INTERNATIONAL CENTRE *for* THEORETICAL SCIENCES

TATA INSTITUTE OF FUNDAMENTAL RESEARCH

ICTS Program on Non-equilibrium Statistical Physics (ICTS-*NESP2010*)

30 January – 08 February, 2010

Venue: Indian Institute of Technology, Kanpur

This event is a part of the Golden Jubilee celebration of
IIT Kanpur : celebrating 50 years of excellence in education and research

IIT KANPUR
GOLDEN JUBILEE

International Centre for Theoretical Sciences

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Abstracts of Lectures

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Advisor:

T. V. Ramakrishnan, IISc, Bangalore & BHU, varanasi

Message from the Director, ICTS

The ICTS Program on Non-equilibrium Statistical Physics at IIT Kanpur seems poised to be a truly interactive research and education event, in a fundamental area of science that spans across several disciplines. The participation of a large number of students and post-docs will no doubt expose them to an exciting environment created by excellent lectures and discussions.

It is also befitting that this program is during the Golden Jubilee of IIT Kanpur. Several speakers and participants are alumnus of this institution that has contributed significantly to a step forward for Indian science and technology.

- ***Spenta R. Wadia***
  Director, ICTS,
  Mumbai

ICTS-NESP2010 Niels BOHR Lecture

&

IITK:GJ Public Lecture

Does the everyday world really obey quantum mechanics?

Anthony J. Leggett

University of Illinois at Urbana-Champaign, USA

Abstract: Quantum mechanics has been enormously successful in describing nature at the atomic level, and most physicists believe that it is in principle the "whole truth" about the world even at the everyday level. However, such a view prima facie leads to a severe problem: in certain circumstances, the most natural interpretation of the theory implies that no definite outcome of an experiment occurs until the act of "observation". For many decades this problem was regarded as "merely philosophical", in the sense that it was thought that it had no consequences which could be tested in experiment. However, in the last dozen or so years the situation has changed very dramatically in this respect. I will discuss the problem, some popular "resolutions" of it, the current experimental situation and prospects for the future.

About the speaker: Sir Anthony James Leggett is the John D. and Catherine T. MacArthur Chair and Center for Advanced Study Professor of Physics at the University of Illinois at Urbana-Champaign. He is widely recognized as a world leader in the theory of low-temperature physics. His pioneering work on superfluidity was recognized by the 2003 ***Nobel Prize*** in Physics. He set directions for research in the quantum physics of macroscopic dissipative systems and use of condensed systems to test the foundations of quantum mechanics. He is also interested in the theory of superfluid liquid 3-He under extreme nonequilibrium conditions and in the newly realized system of Bose-condensed atomic gases. Professor Leggett is an elected fellow / member of all the leading science academies; the list includes the **National Academy of Sciences (USA), Royal Society (UK)**, Russian Academy of Sciences (foreign member), Institute of Physics (UK) as well as the American Association for the Advancement of Science, the American Philosophical Society, the American Academy of Arts and Sciences. He was knighted (KBE) by Queen Elizabeth II in 2004 "for services to physics."

About Niels Bohr: Niels Henrik David Bohr (1885–1962), the philosopher-physicist was one of the most influential thinkers of the 20th century. He received the Nobel Prize in Physics in 1922 for his model of atomic structure. His other important contributions to quantum physics include the principle of complimentarity. He also developed the liquid drop model of atomic nucleus. Bohr responded to some of the fundamental questions on the foundations of quantum theory, which were raised by Einstein at a Solvay congress and in subsequent public debate, thereby enlightening the subtle philosophical issues on the nature of physical reality.

Superfluid 3-He: the early days as seen by a theorist (expanded version of 2003 Physics Nobel Lecture delivered at Stockholm)

Anthony J. Leggett
University of Illinois at Urbana-Champaign, USA

Abstract: I present a very personal account of the way in which, in the approximately 12 months between July 1972 and July 1973,we came to a theoretical understanding of the puzzling experimental data on what we now know as superfluid 3-He. I particularly emphasize the concept of "spontaneously broken spin-orbit symmetry" which turned out to be a key ingredient in understanding the NMR behavior.

ICTS-NESP2010 John G. KIRKWOOD Lecture & Keynote Address

Puzzling Physics, Chemistry, and Biology of liquid water

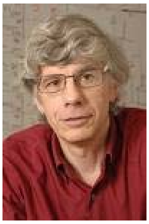
H. Eugene Stanley ,
Boston University, USA

Abstract: I'll discuss the strange properties of water, the "most complex" liquid. Recent progress in understanding these properties has been achieved by using concepts of statistical mechanics to combine information from recent experiments and simulations on water in bulk and nano-confined environments. I'll focus on the unusual behavior of water in biological environments, and whether liquid water can exist in two different phases. I'll also discuss useful analogies between water and other liquids, such as silicon, silica, and carbon, as well as metallic glasses.

About the speaker: **Harry Eugene Stanley** is a University Professor at Boston University. He has made seminal contributions to statistical physics and is one of the pioneers of interdisciplinary science. His current research focuses on understanding the anomalous behavior of liquid water, quantifying fluctuations in DNA sequences, beating heart and Alzheimer brain, financial markets, etc. Professor Stanley received the 2004 **Boltzmann Medal**, the highest recognition awarded by International Union of Pure and Applied Physics (IUPAP) and was elected a member of the **National Academy of Sciences of USA**. He is also a recipient of many awards including the Julius Edgar Lilienfeld Prize of the American Physical Society and David Turnbull Prize from the Materials Research Society. He is an outstanding educator and communicator. He received the Distinguished Teaching Scholar Director's Award (National Science Foundation), Richtmyer Memorial Lectureship Award (American Association of Physics Teachers) and the Massachusetts Professor of the Year (Council for Advancement and Support of Education). Professor Stanley was a Centennial Lecturer, American Physical Society, 1998–1999 and a Platinum Jubilee Lectures, Indian Academy of Sciences, 2009. He was awarded the Nicholson Medal (APS) for his extraordinary contributions to human rights. He has also served as the Co-Editor-in-Chief of Physica A, editor of New Journal of Physics, Nuclear Physics B, and several other journals. Professor Stanley was the chairman of the 16th IUPAP international conference on Statistical Physics.

About John G. Kirkwood: Before his premature death at the age of 52, Professor John Gamble Kirkwood (1907—1959) made major contributions to the fundamental works which laid the foundation of the modern theory of liquids and transport processes. Professor Kirkwood received several awards which include the Langmuir prize, Theodore William Richards medal and G.N. Lewis medal. He also received presidential certificate of Appreciation. He was vice-president of American Chemical Society (1940-41) and foreign secretary of the US national academy of sciences (1955-58). He was buried next to two other giants of statistical mechanics, Josiah Willard Gibbs and Lars Onsager.

ICTS-NESP2010 Jean-PERRIN Lecture
&
IITK:GJ Keynote address



Jamming and the Emergence of Rigidity

Sidney R. Nagel,
University of Chicago, USA

Abstract: When a system jams it undergoes a transition from a flowing to a rigid state. Despite this important change in the dynamics, the internal structure of the system remains disordered in the solid as well as the fluid phase. In this way jamming is very different from crystallization, the other common way in which a fluid solidifies. Jamming is a paradigm for thinking about how many different types of fluids - from molecular liquids to macroscopic granular matter - develop rigidity. As the geometrical constraints between constituent particles become important, it is less easy for a fluid to flow. This occurs in many different contexts. Thus we can hope to gain insight about the process of rigidity formation in molecular fluids by studying flowing granular matter where jamming is readily visible. Moreover, by paying close attention to the normal modes of vibration, we have found that the properties of the marginally-jammed solid are highly unusual and provide a new way of thinking about disordered systems generally.

About the speaker: **Sidney R. Nagel** is the Stein-Freiler Distinguished Service Professor at the Department of Physics, James Franck Institute and Enrico Fermi Institute of the University of Chicago and the College Director of the Materials Research Center. His work has drawn attention to phenomena that scientists have often regarded as outside the realm of physics, such as the science of drops, granular materials and jamming. Another area of emphasis is his attempt to understand the properties of disordered and glassy materials. He is a recipient of the Oliver Buckley Prize, the highest award of the American Physical Society in condensed matter physics. Prof. Nagel is also an elected fellow of the American Physical Society, American Academy of Arts and Sciences, American Association for the Advancement of Science and an elected member of the **National Academy of Sciences of USA**. He has also served as editor of Physical Review B.

About Jean Perrin: Jean Baptiste Perrin (1870–1942) was a pioneer in research on colloidal dispersions. His experiments established the validity of Einstein's theory of Brownian motion thereby settling the century-long dispute on the real existence of molecules. In recognition of this work, he was awarded the Nobel prize for Physics in 1926. He escaped to U.S.A. from Nazi-occupied France and died in New York City. After the War, in 1948, his remains were transported back to France by the battleship Jeanne d'Arc and buried in the Panthéon.

ICTS-NESP2010 Homi BHABHA Lecture

(jointly organized with TIFR on the occasion of birth centenary of Homi J. Bhabha)

Homi J Bhabha : Growing Science and Doing Science

T. V. Ramakrishnan
Indian Institute of Science, Bangalore, India, and
Banaras Hindu University, Varanasi, India

Abstract: It is only natural that we remember the great man whose vision and energy gave us a part of modern India, for example, Atomic Energy and the Tata Institute of Fundamental Research. I will describe these as someone who has lived his life in India, and the man. I then speculate on what might have moved him today, and as a personal offering, talk about an area of physics which seems to be significant for its future, namely that of strongly correlated electrons in solids.

About the Speaker: Tiruppattur Venkatachalamurti Ramakrishnan is a DAE Homi Bhabha professor at BHU, Varanasi and an honorary fellow of TIFR. His density-functional theory of freezing, universally known as the Ramakrishnan-Youssouf theory, and his work on localization in disordered systems opened new horizons of research in condensed matter physics. He is an elected Fellow of INSA, IASc., NASI, TWAS (Trieste), APS (USA), **Royal Society (London), Institute of Physics (UK), and is a Foreign Associate of the Academy of Sciences (Paris).** He is a recipient of S. S. Bhatnagar Award, TWAS prize, Mahendralal Sircar Award, Jawaharlal Nehru Award, C V Raman Centenary Medal, M. N. Saha Medal, Distinguished Material Scientist of the Year (MRS, India), Goel Prize, Trieste Science Prize, Rothschild Visiting Professorship of the Isaac Newton Institute and INSA Srinivasa Ramanujan Research Professorship. He has delivered many prestigious lectures; the long list includes Lecture at the Nobel Symposium 73, Lecture at the conference "Critical Problems in Physics" (a conference to commemorate 250 years of Princeton University), Lecture at "Frontiers in Physics" (a conference on the Fortieth Anniversary of the Abdus Salam ICTP, Trieste). Professor Ramakrishnan has also been a member of the editorial boards of Physical Review B, Journal of Physics Condensed Matter . He has served as the President of IASc, Vice-President of INSA, on the Science Advisory Council to the Prime Minister. He was the chairman of the 22nd IUPAP international conference on Statistical Physics. President of India honored him with a "Padma Sri". Professor Ramakrishnan was a member of the faculty and also an Honorary Distinguished Professor at IIT Kanpur during 1971-1980 and 2004-2008.

About Homi Bhabha: Homi Jehangir Bhabha (1909–1966) was an extraordinary man, a distinguished scientist, a deeply cultured person and an able administrator. As a young student, he worked with some of the greatest physicists of all times including Niels Bohr, PAM Dirac, Wolfgang Pauli, Enrico Fermi, R.H. Fowler and Walter Heitler. His most important contributions are in Electron-positron scattering (later named Bhabha scattering) and cosmic ray showers. He was the builder of modern science in India after independence. He established the Tata Institute of Fundamental Research (TIFR) in Mumbai and the Atomic Energy Commission of India. He also encouraged research in space and radio astronomy. He was elected a Fellow of the Royal Society. The Atomic research center in Mumbai was named after Bhabha after his premature death in an air-crash.

ICTS- NESP2010 Louis NEEL Lecture

Quantum Magnetism and non-Fermi liquids

G. Aeppli ,
London Centre for Nanotechnology,
University College of London, UK

Abstract: Quantum phase transitions in metallic magnets are a popular route to unconventional "non-Fermi" liquids. We review some experiments on this topic, and then describe an alternate route, starting from a non- magnetic insulator. Depending on the impurity used to induce metallicity, different levels of quantum fluctuations are introduced, and Fermi or non-Fermi-liquid behaviour is found.

About the speaker: **Gabriel Aeppli** is the Quain Professor of Physics and the Director of the London Centre for Nanotechnology (LCN). Prior to taking up these posts in the autumn of 2002, he was a Senior Research Scientist for NEC (Princeton) and a Distinguished Member of Technical Staff at Bell Laboratories. His personal research is currently focused on the implications of nanotechnology for information processing and health care. He is also a co-founder of Bio-Nano Consulting (BNC), a firm which provides a range of services from due diligence to testing and prototyping in the nanotechnology arena. Awards and honors he has received include Fellow of the American Physical Society, Royal Society Wolfson Research Merit Award, the **Oliver Buckley Prize**, which is the highest award of APS in condensed matter physics, the **IUPAP Magnetism Award / Neel medal** and the IOP **Mott Prize**.

Louis Eugène Félix Néel (1904–2000) shared the Nobel Prize for Physics in 1970 for his pioneering studies of the magnetic properties of solids. He served as director of the Centre d'Etudes nucléaires de Grenoble from 1956 to 1970. From 1949 to 1969 he was a member of the Board of Directors of the C.N.R.S.; scientific adviser to the French Navy since 1952; French representative at the Scientific Committee of the North Atlantic Treaty Organization.

ICTS-NESP2010 H. KAMERLINGH ONNES Lecture

Electronic properties of graphene

Eva Y. Andrei
Rutgers University, USA

Abstract: The recent discovery of graphene, a one-atom thick membrane of crystalline Carbon, has opened an extraordinary arena for new physics and applications stemming from charge carriers that are governed by quantum-relativistic dynamics. These carriers are expected to behave as massless Dirac fermions and to display highly unusual transport and optical properties: absence of backscattering leading to ballistic transport; a linear density of states which allows easy gate control of the carrier density and opacity of graphene; a square-root sequence of Landau levels in a magnetic field which could allow population inversion. I will present transport and scanning tunneling microscopy experiments that provide access to these unusual carriers and compare with theoretical expectation.

