Titles and Abstracts

TALKS

Name	**Girish. S. Agarwal**
Affiliation	University of Oklahoma
Title	Quantum Interferometry of Independent Systems
Abstract	I demonstrate, contrary to common belief, that interference between independent quantum particles is possible by modification of detection schemes. This new possibility has strict quantum character and has applications in diverse areas such as in quantum imaging, in generation of entanglement between independent systems remote or otherwise. I show the possibility of nonlocality using path entanglement. The key to many applications is that quantum particles like single photons at well known optical elements behave quite differently than the coherent light.

Name	**Dimitris G. Angelakis**
Affiliation	TUC, Crete, Greece; CQT, Singapore
Title	**Photonic Quantum Simulators: Mimicking Condensed Matter Physics using Photons**
Abstract	I will start by describing the basic motivation for using strongly interacting systems of photons to simulate condensed matter phenomena. I will proceed by briefly reviewing our founding results on the simulations of Mott to superfluid phase transitions in coupled cavities [1,2] doped with two level systems, and the applications in measurement based quantum computation [3]. I will also epigrammatically mention the main ideas behind the photonic simulation of quantum spin models [4], the Fractional Hall effect [5], and many-body entanglement in dissipative cavity arrays [6,7]. The main part of talk will be devoted in analyzing recent results in the simulation of quantum Luttinger liquids and spin-charge separation using photons in a hollow fiber filled with atoms [8]. Finally if there is time, I will present ongoing work towards the realization of the sine-Gordon model and the "pinning transition" in the same system [9].

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Name	**Arvind**
Affiliation	IISER, Mohali
Title	Extremal entanglement witnesses and bound entangled states
Abstract	The problems of characterization of quantum states as entangled and separable, remain open despite a lot of work being carried out. In the absence of a `final solution', finding new classes of PPT entangled states and finding new ways of constructing them is useful and provides insights into the classification problem. In this talk, based on a generalization of the Choi map due to Osaka, we construct entanglement witnesses which are more powerful than the original construction, in terms of their capacity to detect entanglement of PPT entangled states.

Name	Alain Aspect

Affiliation	CNRS; Institut d'Optique, Palaiseau
Title	From Einstein's intuition to Bell's inequalities and quantum bits: a new quantum age?
Abstract	In 1935, with co-authors Podolsky and Rosen, Einstein discovered an amazing quantum situation, where particles in a pair are so strongly correlated that Schrödinger called them "entangled". By analyzing that situation, Einstein concluded that the quantum formalism was incomplete. Niels Bohr immediately opposed that conclusion, and the debate lasted until the death of these two giants of physics, in the 1950's. In 1964, John Bell produced his famous inequalities which would allow experimentalists to settle the debate, and to show that the revolutionary concept of entanglement is indeed a reality. Based on that concept, a new field of research has emerged, quantum information, where one uses quantum bits, the so-called "qubits". In contrast to classical bits which are either in state 0 or state 1, qubits can be simultaneously in state 0 and state 1, as a Schrödinger cat could be simultaneously dead and alive. Entanglement between qubits enables conceptually new methods for processing and transmitting information. Large scale practical implementation of such concepts might revolutionize our society, as did the laser, the transistor and integrated circuits, some of the most striking fruits of the first quantum revolution, which began with the 20th century.

Name	**Charles H. Bennett**
Affiliation	IBM Research, New York
Title	Quantum information, the ambiguity of the past, and the complexity of the present
Abstract	The theory of entanglement provides a coherent view of the physical origin of randomness and the growth and decay of correlations, even in macroscopic systems exhibiting few traditional quantum hallmarks. It helps explain why the future is more uncertain than the past, and how correlations can become macroscopic and classical by being redundantly replicated throughout a system's environment. The most private information, exemplified by a quantum eraser experiment, exists only transiently: after the experiment is over no record remains anywhere in the universe of what "happened". At the other extreme is information that has been so widely replicated as to be infeasible to conceal and unlikely to be forgotten. But such conspicuous

	information is exceptional: a comparison of entropy flows into and out of the Earth with estimates of the planet's storage capacity leads to the conclusion that most macroscopic classical information---for example the pattern of drops in last week's rainfall---is impermanent, eventually becoming nearly as ambiguous, from a terrestrial perspective, as the transient result of a quantum eraser experiment. Finally we discuss prerequisites for a system to accumulate and maintain in its present state, as our world does, a complex and redundant record of at least some features of its past. Not all dynamics and initial conditions lead to this behavior, and in those that do, the behavior itself tends to be temporary, with the system losing its memory as it relaxes to thermal equilibrium.

