The Institute of Mathematical Sciences, Chennai

Quarterly Report

April - June 2022

Highlights: research and events

Awards and Honours

Grants, Awards and fellowships:

Dr. Dhiraj Hazra, as a Principal Investigator, received the Indo-Italy mobility grant for the proposal "RELIC - Reconstructing Early and Late Events In Cosmology ". DST sanction number: INT/Italy/P-39/2022 (ER).

As Principal Investigator, received 2022 - 2023 Fulbright-Nehru Academic and Professional Excellence Fellowships from USIEF.

IMSc Outreach

IMSc Ganakam program:

IMSc students have been running a weekend program for staff children to help them with school work etc. The general plan is to help children with whatever they want to learn!

Currently, IMSc volunteers help children with languages (English, Hindi),Mathematics/Science HW/doubts, basic programming (with use of computer lab) as well as some fun activity/experiment sessions. The program runs every Saturday (4:30-6:00pm) and Sunday (3:30-6:00pm) since March, 2022 and has been regularly attended by 20 students from 5th-12th std.

Organizers: IMSc students

Zero Shadow Day: 24 April 2022

Zero Shadow Day is a phenomenon which occurs twice a year when the sun is directly overhead at each latitude in the tropics. IMSc organized a public event on Elliot's Beach, Besant Nagar on 24 April (ZSD in Chennai) for the public to understand and observe the phenomena.
https://www.imsc.res.in/outreach/resources/ZSD_poster.pdf

The event was also covered by the press: NDTV: https://youtu.be/LZatszRn3wA

The Hindu:
https://www.thehindu.com/todays-paper/tp-national/tp-tamilnadu/zero-shadow-day-observed/article65352456.ece

Organizers: Manikandan Sambavasivan and Varuni P

Foldscope workshop (Madurai): 05-06 May 2022

A Foldscope (https://foldscope.com/) is an optical microscope that can be assembled from simple components: a sheet of paper and a lens (magnification 140X). Foldscopes are distributed by Foldscope Instruments which aims to make science accessible to all. We conducted a two day Foldscope training workshop for teachers (32) and middle school students (85+) from Government schools in and around Madurai. Over the course of the workshop, participants assembled and used Foldscopes to observe, document and study microscopic objects around them. This workshop highlighted observation and documentation of plant related materials including pollen, stomata, other stem & leaf structures.
https://www.imsc.res.in/outreach/foldscope2022

Organizers: Manikandan Sambavasivan, Mo. Pandiarajan (Thulir Science Centre) and Varuni P.

Azadi Ka Amrit Mahotsav

The Institute of Mathematical Sciences (IMSc), Chennai, is celebrating the 75th anniversary of India's independence with a year-long calendar of popular scientific talks, a line-up of distinguished lectures, public outreach programmes, exhibitions and educational initiatives.

 Following are the details of the talks organized during April - June, 2022.

More information on Azadi Ka Amrit Mahotsav events conducted by IMSc is available at: https://www.imsc.res.in/akam/

Title   : Using undead stars as natural laboratories to understand theories of physics
Speaker : Prof. Manjari Bagchi, IMSc Chennai
Date   : Wednesday, 13 April 2022
Time   : 1600 Hrs
Venue   : Ramanujan Auditorium, IMSc Chennai

This lecture will also be streamed live to the Public via YouTube.
YouTube Live Stream Link: https://www.youtube.com/watch?v=YYQMywXIXp4

Abstract:
Neutron stars have extremely high densities, ultra-strong magnetic fields, and extremely fast rotations about their own axis. Although nuclear fusion is absent, they still emit energies and often seem to pulsate in the radio wavelengths and are known as radio pulsars. Radio pulsars in binaries are the best laboratories to study various aspects of fundamental physics, starting from theories on the matter at ultra-high densities to test of the general theory of relativity. They are also being used as the detection tools of low-frequency gravitational waves. Today, we will discuss some of exotic aspects of radio pulsars.

Poster:
https://www.imsc.res.in/akam/Posters/AKAM_PopularLecture_Apr13-2022.pdf

Title	:	Number theory in India after Ramanujan
Speaker	:	Prof. R. Balasubramanian, Emeritus Professor, IMSc Chennai
Date	:	Friday, 06 May 2022
Time	:	16:00 Hrs
Venue	:	Ramanujan Auditorium, IMSc Chennai

Abstract:

The impact of Srinivasa Ramanujan on Indian Mathematics was so great that a generation of Indian mathematicians after him took to number theory. We provide an account of varied Indian contributions to Number theory from Ramanujan to relatively recent times.