About the speaker: Eva Andrei is a professor of Physics at the Rutgers University. She is a renowned authority on the dynamics and thermodynamics of correlated electron systems, in particular vortices in superconductors, two dimensional electron systems, including graphene. Prof. Andrei has served on the executive committee of the American Physical Society (APS) and is currently a member of the editorial board of Solid State Communications. She is a Fellow of the American Physical Society and was awarded the French CEA Medal of physics for her work on the Magnetically Induced Wigner Crystal.

About H. Kamerlingh-Onnes: Heike Kamerlingh Onnes (1853–1926) was awarded the Nobel prize in 1913 for developing techniques which made it possible to investigate the properties of matter at temperatures as low as fractions of a degree Kelvin. In particular, he liquefied helium and discovered the phenomenon of superconductivity. In his inaugural lecture at the university of Leiden, he coined the famous phrase "through measurement to knowledge".

ICTS-NESP2010 M. N. SAHA Lecture

Entropy-Induced Ordering

Mustansir Barma
Tata Institute of Fundamental Research, Mumbai, India

Abstract: Consider a system composed of hard objects, with the constraint that they cannot overlap. As the density is increased, there is often a phase transition to an ordered state, despite the absence of an attractive interaction. In this talk we illustrate this through several examples, ranging from the orientational alignment of an assembly of hard needles, to ordering induced by squeezing a system of hard spheres. Paradoxically, it is entropy, a measure of disorder, which drives the system to an ordered state.

About the speaker: Mustansir Barma works on statistical physics, in particular on the dynamics of nonequilibrium systems, phase transitions and disordered systems. Currently he is a Distinguished Professor and the Director at the Tata Institute of Fundamental Research. He is a recipient of the S.S. Bhatnagar prize, and is a fellow of the Indian National Science Academy, the Indian Academy of Sciences, the National Academy of Sciences, India, and the Academy of Sciences for the Developing World (TWAS). He earlier served as the Chair of the Commission on Statistical Physics of the International Union of Pure and Applied Physics (IUPAP), and is currently a vice president of the IUPAP.

About M. N. Saha: Megh Nad Saha (1893–1956) is best known for the Saha ionization formula in statistical physics which is named after him. This equation has found extensive use in astrophysics in determining the state of ionization of the constituents of stars from their spectra. He was the founder of the Institute of Nuclear Physics in Kolkata which was later named after him. He was also the founder president of the National Academy of Sciences, India.

ICTS-NESP2010 S. PANCHARATNAM Lecture

Phases and Phases on the road to Quantum Computation

G Baskaran
Institute of Mathematical Sciences, Chennai, India

Abstract: Last decade has seen an enormous interest in the field of quantum computation. Here quantum mechanics is used in a fundamental way in selection and operation of `Qubits' which are the basic building blocks of a quantum computer. Among a variety of schemes, `Topological Quantum Computation'', as exemplified by the works of Kitaev has a special attraction. Here topologically protected excitations of certain interacting 2 dimensional electron systems such as a 2d p-wave superconducting (Sr2RuO4) phase, 5/2 fractional quantum Hall phase or excitations of certain model quantum spin liquid phase play the role of `topological qubits'. Quantum computation is a programmed adiabatic evolution through a manifold of low energy Hilbert space of quantum condensed matter, where Pancharatnam and Berry phases are fundamental. I will review the search for the novel quantum states in certain condensed matter, including our own recent work.

About the speaker: Ganapathy Baskaran is a senior professor at the Institute of Mathematical Sciences in Chennai. The broad area of his research interest is strongly correlated electron systems which includes non fermi-liquid states, unconventional superconductors, supersolids, quantized Hall systems, quantum processes in biology etc. He is an elected fellow of the Indian National Science Academy, Indian Academy of Sciences and Third World Academy of Sciences. He is also a recipient of the Kastler Prize of ICTP, S.S. Bhatnagar prize and Centenary Distinguished Alumni Award of the Indian Institute of Science."

About S. Pancharatnam: Shivaramakrishnan Pancharatnam (1934-1969) is most famous for his discovery of a type of geometric phase known as Pancharatnam phase for polarized beams passing through crystals. Therefore, what Michael Berry discovered many years later is now often referred to as the Pancharatnam-Berry phase. He was elected a Fellow of the Indian Academy at the early age of 25, but passed away at the age of 35 while working as a Research Fellow of St. Catherine's College, Oxford, working in association with G. W. Series.

ICTS-NESP2010 David SCHOENBERG Lecture

Vortex Ratchets in Highly Anisotropic Superconductors

S.J.Bending (1), D.Cole (1), S.Savel'ev(2,3), F.Nori (2) and T.Tamegai (4)
(1)University of Bath, Claverton Down, Bath, BA2 7AY, UK
(2) Frontier Research System, RIKEN, Saitama 351-0198, Japan
(3) University of Loughborough, UK
(4) University of Tokyo, Japan

Abstract: Biological motors have been the inspiration for new types of nanodevices for controlling the motion of nanoparticles [1]. The most widely studied "ratchet effect" involves the rectification of zero-time-averaged ac driving forces in a spatially asymmetric potential profile and structures have been realised experimentally to manipulate particles in asymmetric silicon pores, charged particles in artificial pores and arrays of optical tweezers. In addition there is major interest in vortex "ratchets" in superconductors [2] with the goal of realising magnetic flux pumps, diodes and lenses. *Spatial asymmetry* is, however, not a fundamental requirement for the control of vortex motion and we have demonstrated that vortex 'lensing' is possible in highly anisotropic superconductors simply under the action of *non time-reversible* trains of in-plane magnetic field pulses [3]. Our devices depend crucially on the existence of 'crossing' pancake vortex (PV) and Josephson vortex (JV) lattices in high Tc Bi2Sr2CaCu2O8+d (BSCCO) single crystals under tilted magnetic fields. An attractive interaction between these two sub-lattices makes it possible to indirectly manipulate the PV distribution by modifying the JV lattice [4,5]. The mechanism leading to lensing will be discussed and results compared with molecular dynamics simulations.

[1] P.Hänggi, F.Marchesoni and F.Nori, Ann. Phys. (Leipzig) **14**, 51 (2005).
[2] J.E.Villegas *et al*., Science **302**, 1188 (2003); R. Wördenweber *et al*., Phys. Rev. B **69**, 184504 (2004).
[3] D. Cole et al. Nature Materials **5**, 305 (2006).
[4] A.N.Grigorenko *et al*., Nature **414**, 728 (2001).
[5] S. Savel'ev and F. Nori, Nature Materials **1**, 179 (2002).

About the speaker: Simon Bending is a professor in the Department of Physics at University of Bath, UK where he leads the Nanoscience Group. His research focuses on understanding the magnetic properties of superconducting and ferromagnetic materials at the nanoscale. He has pioneered the development of novel vortex imaging techniques, particularly Hall probe magnetic imaging and nanomagnetometry systems, including a 300mK scanning Hall microscope. He serves as the advisory editor for Physica E: Low Dimensional Systems and Nanostructures and is a member of the editorial board for PMC Physics B.

About D. Schoenberg: David Schoenberg (1911-2004) was a central figure in Cambridge low-temperature physics. Two of his most favourite topics of research were superconductivity and the de Haas-van Alphen effect. He was an elected fellow of the Royal Society (London). In 1937-38 a lecture by K.S. Krishnan alerted him to the potential value of a torsion balance in magnetic measurements which he exploited in doing classic experiments of his own. Professor Schoenberg helped in initiating low temperature research at the National Physical Laboratory (NPL) spending one year (1953-54) in Delhi at the invitation of K. S. Krishnan,. He delivered the Krishnan memorial lecture in Delhi in 1988.

ICTS-NESP2010 J. C. BOSE Lecture

Centre or limit cycle? RG as a probe

Jayanta K Bhattacharjee
S. N. Bose National Centre for Basic Sciences,
Kolkata, India

Abstract: Finding a limit cycle in a two dimensional dynamical system remains a formidable problem. Our approach begins with the conjecture that for a limit cycle to exist, the two dimensional system with a set of control parameters {p} must possess a linear centre for some value of {p}.The issue then is whether this is a nonlinear centre or a limit cycle. At this point we bring in the renormalisation group (RG) of Chen et al as a probe. The periodic orbit is characterised by an amplitude and a phase. We construct flow equations for these quantities by exploiting the fact that for a given trajectory, the initial point could be anywhere in the past. For a centre the flow of the amplitude has to be identically zero. For a limit cycle the flow equation must have a fixed point.We consider examples from various disciplines to make the point. A generalisation of the Ricatti system of the second kind is carried out to show that the RG can be made to work even when the initial centre does not have a " linear restoring force". Our technique can also be used to probe isochronous oscillations.

About the speaker: Jayanta K. Bhattacharjee is a Senior Professor and Dean of Academics at the S.N. Bose National Centre for Basic Sciences in Kolkata. His research interest covers a broad area of Statistical Physics and Nonlinear Dynamics. In addition to publishing large number of papers in high-impact international journals, he has also authored text books on statistical mechanics and instabilities in fluids. Prof. Bhattacharjee is a legendary teacher and has inspired a generation of young students to choose research as a career option. He is an elected fellow of the Indian Academy of Sciences and National Academy of Sciences India. Prof. Bhattacharjee was a member of the faculty in physics at IIT Kanpur from 1982 to 1995.

About J. C. Bose: Jagadish Chandra Bose (1858–1937) did pioneering work in physical sciences as well as in life sciences. Almost three decades after his death, results of investigations published in IEEE transactions gave full credit to him for his contributions in detection of radio signals. Without this detector Marconi could not have accomplished his Nobel winning demonstration of wireless transmission of signals. With his crescograph, he measured response of plants to various stimuli thereby scientifically establishing close similarity between the biological processes in animal and plants. J. C. Bose was the first from the Indian subcontinent to get a US patent, in 1904.

ICTS-NESP2010 John BARDEEN Lecture

Cold atoms: strongly correlated Bosons

Gianni Blatter
ETH Zurich, Switzerland

Abstract: The phenomena of condensation, superfluidity, and superconductivity, as well as the more speculative supersolid state, are among the most fascinating topics of cold matter physics, be it in atomic or condensed form. I will review these phenomena and their interrelation and then proceed with a discussion of the youngest member in the family, the atomic Bose gas pushed into the strong correlation regime with the help of an optical lattice. I will discuss the phase diagram of this system, its excitations, and their relation to weakly interacting Bosons, making use of various theoretical approaches. Emphasis is given to the relation to superfluids in condensed matter. I will end with a short discussion of a non-equilibrium system, the strongly correlated polariton gas.

This lecture is based on work done in collaboration with Sebastian Huber, Ehud Altman, and Sebastian Schmidt.

About the Speaker: J. W. (Gianni) Blatter is a professor and head of the department of Physics at ETH Zurich. He has made seminal theoretical contributions to the understanding of statistical physics of superconductivity and superfluidity, including vortex phases in superconductors and Bose-Einstein condensates.

About J. Bardeen: John Bardeen (1908–1991) was awarded the Nobel Prize in Physics twice: first in 1956 (with W. Shockley and W. Brattain) for the invention of the transistor; and again in 1972 (with L. N. Cooper and J. R. Schrieffer) for a fundamental theory of conventional superconductivity known as the BCS theory. His fundamental works also had enormous impact on technologies which have improved the quality of life all over the globe. The John Bardeen Prize recognizes theoretical work that has provided significant insights on the nature of superconductivity and has led to verifiable predictions, is awarded triennially by the international superconductivity research community.

ICTS-NESP2010 Lev LANDAU Lecture

Qu-transitions. Phase transitions in the quantum era.

Piers Coleman
Rutgers University, USA

Abstract: Physicists are often so awestruck by the lofty achievements of the past, we end up thinking all the big stuff is done, which blinds us to the revolutions ahead. We are still firmly in the throws of the quantum revolution that began a hundred years ago. Quantum gravity, quantum computers, qu-bits and quantum phase transitions, are manifestations of this ongoing revolution. Nowhere is this more so, than in the evolution of our understanding of the collective properties of quantum matter. Fifty years ago, physicists were profoundly shaken by the discovery of universal power-law correlations at classical second-order phase transitions. Today, interest has shifted to Quantum Phase Transitions: phase transitions at absolute zero driven by the violent jigglings of quantum zero-point motion. Quantum, or Qu-transitions have been observed in ferromagnets, helium-3, ferro-electrics, heavy electron and high temperature superconductors. Unlike its classical counterpart, a quantum critical point is a kind of "black hole" in the materials phase diagram: a singularity at absolute zero that profoundly influences wide swaths of the material phase diagram at finite temperature. I'll talk about some of the novel ideas in this field including " avoided criticality" - the idea that high temperature superconductivity nucleates about quantum critical points - and the growing indications that electron quasiparticles break up at a quantum critical point.

About the speaker: Piers Coleman is a professor of Physics at Rutgers university. He is interested in the collective condensed matter behavior that emerge in complex materials. The focus of his research is "non Fermi liquid" physics, particularly magnetism and superconductivity in heavy fermion, cuprate metals and Kondo insulators. He is an elected fellow of the American Physical Society and Institute of Physics (UK). He is an editor of Reports on Progress of Physics, Journal of Physics Condensed Matter. He had the honor of delivering the first Wohlfarth memorial lecture at Imperial College London.

Lev Davidovich Landau (1908–1968) received the 1962 Nobel Prize in Physics for his theory of superfluidity. He also made fundamental contributions to many other areas of theoretical physics. He developed the density matrix method in quantum mechanics, theories of Landau levels and Landau diamagnetism, Landau-Lifshitz equation for magnetization, Landau theory of phase transitions, the Ginzburg-Landau theory of superconductivity, etc. With his collaborator Evgeny Lifshitz, Landau began writing the famous "Course of Theoretical Physics", ten volumes of this classic series together span the whole of the subject.

ICTS-NESP2010 Pierre-Gilles de GENNES Lecture

Brownian motion a tool to study DNA molecular motors

V. Croquette
Ecole Normale Supérieure, Paris, France

Abstract: In the last ten years, micromanipulation techniques have emerged allowing for the investigation of enzymatic reactions at the single molecule level. We use magnetic tweezers to pull and twist a micron size bead attached to one end of a DNA molecule by biotin / streptavidin while the second end is attached to a glass slide by digoxigenin/antibody.