Name	**Indrani Bose**
Affiliation	Bose Institute, Kolkata
Title	Quantum Discord in the Ground and Thermal States of Molecular Magnets
Abstract	Quantum discord is a general measure of bipartite quantum correlations with a potential role in quantum information processing tasks. Spin clusters are ideal candidates for the implementation of some of the associated protocols. We consider a symmetric spin trimer and a tetramer, which describe a number of known molecular magnets, and compute the quantum discord in the ground and thermal states of the clusters. We report a number of interesting features one of which is that the quantum discord vanishes completely only in the asymptotic limit of temperature $T \rightarrow \infty$. We further study the dynamics of the quantum discord under the effect of a dephasing channel and show that the discord vanishes asymptotically as a function of time.

Name	**Sougato Bose**
Affiliation	University College London
Title	Quantum Entanglement and Indistinguishaibility: How can one aid in probing/generating the other
Abstract	In this talk, I will discuss ways in which quantum indistinguishability (QI) can aid in the generation of the resource of entanglement, as well as how the latter can be used to formulate novel schemes for probing the former. I will first recapitulate an earlier work on how which-way detection in conjunction with QI can result in a generic entangling scheme valid for arbitrary objects. I will then show that QI plays a pivotal role in a deterministic entangling

	quantum gate between flying qubits interacting through spin independent delta functions in one dimension. Following that, I will discuss how QI in isospin space (involving holes and electrons) can be tested using a Majorana medium and how this can also be used to formulate an entangling mechanism. Finally, I will show how the resource of entanglement between separated identical systems can provide an interaction-free test of QI with potential applications in probing its macroscopic limits.

Name	**Samuel L. Braunstein**
Affiliation	University of York
Title	Entangled black holes as ciphers of hidden information
Abstract	Quantum mechanically the mass of a black hole leaks away as featureless Hawking radiation. If so, information about matter that formed the black hole is irretrievably lost, apparently violating a fundamental axiom of quantum mechanics: that of unitary evolution. We consider unitarily evaporating black holes and show that in order to preserve the equivalence principle, the thermodynamic entropy of a black hole must be primarily entropy of entanglement across the event horizon. Any information entering a black hole becomes encoded in correlations within a tripartite quantum system - the quantum analog of a one-time pad. We further show that this information is only decoded into the outgoing radiation very late in the evaporation (over the final and vanishingly small fraction of a large black hole's lifetime). Thus, up until this decoding stage, the signature featureless Hawking radiation is no indicator of a breakdown of unitarity. In fact, this behavior generically describes the unitary evaporation of entangled black holes.

Name	**Gilles Brassard**
Affiliation	Montreal University
Title	Quantum Pseudotelepathy
Abstract	Pseudotelepathy provides an intuitive way of looking at Bell's inequalities. A two-player pseudotelepathy game proceeds as follows: Alice and Bob are individually asked a question and they must provide an answer. They are not allowed any form of communication once the questions are asked, but they may have agreed on a common strategy prior to the execution of the game. We say that they win the game if the questions and answers fulfil a specific relation. A game exhibits pseudo-telepathy if there is a quantum strategy that makes Alice and Bob win the game for all possible questions, provided they

	share prior entanglement, whereas it would be impossible to win this game systematically in a classical world. It is shown that this notion is strictly stronger than the Bell Theorems Without Inequalities, which in turn is a notion strictly stronger than ordinary Bell Inequalities.

	Gavin Brennen
Affiliation	Macquarie University, Sydney
Title	Nonlocality with anyons
Abstract	Pointlike particles in two dimensions can have more general statistics than Bosons or Fermions. Such particles dubbed anyons have nonlocal interactions that are purely statistical in nature produced by topological braiding. I will describe how to reveal this nonlocality using a Bell type inequality with a bound that depends on the topological charge of the anyons.

