



# **33MYM**

## **33<sup>rd</sup> MID-YEAR MEETING**

### **INDIAN ACADEMY OF SCIENCES**

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**08 – 09 July 2022**

**Venue: New Biological Sciences Auditorium  
Indian Institute of Science, Bengaluru**

*Abstract*  
*e-Book*





08 July 2022 Friday  
09:30 – 10:10 h

Session 1A  
Special Lecture

## The Zen of grain boundaries



**ATUL CHOKSHI**

IISc, Bengaluru

Fellow-elected in 2005

Grain boundaries are interfaces between two adjacent crystals; interphase boundaries have crystals on both sides of different chemistry or crystal structure. Grain boundaries are ubiquitous in nature, ranging from conventional metals and ceramics in daily use to minerals and rocks in mountains and tectonic plates. They play an important role in many different areas, such as deformation, failure, sintering, manufacturing, avalanches, and possibly dust coagulation and related processes in outer space. There is a resurgence in the recent interest in grain boundaries because their volume fraction is substantial in nanocrystalline materials.

A common theme underlying this presentation will be the dual role played by grain boundaries under many different conditions, so that they have a yin-yang characteristic of positive and negative effects. As an example, consider the role of grain boundaries in superplasticity, which involves extremely large elongations to failure in polycrystalline materials at high temperatures. On the one hand, they play a positive role in enabling superplasticity, by facilitating grain boundary sliding that is the major strain contributing process.



## **ATUL CHOKSHI**

IISc, Bengaluru

Fellow-elected in 2005

On the other hand, they may hinder superplasticity as grain boundary sliding leads to stress concentrations at junctions where multiple boundaries meet, and this can lead to premature failure by the nucleation, growth and interlinkage of cavities. Many such similar examples will be discussed in the presentation, including strength in nanocrystals.







08 July 2022 Friday

10:10–10:30 h

Session 1B

Inaugural Lectures by Fellows / Associates

## Fractonic phases of matter



**V B SHENOY**

IISc, Bengaluru

Fellow-elected in 2013

After a brief review of the key open problem of classification of phases in condensed matter physics, the recently discovered fractonic phases of matter will be introduced and discussed. These phases are characterized by the presence of excitations that have restricted ("fractional") mobility. A higher rank gauge theoretic framework will be outlined for a phenomenological description of such phases. The talk will illustrate how fractonic physics can provide new perspectives on a wide range of problems from day-to-day phenomena like paper folding to the development of new platforms for quantum memories.





08 July 2022 Friday

10:35 - 10:55 h

## Polymath 14: A crowd-sourced, computer-aided analysis-definition of abelian groups



**APOORVA KHARE**

IISc, Bengaluru

Fellow-elected in 2022

This talk discusses a project that answers a basic question: What are all the groups that have a length-function?

This project connects across algebra, analysis, geometry, probability, and combinatorics. It also provides a nonstandard, modern model for mathematics collaboration in today's fast-evolving world, using both technology (in multiple crucial ways) and crowdsourcing. Research was conducted round-the-clock across multiple timezones and continents, by six colleagues (with contributions from several others), and progress was tabulated on the blog of Terence Tao (UCLA), including via help from a computer. The findings reveal a new identification: a fundamental algebraic structure (abelian torsion free) is precisely the same as a fundamental analysis structure (length-function, aka norm), for an arbitrary group.





08 July 2022 Friday

11:20 – 11:40 h

## **Covid-19 and flame blowout in jet engines: What is in common?**



**R I SUJITH**

IIT, Chennai

Fellow-elected in 2017

Critical phenomena such as stock market crashes, earthquakes, Rayleigh-Taylor instabilities, or avalanches that occur in disparate complex systems, show generic features on approaching a critical point, regardless of the specific physical processes that govern the dynamics. COVID-19 transmission and flame blowout in combustors are two unrelated phenomena; however, we unravel striking similarities between the two. We identified the presence of a hyperexponential growth decorated with log-periodic oscillations preceding flame blowout and during the early phase of extreme COVID-19 waves. In both cases, hyperexponential growth is accompanied by unbounded growth and finite-time singularity. The observation of oscillations decorating the power-law growth, which are periodic in logarithmic scale, known as log-periodic oscillations, unravel the existence of discrete scale invariance. Furthermore, flame blowout in real-world systems, as well as COVID-19 waves, are undesirable. Contrary to commonly believed exponential growth, the faster than exponential growth phase is hazardous and would entail stricter regulations to minimize further spread. Characterizing these log-periodic oscillations enable better prediction of the finite-time singularity in both cases.