We analyze the Brownian motion of the bead and we use Einstein relation. to measure the force applied by the magnetic field gradient This method can be applied to force ranging from fentoNewtons to tens of picoNewtons. Monitoring the position of the bead with nanometer resolution allows us to record the minute changes on the DNA molecule. We have first characterized the molecule elasticity for dsDNA and ssDNA as well as the dsDNA with a torsion constrain. The elasticity of these molecules is very reproducible and is well predicted by statistical models. Many enzymes interact with DNA and alter its elastic behaviour. Measuring the elastic behaviour of a single DNA molecule turns out to be a very efficient mean to study enzymatic activity at the single molecule level. We shall give some examples: we will show how this assay may be used to evidence how the GalR genetic repressor forms a loop on DNA. We shall also discuss how some enzymes alter DNA supercoiling state. In particular we shall illustrate how topoisomerases can remove DNA catenation

About the speaker: Prof. Vincent Croquette is a research director at the Ecole Normale Superieure in Paris (where de Gennes had studied many years ago). He did pioneering work in single molecule biophysics developing novel techniques and studying wide varieties of molecular machines with these techniques. He is an editor of European Physical Journal E and Annales de Physique. In this lecture Professor Croquette will talk about a powerful tool for studying molecular motors which are nano-meter size machines and exert pico-Newton forces.

About P. G. de Gennes: Pierre-Gilles de Gennes (1932-2007) was awarded the Nobel Prize in Physics in 1991. He made fundamental ground-breaking contributions to diverse areas such as magnetism and superconductivity, liquid crystals, polymers, colloids, interfaces and even living matter. He unified several apparently diverse fields of research into a unified new discipline for which he coined the term "soft matter" science. Because of the depth and breadth of his scientific achievements, in the citation for his Nobel Prize, the Royal Swedish Academy described him as the "Isaac Newton of our time". Moreover, de Gennes possessed remarkable pedagogical talents. His classic texts and monographs as well as review articles are models of simplicity, elegance, and deep insight.

ICTS-NESP2010 Aneesur RAHMAN Lecture

Growing length scales and their role in the growth of time scales in glass-forming liquids

Chandan Dasgupta
Indian Institute of Science, Bangalore, India

Abstract: The notion of a growing length scale of "cooperatively rearranging regions" is often invoked to explain the enormous increase in the viscosity and relaxation time of a liquid upon supercooling. Recent studies of spatial heterogeneity in the local dynamics provide fresh impetus in this direction. Using finite-size scaling for the first time for a realistic glass-forming liquid, we establish that the growth of dynamical heterogeneity with decreasing temperature is indeed governed by a growing dynamical length scale. However, the dependence of the simultaneously growing time scale of the long-time alpha relaxation on system size does not exhibit the same scaling behavior as the dynamical heterogeneity: this time scale is instead determined, for all studied system sizes and temperatures, by the configurational entropy, in accordance with the Adam-Gibbs relation. The validity of the "random first-order transition" theory, that provides a rationalization of the Adam-Gibbs relation, is investigated by exploring the relation between the alpha relaxation time and the configurational entropy in two and four dimensions. We also investigate the dependence of the time scale of the short-time beta relaxation on the system size. Surprisingly, this time scale exhibits conventional finite-size dynamic scaling with the length scale that governs the growth of dynamical heterogeneity. This result shows that the dynamics of glass-forming liquids is governed by a growing length scale even in the short-time "caging" regime, and suggests a close connection between the short-time dynamics and dynamical heterogeneity at time scales of the order of the alpha relaxation time. This talk is based on work done in collaboration with Smarajit Karmakar and Srikanth Sastry.

About the speaker: Professor Chandan Dasgupta is a professor and, currently, the chairman of the physics department of Indian Institute of Science, Bangalore. He is also a J.C. Bose fellow. He is a leading expert of computational physics of disordered and glassy systems. Professor Dasgupta served on the faculty of University of Minnesota (as a colleague of Aneesur Rahman) and was an Alfred P. Sloan Foundation fellow before joining IISc. Bangalore in 1986. He is an elected fellow of Indian National Science Academy (INSA), Indian Academy of Sciences (IASc.), National Academy of Sciences, India (NASI) and TWAS (Trieste).

About A. Rahman: Aneesur Rahman was born in Hyderabad, India. After a 25-year tenure as a physicist at the Argonne National Laboratory, he joined the faculty at the University of Minnesota as a professor of physics and fellow at the Supercomputer Institute. Professor Rahman is widely regarded as the father of molecular dynamics which revolutionized computational approaches to problems of physics. Since 1993, the American Physical Society annually awards the Aneesur Rahman Prize, which is the highest recognition of the society in the field of computational physics.

ICTS-NESP2010 P. C. MAHALANOBIS Lecture

Growing sand piles: a model of proportionate growth

Deepak Dhar
Tata Institute of Fundamental Research, Mumbai, India

Abstract: Adding sand grains at a single site in the Abelian sand pile models on an initially periodic background configuration produces beautiful but complex patterns. These show the very interesting property of *proportionate growth*, familiar in biology, where different parts of the growing animal grow at roughly the same rate. We will discuss a special case where the resulting pattern can be characterized in detail. The relationship to more general problem of approximating a function by piecewise-linear or –quadratic approximants will be discussed. We will also discuss changes in the patterns produced near absorbing boundaries.

About the speaker: Deepak Dhar is a Distinguished Professor at the Tata Institute of Fundamental Research in Mumbai and a J. C. Bose fellow. Over time, his research interests have many areas of mathematical statistical mechanics. He has made fundamental contributions to percolation, fractals, self-organized criticality. Professor Dhar is an elected fellow of the Indian National Science Academy, Indian Academy of sciences, National Academy of Sciences India and TWAS (Trieste). He is a recipient of the S.S. Bhatnagar prize, TWAS prize, J.R. Schrieffer prize, and the S.N. Bose medal of INSA. He is a member of the editorial board of Physical Review E, Journal of Statistical Physics, JSTAT: Theory and Experiment, and Pramana. Professor Dhar also served as a member of the IUPAP commision on statistical physics during 1992-95.He is an alumnus of IIT Kanpur (M.Sc, 1972).

About P.C. Mahalanobis: Prasanta Chandra Mahalanobis (1893–1972) was an applied statistician who founded the Indian Statistical Institute. His most famous contribution is "Mahalanobis distance" which is a useful way of determining similarity of an unknown sample set to a known one. He was an elected Fellow of the Royal Society, London, Fellow of the Econometric Society, U.S.A., Honorary Fellow of the Royal Statistical Society, U.K., Foreign member of the Soviet Academy of Sciences and Fellow of the American Statistical Association.

ICTS-NESP2010 A. V. HILL Lecture

Mechano-sensation by critical oscillators

Tom Duke
London Centre for Nanotechnology,
University College of London, UK

Abstract: Hair cells of the inner ear detect mechanical stimuli by deflections of the hair bundle, which open tension-gated transduction channels in the cell membrane to admit cations from the surrounding fluid. Recent experiments have shown that the hair bundle has an active response and is not just a passive elastic structure. Indeed, spontaneous oscillations of the bundle have been observed in the absence of a stimulus. The general concept of ‘self-tuned criticality’ explains why such oscillations occur, and how they help the ear to hear. According to this idea, when working normally each hair cell is maintained at the threshold of an oscillatory instability. Poised on the verge of vibrating at a characteristic frequency, a hair bundle is especially responsive to weak periodic stimuli at that frequency. In this talk I will provide an overview of the characteristic nonlinear response of a noisy critical oscillator and outline the novel features that arise when critical oscillators are coupled together in various different ways. The talk will be illustrated with examples from the auditory systems of insects, amphibians, reptiles and mammals.

About the speaker: Tom Duke is currently Deputy Director, Life Sciences at the London Centre for Nanotechnology and Professor of Physics at University College London (where A. V. Hill was a professor in the Department of Physiology). Before moving to his current position, he served as a member of the faculty of the Cavendish Laboratory at Cambridge University, and as a fellow of Trinity College (the alma mater of A.V. Hill). Professor Duke's research concerns the physical modeling of biological systems at the cellular or supramolecular level and applications in bionanotechnology. He is an adjunct Associate Editor of Physical Review Letters and a member of the Editorial Board of Physical Biology.

About A. V. Hill: Archibald Vivian Hill (1886–1977) shared the 1922 Nobel Prize in Physiology for his elucidation of the production of heat and mechanical work in muscles. Even his first paper, which he co-authored in 1909, is a path breaking work on the theory of receptors. He is regarded, along with Hermann von Helmholtz, as one of the founders of biophysics. He has also been prominent in public life; he represented Cambridge University in the House of Commons of the British parliament as an Independent member during 1940-1945.

ICTS-NESP2010 Ilya PRIGOGINE Lecture

Microreversibility and time asymmetry in nonequilibrium statistical mechanics and thermodynamics

Pierre Gaspard
Free University of Brussels, Belgium

Abstract: The microreversibility of Newton's equations does not preclude that phase-space trajectories may be physically distinct from their time reversals. In statistical mechanics, a trajectory and its time reversal can thus have different probability weights, which induces the breaking of time-reversal symmetry in the statistical description of nonequilibrium processes. From this viewpoint, microreversibility turns out to be compatible with the time asymmetry of thermodynamics and other phenomena. This fundamental observation is at the origin of recent advances in nonequilibrium statistical mechanics and thermodynamics such as the fluctuation theorems, which open new perspectives in our understanding of nonequilibrium systems down to the nanoscale.
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About the speaker: Pierre Gaspard is Professor at the Université Libre de Bruxelles, where he is director of the Service for the Physics of Complex Systems and Statistical Mechanics, and member of the Center for Nonlinear Phenomena and Complex Systems. He has made fundamental contributions to several areas of statistical mechanics, particularly in dynamical systems, fluctuation theory and stochastic processes in complex systems. In addition to research papers, he also authored a book titled "Chaos, Scattering, and Statistical Mechanics" (Cambridge University Press). Professor Gaspard was awarded the Francqui Prize 2006 and is an elected member of the Royal Academy of Science, Humanities and Fine Arts of Belgium. He served the IUPAP Commission on Statistical Physics as a member from 2002 to 2008. He has been member of the editorial boards of the "Journal of Statistical Physics", ``Nonlinearity", "Chaos: An Interdisciplinary Journal of Nonlinear Science", the "European Physical Journal D", and is on duty for "New Journal of Physics" and the series "Advances in Chemical Physics".

About I. Prigogine: Ilya Prigogine (1917-2003) was awarded the Nobel Prize for Chemistry in 1977 for his contributions to nonequilibrium thermodynamics, particularly the theory of dissipative structures, carrying forward the conceptual revolution initiated by Lars Onsager in formulating the thermodynamics of irreversible processes. Prigogine's approach bridged the gaps between the methods of studying systems in physics, chemistry, biology, and social sciences. He was Director of the International Solvay Institute of Physics and Chemistry in Brussels where, together with his colleague G. Nicolis, he led the famous Belgian school of nonequilibrium thermodynamics and statistical mechanics. He was Professor at the Université Libre de Bruxelles and the University of Texas at Austin. In 1989, he was awarded the title of Viscount by the King of Belgium.

ICTS-NESP2010 J. H. VAN VLECK Lecture

Physics in the one dimensional quantum world:
the Luttinger liquid paradigm and beyond

T. Giamarchi
University of Geneva, Switzerland

Abstract: The effect of interactions on quantum particles is a long standing question, with important consequences for most realistic systems. In one dimension interactions usually lead to a radically new type of physics, very different from the one we know for higher dimensional systems. I will present the main concepts underlying this physics, known as Luttinger liquids, and show the various realizations of such systems that recent progress in material science, nanotechnology and cold atomic physics have provided. I will discuss where the field is standing now, and what are today's challenges, such as going beyond the Luttinger liquid concept.

About the speaker: Thierry Giamarchi is a professor of condensed matter physics at the university of Geneva. Before moving to Geneva, he has been a permanent member of the french CNRS for more than fifteen years. His research work deals with the effects of interactions in low dimensional quantum systems, such as quantum magnetism, Luttinger liquids, and on the effects of disorder in classical and quantum systems. In addition to publishing large number of original research papers in leading international journals, he has authored a highly acclaimed monograph, titled ``Quantum physics in one dimension'', published by the Oxford university press. Professor Giamarchi received the Abragam prize from the French Academy of Sciences. He has been an editor of Europhysics Letters and has been recognized as an ``Outstanding Referee" by the American Physical Society. He has also served on the board of several scientific institutions such as the CNRS theory committee and the ``Les Houches school" administrative board.

About J. H. Van Vleck: John Hasbrouck Van Vleck (1899–1980) shared the 1977 Nobel Prize in Physics. He is regarded as the father of modern quantum theory of magnetism; Van Vleck paramagnetism is named after him.

ICTS-NESP2010 Max DELBRÜCK Lecture

Motor Proteins as Nanomachines: force, friction and fluctuations

Jonathon Howard,
Max-Planck Institute of Molecular Cell Biology & Genetics,
Dresden, Germany

Abstract: Motor proteins such as myosin, dynein and kinesin, are enzymes that convert chemical energy derived from the hydrolysis of a small molecule called ATP into mechanical work used to power directed movement along cytoskeletal filaments inside cells. A central question concerns the roles played by thermal fluctuations, diffusion and Brownian motion in the motor reaction. In this lecture, I discuss several molecular models for motor proteins, including so-called ratchet and powerstroke models, and compare predictions of these models to experimental results for the microtubule-based motor protein kinesin (Howard, in Bio-Physique, XII-th Poincaré Seminar 2009). Another key question is the extent to which macroscopic concepts such as force and friction apply to nanomachines. I describe an experiment in which we measure the friction force experienced by a single-kinesin molecule as it is dragged along the surface of a microtubule. Friction limits the maximum speed and efficiency (Bormuth, Varga et al., Science 2009). Under some circumstances, motors can exhibit "negative friction," meaning that force can activate or gate the motor reaction, like a voltage can gate current through a transistor. Such behavior gives rise to positive feedback, and might be responsible for the switching and oscillations observed during the beating of sperm and in mitosis (Howard, Ann. Rev. Biophys. 2009).

About the speaker: Jonathon Howard is a director at the Max Planck Institute of Molecular Cell Biology & Genetics in Dresden and an Honorary Professor of Biophysics at the Technical University, Dresden. He is a member of the European Molecular Biology Organization (EMBO). He has been a recipient of the John Simon Guggenheim Fellowship, the Alfred P. Sloan Research Fellowship and the Fondation pour l'Etude du Système Nerveux Fellowship. His other honors include the George A. Feigen Memorial Lecture at Stanford University and Timoshenko Fellow, Mechanical Engineering, Stanford University. In addition to the scholarly papers, he has also authored a classic book, titled "Mechanics of Motor Proteins and the Cytoskeleton", which has successfully narrowed the gap between the communities of physicists, chemists, biologists and engineers working on molecular motors.