Name	**Subhash Chaturvedi**
Affiliation	University of Hyderabad
Title	Non classicality and entanglement in multimode radiation fields under the action of classicality preserving systems
Abstract	In this work we examine the the possibilities of converting quantum optical nonclassicality into entanglement in multimode radiation fields under the action of classicality preserving systems like beamsplitters. While the single mode case is amenable to a complete analysis, non availability of the classical theory of moments in multimode situation forces us to treat these cases with a lesser degree of generality by taking recourse to the familiar the Mandel parameter criterion and its extensions. We generalize the Mandel matrix from one-mode states to the two-mode situation, leading to a natural classification of states with varying levels of nonclassicality. For two--mode states we present a single test which, if successful, simultaneously shows nonclassicality as well as NPT entanglement. We develop a test for NPT entanglement after beamsplitter action on a nonclassical state, tracing carefully the way in which it goes beyond the Mandel nonclassicality test. In the same spirit, we analyse the result of three--mode `beamsplitter' action after coupling to an ancilla in the ground state. The concept of genuine tripartite entanglement, and scalar measures of nonclassicality at the Mandel level for two-mode systems, are discussed and illustrated with the help of several examples

Name	**John Corbett**
Affiliation	Macquarie University, Sydney
Title	The quantum spatial continuum is not classical
Abstract	The spatial continuum for quantum phenomena is usually assumed to be classical. However (a) experiments that use quantum entanglement and (b) the two slit experiments provide puzzling consequences of this assumption. In (a) entangled two particle systems appear to contravene the Einstein separability principle, in (b) a single quantum particle is non-localized (wave-like) because it can pass simultaneously through two spatially separated slits,. There is a different quantum spatial continuum in which these puzzles are resolved. It is constructed from standard Hilbert space entities using topos theory. The points of the quantum space are assumed to be in one-to-one correspondence with triplets of quantum real numbers (qr-numbers), the topos real number values of the particle's position operators; they correspond to open subsets of the classical space. The qr-number descriptions of these experiments are given, they strongly support the conclusion that the spatial continuum of a quantum system should be a qr-number continuum. The construction works both for Galilean and special relativistic massive quantum particles. The talk is based on two recent papers with Thomas Durt, [5, 6], as well as the earlier work in [4]. These papers contain more of the mathematical details.

Name	**Artur Ekert**
Affiliation	Oxford; NUS, Singapore
Title	Entangled with security
Abstract	Quantum entanglement has been singled out by Erwin Schrödinger as ``...the characteristic trait of quantum mechanics, the one that enforces its entire departure from classical lines of thought." Indeed, after playing a significant role in the development of the foundations of quantum mechanics, quantum entanglement became a new physical resource with potential commercial applications. In particular it can be used to construct new methods of secure communication. I will outline the evolution of the concept from its origin, in around 1932, till today and describe some of its current applications.

Name	**Sibasish Ghosh**
Affiliation	IMSc, Chennai
Title	Quantum to classical transition and entanglement sudden death in Gaussian states under local heat bath dynamics
Abstract	Entanglement sudden death in spatially separated two-mode Gaussian states coupled to local thermal and squeezed thermal baths is studied by mapping the problem to that of the quantum-to-classical transition. Using Simon's criterion concerning the characterisation of classicality in Gaussian states, the time to ESD is calculated by analysing the covariance matrices of the system. The results for the two-mode system at T=0 and T>0 for the two types of bath states are generalised to n-modes, and are shown to be similar in nature to the results for the general discrete n-qubit system.

Name	**Debabrata Goswami**
Affiliation	IIT, Kanpur
Title	Towards Using Moleculer States as Qubits
Abstract	Molecular states can be used for qubits as long as they can be isolated. Theoretically, density matrix approaches to study ensemble coherence of the molecular states would be presented. Experimentally, one of the approaches to isolate molecules would be in the gas phase. Other could be in the liquid phase as in optical tweezers. In the molecular beam case, as an example, non-resonant molecular fragmentation of n-propyl benzene with femtosecond laser pulses is dependent on the phase and polarization characteristics of the laser. We find that the effect of the chirp and polarization of the femtosecond pulse

	when applied simultaneously is mutually independent of each other, which makes chirp and polarization as useful 'logic' implementing knobs. Issues in liquid phase using optical Tweezers will also be discussed.