08 July 2022 Friday

11:45 – 12:05 h

## Nucleic acids directed synthesis for therapeutic applications



**JYOTIRMAYEE DASH**

IACS, Kolkata

Fellow-elected in 2022

Nucleic acids play crucial roles in the transfer of cellular information as well as gene regulations. DNA and RNA have been implicated in many human diseases, thereby offering opportunities for exploring small molecule-based therapeutics. However, development of target-selective molecules possessing well-defined biological activity has always been challenging. In the current scenario of continuous threat of infectious disease outbreaks, it is important to expand the scope of chemical toolsets to assist conventional drug discovery strategies for the easy identification and optimization of therapeutically relevant drug candidates. Template directed synthesis (TDS) is a promising tool for rapid drug discovery as it allows a biological target to template the selection or synthesis of its own ligands from a pool of reactive fragments. There are two main strategies of TDS: dynamic combinatorial chemistry (DCC) and kinetically controlled target-guided *in situ* synthesis. Though discovered only two decades ago, as compared to protein targets, nucleic acid templated TDS techniques are relatively unexplored in the arena of drug discovery. In this talk, I would like discuss the use of TDS approaches for the synthesis of selective ligands for nucleic acid targets like DNA quadruplexes, i-motifs and HIV-TAR RNA<sup>1-3</sup>.