This lecture was also streamed live to the Public via YouTube.
https://www.youtube.com/watch?v=j020_4YsooA

Poster: https://www.imsc.res.in/akam/Posters/AKAM_DistinguishedLecture_May6-2022.pdf

Title   : Succinct representations

Speaker   : Prof. Venkatesh Raman, IMSc Chennai

Date   : Friday, 17 June 2022

Time   : 1600 Hrs

Venue   : Ramanujan Auditorium, IMSc Chennai

This lecture was also streamed live to the Public via YouTube.
YouTube Live Stream Link: https://www.youtube.com/watch?v=BOedYdDr4eE

Abstract:

Trees form an important data structure in computer science. How much space (in terms of the number of bits) does a standard representation take to represent an n node tree? How much space is necessary? How much space is sufficient to perform the required navigation operations? We address these questions for trees and other objects like sets. The bulk of the talk will be on motivating why these questions are important. We will discuss these through the representation of suffix trees, a popular data structure for search engine (like Google) and computational biology applications!

https://www.imsc.res.in/akam/Posters/AKAM_PopularLecture_Jun17-2022.pdf

Title   : Emergence and indecision – the physics of quantum magnets
Speaker   : Prof. R. Ganesh, Brock University, Canada
Date   : Tuesday, 21 June 2022
Time   : 1600 Hrs
Venue   : Ramanujan Auditorium, IMSc Chennai

This lecture was also streamed live to the Public via YouTube.
YouTube Live Stream Link: https://youtu.be/PS9e9Tx77Zk

Abstract:
A collection of entities, at a certain scale and complexity, can acquire a new `emergent' identity. This is a deep idea that underlies all of physical science. As a highly non-linear process, emergence cannot be predicted. However, it follows a predictable pattern in class of materials called 'quantum magnets'. In some materials, this leads to a peculiar effect. When a quantum system arrives at a crossroads, it freezes as if it were unable to pick a direction. This talk illustrates these ideas with examples.
https://youtu.be/PS9e9Tx77Zk

IMSc60:

To celebrate World Book Day, IMSc and The Tamil Nadu Science forum (TNSF) held a book release event on Saturday, April 23 at 10:30 am in the Ramanujan auditorium on the IMSc campus. TNSF brought out a set of books in Tamil to commemorate IMSc's 60th anniversary, and the first set of 7 books were released at this event. Mr. Sudhan (IAS), State Project Director of Samagra Shiksha, TN Education Department was the chief guest at this event.

The 7 Mathematics books in Tamil that were released are as follows:

1. பேராசிரியர் முனைவர் ஆர். இராமானுஜம் எழுதிய "வரலாறு மறந்த பெண் கணித அறிஞர்கள்"
2. பேராசிரியர் முனைவர் இரா பிரபாகரன் எழுதிய "கோட்டையை மீட்ட சதுரங்கள்"
3. பேராசிரியர் முனைவர் இரா பிரபாகரன் எழுதிய "கோணம் மீட்ட கோமகன்"
4. பேராசிரியர் முனைவர் இரா பிரபாகரன் எழுதிய "உயிரை மீட்ட உன்னத எண் 'பை' "
5. கணிதத்தின் அதிசய உலகம்
6. பேராசிரியர் முனைவர் இரா பிரபாகரன் எழுதிய கணித மேதைகளுடன் சில நிமிடங்கள்
7. பேராசிரியர் முனைவர் இரா பிரபாகரன் எழுதிய நாட்டை மீட்ட வட்டம்

Here is a link to download the poster for this event:
https://www.imsc.res.in/akam/Posters/WBD-TNSF-IMSc60.pdf

Title   : The elusive prediction of L-values
Speaker   : Prof. Loïc Merel, Institut de Mathématiques de Jussieu-Paris Rive   Gauche, Université Paris Cité
Date   : Wednesday, 18th April 2022
Venue   : Ramanujan Auditorium, IMSc.