About Max Delbrück: Max Ludwig Henning Delbrück (1906–1981) shared the Nobel Prize in Physiology in 1969. He applied biophysical methods to problems in sensory physiology. Delbrück was one of the most influential personalities in the movement of physical scientists into biology during the 20th century. His ideas about the physical basis of life stimulated Erwin Schrödinger to write the book, "What Is Life" which, in turn, had strong influence on the pioneers of structural and molecular biophysics in mid-twentieth century. The Biological physics prize awarded by the American Physical Society to recognize and encourage outstanding achievement in biological physics research was renamed in 2006 as the Max Delbrück prize.

ICTS-NESP2010 Enrico <u>FERMI</u> Lecture

Fractional quantum Hall effect: Why should others care

Jainendra K. Jain
Pennsylvania State University, USA

<u>Abstract</u>: The conceptual structures discovered in condensed matter systems sometimes provide a key ingredient for important problems in other areas in physics, two prominent examples being spontaneous symmetry breaking in magnets and Bose condensates and the Anderson-Higgs mechanism in superconductors. The fractional Hall quantum liquid constitutes a new paradigm in physics where collective quantum mechanical behavior occurs without spontaneously broken symmetry or Bose-Einstein condensation. In this talk I will summarize my view of the general principles learned from the theory of the fractional quantum Hall effect that may possibly carry over to other fields. These include: emergent particles, topological quantum order, mass generation, dynamical generation of a gauge potential, charge and statistics fractionalization, resolution of a degeneracy problem, realization of the Chern-Simons field theory, and the relevance of conformal field theory.

<u>About the speaker</u>: Jainendra K. Jain is the Erwin W. Mueller Professor of Physics at the Pennsylvania State University. He is best known for the discovery of exotic particles that he named "composite fermions" and for the theoretical explanation of the fractional quantum Hall effect. He is a recipient of the Oliver E. Buckley Prize, the highest award in the United States in the field of condensed matter physics, and has been elected Fellow of the American Academy of Arts and Sciences. Among his other honors are the Distinguished Scholar Prize of the American Chapter of the Indian Physics Association, and fellowships of the American Physical Society, the Alfred P. Sloan Foundation, and the John Simon Guggenheim Memorial Foundation. He currently serves as a member of the Executive Committee of the Division of Condensed Matter Physics of the American Physical Society, and as a Divisional Associate Editor for the Physical Review Letters. In addition to scholarly articles, he has authored a monograph titled "Composite Fermions." Professor Jain is an alumnus of IIT Kanpur (M.Sc. 1981) and a recipient of the Distinguished Alumnus award of IIT Kanpur .

<u>About Enrico Fermi</u>: Enrico Fermi (1901–1954) was awarded the Nobel Prize in Physics in 1938 for his work on radioactivity. In addition, he made path breaking fundamental contributions to quantum theory and statistical mechanics. Acknowledged as a unique physicist who was equally accomplished in both theory and experiment, he played a key role in the development of the atomic bomb. Fermions, which comprise one of the two classes of elementary particles, are named after him. Fermi died prematurely at the age of 53 from cancer caused by excessive exposure to radioactive materials.

ICTS-NESP2010 Edward M. PURCELL Lecture

Steering helical swimmers

Frank Jülicher
Max-Planck Institute for the Physics of Complex Systems,
Dresden, Germany

Abstract: Many eukaryotic cells possess motile cilia to propel their swimming motion. These cilia contain filament bundles arranged in a characteristic 9+2 geometry. Large numbers of motor molecules induce filament sliding and bending of the cilium, thereby generating propagating bending waves. An important model system for ciliar motility are sperm cells. We discuss the physics underlying the ciliar beat and show that the quantitative observation of sperm beating patterns can be accounted for by theory. We furthermore discuss the role of chirality of the ciliar structure. Microswimmers driven by chiral beating patterns can be steered reliably in a chemical concentration field using a simple and general principle. We discuss sperm chemotaxis as an example where sperm find the egg by following a chemoattractant gradient.

About the speaker: Professor **Frank Jülicher** is a director at the Max-Planck Institute for the Physics of complex systems and heads the biological physics division there. He is also a Professor of Biophysics at the Technical University, Dresden. The main focus of Prof. Jülicher's research are theoretical approaches to understand active dynamic processes in cells and tissues. These include the study of cellular oscillations, cellular signaling, dynamics of cell division and cell motility (i.e., swimming and crawling of cells), etc. He is a recipient of the Robert-Wichard-Pohl Prize, Raymond and Beverly Sackler International Prize in Biophysics. He is the editor-in-chief of the European Physical Journal E. Earlier Profesor Julicher served as a member of the boards of editors of Physical Biology and New Journal of Physics and also as the Chairman of the Division of Biological Physics of the German Physical Society.

About Edward M. Purcell: Professor Edward Mills Purcell (1912-1997) shared the 1952 Nobel Prize for Physics for his independent discovery of nuclear magnetic resonance in condensed matter. His pioneering later work on swimming of bacteria, published in 1977 under the title "Life at Low Reynolds Number", was originally delivered as a talk at a symposium held in honor of Victor Weisskopf. The main message of this paper is usually encapsulated by the dogma known as Purcell’s scallop theorem. Purcell shared the Biological Physics Prize of the American Physical Society in 1984 for this work.

ICTS-NESP2010 Satyendra Nath BOSE Lecture

Ultra Cold Atoms in Optical Lattices as ``Emulators'' of Quantum Condensed Matter Systems

H R Krishnamurthy
Indian Institute of Science, Bangalore

Abstract: In 1982 Richard Feynman proposed the concept of a ``quantum analogue simulator", with one “designer” quantum system emulating the Hamiltonian of another physical system. Now, a quarter century later, amazing advances in laser-cooling and trapping of atoms and ions using their interaction with electromagnetic fields, especially optical lattices, (recognized by 2 Nobel Prizes,) are bringing Feynman’s vision close to realization. Such ``optical lattice emulators" may some day guide the development of novel materials, shed light on poorly understood phenomena in materials science, and elucidate interesting quantum effects in condensed matter systems such as high-Tc superconductivity and quantum phase transitions. As a bonus, they also allow access to some very interesting non-equilibrium experiments which would be hard to carry out in their condensed matter counterparts. In this talk I will review, at as non-technical a level as possible, the physics involved in these advances, and discuss their implications for our understanding of strongly correlated quantum condensed matter.

About the speaker: H. R. Krishnamurthy is a professor and JC Bose National Fellow at the Centre for Condensed matter Theory, Department of Physics, Indian Institute of Science Bangalore. He is also an honorary professor at the Jawaharlal Nehru Center for Advanced Scientific Research. He works in and has made significant contributions to the area of quantum many-body theory, with particular emphasis on strongly correlated fermions and bosons in condensed matter. He has been honored with the INSA Young Scientist medal, the Young Associateship of the Indian Academy of Sciences, the Raja Ramanna Prize and the IISc Alumni award for excellence in research. He is a fellow of the Indian National Science Academy, Indian Academy of Sciences and the National Academy of Sciences India. Professor Krishnamurthy is an alumnus of IIT Kanpur (M.Sc. 1972)

About S.N. Bose: Satyendra Nath Bose (1894–1974) is best known for his work on the statistics of indistinguishable particles which were later named after him as "Bosons". Einstein, who translated Bose's manuscript into German, extended Bose's work and predicted an unusual phenomenon which was subsequently named as "Bose-Einstein condensation". Surprisingly, Bose was never awarded the Nobel Prize in spite of the fact that his contribution was one of the most important discoveries of physics in the twentieth-century.

ICTS-NESP2010 Ronald FISHER Lecture

Evolution of sexual and asexual populations on rugged fitness landscapes

Joachim Krug
University of Cologne, Germany

Abstract: A fitness landscape is a mapping from the high-dimensional space of genetic sequences to a single real-valued number representing the expected number of offspring of an individual. Although fitness landscapes have played a central role in evolutionary theory for more than 70 years, empirical insights into their structure are becoming available only recently. Based on such an empirical data set, I will discuss some statistical properties of fitness landscapes and then focus on the consequences of landscape topography for the adaptive dynamics of a population. In particular, I will explain why (contrary to common wisdom) sexual recombination generally slows down the adaptation process, to the extent that adaptation may come to a complete halt beyond a critical recombination rate. The talk is based on joint work with Su-Chan Park, Arjan de Visser and Kavita Jain.

About the speaker: Joachim Krug is a professor of theoretical physics at the university of Cologne. He has made outstanding contributions to theories of crystal growth and interfacial dynamics. The topics of his current research include systems of driven interacting particles, extreme value statistics and the theory of biological evolution. He discovered the "maximum current principle" for driven-diffusive non-equilibrium systems. He is an editor of the Journal of Statistical Mechanics: Theory and Experiment and a member of the editorial board of the Journal of Statistical Physics.

About Ronald Fisher: Sir Ronald Aylmer Fisher (1890–1962) was a statistician, evolutionary biologist and geneticist. His contribution to the theory of population genetics was comparable to those of the two other pioneers, namely, Sewall Wright and J.B.S. Haldane. In addition to founding modern quantitative genetics, he also introduced a partial differential equation, named after him, which is one of the most important models of reaction-diffusion systems. He received many notable awards; these include Royal Medal, Copley Medal and Linnean Society of London's Darwin-Wallace Medal.

ICTS-NESP2010 Hermann von HELMHOLTZ Lecture

Chemomechanical coupling of molecular motors

Reinhard Lipowsky
Max-Planck Institute for Colloids and Interfaces, Golm, Germany

Abstract: All eukaryotic cells including those of our body contain a large variety of molecular machines that convert the chemical energy released from nucleotide hydrolysis into mechanical work. The theoretical description of this chemomechanical coupling starts from the enzymatic activity of the motor and its different nucleotide states. The chemical transitions between these states are uniquely determined by the underlying processes of nucleotide hydrolysis and synthesis. The chemical network is then complemented by mechanical transitions corresponding to the motor's spatial displacements. This network representation provides a general classification scheme for the different cycles of the motor and reveals novel balance conditions between the kinetic and thermodynamic parameters of the motor. [1] For the kinesin motor, a detailed comparison with single motor experiments shows that this motor is governed by a network of chemomechanical cycles. [2] The theory also provides a general framework for computer simulations of motor proteins.

[1] R. Lipowsky, S. Liepelt, and A. Valleriani. J. Stat. Phys. 135, 951-975 (2009)
[2] S. Liepelt and R. Lipowsky. Phys. Rev. Lett. 98, 258102 (2007)

About the speaker: Professor Reinhard Lipowsky is a director of the Max-Planck Institute for Colloids and Interfaces at Golm and heads the division on "Theory and Bio-Systems". He is an honorary professor at the university of Potsdam (where Helmholtz was born) and an honorary professor at the Humboldt University of Berlin (where Helmholtz was the founder director of the institute of physics). Before joining the Max-Planck institute, Professor Lipowsky was a director at the Research Center Jülich. His research interest is in statistical mechanics and its applications to soft and bio-materials. He is a managing editor of Biophysical Reviews and Letters and an editor of Journal of Statistical Physics, Biophysical Journal and Modern Physics Letters B.

About Hermann Helmholtz: Hermann Ludwig Ferdinand von Helmholtz (1821–1894) was a German physician and physicist who made significant contributions to several widely varied areas of modern science. He made major contributions in the formulation of several key concepts of thermodynamics, including the first law of thermodynamics. His pioneering contributions in biophysics include the theories of vision and hearing. A large association of German research institutions, the Helmholtz Association, is named after him.

ICTS-NESP2010 D'Arcy <u>THOMPSON</u> Lecture

The Design and Mechanics of Biological Macromolecular Springs

Paul Matsudaira
National University of Singapore

<u>Abstract</u>: Nature has designed two extreme examples of very fast (msec-sec) and long distance (µm-mm) movements by single cells. Curiously both are powered by spring-like mechanisms and calcium ions play critical roles in controlling the movement. Fertilization of a horseshoe crab egg begins when the sperm cell sends out a 100µm-long finger of membrane from the head of the sperm and contacts the egg. This reaction is activated by calcium ions and completed within five seconds. The movement is powered by releasing strain in an over-twisted bundle of actin filaments. The second example of a spring is the shortening into a helix of a 0.3 mm-long stalk that tethers the cell body of the ciliated peritrich, *Vorticella convallaria*, to the underlying substratum. The contraction is powered by calcium ions and is complete within a few msec. The contractile machine is the spasmoneme, a bundle of filaments and membrane tubules, which is capable of generating up to 400 nNs of force. This lecture will describe the forces, structures, and source of energy that power these movements.

<u>About the speaker</u>: Professor **Paul Thomas Matsudaira** is currently the head of the department of biological sciences at National University of Singapore (NUS) and is the co-director of the Research Center of Excellence in Mechanobiology. He was a professor of biology and bioengineering at MIT and a member of the Whitehead Institute for Biomedical Research for 23 years before joining NUS. He is one of the authors of the classic text "Molecular Cell Biology" by Lodish et al. His research areas include mechanobiology of cells and tissues, particularly mechanics of the actin cytoskeleton. He is the series co-editor of Methods in Cell Biology.

<u>Sir D'Arcy Wentworth Thompson</u> (1860-1948), a pioneer in research on biomechanics or mechanobiology, is remembered mainly for his classic book, titled "On Growth and Form". In this book he emphasized the role of the laws of physics, particularly mechanics, in determining the structure and dynamics of living matter. In recognition of his outstanding contributions, he was knighted in 1937, was elected a Fellow of the Royal Society and awarded the Darwin Medal.

ICTS-NESP2010 Paul LANGEVIN Lecture

Effective long-range interactions in driven non-equilibrium systems

David Mukamel
Weizmann Institute of Science, Rehovot, Israel

Abstract: Driven systems with conserving dynamics tend to exhibit long-range correlations, resulting from the non detailed balance nature of the dynamics. Such correlations can sometimes be expressed by effective long-range interactions, even in cases where the dynamics is local. On the other hand studies of systems with long-range interactions have demonstrated that they exhibit some unusual properties, such as inequivalence of statistical ensembles and slow relaxation processes, with diverging characteristic time with the system size. Such features in driven systems with local dynamics will be demonstrated, and the interplay between non-equilibrium systems and those with long range interactions will be discussed.

About the speaker: David Mukamel is a professor and a former Dean at the Weizmann Institute of Science. He is a holder of Heiny Glasberg Career development Chair and Harold J. and Marion F. Green Professorial Chair. His main research interest is in the symmetry and symmetry breaking in the context of phase transitions in equilibrium systems as well as in systems driven far from equilibrium. Professor Mukamel served as the chairman of the IUPAP (International Union of Pure and Applied Physics) commission on Statistical Physics during 2005-2008. He is a recipient of Miphal Hapais prize, M. Landau prize, J.F. Kennedy prize, Sara Zinder Leedy memorial award, Keren Bat-Sheva de Rotschild Fellowship, The Jeanette and Samuel Lubell prize. He is an editor of the Journal of Statistical Mechanics: Theory and Experiment.