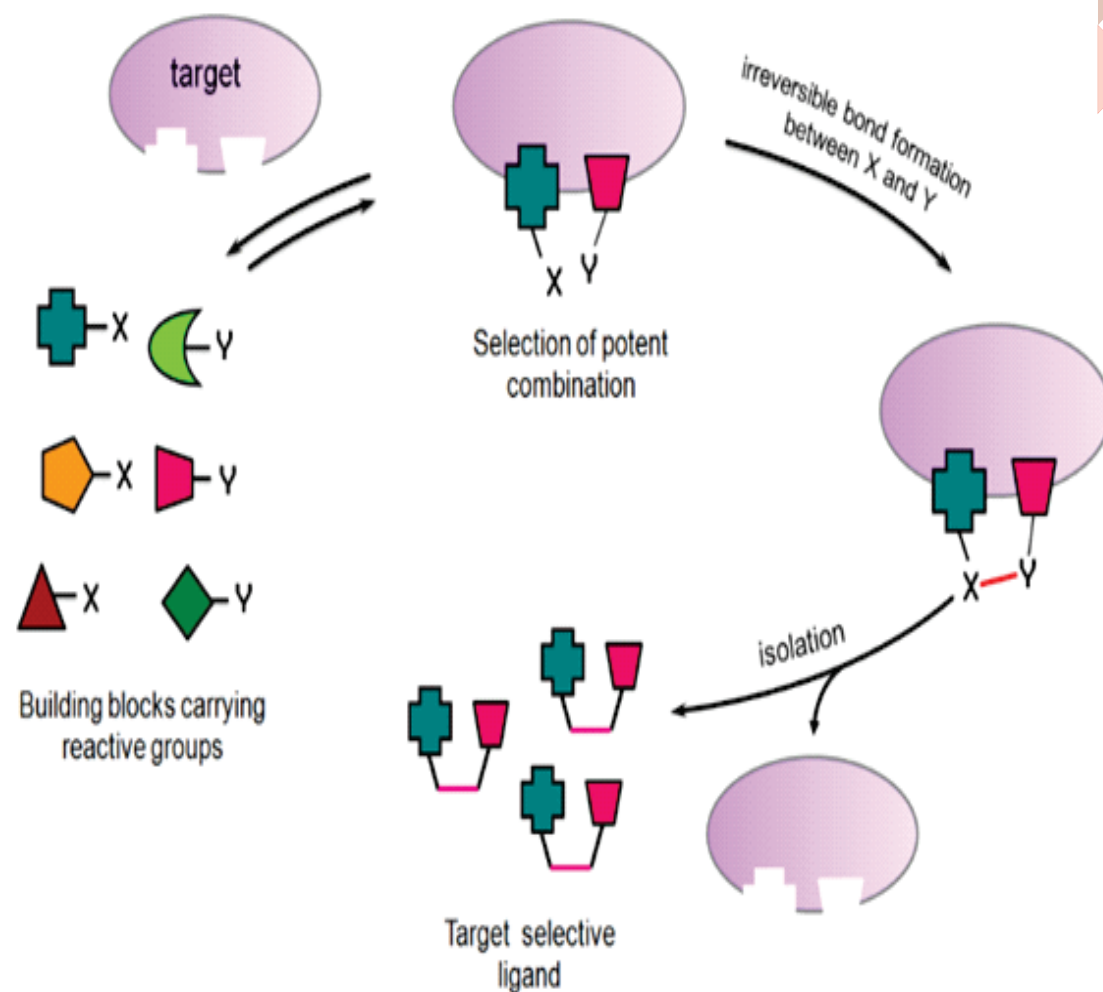
08 July 2022 Friday

11:45 – 12:05 h

**JYOTIRMAYEE DASH**

IACS, Kolkata

Fellow-elected in 2022



**Figure.** *in situ* template directed synthesis for the development of ligands for biomolecular targets.

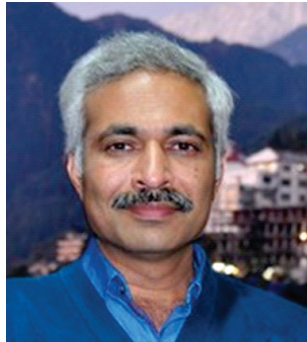




08 July 2022 Friday

12:10 – 12:30 h

## Exploring intersexual genomic conflict using *Drosophila Melanogaster*



**N G PRASAD**

IISER, Mohali

Fellow-elected in 2021

In promiscuous species, the evolutionary interests of males and females can diverge. Each sex can evolve characters that can increase its own Darwinian fitness but reduces the fitness of the other sex. This can lead to a Red Queen process where males and females get locked into open-ended bouts of adaptation and counter adaptation. Such antagonistic co-evolution can have major effects on a large number of individual traits, and can lead to speciation. Over the years, we have explored such processes using a set of well-defined laboratory system of *Drosophila Melanogaster*. Our results suggest that altering levels of intersexual competition can drive changes in traits related to life history, immunity, behaviour, and cognition. We even find evidence of incipient speciation because of such antagonistic coevolution.





08 July 2022 Friday

12:35–12:55 h

## Liquid-liquid phase separation is a generic property of proteins and polypeptides



**SAMIR K MAJI**

IIT, Mumbai

Fellow-elected in 2022

Liquid-liquid phase separation (LLPS) of bio-macromolecules has shown to be associated with membrane-less organelles formation in cells. The cell actively sequesters macromolecules such as proteins and nucleic acids to form liquid condensates for performing various biological functions of the host organism. The phase separation of proteins has also emerged as a crucial nucleation mechanism for protein aggregation associated with various neurodegenerative disorders such as Parkinson's and Alzheimer's disease. These protein condensates are dynamic, formed by multivalent interactions, and facilitated by the presence of unstructured and intrinsically disordered domains. We recently showed that LLPS is a generic property of proteins and polypeptides under high crowding or with conditions favouring high intermolecular interactions. We further showed that exposed hydrophobic surface or charge-based interaction, and hydrogen bonding drive the protein/polypeptide LLPS for both single and multicomponent LLPS.





**33MYM**  
**33<sup>rd</sup> MID-YEAR MEETING**  
**INDIAN ACADEMY OF SCIENCES**

**Symposium on**  
**“The International Year of Basic Sciences**  
**for Sustainable Development”**  
**organized by**  
**Arun Grover and N Sathyamurthy**

08 July 2022 Friday 14:30-16:30







08 July 2022 Friday  
14:30–14:50 h

Session 1D

## Measuring what matters in public health



**GAGANDEEP KANG**

CMC, Vellore

Fellow-elected in 2011

Measurement matters. It makes a problem and its size is visible. It provides evidence to inform decision-making and implementation. Continued, effective measurement is essential to tracking trajectories and impact. Measurement determines where public resources are allocated and what goals will be pursued. Yet we frequently measure what does not matter and set indicators that have no or little relationship to the outcome we want.