Abstract :

An early wonder of our mathematical life happens when we come across the identity : $\sum_{n=1}^{\infty} \frac{1}{n^2} = \frac{\pi^2}{6}$. Even better, in Euler product form, $\prod_p \frac{1}{(1-1/p^2)} = \frac{\pi^2}{6}$, where p runs through the prime numbers. In the course of the ninetieth century, it appeared that the (zeta) function of a complex variable $\zeta(s) = \sum_{n=1}^{\infty} \frac{1}{n^s}$, and its variants, is key to understand some of the subtle laws that govern prime numbers. Thus have the hearts of analytic number theorists been set beating. Meanwhile, algebraic number theorists have attempted to understand the meaning of "$\frac{\pi^2}{6}$". And, out of arithmetic geometry, they have defined a class of variants of ζ: the L-functions, series of the form $\sum_{k=1}^{\infty} \frac{a_k}{k^s}$ that can also be expressed as Euler products. Their valuations at integers produce the mysterious L-values, that we seek to understand. Well established conjectures now predict what the correct replacement for $\frac{\pi^2}{6}$ should be. But is the prediction complete? Contrary to what is often believed, not quite. Explanation for all this, including why elaborate conjectures still fall short, will not rely on general explanation of what L-functions are, but on illustrative examples based on elliptic curves and Dirichlet characters. An intriguing formula involving L-values will be offered to help reflect on the "not quite".

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Title	:	Emergent electromagnetism in Jammed granular solids
Speaker	:	Prof. Subhro Bhattacharjee, ICTS-TIFR Bengaluru
Date	:	Wednesday, 4th May 2022
Time	:	4:00 PM IST
Venue	:	Ramanujan Auditorium, IMSc.

Abstract :

Emergence of low energy degrees of freedom is a recurrent theme in condensed matter systems. In more familiar systems such as crystalline solids the emergence of phonons as collective modes of vibration are associated mainly with broken translational symmetry that governs the physics at low temperatures. However, in a wide class of systems, local energetic constraints may take the form of Gauss's law giving rise to an emergent electromagnetism at low energies. In this talk, I shall start with a brief review of such emergent electromagnetism in discussing their basic features as well as the general settings in which they appear. Then I shall apply it to understand the mechanical response of naturally abundant granular solids such as sand grains where local conditions of mechanical equilibrium, i.e., force and torque balance on each grain, as I shall show, have the mathematical structure of a generalized Gauss's law for a rank-2 U(1) electromagnetism. The electrostatic limit of this tensor electromagnetism successfully captures the anisotropic "elasticity" of granular solids and provides a new framework to understand a large class of such systems.

Title   : Dispersion Relations: From Classical Optics to String Theory
Speaker   : Prof. N. D. Hari Dass, Retd. Senior Professor, IMSc
Date   : Wednesday, 11th May 2022
Time   : 4:00 PM IST
Venue   : Ramanujan Auditorium, IMSc.

Abstract :

Gives a pedagogical narration of how a simple, but intriguing relation about colors in classical optics impacted the most modern developments in physics, even to the point of anticipating String Theory. The strong thread that held these pearls of scientific creativity was the powerful mathematical idea of analyticity, which in this physical context turned out, rather surprisingly, to be a consequence of the deeply cherished physical principle of causality. The talk will be at a level accessible to a wide audience.

Title   : Supercomputing the properties of strong interaction
                        matter
Speaker   : Prof. Dr. Frithjof Karsch, Bielefeld University
Date   : Wednesday, 13th May 2022
Time   : 4:00 PM IST
Venue   : Online and screened live at Ramanujan Auditorium, I

IMSc.
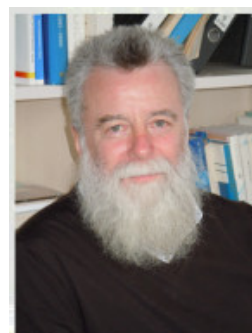
Abstract :

Strongly interacting matter at temperatures more than 100.000 times larger than in the interior of our sun and at an order of magnitude larger densities than in atomic nuclei existed in the early universe and is studied today experimentally on earth in ultra-relativistic collisions of heavy-ions. The exploration of properties of such hot and dense matter also is subject to intensive theoretical research. Computer simulations of the theory of strong interactions, Quantum Chromodynamics (QCD), performed on discrete space-time lattices provide a powerful framework for the study of such matter. These simulations provide insights into the phase structure of strong interaction matter described by QCD and allow first principle calculations that can be confronted with experimental results obtained in heavy-ion collisions. We give a brief overview of the development of lattice QCD calculations at finite temperature and density and discuss computational requirements for state-of-the-art numerical calculations. We furthermore present results from studies of the chiral phase transition in QCD as well as a new, high statistics determination of the QCD equation of state. Some results on fluctuations of conserved charges and their higher order cumulants will be discussed and compared with experimental results.