About Paul Langevin: Paul Langevin (1872–1946) is one of the founders of the mathematical formalisms of non-equilibrium statistical physics. He proposed an equation, now named after him, which is one of the most fundamental equations for describing the noisy and irreversible "Brownian dynamics". His other fundamental contributions to physics include theory of paramagnetism. He is one of the leading French physicists buried at the Panthéon.

ICTS-NESP2010 Satish DHAWAN Lecture

Turbulence: A Grand Challenge

Rahul Pandit
Indian Institute of Science Bangalore, India

Abstract: Turbulence is often described as the last great unsolved problem of classical physics. In this talk I present an overview of challenging problems in the statistical characterisation of turbulence. In particular, I provide examples from our recent numerical and theoretical studies of three- and two-dimensional fluid turbulence, the turbulent advection of passive scalars, turbulence in the one-dimensional Burgers equation, and fluid turbulence in the presence of polymer additives.

This talk is based principally on work that I have done with Dhrubaditya Mitra, Prasad Perlekar, and Samriddhi Sankar Ray.

About the speaker: Rahul Pandit is MSIL Chair Professor of Physics and at the Indian Institute of Science Bangalore. He has carried out research on a wide variety of problems in condensed-matter theory ranging from phase transitions to turbulence. He is a J.C. Bose Fellow of the Department of Science and Technology, a Fellow of the Indian Academy of Sciences and the Indian National Science Academy, and a recipient of the Bhatnagar Prize of the CSIR, and the M.N. Saha Award of the UGC. He serves as a Divisional Associate Editor of Physical Review Letters and is a member of the Advisory Editorial Board of Physica A.

About Satish Dhawan: Professor Satish Dhawan (1920-2002) was the father of experimental fluid dynamics research in India. He carried out path-breaking research on boundary layers and set up the first supersonic wind tunnel in India at the Indian Institute of Science, Bangalore. He served with great distinction as the Director of the Indian Institute of Science from 1962-1981 and then was Chairman of the Indian Space Research Organisation and the Space Commission. He was President of the Indian Academy of Sciences from 1977-1979 and a member of U.S. National Academy of Engineering. He received several awards and honors including the Padma Vibhushan.

ICTS-NESP2010 Sivaramakrishna CHANDRASEKHAR Lecture

Nonequilibrium soft matter:
Self-propelled, drifting, and stuck

Sriram Ramaswamy
Indian Institute of Science, Bangalore

Abstract: Collections of interacting particles can be out of equilibrium in a variety of ways. They could be metastably trapped in a glassy state, or driven by an external gravitational or electric field, or internally propelled. Each of these cases presents interesting problems in nonequilibrium statistical physics, and my talk will summarize our group's efforts in these areas.

About the speaker: Sriram Ramaswamy is a professor and a J. C. Bose fellow at the Indian Institute of Science Bangalore. He is also associated with the JNCASR and is an adjunct professor at the International Centre for Theoretical Sciences. He has made fundamental contributions to the nonequilibrium statistical mechanics of soft and living matter, most recently to the collective behaviour of self-propelled particles. Liquid-crystalline order is a recurring theme in his work. Professor Ramaswamy is the Vice-Chair of the IUPAP commision on Statistical Physics. He has been elected a Fellow of the Indian Academy of Sciences and Indian National Science Academy. He is recipient of the N.S. Satyamurthy award, NASI Young Scientist Millenium Award, the S.S. Bhatnagar prize, G. D. Birla Prize, B.M. Birla Memorial Prize. He is the current or past member of the advisory or editorial boards of several journals; these include European Physical Journal E, Advances in Physics, JSTAT: Theory and Experiment, Soft Matter, Liquid Crystals and Physical Review E.

About S. Chandrasekhar: Sivaramakrishna Chandrasekhar (1930-2004) established the world class laboratory for research on Liquid Crystals at the Raman Research Institute in Bangalore. He predicted and discovered a new class of liquid crystal, called discotic liquid crystals. His classic book on Liquid Crystals was published by Cambridge University Press. Besides getting most of the highest recognitions in India, Chandrasekhar received numerous international awards and honours. He was elected a Fellow of the TWAS, Royal Society, Institute of Physics (UK). He was recipient of the Royal Medal of the Royal Society, V.K. Friedericksz medal of the Russian Academy of Sciences and the Niels Bohr Gold Medal of UNESCO. He was the founder-president of the International Liquid Crystal Society. The French Government conferred on him the title Chevalier dans l’Ordre des Palmes Academiques.

ICTS-NESP2010 K. S. KRISHNAN Lecture

Do precision physical measurements carry any value? case study of measurements of thermal fluctuations in molecules of life

Arup K. Raychaudhuri
S. N. Bose national Centre for Basic Sciences,
Kolkata, India

Abstract: The most potent tool of Physics is that it can probe the nature and natural phenomena with high precision measurements. Often very fundamental questions can be probed with measurements that are simple in concept. In this talk we discuss example of simple calorimtry experiment (of a new type) where one probes the thermal fluctuations associated with biomolecules like DNA and Chromatin when they undergo thermal denaturation. The experiment reveals the fundamental energy landscape that are associate with the denaturation process and other information that are not obtainable from other experiments.

About the speaker: Arup Raychaudhuri is a senior professor and Director of the S. N. Bose National Centre for Basic Sciences, Kolkata. For a few years, he was the Director of the National Physical Laboratory which was founded by Professor K. S. Krishnan. Before shifting to Kolkata, Professor Raychaudhuri served on the faculty of the Indian Institute of Science Bangalore for more than two decades. He is a leading expert in low-temperature physics, nanoscience, noise and fluctuation, etc. Among the long list of awards he has received, the most notable are the S. S. Bhatnagar Award, Millenium Medal of the Indian Science Congress, ICS Gold Medal of the MRS of India, FICCI Award in materials science and applied science. Professor Raychaudhuri is an elected fellow of Indian National Science Academy, Indian Academy of Sciences, National Academy of Sciences and Asia-Pacific Academy of Materials. He is an alumnus of IIT Kanpur (M.Sc., 1975).

About K. S. Krishnan: Kariamanickam Srinivasa Krishnan (1898–1961) carried out some of the experiments, with his mentor C. V. Raman, which were crucially important for the discovery of the Raman effect. On the occasion of his birth centennary, T. V. Ramakrishnan wrote, "for almost a quarter of a century, Krishnan seems to have been more or less the lone Indian practitioner of the quantum approach to understanding phenomena in condensed matter". Professor Krishnan was an elected fellow of the Royal Society London, a Foreign Associate of the US National Academy of Sciences and the first recipient of the S.S. Bhatnagar prize. He was a founder member of the International Union of Crystallography, a Vice President of the International Union of Pure and Applied Physics and International Council of Scientific Unions. He was also awarded the Padma Bhushan by the Government of India.

ICTS-NESP2010 N. F. MOTT Lecture

Theory of nonequilibrium current carrying states in type II superconductors with artificial pinning array at matching magnetic field.

B. Rosenstein,
National Chiao Tung University, Hsinchu, Taiwan

Abstract: Current carrying steady state of the pinned flux line lattice created by magnetic field is described. Its energy is higher than that of the equilibrium state. We calculate analytically the critical current for the case of the matching field (when number of vortices is equal to that of the pinning centers) using the framework of Ginzburg-Landau model. The vortex cores are deformed and displaces in the current carrying state. Displacement of the centers of the vortices with respect to pinning centers and structure of these states is determined.

About the speaker: Baruch Rosenstein is a professor at the National Center for Theoretical Sciences and Department of Electrophysics, National Chiao Tung University, Taiwan. He has made seminal theoretical contributions in understand the glassy phases and phase transformation in the driven and static phases of the vortex matter in superconductors. He has also worked on mechanisms of transport in graphene.

About N. F. Mott: Sir Nevill Francis Mott (1905–1996) was awarded the Nobel Prize for Physics in 1977 for his work on the electronic structure of magnetic and disordered systems. He was Cavendish Professor of Physics and Master of Gonville and Caius College at the university of Cambridge. In his obituary, P. W. Anderson (who shared Nobel prize with him in 1977) wrote "no worldly honor can do justice to a sciuentific career that retained its fertility for 70 years, which included a major role in the creation of several entirely new sciences and a beneficent influence on several others".

ICTS-NESP2010 Lars ONSAGER Lecture

Stochastic thermodynamics: Theory and experiments

Udo Seifert
University of Stuttgart, Germany

Abstract: Stochastic thermodynamics provides a framework for describing small systems embedded in a heat bath and externally driven to non-equilibrium [1]. Examples are colloidal particles in time-dependent optical traps, single biomolecules manipulated by optical tweezers or AFM tips, and motor proteins driven by ATP excess. A first-law like energy balance allows to identify applied work and dissipated heat on the level of a single stochastic trajectory. Total entropy production includes not only this heat but also changes in entropy associated with the state of the small system. Within such a framework, exact results like an integral fluctuation theorem for total entropy production valid for any initial state, any time-dependent driving and any length of trajectories can be proven [2]. These results hold both for mechanically driven systems modelled by over-damped Langevin equations and chemically driven (biochemical) reaction networks [3]. These theoretical predictions have been illustrated and tested with experiments on a colloidal particle pushed by a periodically modulated laser towards a surface [4]. Key elements of this framework like a stochastic entropy can also be applied to athermal systems as experiments on an optically driven defect center in diamond show [5,6]. Optimization within stochastic thermodynamics looks for the optimal protocols connecting two different states in finite-time with the least amount of dissipation [7]. Using this concept, the efficiency of stochastic heat engines and molecular motors at maximum power can be discussed [8,9].

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About the speaker: Udo Seifert is a Professor at the university of Stuttgart. His research interests are in the area of non-equilibrium statistical mechanics and in physics of soft- and bio-materials. He has been playing a leading role in the recent revolution in stochastic thermodynamics. He introduced the novel concept of entropy for individual trajectories in the context of fluctuation theorems and irreversibility. He is divisional Associate Editor of Physical Review Letters, a Co-editor of Europhysics Letters and an editor of Biophysical Reviews and Letters.

About L. Onsager: Lars Onsager (1903–1976) was the recipient of the 1968 Nobel Prize in Chemistry. He was the Gibbs Professor of Theoretical Chemistry at Yale University. Professor Onsager made a number of contributions to physics and chemistry which can be regarded as milestones in the development of science; one example being the exact solution of the two-dimensional Ising model. But, his discovery of the reciprocal relations, for which he received the Nobel prize, is one of the greatest advances in science during the 20th century. It was also the first significant step in developing theoretical foundation of Non-equilibrium Statistical Physics.

ICTS-NESP2010 C. V. RAMAN Lecture

Order and Chaos in Flow of Soft Matter

A.K. Sood
Indian Institute of Science, Bangalore, India

Abstract: Soft matter under shear flow is not only of industrial relevance but also is a paradigm for fascinating non-equilibrium physics. My talk will show case this by taking examples from our on-going work on visco-elastic gels, concentrated surfactant systems and colloidal glass. We will show that the viscosity of these systems increase with time on application of stress ,leading to a jammed state, displaying anomalously large fluctuations in viscosity showing positive and negative values . These unusual results can be understood in the framework of recently known theorems in non-equilibrium physics [1]. Another fascinating example will be of spatio-temporal chaos – irregular time dependence in the stress at constant shear rate or vice versa, that has been established to be a flow instability occurring practically at zero Reynolds number [2,3]. A theme will emerge in the talk on the novel flow behavior of soft matter which are ubiquitous all around us.

[1] S. Mazumdar and A.K. Sood, Phys. Rev. Lett. **101**, 078 301 (2008) and unpublished results.
[2] R. Ganapathy and A.K. Sood, Phys. Rev. Lett. **96**, 108 301 (2006).
[3] R. Ganapathy, S. Mazumdar and A.K. Sood, Phys. Rev. **E 78**, 021 504 (2008) and unpublished results.

About the speaker: Ajay K. Sood is a Professor of Physics and a former Chairman of the Division of Physical and Mathematical Sciences at the Indian Institute of Science, Bangalore. He is internationally renowned for his research based on Raman and Brillouin scattering, ultrafast spectroscopy, transport measurements, dynamic light scattering, rheology, etc. His systems of interest include both hard and soft condensed matter. Professor Sood is an elected fellow of INSA, IASc, NASI, TWAS (Trieste). He has served as a Vice-president of INSA; at present he is the President of the IASc (2010-2012). He also serves as an Executive Editor of Solid State Communications. Professor Sood received the S. S. Bhatnagar Award, TWAS Award, G.D. Birla Science Award, FICCI (Federation of Indian Chambers of Commerce and Industry) Award, Bhabha Medal of INSA, MRS (India) Medal, Millennium Gold Medal and M.N. Saha Birth Centenary Award of Indian Science Congress, IISc Alumni Award for Excellence in Research for Science, Goyal prize, DAE Raja Ramanna award of JNCASR, National Award in Nanoscience and Nanotechnology of DST and Bhatnagar Fellowship of CSIR,etc. He also received the Sir C.V. Raman Award of UGC and served as a member of the International Steering Committee of Raman Spectroscopy (1994-1999).

About C. V. Raman: Sir Chandrasekhara Venkata Raman (1888-1970) was awarded the Nobel prize in physics in 1930 for the discovery of the Raman effect, which is named after him. He was the first Asian to get any Nobel Prize in the sciences. Professor Raman served as the director of IISc Bangalore. He was appointed the first National Professor by the government of Independent India in1947 and was awarded the Bharat Ratna in 1954. He was the founder of the Indian Academy of Sciences. India celebrates National Science Day on 28th February of every year to commemorate the discovery of the Raman effect in 1928.

ICTS-NESP2010 Rudolf PEIERLS Lecture

Universality, and Non-universal Dynamics in Non-equilibrium Systems
R. B. Stinchcombe,
University of Oxford, UK

Abstract: Peierls and other inspirational pioneers saw theoretical physics from a unified perspective, and that view continues to provide valuable cross fertilisation today. Very brief mention will be made of phenomena or methods originating in one area and extremely important in another, eg Goldstone and Higgs symmetry-breaking, and renormalisation. The latter was beautifully rephrased in Wilson's Renormalisation Group to handle the diverging correlation length seen in continuous equilibrium phase transitions near the transition/critical point. This, and how it leads to Universality, will be outlined. In recent years these ideas have been extended to non-equilibrium and quantum systems, which are actually related. Generalised views of Universality pervade collective behaviour, even beyond physical systems. Non-universal behaviour in static or dynamic critical behaviour is rare and puzzling. Nevertheless, recent numerical investigations of a basic non-equilibrium model will be presented which exhibit remarkable non-universal critical dynamics when the rates have (binary) disorder. Far from the expectations of universal critical behaviour, the dynamic exponent z varies continuously with a concentration parameter p, and even diverges at a critical concentration p_c. A brief description of the physics underlying this and its theoretical explanation will be given. The theory involves a first passage problem with a biased random walk of a complex phase variable. z(p) is given exactly in terms of the mean bias and diffusion constant of the walk, and p_c is determined exactly by the vanishing of the mean bias, in good agreement with the numerical results. This work on the particular basic model suggests conditions under which other non-equilibrium systems will show interesting non-universal critical dynamics, as well as theoretical approaches to which they should be amenable.