In public health, research needs to be carefully designed and done, so that researchers contribute actionable information and tools. Examples from my several failures, many course corrections, and occasional successes will illustrate the importance of identifying lacunae, issues with overlap and interpretation, standardization, timing, and tracking in public health research in India. These issues have become particularly relevant in the past 30 months, but are not new to public health practice in India.





08 July 2022 Friday

14:55–15:15 h

## Water: Gaps and opportunities



**T PRADEEP**

IIT, Chennai

Fellow-elected in 2009

Water is both local and global, just as carbon dioxide. However, while number of water molecules on the planet is roughly constant at  $33.4 \times 10^{45}$ , total  $\text{CO}_2$  continues to rise. India has just 4% of the global freshwater resources but  $\sim 18\%$  of the world's population. The country, which was largely rural years ago, has en-masse become urban in the past two decades. With a growth rate over 6% in gross domestic product (GDP), the most populous countries, such as India and China, are increasing their chemical, pharmaceutical, agrochemical, automotive, petrochemical, semiconductor, and many other outputs, which will eventually “enrich” our ecosystem materially. Simultaneously, their rapidly declining water resources will be burdened by unprocessed industrial waste. The World Bank has predicted that achieving a growth rate of 8% or above for India will be possible only with a robust water management system. These emerging issues, like those existing throughout the world, present a complicated suite of problems that will require technological advances, limits on usage, and collective wisdom, and compassion to create sustainable solutions. For instance, the control over carbon emissions by developed countries is probably not the reason for the globe's survival, but the lack of development in less-developed countries, according to the Intergovernmental Panel on



**T PRADEEP**

IIT, Chennai

Fellow-elected in 2009

Climate Change (IPCC). Sustainable economic and technological development for all is needed, although acquiring a quality of life comparable to the United States for the rest of the world would require significant advances in treating, purifying, and managing water.

Water footprint, estimated by considering production and consumption of goods and services, works out to 2842, 1071 and 1089 m<sup>3</sup> per capita per year (PCPY), respectively for USA, China and India, the global average being 1385 PCPY. Therefore, with a water availability of around 1100 m<sup>3</sup> PCPY, India has no water to lose and no water to dirty during diverse activities. Besides, the country experiences extremes such as ambient temperatures in the range of -40 to +50°C and rainfall between 210 to 11800 mm, making every possible water technology necessary. Where do we look for new innovations to address water challenges? Let us look at two suggestions: (1) Make desalination net zero. Global CO<sup>2</sup> emissions due to desalination were nearly 76 million tons (MT) in 2015, and global methanol requirements in that year were approximately 75 MT. Can an efficient catalytic system make CO<sup>2</sup>-to-methanol conversion possible with renewable energy so that India contributes to net zero as far as desalination is



## **T PRADEEP**

IIT, Chennai

Fellow-elected in 2009

concerned (and subsequently in other sectors)? (2) Implement water audit on every product. We need to count the water cost from food to toiletries. For example, cradle-to-grave life cycle assessments of the process of washing 5 kg of laundry (requiring medium hardness water at 40°C and consuming 120 g of liquid detergent, 49 L of water, and 0.53 kWh of electricity per washing cycle) reveals a primary energy footprint of 6.57 MJ equivalent and a carbon footprint of 0.54 kg CO<sup>2</sup> equivalent. This understanding may change the consumer's choice of detergents, packaging materials, chemicals, building materials, clothing, etc., and consequently lead to new products which are less harmful to the environment, while being affordable. This thought would extend to create new agriculture, clothing, infrastructure, transportation, etc. We may move to more efficient irrigation, 'water smart' foodstuff, which will also be animal friendly. Water for all sustainably calls for radically new innovations.

It is clear that water is big in every scale—gaps, opportunities, wealth and ultimately professional satisfaction.





08 July 2022 Friday

15:20 – 15:40 h

## Basic sciences for environmental sustainability



**M RAJEEVAN**

MoES, New Delhi

Fellow-elected in 2012

Basic sciences have an important contribution to make to progress towards a sustainable world. They enable us to understand the impacts on the climate, life on Earth and the aquatic environment, and to reduce these impacts. In this lecture, three important issues (air pollution, heatwaves and urban floods) that are related to sustainable living will be discussed.