Name	**Jozef Gruska**
Affiliation	University of Masaryk
Title	The role entanglement play in a new perception of Informatics
Abstract	Quantum physics and Informatics can be seen, arguable, as the main achievements of science and technology of 20th century the marriage of which is expected to play a very important role in 21st century - in many ways. One of the important outcome of this symbiosis is a recent development of a new perception of Informatics - as a fundamental science Informatics is seen as having similar goals as physics and as representing together with physics two windows to see, explore and study our physical and information worlds. One of the roots and impulses to this new perception of informatics is a discovery that information processing plays and has always played a very important role in the development of both physical and biological worlds. Entanglement and related non-localities play by that a very special role. The talk is to disk the role the entanglement (has been playing) and is expected to play in such a broader scientific context. In particular, in dealing with some of the Grand challenges of Informatics and science.

Name	**N. D. Hari Dass**
Affiliation	CQIQC, Bangalore; IISc, & CMI
Title	Experimental Tests for a Pragmatic Interpretation of Protective Measurements
Abstract	I shall describe Aharonov, Anandan & Vaidman´s proposal for protective measurements and their claims of providing an ontological interpretation for a certain class of wavefunctions through this type of measurement. I shall then describe work done with Tabish Qureshi which dispels this myth. I will show how the AAV proposal may be useful in a pragmatic sense and provide a concrete experimental setup using cold atoms. In particular, I will discuss how

	techniques developed by the Schmiedmayer group in Vienna for single-particle-sensitive imaging of freely propagating cold atoms could be adopted for this purpose. I will conclude with a brief description of my work with Anirban Das on adiabatic interactions between spin-systems and a proposal for its experimental realisation.

Name	**Yuji Hasegawa**
Affiliation	Atominstitut, Vienna
Title	Quantum contextulity and uncertainty relation explored with neutrons
Abstract	Since the early stage of the development, quantum theory is bizarre: in trying to understand it, we had to forgive everything we know about causality, reality, certainty and so on. This is a completely different world, ruled by its own probability law. Neutron optical approach is one of the most suitable strategies to study quantum mechanics, where quantum interference effect of matter waves can be observed in a macroscopic scale. Recently we performed neutron interferometer and polarimeter experiments concerning noncontextual hidden-variable theories (NCHVTs). NCHVTs are a kind of hidden variable models of quantum mechanics, trying to give realistic view of quantum phenomena, which are less stringent than local hidden variable theories. Entangled states between degrees of freedom in single neutrons are exploited: violation of a Bell-like inequality, Kochen-Specker-like phenomena, and quantum tomography of bipartite Bell-like state are successfully demonstrated. In addition, studies of tripartite-entanglements such as a Greenberger-Horne-Zeilinger-like (GHZ-like) state as well as a contextual model *à la* Leggett were carried out. In parallel, uncertainty relation, which was suggested by Heisenberg and indeed one of the most fundamental and famous features of quantum mechanics, was investigated: neutron polarimeter was used to test the uncertainty relation between the error and the disturbance of successive spin-measurements. The results illustrate that the trade-off relation violates the Heisenberg's uncertainty relation in a wide range of an experimental control parameter and obeys a recently-derived universally valid uncertainty relation. The solution of a long-standing problem is confirmed to describe the relation between the measurement accuracy and the disturbance caused by that measurement. I am going to give an overview of these optical experiments with neutrons and discuss their future perspectives.

Name	**Dipankar Home**, A. S. Majumdar, T. Pramanik, N. Ganguly
Affiliation	Bose Institute, Kolkata
Title	Generalized uncertainty relation as a tool for measuring mixedness of two qubit states
Abstract	A hitherto unexplored line of study is initiated in this work by invoking the Generalized Uncertainty Relation (GUR) for the purpose of quantitatively testing the mixedness (purity) of two qubit states. To this end, the GUR is recast in a suitable form in order to define an appropriate quantity (Z) which involves the mean values and variances of observables that act as what may be called the *mixedness witness operators*. Calculated values of Z for different classes of two qubit states provide testable measures of the mixedness of such states, in agreement with the standard measure of mixedness of states in terms of linear entropy (SL) which is not a measurable quantity.