About the speaker: Robin Stinchcombe wrote his Ph.D. thesis under the supervision of Rudolf Peierls. He has been on the faculty of Oxford University and a Fellow of New College for more than four decades. Though now Emeritus, he is still active in research, and in participation on advisory boards, etc. His fundamental works on a wide range of topics in statistical physics and condensed matter provide deep understanding of complex systems and phenomena. He has also made novel applications of nonequilibrium statistical mechanics in economics. Earlier he served as an editor of Journal of Physics A.

About Rudolf Peierls: Sir Rudolf Ernst Peierls, (1907-1995) made outstanding contributions to almost all areas of physics, ranging from nuclear physics, and quantum field theory, to statistical mechanics and condensed matter physics. He received many international awards and honors; for example, Royal Medal, Lorentz Medal, Max Planck Medal, Enrico Fermi Award, Matteucci Medal, Copley Medal. After leading one of the most creative centers of theoretical physics at Birmingham for more than twenty five years, he moved to Oxford University as the head of the department of theoretical physics and a fellow of New College, In 2004, the department of Theoretical Physics at the University of Oxford was formally named the Sir Rudolf Peierls Centre for Theoretical Physics.

ICTS-NESP2010 Subrahmanyan CHANDRASEKHAR Lecture

The Maldacena duality conjecture and applications

Spenta R. Wadia
Tata Institute of Fundamental Research and
International Centre for Theoretical Sciences, Mumbai, India

Abstract: The microscopic understanding of black hole entropy and Hawking radiation within the framework of string theory paved the way to the conjecture of Maldacena that quantum gravitational phenomena in a space-time that is asymptotically anti-deSitter is coded holographically in a quantum field theory on the boundary of the space-time. This weak - strong coupling duality enables further understanding of the structure of space-time and also enables strong coupling calculations in the theory on the boundary. The relationship to fluid dynamics and applications to condensed matter systems will also be discussed.

About the speaker: Spenta R. Wadia is a Distinguished Professor and the Chair of the department of Theoretical Physics at TIFR. He is the Director of the International Centre for Theoretical Sciences of TIFR and is a J.C. Bose fellow. He is an international leader in research on string theory. Professor Wadia is an elected fellow of the Indian National Science Academy, Indian Academy of Sciences, National Academy of Sciences India, TWAS and the New York Academy of Sciences. He has served IUPAP as a member of the Commission on Mathematical Physics. He is a recipient of the TWAS prize and the Steven Weinberg prize. Professor Wadia is an alumnus of IIT Kanpur (M.Sc. 1973).

About S. Chandrasekhar: Subrahmanyan Chandrasekhar (1910–1995) was awarded the Nobel prize in physics for his work on the evolution of stars. He had a unique style of his working continuously in one specific area of physics for a number of years and then writing an authoritative monograph on that topic before moving onto a new topic of research. His pedagogical review article on stochastic processes, published in the Reviews of Modern Physics in 1943, remains a compulsory reading for beginners in Non-equilibrium Statistical Physics even today.

ICTS-NESP2010 P. Kapitza Lecture

Vortex matter dynamics and nano-SQUID on a tip

Eli Zeldov
Weizmann Institute of Science, Rehovot, Israel

Abstract: The thermodynamic vortex matter phase diagram in $Bi_2Sr_2CaCu_2O_8$ crystals is investigated employing vortex shaking by in-plane ac field in order to equilibrate the vortex system. A second-order glass transition line Tg is found to bisect the first order melting line Tm, defining four thermodynamic vortex phases. To elucidate the nature of the different phases we probe their bulk inductances to extract their respective resistances down to three orders of magnitude below the noise level in transport measurements. Our technique allows accurate determination of the bulk resistance in the weakly pinned vortex solid, which is immeasurable in the regular transport studies. We find thermally activated bulk resistance that indicates a critical behavior on approaching Tg. We have developed a novel method for fabrication of a nanoscale superconducting quantum interference device (SQUID) on a sharp tip. A hollow quartz tube is pulled to an apex of 100 to 400 mm diameter. Three aluminum evaporation steps from different angles form self-aligned superconducting leads and a SQUID loop containing two weak links, without any need for lithographic processing. The nanoSQUIDs on tip operate over a wide range of fields up to 0.5 T. A nanoSQUID with effective diameter of 208 nm displays flux sensitivity of $1.8 \times 10^{-6}\ \Phi_0\ /Hz^{1/2}$ at 300 mK and expected spin sensitivity of $65\ \mu_B/Hz^{1/2}$. We have constructed a scanning SQUID microscope based on these devices with the aim of investigation of vortex dynamics in superconductors with single vortex resolution.

About the Speaker: Eli Zeldov is a professor at the Weizmann Institute of Science, Israel. He currently holds The David and Inez Myers Professorial Chair. He is a leader in the field of physics of vortex matter, particularly thermally induced phase transitions and effects of disorder on the vortex lattice in superconductors. He has also developed a diverse array of sensitive instruments to probe local magnetic properties of materials. He is a recipient of the Kammerling Onnes prize.

About P. Kapitsa: Pyotr Leonidovich Kapitsa (1894–1984) received the Nobel prize for Physics in 1978 "for basic inventions and discoveries in the area of low-temperature physics". In the Nobel prize presentation speech, it was stated, "Kapitsa stands out as one of the greatest experimenters of our time, in his domain the uncontested pioneer, leader and master. Kapitsa was the director of the Institute for Physical Problems in Moscow. He was a member of the Presidium of the USSR Academy of Sciences and one of the founders of the Moscow Physico-Technical Institute. He also served as the editor-in-chief of the Journal of Experimental and Theoretical Physics (JETP).

ICTS-NESP2010 Distinguished Colloquium

Fluctuations, Response, Entropy and "Temperature" in Granular Packings

Bulbul Chakraborty,
Brandeis University, Waltham, Massachusetts, USA

Abstract: Understanding jamming, the transition from a flowing fluid state to a disordered solid state, in granular systems is important from a technological, environmental, and basic science perspective. Jamming of grains in solids cause catastrophic failures. Avalanches are examples of unjamming, which we need to understand to prevent and control. The phenomenon poses fundamental challenges in basic science because there is no known framework leading from the microscopic, grain level interactions to the macroscopic properties that reflect collective behavior. Jamming in granular matter is intimately related to stress propagation, and the nature of jamming will depend on whether the material is under shear or isotropic compression. It will also depend on whether there is sustained motion with the grain having a finite kinetic energy or if the system is at rest and is being slowly deformed. In this talk, I'll present a statistical mechanics framework that bridges the microscopic with the macroscopic, and present results for stress fluctuations and force chains in granular packing.

ICTS-NESP2010 Distinguished Colloquium

Cooling rate dependencies in classical coarsening systems: extension of the Kibble-Zurek mechanism

Leticia F. Cugliandolo
Universite Pierre et Marie Curie, Paris VI, France

Abstract: When a macroscopic system is driven through a second order phase transition (a quench) it undergoes an ordering process that is called domain growth or phase ordering. This phenomenon is possibly the simplest example of macroscopic aging dynamics with many similarities and some differences with that is observed in more complex glassy systems in which the mechanism underlying the relaxation is not known. In this talk I shall focus on the time and quench rate dependence of the typical growing length in coarsening systems with scalar order parameter as, for example, the well-known ferromagnetic Ising model. By combining scaling and numerical analysis I shall show that the typical growing length determines the density of topological defects left over in the symmetry broken phase, far from the critical region. Our results, presented in [1], extend the so-called Kibble-Zurek mechanism.

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ICTS-NESP2010 Distinguished Colloquium

Record theory and applications: Global warming and market fluctuations

Joachim Krug
University of Cologne, Germany

Abstract: A record is an entry in a time series that is larger or smaller than all previous entries. Records from independent, identically distributed random variables provide a well-understood paradigm of non-stationary dynamics dominated by rare events, but modifications of this basic model have been considered only recently. In this talk I will describe examples of record processes with correlated and non-identically distributed random variables, and discuss applications to two empirical data sets: Temperature records under the influence of global warming, and stock market fluctuations. The talk is based on joint work with Gregor Wergen and Miro Bogner.

ICTS-NESP2010 Distinguished Colloquium

Understanding Search Trees via Statistical Physics

Satya N. Majumdar
Universite de Paris-Sud, France

Abstract: Search trees are random structures that play a vital role in data storage in computer science. This talk aims at understanding the statistical properties of various random search trees using simple techniques of statistical physics. In particular, we will focus on three observables: the height, the balanced height and the number of nodes needed to store data of a given size on a search tree with m branches. Via a mapping to a random fragmentation problem, we show how a rather striking phase transition appears in the fluctuations of the number of nodes needed to store a random data of size N, as a function of the branching ratio m of the tree at a critical value m_c=26!

ICTS-NESP2010 Distinguished Colloquium

The Mechanics of the Fastest Cellular Movement - The Contraction of the *Vorticella convallaria* Spasmoneme

Paul Matsudaira
National University of Singapore

Abstract: In the mid-seventeenth century, Antoine Van Leeuwenhoek peered through a simple microscope and described the movement of a curious organism in pond water. We think he watched the cycles of shortening and extension by the spasmoneme of the ciliated peritrich, *Vorticella convallaria*. The spasmoneme is an intracellular fiber, composed of 2 nm-diameter filaments and tubular membranes, that shortens when bound with calcium ions. This movement draws the 20μm diameter cell body a distance of 0.3 mm in a few msec toward the substrate, an order of several hundred cell lengths/sec. These speeds and forces are the largest known for an individual cell. To estimate the contractile force, previous studies have assumed ideal Stoke drag conditions. However, the movement is of the cell body through water occurs at a Reynolds number >1 and in non-ideal Stokes flow. My lab has studied the structure of the spasmoneme and the loaded and unloaded forces produced during contraction. I'll describe how particle flow velocimetry and computational fluid dynamics simulations estimate a drag force of 28 nNs and how controlled flow in a microfluidic channel can generate stalling forces of up to 250 nNs. However, the maximum stall force is dependent on the stalk length and the power developed during contraction is bounded. The force and power provide a unique insight into the molecular mechanism of contraction.

ICTS-NESP2010 Distinguished Colloquium

Statistical Mechanics of Extreme Events

G. M. Schütz
Research Center Julich, Germany

Abstract: The study of extreme events in systems with many degrees of freedom belongs to the foundations of equilibrium statistical mechanics, but is important also outside equilibrium in optimization problems or when damage may arise as consequence of an extreme event. The causes of extreme events in non-equilibrium systems are generally very difficult to investigate theoretically since their properties are encoded in the tails of the unknown probability distribution of some complicated many-body dynamics. In the last decade, however, there has been substantial progress in understanding several key features of probability tails in systems far from thermal equilibrium. In particular, the Gallavotti-Cohen symmetry provides a quantitative prediction for the entropy production. We discuss the significance of this symmetry relation and show in the context of a generic class of mass transfer models that the occurrence of an extreme event, viz., a condensation phenomenon, causes a breakdown of the Gallavotti Cohen symmetry. From a broader perspective this result is an encouraging instance where a statistical mechanics model provides detailed insight into the dynamical origin and consequences of extreme events. It leads us beyond the purely descriptive treatment of traditional extreme value statistics.

ICTS-NESP2010 Frontier Overview

Modeling traffic with exclusion processes: from molecules to vehicles

Debashish Chowdhury
Indian Institute of Technology, Kanpur, India

Abstract: Totally asymmetric simple exclusion process (TASEP) is one of the simplest models of a non-equilibrium system of self-driven interacting particles. Motivated by the traffic-like collective movements of molecular motors in living cells, this model has been extended by (i) replacing the particles by rigid rods with "internal states" and (ii) allowing the possibility of their attachments and detachments from the lattice. Moreover, traffic of social insects on their trails and vehicular traffic on highways have also been modeled by appropriate extensions of TASEP. In this talk, I'll present a pedagogical overview of these models and results.

ICTS-NESP2010 Frontier Overview

Active Forces and Flows in the Establishment of Cellular Polarity

Stephan W. Grill
MPI-PKS and MPI-CBG, Dresden, Germany

Abstract: Active material flow of the contractile actomyosin cortex is important for many cell biological processes, amongst which is the segregation of specific proteins to distinct domains of the cell during cellular polarization. Here I report on the physical mechanisms that underlie coordinated and large-scale flow of the cellular cortex in *Caenorhabditis elegans* embryos, which we have investigated in a combined experimental and theoretical approach. Through advection, flow appears to switch a set of PAR proteins to obtain a non-homogeneous distribution, which we have analyzed in the framework of reaction-diffusion. Our results reveal how cellular mechanics and biochemistry interact to establish cellular polarity.

ICTS-NESP010 Frontier Overview

Theoretical studies of coupled parallel exclusion processes

Anatoly B. Kolomeisky
Rice University, USA

Abstract: Exclusion processes are critical for understanding fundamental mechanisms of non-equilibrium processes, and they are also important for modeling many chemical, physical and biological processes. Here we present our results of theoretical investigations of coupled exclusion processes. It is found, using advanced mean-field methods and exact solutions, that stationary-state dynamics for these systems is mainly determined by the symmetry, strength and homogeneity of the coupling, as well as properties along the channels. Our theoretical predictions are well supported by extensive computer Monte Carlo simulations.

ICTS-NESP010 Frontier Overview

Fluctuation relations for molecular motors

David Lacoste
École Supérieure de Physique et de Chimie Industrielles, Paris, France

Abstract: Molecular motors typically operate far from equilibrium in a regime where the usual thermodynamical laws do not apply. For simple theoretical models of molecular motors, we illustrate general relations, valid arbitrarily far from equilibrium, such as the Gallavotti-Cohen relation. A special emphasis is made on two states ratchet models, similar to the flashing ratchet model.