Air pollution is a serious environmental issue, especially in north India due to the accumulation of pollutants from human activities. The science of air pollution and the development of air pollution warning systems will be discussed. Due to global warming, extreme temperature events like heat waves are increasing in India. Heat waves impact health, agriculture, and energy systems. The recent heat waves over Pakistan and India provide us a lesson about the possible impact we can expect in future. Another major environmental risk for sustainable living is the increasing frequency of urban floods. Frequent urban flooding occurs due to changes in the characteristics of precipitation in urban areas and increasing influence of human activities. The physical mechanisms of heat waves and urban floods and their prediction capabilities will be discussed.



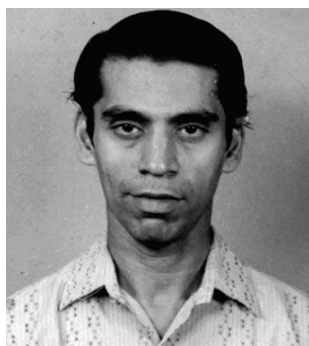




08 July 2022 Friday

15:45 – 16:05 h

## Talent supply chain management for basic sciences and SDG goals



**T RAMASAMI**

Anna University, Chennai

Fellow-elected in 1990

The year 2022 is observed as the International year of basic sciences for sustainable development centre stages the importance of investments in the talent supply chain for basic research. While the nation states are focusing on intensification of research and development, the critical roles played by inspiration among talented youth for the advancement of pure sciences cannot be underestimated. Physical infrastructure and facilities are supporting elements of a vibrant research ecosystem. Research is done by the people. Their motivational and inspirational aspects are key to their scientific research contributions. Investing in the talent supply chain for research in general and basic sciences in particular forms an important aspect of planning a sustainable development path. It could even be seen as a crosscutting input for the delivery of all the 217 sustainable development goals. Some key measures and steps initiated by India in addressing the supply chain management of basic sciences in the new millennium will be outlined and some initial evidence for directional changes shared. A case for a good beginning with a hope for the best to come in talent supply chain management will be made.





08 July 2022 Friday  
16:10–16:30 h

## Gender (in)equity in science: Reasons and possible actions



**ROHINI M GODBOLE**

IISc, Bengaluru

Fellow-elected in 1992

In this talk, I will very briefly discuss the role of gender equality as an ingredient and indicator for development in general. I will focus, however, on a rather small part of this vast canvas, viz., gender equity in science. After giving some numbers to indicate the present status on (in)equity, I will discuss the reasons for it, focusing on the invisible and unconscious biases. I will also argue that as scientists, we also need to focus on the science of gender equity. I will end with some suggestions as to what steps we as a science academy can take to progress towards a more equitable situation.





08 July 2022 Friday

18:00 – 19:00 h

Session 1E  
Public Lecture



**G N DEVY**

The People's Linguistic Survey of India

## Language, memory and aphasia– As we witness them in our time

The lecture will briefly describe the context of the emergence of language in prehistoric times as a means of communication. It will detail the range of diversity of natural languages during the last century. Comments on the emergence of natural memory will be offered and the historical processes leading to the creation of artificial memory will be described. The main focus of the lecture will be the collective aphasia surrounding natural languages in our time and, the condition of languages that have existed for centuries or millennia. My examples will be mostly from Indian languages.





09 July 2022, Saturday

09:30 – 10:10 h

Session 2A  
Special Lecture

## The biomechanics of insect flight



**SANJAY P SANE**

NCBS, Bengaluru

Fellow-elected in 2018

Insects are ubiquitous and incredibly diverse. They comprise >80% of the world's species and can be found in virtually all habitats on earth. A key factor of their evolutionary success is their ability to fly, which allowed them access to remote habitats and an edge in the competition for survival. Even today, we experience spectacular feats of insect flight, ranging from long-distance migrations of the Globe Skimmer dragonflies or Monarch butterflies, to the incredibly fast aerial maneuvers of even common insects such as houseflies or mosquitoes. For instance, a common housefly can flap its wings more than 200 times a second, and make and execute complex decisions within the duration of the proverbial eye blink. The need for rapid wing movement puts extreme demands on insect physiology and nervous system, which also means that flight-related adaptations are some of the most compelling examples of evolution. To be able to carry out such aerial feats, insects need to sense and process their world, and generate motor output from their nervous system at very high rates. Not surprisingly, the study of the insect nervous system has been a major preoccupation of comparative physiologists. Equally important has been the study of the mechanics and control of flight,



## **SANJAY P SANE**

NCBS, Bengaluru

Fellow-elected in 2018

which ensures that the flapping wings generate sufficient aerodynamic forces to ensure flight, while also making subtle changes in the wing attitude to ensure finely controlled manoeuvres. In my seminar, I will focus on the topic of insect flight mechanics, and go over some recent work in my laboratory that relates to how wing movement is coordinated relative to the body to ensure the fine control of flight.