Name	**Pramod Joag**
Affiliation	Pune University
Title	Geometric measure of quantum discord for an arbitrary state of a bipartite quantum system
Abstract	Quantum discord, as introduced by Olliver and Zurek [Phys. Rev. Lett. 88, 017901 (2001)], is a measure of the discrepancy between quantum versions of two classically equivalent expressions for mutual information. Dakic, Vedral, and Brukner [arXiv:1004.0190 (2010)] introduced a geometric measure of quantum discord and derived an explicit formula for any two-qubit state. Luo and Fu [Phys. Rev. A 82, 034302 (2010)] introduced another form for geometric measure of quantum discord. We find an exact formula for the geometric measure of quantum discord for an arbitrary state of a $m \times n$ bipartite quantum system. This formula can be experimentally implemented.

Name	**Vladimir Korepin**
Affiliation	SUNY, New York
Title	MEASURES OF ENTANGLEMENT IN SPIN CHAINS

Abstract	Two different measures will be considered: negativity and entropy of a sub-system. Corresponding spin chains are VBS and Heisenberg. Exact analytical results will be presented.

Name	**Anil Kumar**, Jharana Rani Samal, K. R. Koteswara Rao and V.S. Manu
Affiliation	CQIQC, IISc Bangalore
Title	Recent developments in Quantum Information Processing by NMR
Abstract	Recent experimental developments in our laboratory include: 1. Experimental proof of No-Hiding theorem. 2. Non-Destructive discrimination of Bell States. 3. Discrimination of arbitrary set of orthogonal quantum States by phase estimation. 4. Use of Nearest Neighbour Heisenberg XY interaction for creation of entanglement on end qubits in a linear chain of 3-qubit system. These developments will be described, with experimental spectra/tomography of the density matrix.

Name	**Arul Lakshminarayan**
Affiliation	IIT, Chennai
Title	Entanglement transitions in random states
Abstract	We summarize some of our recent work dealing with the question of entanglement between arbitrary subsystems of a random state. For a fully random state, if the subsystem sizes add up to more than half of the system size we show that the fraction of unentangled states is exponentially small, by applying results from the theories of extreme value statistics and large deviations. For definite particle random states we point to a sharp transition that happens when the subsystem sizes add up to more than the particle number. Possible applications to disordered systems like spin glasses as well as to quantum chaotic systems are discussed.

Name	**Anthony J. Leggett**

Affiliation	University of Illinois
Title	Testing quantum mechanics towards the level of everyday life: recent progress and current prospects
Abstract	I start by briefly sketching the traditional objections to the idea of looking for evidence of "macroscopic superposition" and why they are deeply flawed. Then I review some of the actual experiments which have been done over the last ten years or so in this direction in the areas of heavy-molecule diffraction, mesoscopic ferromagnets, quantum-optical systems and Josephson devices. I conclude by commenting on some interesting recent experiments which work towards a definitive test of the predictions of quantum mechanics versus those of the whole class of "macrorealistic" theories.

Name	**T. S. Mahesh**
Affiliation	IISER, Pune
Title	Nuclear Singlets as Quantum Testbeds
Abstract	It has been discovered recently that due to certain symmetry properties, the singlet state of an ensemble of spin-1/2 nuclear pairs can retain the coherence for durations much longer than other non-equilibrium states. We utilize the long-lived nature of singlet states to initialize the spin systems into high fidelity coherent pseudopure states including Bell states. Such states are useful to study a variety of interesting quantum phenomena. In this work, we study Electromagnetically Induced Transparency (EIT) using a two-qubit system. The singlet state of a two qubit system acts as a dark state. Then using a three-qubit system, we describe an experiment to verify Peres quantum contextuality, which asserts that quantum systems can not be described by certain types of local hidden variable models. Our initial attempts in verifying Leggett-Garg inequality will also be presented.

Name	**Archan S. Majumdar**, S. Adhikari, D. Home, A. K. Pan, T. Pramanik
Affiliation	S. N. Bose National Centre for Basic Sciences, Kolkata
Title	Single particle entanglement as resource for information processing
Abstract	We discuss the generation of entanglement between different variables of

	single particle states. In particular, we show how single particle path-spin entangled states could be used for performing information processing tasks. A protocol for the swapping of such entanglement on to the entanglement of two separate qubits is first described. We then show how single particle entangled states could be used as resource for teleportation. Finally, we describe a key generation scheme where single particle entanglement is used for testing the security of the protocol.