ICTS-NESP2010 Frontier Overview

Stretching Fluctuations and Loop Formation in Short Double-Stranded DNA molecules

Gautam I. Menon
Institute of Mathematical Sciences, Chennai, INDIA

Abstract: Many of the physical properties of DNA are well modeled in terms of the mechanics of a homogeneous semi-flexible polymer (the worm-like chain), particularly at scales much larger than the individual base-pair. For very short DNA strands (say 1-20 base pairs), on the other hand, more microscopic atomic-scale descriptions would seem more appropriate. Recent experiments on DNA cyclization and DNA stretching probe a length regime intermediate between these extremes (between 35-90 bp's), providing evidence both for an anomalously enhanced tendency for DNA at this scale to form loops as well as for cooperative stretching fluctuations. Neither of these are explained by conventional approaches based on the worm-like chain model. I will describe our approach to this problem, presenting a comparison of predictions from theory with experimental data, suggestions for new methods of looking at the data itself and a physical picture for the experiments.

ICTS-NESP2010 Frontier Overview

Traffic signals inside a cell:
an update on kinesin-dependent intracellular transport and its regulation

Krishanu Ray
Tata Institute of Fundamental Research, Mumbai, India

Abstract: Cellular interior is a complex space containing diverse mix of compartments of different chemical compositions. The diversity and intracellular organizations of these compartments define the cellular identity and function in a tissue. Therefore, maintaining the inhomogeneity of these compartments is as critical as life. Motor proteins are evolutionarily conserved mechanochemical ATPases. They bind microtubule, or, actin filaments and transport various cellular ‘cargoes’, and thus, maintain the inhomogeneity. The situation is analogous to a railway network. One of the most important questions is how this traffic is managed so that it always delivers cargoes to their rightful destinations. Kinesins are conserved family of motors involved in microtubule-dependent transports within a cell. Different subfamilies of kinesin motors are engaged in specific sets of transports. The process is also conserved. For example, the cargoes of kinesin-1 and their intracellular destinations are similar in different cell types and species. Recent studies have further identified several new ‘non-cargo’ protein interactors of kinesins. Some of these are signalling molecules that could coordinate the kinesin based traffic. Together these provide some insight to the traffic regulation system inside a cell, which will be discussed in the talk.

ICTS-NESP2010 Frontier Overview

Aster formation and rupture transition in semi-flexible fiber networks
with mobile cross-linkers

P. B. Sunil Kumar
Indian Institute of Technology, Chennai, India

Abstract: Fibrous active network structures whose properties are regulated by motor proteins are fundamental to life. In this talk, a three dimensional elastic model for such networks with motors will be presented. We demonstrate that, when the effects of surface anchoring are accounted for, for unidirectional motors two basic contractile phases emerge in these systems. The transition from one to the other is governed by a single parameter (\tau_b/\tau_c) which is the ratio of the breaking strain (τ_b) and the motility limiting strain (\tau_c) of the motors. For \tau_b/\tau_c \lesssim 2 and clamped boundaries, the network ruptures, resulting in the formation of local asters with a high density of motors at the centre and the fibers radially spanning out. This phase displays contraction strain during the formation of asters but the network stress is relaxed once the asters have emerged, demonstrating that the formation of aster-like structures provides a mechanism for stress relaxation. For 2 \lesssim \tau_b/\tau_c the network is not ruptured, but reaches a force equilibrium with a high contraction strain in the case of clamped boundaries. In the case of free boundaries the network collapses onto one single aster. We also show that the distribution of energy on the motors is a power law with the exponent -0.5.

ICTS-NESP2010 Frontier Overview
Majorana Modes and Non-Abelian Anyons in Spin Systems

R. Shankar
Institute of Mathematical Sciences, Chennai, India

Abstract: The concept of topological quantum computation has been receiving much attention in the recent past as a way of implementing fault tolerant quantum computation. The qubits in this scheme are non-abelian anyons. The braiding properties of these anyons can be used to efficiently realise quantum circuits. In this talk we will review the work of Kitaev, who showed how non-abelian anyons can be realised in a class of quantum spin models. We will also present some of our results in this context.

ICTS-NESP2010 Plenary Lecture

M. Manosas(1), V. Croquette(1), M. Spiering(2) and S. Benkovic(2)
(1) Ecole Normale Superieure, Paris, France
(2) Pennsylvania State University, University Park, USA

Abstract : The replisome is a central element of any replication system and is responsible for the separation and replication of the parent DNA strands. The T4 bacteriophage system offers a simple model for replication. The replisome is formed by the primosome (the helicase (gp41) and primase (gp61) complex) and two holoenzymes (the polymerases (gp43) and their accessory proteins). The helicase separates the DNA strands while the primase synthesizes small RNA primers required to initiate Okazaki fragments, whereas the polymerases synthesise the new DNA strands. Many questions remain concerning these complexes, including how the helicase, primase and polymerase activities and motions are coupled. Here we use magnetic tweezers to manipulate a single tethered DNA hairpin. The substrate extension is used as a real-time reporter of the replisome-activity. We have first investigated the action of the helicase in complex with primase. Next we have studied the coupling between the helicase and polymerase. In the primosome, the helicase and the primase work together in a very tight complex in other virus like T7 these two enzymes even form a single enzyme. These two enzymes are molecular motors moving along one strand of the DNA. Surprisingly, these two motors runs in opposite direction! By visualizing in realtime the activity of these enzyme on a DNA hairpin corresponding to a simple replication fork we have observe that two scenario occur: a dissociation one in which one part of the primase dissociate from the complex staying bound to the primer, and a looping one where both enzyme stay bound but a ssDNA loop is extruded. Although these mechanisms had been predicted, the magnetic tweezers enabled to visualized them for the first time. Finally we shall discuss how the polymerase works with the primosome and how these enzymes collaborate to perform an efficient DNA replication.

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ICTS-NESP2010 Plenary Lecture

Force generation in the lamellipodium of crawling cells

Tom Duke
London Centre for Nanotechnology, University College of London, UK

Abstract: Many cells spread on surfaces and crawl across them by extending an actin-rich lamellipodium – a thin section at the perimeter of the cell that is typically several micrometres broad, but less than 200nm high. The precise mechanism by which propulsive force is generated within the lamellipodium is unknown. One popular model posits that protrusion operates by a Brownian ratchet mechanism, as actin filaments polymerize behind the fluctuating cell membrane and support its forward motion. We propose, rather, that excluded volume interactions between growing actin filaments are a more significant cause of the propulsive force. In our model, branched actin filaments are nucleated at the leading edge, where the Arp2/3 complex is activated by proximity to highly-curved membrane. As the filaments polymerize, they form a dense, glass-like gel and because longer filaments pack less efficiently than shorter ones, excluded volume effects cause the gel to expand. If some of the actin filaments are bound by adhesions to the surface, this expansion results in forward motion of the leading edge. By conducting stochastic simulations of this non-equilibrium process in the steady-state regime, we show that our model can reproduce the characteristic force-velocity relation of motile cells, as well as the retrograde flow of actin. Our model also suggests why actin is branched within lamellipodia, and provides a potential explanation for the characteristic lamellipodium height.

ICTS-NESP2010 Plenary Lecture

Out-of-equilibrium directionality and information processing in biophysical nanosystems

Pierre Gaspard
Free University, Brussels, Belgium

Abstract: The breaking of time-reversal symmetry in the statistical description of nonequilibrium processes naturally explains the directionality which is observed out of equilibrium, especially, in biological systems. This directionality is characterized by the fluctuation theorems and other large-deviation relationships, which provide new methods to understand the thermodynamics of nonequilibrium nanosystems such as molecular motors, as well as information processing at the nanoscale during copolymerizations as it is the case in DNA replication.

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ICTS-NESP2010 Plenary Lecture

Multiscale motility of molecular motors

Reinhard Lipowsky
Max-Planck Institute for Colloids and Interfaces, Golm, Germany

Abstract: All eukaryotic cells including those of our body contain a large variety of molecular machines that convert chemical energy into mechanical work. This talk will focus on cytoskeletal motors which walk along filaments with two motor heads and have been intensely studied by single molecule experiments. The behavior of these motors covers a wide range of length and time scales: (i) Stepping of single motors with a step size of the order of 10 nanometers; (ii) Cooperative transport by motor teams that move intracellular cargo from tens of micrometers up to a few meters [1]; (iii) Bi-directional transport by antagonistic motor teams that perform a stochastic tug-of-war [2]; (iv) Composite motor walks consisting of directed transport interrupted by diffusive motion [3]. Particularly intriguing examples are provided by axonal transport in nerve cells.

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ICTS-NESP2010 Plenary Lecture

Slow dynamics in systems with long-range interactions

David Mukamel
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Abstract: Systems with long-range interactions, in which the two-body potential decreases at large distances, R, with a rate slower than 1/R^d in d dimensions are not additive. As a result many of the thermodynamic features which characterize the more commonly studied systems with short range interactions are qualitatively modified. In this talk relaxation processes in systems with long-range interactions will be reviewed. In many cases these processes become unusually slow, with relaxation times which diverge with the system size. Models exhibiting these and other features will be presented.

ICTS-NESP2010 Plenary Lecture

Pattern Formation in Granular Materials

Sanjay Puri
Jawaharlal Nehru University, New Delhi

Abstract: An important property of granular materials or powders is that the grains lose energy through inelastic collisions. In this talk, we will discuss the dynamical properties of granular materials. These arise in two contexts. First, a powder can be driven into a nonequilibrium steady state by the application of an external drive. Second, a freely-evolving powder undergoes clustering and aggregation. We will discuss examples of pattern formation from both classes of problems.

ICTS-NESP2010 Plenary Lecture

Slow Relaxation and jamming in simple glass formers

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Abstract: Slow dynamics and structural arrest are of interest in a wide range of systems. In the first part of this talk, I describe investigations of the relaxation dynamics of a simple lattice gas model (the Kob-Andersen lattice gas) which exhibits many typical features of relaxation of glass forming liquids. Using computer simulations, we investigate the spatially heterogeneous dynamics of particles, and the insights into the nature of relaxation in glass formers obtained from these investigations are described. In the second part of the talk, I describe investigations of jamming if frictionless spheres, and the dependence of the packing fraction and the behavior near the jamming point on the ensemble of initial fluid configurations that are subjected to rapid compression leading to jamming. The packing fraction of the jammed configurations is protocol dependent, but the jamming transitions share a common critical-like behavior. The

ICTS-NESP2010 Plenary Lecture

Condensation in Temporally Correlated Zero-Range Dynamics

G. M. Schütz
Research Center Jülich, Germany

Abstract: Condensation phenomena in non-equilibrium systems have been modeled by the zero-range process, which is a model of particles hopping between boxes with Markovian dynamics. In many cases, memory effects in the dynamics cannot be neglected. In an attempt to understand the possible impact of temporal correlations on the condensate, we introduce and study a process with non-Markovian zero-range dynamics. We find that memory effects have significant impact on the condensation scenario. Specifically, two main results are found: (1) In mean-field dynamics, the steady state corresponds to that of a Markovian ZRP, but with modified hopping rates which can affect condensation, and (2) for nearest-neighbor hopping in one dimension, the condensate occupies two adjacent sites on the lattice and drifts with a finite velocity. The validity of these results in a more general context is discussed.

ICTS-NESP2010 Plenary Lecture

Micro-structure selection in solid-solid transformations: a space-time transition of particle trajectories?

Surajit Sengupta
IACS and SNBNCBS, Kolkata, India

Abstract: Quite generally, a quench across a solid-solid transformation results in the nucleation and growth of the product with specific micro-structure (the long-lived, mesoscale ordering of atoms, which depends not only on symmetry relations between parent (high temperature solid) and product (low temperature solid), but also on the quench protocol, viz., the depth and rate of quench. Since the parent and product solids are often incompatible, with considerable mismatch or *frustration* at the interface, this mismatch need to be accommodated which the solid does in a variety of ways. This gives rise to myriad micro-structures, the most common characterized ones being *ferrite* and *twinned martensite*. While the ferrite is associated with a disorderly (or "civilian") movement of atoms, hence giving rise to extensive rearrangement of atomic coordinates, the martensite is characterized by coordinated (or "military") movement of atoms, resulting in a typical micro-structure of alternate variants of the product solid which share a common crystallographic mirror plane (twins). We show that accommodation of inter-facial mismatch is facilitated by the appearance of dynamical heterogeneities in solids undergoing structural transformation. We study these dynamical heterogeneities in terms of a thermodynamics of space-time trajectories of active particles, represented by a dynamical action and an appropriate order parameter characterizing the nature of trajectories of active particles defining a thermodynamics of phase transitions in trajectory space. The active particles exhibit intermittent jamming and flow -- in this sense the underlying physics of solid-solid transitions share common features with the physics of plasticity, glass and granular systems.

ICTS-NESP2010 Plenary Lecture

Mechanoregulation of Nuclear Organization & Genome Function

G. V. Shivashankar
National University of Singapore, Singapore, and
National Centre for Biological Sciences, Bangalore, India

Abstract: Cells in physiology, sense physical forces on the nanoscale & convert them into appropriate biochemical signals to modulate gene expression programs. In addition recent evidence suggests that the 3D organization of gene position and its interaction with the transcription apparatus within the crowded cell nucleus is vital to orchestrating gene regulation. While a variety of mechanochemical signaling events and epigenetic modifications have been worked out, very little is known about how mechanical cues are physically integrated with the nucleus to differentially regulate spatio-temporal aspects of genome function. Using live-cell functional imaging combined with fluorescence spectroscopy and biomechanics methods, we map the transmission of mechanical cues via cellular architecture to regulate genome plasticity and function within single living cells. These studies begin to reveal some of the mechanistic principles underlying genome assembly and transcription compartments within living cells and how transitions in their assembly accompany cellular differentiation and developmental programs.

ICTS-NESP2010 Invited Talk

Violation of the Porod law in a freely cooling granular gas in one dimension.

Dibyendu Das
Indian Institute of Technology, Mumbai, India

Abstract: A freely cooling granular gas is an interesting nonequilibrium system. As it cools, it undergoes coarsening with a growing clustering length scale. We studied this inhomogeneous clustering regime (ICR) of a freely cooling granular gas of point particles in one dimension, using event driven molecular dynamics simulations. Interestingly, we find that for inelastic collisions with a "velocity dependent restitution co-efficient", there is an emergent time scale t_1 which divides the ICR into two sub-regimes. Several macroscopic statistical quantities behave distinctly in the two sub-regimes. In particular, for times t > t_1, the spatial density-density correlation function violates the Porod law. A scaling theory and numerical study of the dynamics of coarse-grained mass clusters reveal the cause of the enhanced fluctuations beyond t_1.