09 July 2022, Saturday  
10:10 – 10:30 h

Session 2B  
Inaugural Lecture by Fellows / Associates



**VIJAYALAKSHMI TRIVEDI**

TIFR, Mumbai

Fellow-elected in 2022

## The Hilbert–Kunz density function and its applications

Here, we introduce a compactly supported continuous function called HK density function and discuss its applications to study some well-known positive characteristic invariants of rings.





09 July 2022, Saturday

10:35–10:55 h

## The Indian plate as a museum and evolutionary cradle for tropical angiosperms



**VANDANA PRASAD**

BSIP, Lucknow

Fellow-elected in 2022

Tropical angiosperms are the main constituents of tropical biodiversity hotspots. Tracing the evolution of tropical angiosperms is arguably a challenging and relevant issue in plant evolution. The dramatic geological history of the Indian Plate puts in view its significant role in shaping the biogeography of tropical angiosperms. Dispersal routes between India and Madagascar till ~90-88 Ma with Seychelles till 66 Ma, with Africa through Kohistan Ladakh Arc (KLIA) during ~70-60 Ma, and finally suturing with the Asian Plate ~50 Ma onwards provides changing vegetation pattern on India plate as evident in the form of its fossil records. Early and Mid-Cretaceous sedimentary records of India have not provided any evidence of angiosperm fossils so far. Ecological opportunities due to the latitudinal shift of the Indian plate in the tropical zone during Late Cretaceous-Early Paleogene and the formation of dispersal routes with tropical Africa (via KLIA), and through that with Europe and later with Southeast Asia sheds light on the longstanding debate of lack of endemism of the Indian fossil flora despite isolation of the Indian plate as an island. KLIA acted as a filter corridor for dispersal of tropical angiosperms from Africa to India. Perhumid climatic setting



## **VANDANA PRASAD**

BSIP, Lucknow

Fellow-elected in 2022

due to equatorial positioning of Indian Plate under warm climate of early Paleogene provided an ecological release for the rapid diversification and speciation of aseasonal tropical angiosperms. Post-India Asia collision led to the dispersal of the aseasonal tropical angiosperms to the low-lying tropical regions of Southeast Asia where they got an ecological release afresh, helping them speciate again and diversify to finally develop as dense tropical rain forests. These warm and humid climatic conditions were maintained for the sustainability of tropical angiosperms on Indian plate till the initiation of monsoonal climate. Lesser precipitation and long periods of dry climatic conditions with the advent of monsoonal climate led to the retraction of aseasonal tropical angiosperms from larger parts of India and restricted them to the perhumid climate of the Southwestern Ghats of India and Sri Lanka as Gondwana relic forests. The Indian Plate hence acted as both museum and cradle for tropical biodiversity and was the main driver for the emergence of tropical rain forest in Southeast Asia.





09 July 2022, Saturday

11:20 – 11:40 h

Session 2C

Inaugural Lecture by Fellows / Associates



**MADDIKA SUBBA REDDY**

CDFD, Hyderabad

Fellow-elected in 2021

## Mapping interaction network of human phosphatases

Phosphatases play a crucial role in biological functions and control nearly every cellular process, including metabolism, gene transcription, translation, cell-cycle progression, protein stability, signal transduction, and apoptosis. However, the functional map of all human phosphatases and their interactome is not fully available. By using a biochemical purification followed by proteomic analysis, our lab has established the interaction network of nearly every human protein phosphatase in the cell. We found phosphatases associated with the components of varied cellular processes. Our work on some of the new functional phosphatase interactions will be discussed.







