIFR ◊ Renowned mathematician Gopal Prasad and his wife Indu with the bust of Harish-Chandra they presented to ICTS. The bust has been sculpted by Charlotte Langlands ◊ The winning team of the badminton finals ◊ ICTS children perform during Independence Day ◊ ICTS members with the pookkalam they created to celebrate Onam. The pookkalam had a representative image of a binary neutron star inspiral. ◊ Photo credit: S. Shantaraj/A.S. Sumukh

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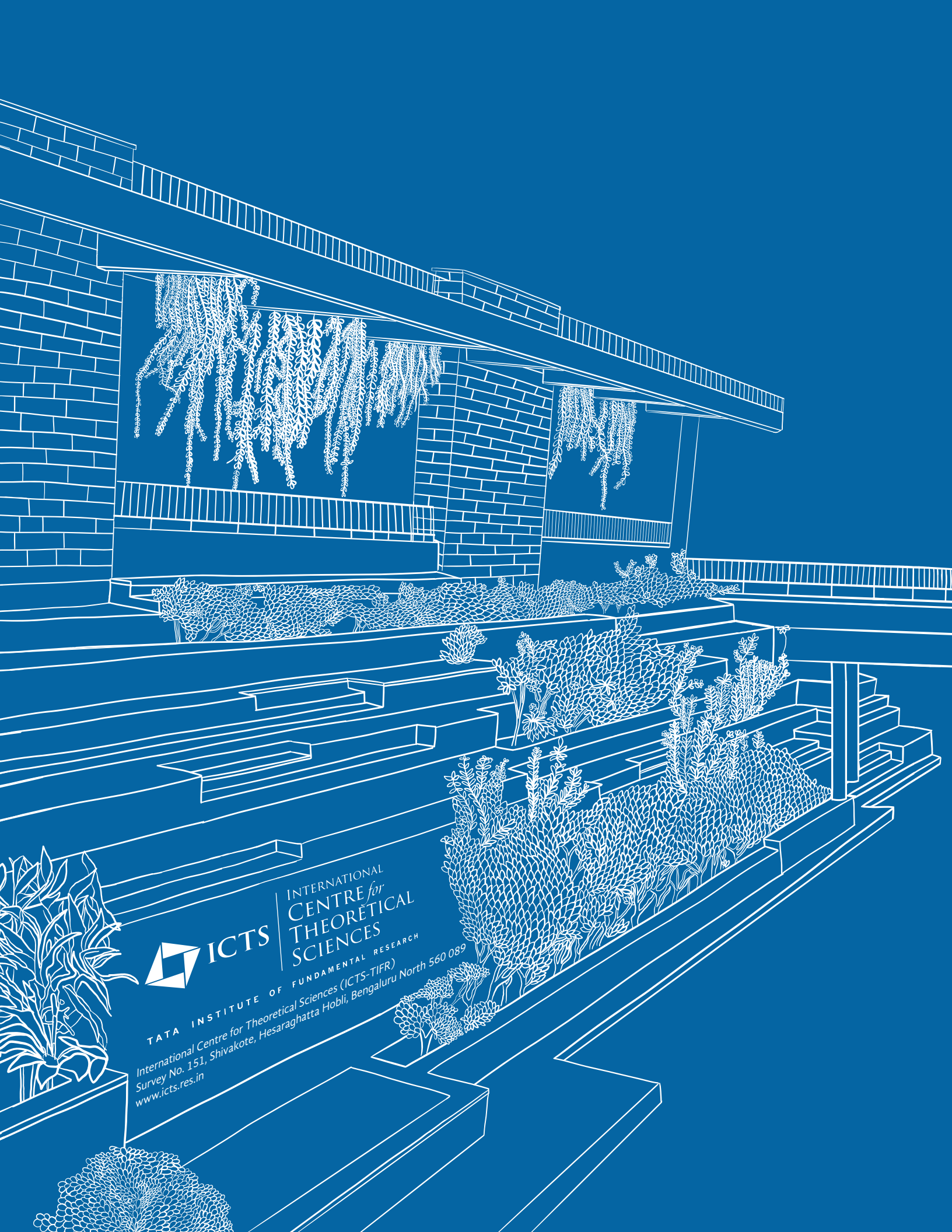
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