Name	**Paolo Mataloni**
Affiliation	University of Rome
Title	Using hyperentanglement in quanum information
Abstract	Many quantum information tasks, dealing both with foundational concepts and with advanced communication and computation protocols, are based on multiqubit entangled photon states. In quantum optics these states, realized by spontaneous parametric down conversion, may be implemented by encoding the information in different degrees of freedom of the photons. I will present the results of some experiments performed with 2-photon n-qubit hyperentangled states and discuss their possible future applications based on integrated waveguide technology.

Name	**Alexandre Matzkin**
Affiliation	CNRS; University of Cergy, France
Title	Entanglement in the classical limit: quantum correlations from classical probabilities
Abstract	We investigate entanglement in a composite closed system having a classical counterpart. The system is endowed with a scaling property allowing to keep the dynamics invariant while the effective Planck constant is varied. We find that entanglement increases as the Planck constant goes to zero. We show that for sufficiently low values of the Planck constant the evolution of the quantum correlations (encapsulated for example in the quantum discord) can be obtained from the time-dependent probability distributions of the corresponding classical system.

Name	**Kavan Modi**

Affiliation	NUS, Singapore
Title	A Unified View of Quantum and Classical Correlations and Potential Applications
Abstract	We ask the question if entanglement captures all there is to quantumness of correlations? We initiate our investigations by putting quantum entanglement and other measures of quantumness, e.g. quantum discord and quantum dissonance (discord without entanglement), and classical correlations on equal footing. This allows us to carry out cross comparative studies for several applications the roles that various quantum and classical correlations play therein. We will try to work through two tasks: deterministic quantum computation with one qubit (DQC1) and quantum metrology with mixed states. In the former, we will show that within specific limits quantum correlations (including discord and entanglement) vanish, yet a classically hard task is carried out with exponential speed up. Yet, for the latter task, if the mixedness of the probe is fixed, we find that square of N advantage is retained independent of entanglement, but with quantum discord present. Finally we, question how entanglement and quantum discord are related and attempt to simplify a seemingly complicated concept.

Name	**N. Mukunda**
Affiliation	IISc, Bangalore
Title	Quantum Optical Nonclassicality for Single Mode Radiation Fields and conversion to Entanglement
Abstract	For multimode radiation fields, the well known concept of nonclassicality is a prerequisite for entanglement. For single mode fields where entanglement is not meaningful, we study the possibilities of conversion of nonclassicality to entanglement after action by passive classicality preserving devices like beam splitters. The theorems provided by the classical theory of moments play a key role in these considerations and lead to a complete answer to the problem.

Name	**Ranjit Nair**
Affiliation	CPFS, New Delhi
Title	Where is the knowledge we have lost in information? Informational interpretations of quantum mechanics

Abstract	The advent of quantum information theory was arguably a consequence of attempts to resolve the perplexities of the foundations of quantum mechanics. The idea of the wave function as an entity that is fundamentally psychophysical originated with Wolfgang Pauli early on, while von Neumann's formalization of quantum mechanics made explicit use of psychophysical parallelism to include observers *qua* conscious agents in the measurement process. For Wheeler, Deutsch, Zeilinger and others, quantum information processing, made possible by key features such as superposition and entanglement, highlight the ontological subtleties of the quantum world, ostensibly without invoking knowledge, as observers are treated no differently from other measuring devices registering binary outcomes. Whether the informational interpretation's displacement of knowledge from centre-stage in favour of information results in an adequate understanding of the classical/quantum divide, admitted to be a genuine problem even by theorists like Hawking who maintain that 'philosophy is dead', is the question addressed in this paper.