ICTS-NESP2010 Invited Talk

Heat conduction and phonon localization in disordered harmonic crystals

Abhishek Dhar
Raman Research Institute, Bangalore, India

Abstract: We investigate the system size dependence of the heat current in two and three dimensional disordered harmonic crystals. Both nonequilibrium simulations as well as direct numerical evaluation of phonon transmission coefficients are performed. In the presence of a pinning potential we find that Fourier's law is valid in three dimensions while in two dimensions we obtain a heat insulator. In the absence of pinning the heat conductivity is found to have a power-law divergence with system size and our study suggests the presence of super-diffusive phonon states.

ICTS-NESP2010 Invited Talk

Quasispecies dynamics on correlated fitness landscapes

Kavita Jain
Jawaharlal Nehru Centre for Advanced Scientific Research, Bangalore, India

Abstract: We study the distribution of the maximum of a set of random fitnesses with fixed number of mutations in a model of biological evolution. The fitness variables are not independent and the correlations can be varied via a parameter $\ell=1,...,L$. We present analytical calculations for the following three solvable cases: (i) one-step mutants with arbitrary ℓ (ii) weakly correlated fitnesses with $\ell=L/2$ (iii) strongly correlated fitnesses with $\ell=2$. In all these cases, we find that the limit distribution for the maximum fitness is not of the standard Gumbel form.

ICTS-NESP2010 Invited Talk

Time-temperature superposition in soft glassy materials

Varun Awasthi and Yogesh M Joshi
Indian Institute of Technology Kanpur, India

Abstract: The effect of temperature on aging behavior of aqueous Laponite suspension, a model soft glassy material, is studied by carrying out oscillatory and creep experiments. It is observed that evolution of elastic modulus with time shifted to lower age at higher temperature in the oscillatory experiments suggesting that the mechanism responsible for the same became faster at higher temperature. On the other hand, superposition of creep curves at various ages yielded rate of evolution of characteristic timescale with respect to age, which decreased with increase in temperature. We present a simple mathematical framework, which suggests that this interdependence is due to linear dependence of elastic modulus on barrier height while Arrhenius dependence of relaxation time on barrier height normalized by kT.

ICTS-NESP2010 Invited Talk

Transcription of ribosomal RNA - a central task for rapid (bacterial) cell growth

Stefan Klumpp
Max-Planck Institute for Colloids and Interfaces, Golm, Germany

Abstract: Synthesis of ribosomes is essential for rapid cell growth and fast growing cells from bacteria to cancer cells devote a substantial fraction of their transcriptional activity to making ribosomal RNA (rRNA). I will discuss quantitative aspects of rRNA transcription related to physiological constraints due to fast cell growth, focusing on the bacterial case. First, transcription of rRNA is characterized by dense traffic of RNA polymerases (RNAPs) along the rRNA genes, while transcription rates for mRNA-encoding genes are typically low. As dense traffic is susceptible to traffic jams due to stochastic pausing of RNAPs, we asked whether there are specific constraints that govern transcription in a dense traffic situation. This perspective allows us to propose novel functions for termination/antitermination systems in bacterial rRNA transcription [1]. Second, rRNA transcription dominates the total cellular transcription. A longstanding question is therefore whether a stop of rRNA transcription affects other genes as more RNAPs become available for transcribing them. We address this question with an RNAP partitioning model [2]. The model is also used to study the growth-rate dependence of transcription rates [2], an important ingredient to understand genetic circuits under different physiological conditions [3].

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ICTS-NESP2010 Invited Talk

Spatial fluctuations strongly affect dynamics of motor proteins

Anatoly B. Kolomeisky,
Rice University, Houston, USA

Abstract: Motor proteins are active biological molecules that perform their functions by converting chemical energy into mechanical work. Recent single-molecule experiments indicated that motor proteins experience significant spatial fluctuations during its motion. The effect of these spatial fluctuations is analyzed explicitly by considering discrete-state stochastic models that allow us to compute exactly all dynamic properties. It is shown that for symmetric fluctuations there is no change for mean velocities for weak external forces, while dispersions and stall forces are strongly affected at all conditions. Our method is applied for analysis of the motion of myosin-V motor proteins. It is argued that spatial fluctuations might be used to control and regulate the dynamics of motor proteins.

ICTS-NESP2010 Invited Talk

Structure and dynamics of water under nano-confinement

Prabal K. Maiti
Indian Institute of Science, Bangalore, India

Abstract: We study various translational and orientational dynamics of water molecules confined inside carbon nanotube using atomistic Molecular dynamics simulation (MD). The water molecules inside the nanotube show solid-like ordering at room temperature and surprisingly exhibit Fickian diffusion instead of single-file even if the particles can not cross one another. We propose model systems where single-file diffusion can be observed and test the prediction doing simulation in a nanoring. The confinement leads to strong anisotropy in the reorientational relaxation of the confined water molecules. The time scale of the relaxation of the dipolar correlations become ultra-slow. In contrast, the relaxation of the vector that joins the two hydrogens in a molecule becomes much faster. The relaxation proceeds by angular jumps between the two stable states. These jumps cause the ratio of the timescales of the first and second order reorientational correlation functions to exceed the value in the diffusive limit.

ICTS-NESP2010 Invited Talk

Dynein and Kinesin: Built differently to work together ?

Roop Mallik
Tata Institute of Fundamental Research, Mumbai, India

Abstract: Dynein and Kinesin are the two major microtubule motors for intracellular transport. These motors are simultaneously present on single motile organelles in the cell, but generate force in opposite directions. How is this opposing activity regulated and harnessed in a useful manner inside the cell? To address this question, we performed optical trap based force measurements on endosomes inside live cells, in cell extract, and with purified motors to quantify ensemble function of motors. Precise motion analysis shows directly that reversals during endosome motion are caused by a tug-of-war between kinesin and dynein. Further, we make the surprising discovery that endosome transport uses many (~ 4 to 8) weak and detachment-prone dyneins in tug-of-war against a single strong and tenacious kinesin. We elucidate how this clever choice of dissimilar motors and motor-teams achieves net transport together with endosome fission, both of which are important in controlling the balance of endocytic sorting. This appears to be the first demonstration that dynein and kinesin function differently in vivo at the molecular level, and how this difference is utilized in a specific cellular process during cooperative function of these motors.

ICTS-NESP2010 Invited Talk

Spatial Correlations in Exclusion Models corresponding to Zero Range Process

Pradeep K. Mohanty
Saha Institute of Nuclear Physics, Kolkata, India

Abstract: I will discuss that the steady state weights of all one dimensional exclusion models which are mapped to Zero Range Process (ZRP) can be written in a matrix product form, where the required matrices depend only on the steady state weights of ZRP. In contrast to the usual matrix product ansatz which does not always guarantee a solution for the dynamics dependent algebra that the matrices need to satisfy, here we provide an infinite dimensional representation which works for generic systems. The formulation helps us study the spatial correlations of these exclusion processes which are hardly possible to obtain directly from their ZRP correspondence. I will illustrate this method with a few examples.

ICTS-NESP2010 Invited Talk

In-silico reconstitution of spindle assembly: speed and error of search and capture

Raja Paul,
Indian Association for the Cultivation of Science, Kolkata, India

Abstract: During mitosis, in prometaphase, a bipolar spindle, in which microtubules connect centrosomes at the 'poles' to chromosomes at the 'equator' self-assembles. Whether this assembly goes through centrosomal (dynamically unstable microtubules search in space until kinetochores are captured) or chromosomal (microtubules grow from chromosomes and get focused to the centrosomes by motors) pathway is still uncertain and seems to be cell type-specific. Furthermore, some evidence suggests that these two pathways are not mutually exclusive. Using extensive numerical simulations, we analyzed the effects of chromosomal volume and movements on the speed and accuracy of the spindle assembly when these two pathways are combined. Our results suggest that an optimal spindle assembly is achieved when rates of chromosomal movements are of the same order of magnitude as rates of the microtubule dynamic instability. We further quantify syntelic and merotelic errors, which occur with surprising frequency in the simulations, and discuss how the error numbers depend on geometry and kinetics of the spindle assembly.

ICTS-NESP2010 Invited Talk

Dynamics of nucleosome assembly and disassembly

P. Ranjith
Indian Institute of Technology, Mumbai, India

Abstract: We present a theory of chromatin fiber dynamics in ATP-depleted Xenopus egg extracts, based on assembly, displacement, and sliding of nucleosome units. With the help of recent experimental data we determine the force-dependant nucleosome assembly rate, disassembly rate as well as the nucleosome sliding rate. Our theory explains many features of the nucleosome displacement kinetics observed in constant-force and constant-pulling velocity experiments. We also show that moderate (2-5 pN) forces perturb nucleosome distribution in a sequence-dependent manner and that a chromatin fiber possesses a ‘‘memory’’ of nucleosome rearrangement events.

ICTS-NESP2010 Invited Talk

Integer partitions and exclusion statistics

Sanjib Sabhapandit
Raman Research Institute, Bangalore, India

Abstract: I will talk about the connection between the exclusion statistics and the integer partition problem. In the context of the partition problem, the limit shapes of the Young diagram will be discussed. A simple physical interpretation for the limit shapes will also be provided.

ICTS-NESP2010 Invited Talk

A biological mechanism that utilizes intrinsic curvature of filaments

Anirban Sain
Indian Institute of Technology, Mumbai, India

Abstract: Protein filaments are ubiquitous in biological systems. FtsZ filaments in bacteria are part of the bacterial cytoskeleton and takes active part in cell division. Interestingly, these semiflexible filaments have intrinsic curvature which plays a crucial role in guillotining the bacteria at its middle. This occurs via the formation, and subsequent contraction of a polymeric ring made of FtsZ filaments. We first review our model for this mechanism and then present some general results on filaments with intrinsic curvature.

ICTS-NESP2010 Contributed Talk

Asymptotic shape of the region visited by an Eulerian Walker

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(2) Tata Institute of Fundamental Research, Mumbai INDIA.

circle whose radius grows as $N^{1/3}$, for large N. If stochasticity is introduced in the evolution rules, the mean square displacement of the walker, $\langle R_{N}^{2} \rangle \sim N^{2\nu}$, is shown to have a crossover from the Eulerian ($\nu = 1/3$) to a simple random walk ($\nu=1/2$) behaviour.

ICTS-NESP2010 Contributed Talk

Kinetic networks of molecular motors

Steffen Liepelt
Max-Planck-Institute of Colloids and Interfaces, Science Park Golm, Potsdam, Germany

Abstract: Biochemical cycle kinetics is used to study the dynamics of molecular motors. Particularly we are interested in the non-equilibrium thermodynamics of the stationary state of motor operation. Introducing a non-equilibrium balance relation we illustrate the constraints of thermodynamic laws on kinetic models. This relation between energy balance and irreversibility is used in the analysis of a concrete system. Kinesin is a cytoskeletal motor, that walks via coordinated movement of its two heads on microtubule-tracks. To find a description that is consistent with diverse experimental observations, here we explore a network description including several alternative and competing chemomechanical pathways. The computation of the stepping interval time distributions may give new implications for larger scale phenomena, such as motor traffic.

ICTS-NESP2010 Contributed Talk

Role of GTP remnants in micro-tubule dynamics

Sumedha (1) and Bulbul Chakraborty(2), M. F. Hagan (2)
(1) Harishchandra Research Institute, Allahabad,
(2) Brandeis University, Waltham, Massachusetts, USA

Abstract: Microtubules are essential part of cytoskeleton in eukaryotes. They are involved in many physiological processes like mitosis and cell transport inside the cell. In order to perform these tasks they show phases of rapid growth and shrinkage both in-vivo and in-vitro. In spite of lot of activity in this area, the exact mechanism of their assembly/disassembly is not well understood. Many different models have been proposed which mainly differ in the mechanism assumed for hydrolysis of tubulin dimers. I will discuss stochastic hydrolysis and show that it allows for alternative rescue mechanism, and enhances fluctuations of filament lengths.

ICTS-NESP2010 Contributed Talk

Microtubules but not the anterograde Kinesin motor regulate non-random distributions of mitochondria in neurons

Guruprasada Reddy Sure, Eva Romero, Anjali Awasthi, Sudip Mondal, Sandhya P Koushika
National Centre for Biological Sciences, Bangalore, India

Abstract: Mitochondria synthesize ATP, buffer intracellular calcium and regulate cell death. In highly polarized cells like neurons, mitochondria accumulate at the sites of high metabolic activity such as synapses, growth cones and nodes of Ranvier. However majority of the mitochondria in a neuron are not present at the described high metabolic demand regions but are distributed along the entire neuronal process. We wished to understand whether the axonal mitochondria show regulated distributions along the process and determine what factors may play a role in this process. We developed a transgenic strain *jsIs609*, where mitochondria in the Touch Receptor Neurons are marked with GFP. Using this strain we observe a linear correlation of mitochondrial number with the length of the neuronal process and non-random distributions of mitochodria. The distributions are regulated such that two neighbouring mitochondria maintain a suitable minimum distance between them. In Kinesin-I mutants the total numbers of mitochondria reduce in the axon but their distributions remain close to those observed in wild type neurons. However, in microtubule mutants the numbers of mitochondria in the axon increased but their distributions become similar to random distributions obtained using simulations. Analysis of electron micrographs of these neurons reveals the presence of filamentous links that connect mitochondria to both microtubules as well as the plasma membrane. These molecules that form these structures may underlie the regulated distributions observed in neurons. I will also discuss the behavioural implications of regulated distributions of mitochondria.

ICTS-NESP2010 Contributed Talk

Lithographic Approaches to Artificial Spindle Assembly

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Abstract: Microtubule and kinesin system transport intracellular cargo and, play an important role during cell division by constituting mitotic spindle that segregates chromosomes. Microtubule dynamics referred to microtubule polymers continually undergoing growth and depolymerisation phase. Disruption in microtubule dynamics induces cell cycle arrest and lead to apoptosis. As a result, several chemotherapeutic agents that manipulate microtubule dynamics are already under clinical trials. To ensure better understanding of microtubule dynamics for improved cancer care, it is imperative to understand the role and interaction mechanism of proteins that participate in microtubule dynamics. However, due to the cell background and redundant nature of motor proteins it becomes challenging to single out specific role of proteins on microtubule dynamics. To overcome this, a simple bottom up approach is proposed here, which uses artificial microtubule spindle structure using microfabrication. To achieve this goal, kinesin was patterned at specific locations using electron beam lithography on glass and microtubule seeds were immobilized on kinesin patterns. Compatibility of microfabrication processes with proteins was assed using fluorescent microscopy. Microtubule guiding using kinesin patterns was also studied. Patterned microtubule seeds, when polymerized under physiological environment result in spindle like structure. Using these results, role of chemical and biological stimulus on microtubule dynamics and spindle assembly can be characterized by polymerizing patterned microtubule seeds.

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