Title	:	A Golden Age in High Energy Nuclear Physics
Speaker	:	Prof. Rob Pisarski, Brookhaven National Laboratory
Date	:	Wednesday, 18th May 2022
Time	:	5:30 PM IST
Venue	:	Online and screened live at Ramanujan Auditorium, IMSc.

Abstract :

Briefly reviews the modern theory of strong interactions, Quantum ChromoDynamics, and why we believe that a qualitatively new state of matter, a Quark-Gluon Plasma, is created in the collisions of heavy ions at very high energies. I discuss, in particular, why it may be the most "ideal" liquid on earth, and the phenomenon of jet quenching. I conclude by discussing what happens when one goes down in energy, and how that may probe qualitatively new states, including a Critical End-Point and Quantum Pion Liquids.

Title	:	Athermal Elasticity: From Crystalline to Amorphous Packings
Speaker	:	Prof. Kabir Ramola, TIFR Hyderabad
Date	:	Wednesday, 20th May 2022
Time	:	4:00 PM IST
Venue	:	Ramanujan Auditorium, IMSc.

Abstract :

Elasticity is a fundamental macroscopic property that emerges in any collection of interacting particles. However, at sufficiently low temperatures where thermal fluctuations are negligible, a free energetic description of such macroscopic properties is not available. Granular materials and glasses offer a paradigm where disorder in the arrangements of particles plays a fundamental role in determining the energy landscape, and thereby their stability, response and elasticity properties. Gradually introducing disorder into athermal crystalline packings can be used to build a relation between the well-established physics of crystals and that of amorphous solids. Such studies can also reveal interesting phenomena peculiar to athermal systems such as hidden order-disorder transitions. In this talk I will outline the development of exact theoretical techniques which can be used to characterize fluctuations in positions, forces and interaction energies in near-crystalline athermal systems, which offer a route towards understanding the emergent elasticity properties of ubiquitous amorphous solids.

Title	:	Quantum channels and black holes
Speaker	:	Prof. Ayan Mukhopadhyay, IIT Madras
Date	:	Wednesday, 25th May 2022
Time	:	4:00 PM IST
Venue	:	Ramanujan Auditorium, IMSc.

Abstract :

Black hole information paradoxes are at the heart of the mysteries of quantum spacetime. Black hole interiors pose the most profound challenges of our understanding of the holographic principle which states that quantum spacetime can be encoded into degrees of freedom of an ordinary quantum system living at the boundary. Recently quantum information theory together with some simple tractable models has played a major role in elucidating how the long standing information paradoxes of black holes can be resolved, and how the black hole interiors can be decoded from the Hawking radiation via appropriate

quantum channels. Other developments have pointed out that black hole dynamics can teach us the basic principles of quantum thermodynamics necessary to realize constructions of fault tolerant quantum memory and quantum gates, and efficient ways for constructing other quantum channels such as teleportation channels using strongly interacting systems, I will review some aspects of these developments, and briefly some reasons to believe why black hole microstates can also give us the key to understanding some phases of matter like strange metals.

Title	:	Machine learning for lattice field theory and back
Speaker	:	Prof. Gert Aarts, Director, ECT* Trento and Swansea University, Department of Physics
Date	:	Wednesday, 1st June 2022
Time	:	4:00 PM IST
Venue	:	Online and screened live at Ramanujan Auditorium, IMSc.

Abstract :

Recently, machine learning has become a popular tool to use in fundamental science, including lattice field theory. Here I will report on recent progress, starting with (by now) basic applications (phase transitions and critical exponents), moving on to new ideas for the Inverse Renormalisation Group and ending with more speculative suggestions on quantum-field theoretical machine learning.