Name	**Prasanta Panigrahi**
Affiliation	IISER, Kolkata
Title	Sub-Planck structures in phase-space of kitten and cat states: Application to quantum metrology
Abstract	Phase space structures of cat, kitten and entangled cat states are explored, wherein sub-Planck structures arise due to interference in phase- space. The use of these states for Heisenberg limitted quantum metrology is illustrated. The robustness of these structures are then demonstrated in a number of quantum systems. Production of cat and kitten states through fractional revival in molecular wave-packets and that of entangled cat states in a dissipative quantum system is then explicated. We illustrate a cold atom system, wherein appropriate measurements can produce entangled cat states. **References:** 1. A Moinuddin, A Kumar, P K Panigrahi, Phys. Education Vol. 27, Number 2, April-June, 2010, ISSN 0970-5953. 2. A Kumar, S Ghosh, P K Panigrahi, to appear in Asian J. Physics. 3. J.R. Bhatt, P. K. Panigrahi and M. Vyas, Phys. Rev. A 78, 034101 (2008) 4. S Choudhury, P. K. Panigrahi, arxiv:1004.2163. 5. U. Roy, S, Ghosh, P. K. Panigrahi and D. Vitali, Phys. Rev. A 80, 052115 (2009). 6. S. Ghosh, A. Chiruvelli, J. Banerji and P.K. Panigrahi, Phys. Rev. A 73, 013411(2006) 7. T. Shreecharan, P. K. Panigrahi, and J. Banerji, Phys. Rev. A 69, 012102 (2004).

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Name	**Apoorva D. Patel**
Affiliation	IISc, Bangalore
Title	Efficient energy transport in photosynthesis: Roles of coherence and entanglement
Abstract	Recently it has been discovered---contrary to expectations of physicists as well as biologists---that the energy transport during photosynthesis, from the chlorophyll pigment that captures the photon to the reaction centre where glucose is synthesised from carbon dioxide and water, is highly coherent even at ambient temperature in the cellular environment. This process and the key molecular ingredients that it depends on will be described. By looking at the process from a computer science view-point, we can study what has been optimised and how. A spatial search algorithmic model based on robust features of wave dynamics will be presented.

Name	**Arun Kumar Pati**
Affiliation	IOP, Bangalore
Title	Quantum States, Entanglement and Closed Timelike Curves
Abstract	In this talk we will discuss nature of quantum states and entanglement in quantum theory with closed timelike curves. In standard quantum theory any mixed state can be purified in an enlarged Hilbert space by bringing an ancillary system. The purified state does not depend on the state of any extraneous system with which the mixed state is going to interact and on the physical interaction. However, it is not possible to purify a mixed state that traverses a closed time like curve (CTC) and allowed to interact in a consistent way with a causality-respecting (CR) quantum system. Thus, in quantum theory with CTCs there can exist 'proper' and 'improper' mixtures. Then, we will discuss what kind of entangled states are allowed in the presence of CTCs. We argue that the nature of entanglement can be different in the presence of such exotic objects.

Name	**Roger Penrose**
Affiliation	Oxford University
Title	Twistors, Cohomology, and Quantum Non-Locality
Abstract	An early motivation for twistor theory was a hope that it might provide a framework for an understanding of non-local aspects of quantum mechanics. Not until decades later it was realized that the 1st-cohomological nature of the twistor description of 1-particle wavefunctions actually reflects the non-locality of 1-particle states. This talk explores how twistor 2nd-cohomology might reflect the EPR character of 2-particle states.

Name	**Fabrizio Piacentini**
Affiliation	INRIM, Italy
Title	Foundations of Quantum Mechanics: recent developments at INRIM
Abstract	In these years, the studies on the foundations of Quantum Mechanics have gained more and more interest from the whole scientific community, being some of their aspects of the utmost relevance also for several applicative research fields (e.g. Quantum Communication and Information, Quantum computation, etc.). In this talk will be presented some of the experimental results obtained in the quantum optics "Carlo Novero" labs of the National Institute of Metrological Research (Turin, Italy), ranging from the test on some specific and loophole-free local realistic models to the very quantum essence of a single particle.