09 July 2022, Saturday

11:45 – 12:05 h

## Learning without labels with help from Computational Geometry and Statistical Mechanics



**CHIRANJIB BHATTACHARYYA**

IISc, Bengaluru

Fellow-elected in 2022

Artificial Intelligence (AI) based systems have made rapid progress in the last decade leading to revolutionary changes in several disciplines such as medical imaging, autonomous driving etc. However, most of today's AI systems are largely based on supervised learning, wherein the underlying machines are trained by inputs labelled by humans. The ability to learn from the environment without labels, often called unsupervised learning, is now considered as the next big challenge in AI. In this talk, we will focus on the foundations of unsupervised learning where many fundamental challenges remain. Some are statistical in nature, such as model complexity and sample complexity, while some are algorithmic, including the challenge of provably learning the parameters of the model from a finite amount of data in polynomial time. I will present several recent results, derived from ideas drawn from the disciplines of Computational Geometry and Statistical Mechanics, which furthers the theory behind several unsupervised learning models.





09 July 2022, Saturday  
12:10 – 12:30 h



**K V SUBRAHMANYAM**

NARL, Hyderabad  
Associate 2019

## Three-dimensional structure of cloud type distribution over the Indian summer monsoon region using space based W-band radar observations

Clouds have an enormous influence on the Earth's energy balance, climate and weather and is a key factor of the planet's temperature. The observations of clouds are more important for improving and validating the numerical models of Earth's weather and climate predictions. There has been plethora of studies on the spatial and vertical distribution of clouds using various satellite observations. These studies have enhanced the understanding of cloud dynamics and their representation in general circulation models. However, one of the outstanding research problems in cloud realms is the vertical distribution of various types of clouds, including multi-layered cloud distribution and their associated dynamics. The present study brought out the three-dimensional distribution of various types of cloud and their associated dynamics over the Indian Summer Monsoon (ISM) region using space-based W-band radar observations on-board CloudSat satellite. The results highlight the preferential regions of occurrence of each cloud type over the ISM region for the first time. The prevailing dynamical features during the ISM period and their role in the preferential formation of cloud types over a given region are investigated. More importantly, the vertical structure of latent



## **K V SUBRAHMANYAM**

NARL, Hyderabad

Associate 2019

heating associated with various cloud types is also discussed. Distribution of vertically resolved multi-layered clouds and the role of large scale dynamics in controlling the formation of multi-layered cloud is also studied. Further, I have explored the use of multi-frequency radar observations to improve the retrieval of hydrometeor properties. The significance of the present study lies in establishing the vertical distribution of various types of cloud and including vertically resolved multi-layer clouds and their associated dynamics for the first time. The present results will aid in estimating cloud radiative properties, which will be helpful for evaluating climate models and studying their role in modifying the large-scale atmospheric circulation.





09 July 2022, Saturday

12:35–12:55 h

## Mechanistic underpinnings and therapeutic interventions for major prostate cancer subtypes



**BUSHRA ATEEQ**

IIT, Kanpur

Fellow-elected in 2022

Prostate cancer (PCa) represents a heterogeneous collection of malignancies with diverse molecular frameworks. Earlier, we showed that ~50% of PCa patients from India, harbor TMPRSS2-ERG gene fusion, while ~14% with the advanced-stage disease showed higher SPINK1 levels. We also elucidated the underlying mechanism involved in SPINK1 upregulation, wherein microRNA-338-5p/-421 negatively regulates its expression, and EZH2, an epigenetic regulator, silences the expression of these miRNAs. Regardless of molecular subtype, androgen-deprivation therapy (ADT) remains the mainstay treatment for locally advanced and metastatic PCa patients, but a majority of these individuals eventually progress to castration-resistant disease. We found that anti-androgen drugs commonly used for treating advanced-stage patients are counterproductive in the long-term. For instance, ADT in mice xenograft models and patients results in elevated SPINK1 levels accompanied by neuroendocrine-like features. Furthermore, we established the utility of DLX1 as a prognostic marker and a drug target, which is highly expressed in ~60% of the organ-confined or metastatic CRPC patients. We showed that bromodomain and extra-



## **BUSHRA ATEEQ**

IIT, Kanpur

Fellow-elected in 2022

terminal inhibitors disrupt AR and ERG-mediated DLX1 transcriptional circuitry, thereby mitigating tumorigenesis and metastases. Taken together, we have been working at the forefront of translational molecular oncology, which would have an impact on clinical decision-making, diagnosis, and therapeutic interventions.









# *Abstract* *e-Book*

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Venue: New Biological Sciences Auditorium  
Indian Institute of Science, Bengaluru

Enquiries: 91-22661203/execsec@ias.ac.in