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Title	:	The QCD critical point
Speaker	:	Prof. Thomas Schaefer, North Carolina State University
Date	:	Wednesday, 8 June 2022
Time	:	5:30 PM IST
Venue	:	Online and screened live at Ramanujan Auditorium, IMSc.

Abstract :

The arguments that suggest that the phase diagram of QCD, the theory of quarks and gluons, has a critical endpoint which is analogous to the endpoint of the water-vapor transition were

summarized. This point marks the onset of a first order phase transition between a quark-gluon vapor and a hadronic liquid. I will argue that the critical point can be searched for in collisions of relativistic heavy ions. The main observables are fluctuation measurements, and the expected signatures are related to critical opalescence. I summarize the ongoing theoretical and experimental efforts devoted to observing signatures of critical fluctuations. I argue that along the way, we have gained new insights into an old theory, fluid dynamics.

Title	:	Decoding the Path Integral: Resurgence and non-perturbative Physics
Speaker	:	Prof. Gerald Dunne, University of Connecticut
Date	:	Wednesday, 15 June 2022
Time	:	5:30 PM IST
Venue	:	Online and screened live at Ramanujan Auditorium, IMSc.
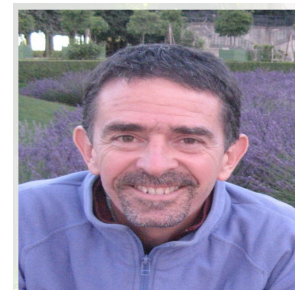
Abstract :

How do quantum systems behave under extreme conditions such as ultra-high density and ultra-high intensity? This question has applications in a wide range of physical contexts, from condensed matter to particle and nuclear physics, and to astrophysics. The answer requires going beyond perturbation theory, directly to the path integral representation of quantum field theory. However, there are several important conceptual and computational problems concerning quantum path integrals under extreme conditions, which have recently been approached from new perspectives motivated by resurgent asymptotics, a novel mathematical formalism that effectively unites perturbative and non-perturbative physics. This talk will review the basic ideas behind the connections between resurgent asymptotics and physics, starting from the work of Airy and Stokes on rainbows, and the development of trans-series by Ecalle, and then turn to some recent applications in quantum mechanics and quantum field theory.

Title	:	Topology at High Temperature from the Lattice
Speaker	:	Prof. Dr. Guy Moore, Technische Universität Darmstadt
Date	:	Wednesday, June 29 2022
Time	:	16:00 - 17:00
Venue	:	Live screened at the Ramanujan Auditorium

Abstract:

QCD fields can possess nontrivial topology – instantons. The density of instantons is strongly temperature dependent, and this temperature dependence is important to the early-Universe dynamics of the hypothetical axion particle, which may form the dark matter of the Universe. A secure lattice measurement of topological susceptibility up to about 1.1 GeV temperatures would allow a precision prediction of the axion mass. The obstacles to such a determination are explained , and a novel set of computational techniques are introduced which can help to overcome them.

For the poster of this talk and details of IMSc diamond jubilee celebrations visit:
https://www.imsc.res.in/imsc60

BOLTZMANN DAY

Title	:	The Geometrical Phase Transitions in a system of Long Rods on a Lattice
Speaker	:	Prof. Deepak Dhar, Distinguished Emeritus Professor of Physics, IISER Pune.
Date	:	Wednesday, June 28 2022
Time	:	15:00 IST
Venue	:	Live screened at the Ramanujan Auditorium

Abstract:

The problem of phase transitions in a solution of long cylindrical rods with only hard core interactions is a classical problem in statistical physics, starting with the work of Onsager in 1949, who showed that if the density of rods is large enough, the system has a phase transition with spontaneous symmetry breaking to a phase with the rods getting aligned in some direction. I will discuss some recent work with A. Shah and R. Rajesh about long needles on a d-dimensional lattice, where we argue that at densities close to full-packing, the nematic state undergoes a second transition to a state in which the system breaks into nearly noninteracting two-dimensional layers, with most rods with orientations along the layer, but no orientational order within a layer. I will discuss the evidence for some interesting conjectures about this transition in arbitrary dimension d in the limit of long rods.
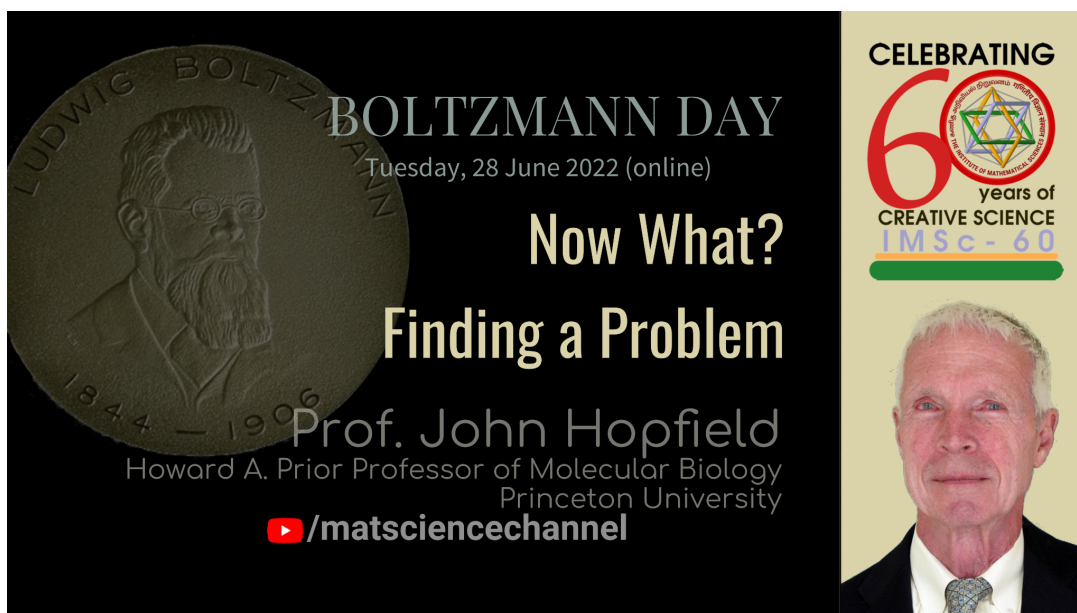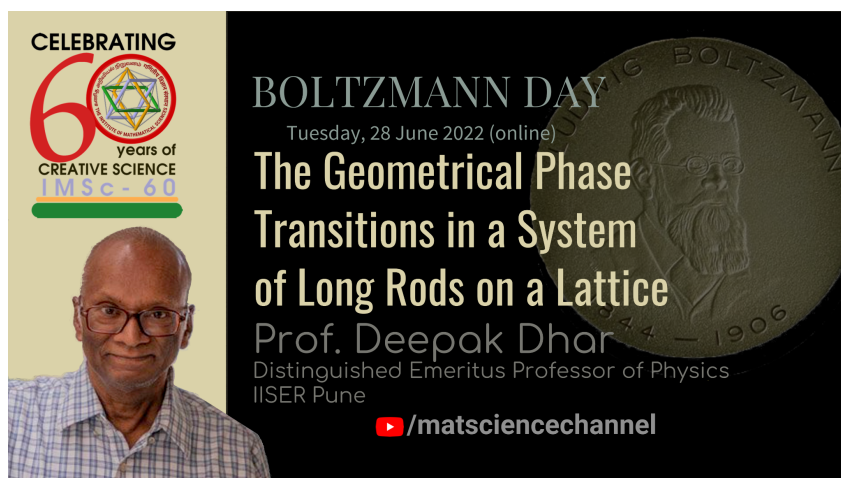
Title	:	Now What? Finding a Problem
Speaker	:	Prof. John Hopfield, Howard A Prior Professor of Molecular Biology, Princeton University.
Date	:	Wednesday, June 28 2022
Time	:	17:00 IST
Venue	:	Live screened at the Ramanujan Auditorium

Abstract:

The apt choice of research direction for tomorrow, next week, and next year are key to a career in science. This sounds like a logical enterprise in long-range planning. However, the choice of unusual problems has been the hallmark of my scientific career. I will illustrate for my two most significant papers how the development of the intellectual thrust depended heavily on chance, my willingness to explore, and writing papers to communicate with multiple disciplines.

BOLTZMANN DAY
Tuesday, 28 June 2022 (online)

Now What?

Finding a Problem

Prof. John Hopfield
Howard A. Prior Professor of Molecular Biology
Princeton University
/matsciencechannel

CELEBRATING
60
years of
CREATIVE SCIENCE
IMSc - 60