Name	**Helmut Rauch**
Affiliation	Atom Institut, Vienna
Title	Coherence and decoherence in neutron particle optics
Abstract	Neutron optics experiments, especially such done with neutron interferometers, have shown their capacities to demonstrate many basic features of quantum mechanics. They deal with self-interference of hadrons and they show strong, magnetic and gravitational effects. All effects can be described by quantum phases, where dynamical and geometrical phases can be defined and measured. They are differently sensitive to fluctuations and

	dissipative forces and their relaxation in noisy fields may help in the understanding of the transition of a quantum to a classical world. Whereas the dynamical phases are sensitive to the strength of the interaction with the environment the geometric phases depend only on the shape of the excursion curve in phase space. The behaviour of dynamical phases has been investigated by decoherence and dephasing experiments using neutron interferometer methods [1] and the geometric phases have been measured with ultra-cold neutrons using spin-echo methods. The results showed that the geometric phase becomes better defined when the system interacts longer with the related environment, i.e. they showed their robustness against disturbances [2]. This may have important consequences for quantum communication networks. [1] G. Solyuk, Y. Hasegawa, J. Klepp, H. Lemmel, H. Rauch, *Noise-induced dephasing in neutron interferometry"*, Phys.Rev. A 81 (2010) 053609 [2] S. Filipp, J. Klepp, Y. Hasegawa, C. Ponka-Spehr, U. Schmidt, P. Geltenbort, H. Rauch, *Experimental Demonstration of the Stability of Berry`s Phase for Spin-1/2 Particles,* Phys.Rev.Lett. 102 (2009) 030404

Name	**Shasanka Mohan Roy**
Affiliation	Homi Bhabha Centre for Science Education, TIFR, Mumbai
Title	Uncertainty Principle, Position-Momentum Symmetric Causal Quantum Mechanics and Experimental Tests
Abstract	Bell Inequalities strikingly reveal the conflict of quantum mechanics with Einstein's hypothesis of Local Reality. Experiments have confirmed quantum correlations in entangled states even when they violate local reality predictions. The quest for a causal quantum theory must therefore abandon Einstein Locality. The earliest such causal quantum mechanics constructed by De Broglie and Bohm reproduces quantum position probability densities exactly but not quantum momentum probability densities. This breaking of the fundamental symmetry between position and momentum is however unsatisfactory and unnecessary. We describe the Roy-Singh causal quantum mechanics which, for any quantum state, entangled or not, exactly reproduces quantum position and momentum probability densities as marginals of a single joint probability density. This theory therefore is consistent with Heisenberg's uncertainty principle. However, for experimental tests of the joint probability density we need an extension of the von-Neumann quantum measurement theory to approximate simultaneous measurement of non-

	commuting observables such as that proposed by Arthurs and Kelly, and refined by Busch, Heinonen,Lahti and others. We find that for free particle Gaussian states, the causal joint probability density is in agreement with Arthurs-Kelly measurement theory in the limit of their instrumental position and momentum errors being much smaller than the dispersions in position and momentum respectively of the state. Detailed tests for other quantum states are in progress.

Name	**R. Shankar**
Affiliation	IMSc, Chennai
Title	Manipulating Majorana fermions for quantum computation
Abstract	One mechanism of realising non-abelian anyons for topological quantum computation is by creating "unpaired" Majorana fermions and exchanging them. We will discuss some physical mechanisms to do this in spin models which, in principle, can be engineered.

Name	**Valerio Scarani**
Affiliation	NUS, Singapore
Title	Information causality as a new physical principle
Abstract	Quantum mechanics is usually defined by describing its formalism: physical systems are described in Hilbert spaces, with some rules. In the past decades, several schools tried to start from sets of reasonable axioms: they ended up identifying a large set of "generalized probabilistic theories" but failed to single out quantum physics among those. In 1994, Popescu and Rohrlich showed that the possibility of "non-locality without signaling" is also not enough to define quantum physics: the set of no-signaling probabilities is strictly larger than the set of probabilities that can be obtained by measuring quantum systems. In the past few years, it has been an open problem in quantum information science to find criteria that would allow ruling out "more-than-quantum" probability points. In this talk, I shall review the pioneering works, then I shall present our contribution: the principle of "information causality". I shall show how, by enforcing this principle, one comes very close to identifying the quantum set [1,2] and present some recent extensions [3,4].

	Refs: [1] M. Pawlowski et al, Nature 461, 1101 (2009) [2] J. Allcock et al, Phys. Rev. A 80, 040103 (2009) [3] A. Ahanj et al., Phys. Rev. A 81, 032103 (2010) [4] D. Cavalcanti et al., arXiv:1008.2624

Name	**R. Simon**
Affiliation	IMSc, Chennai
Title	Operator-sum Representation for Bosonic Gaussian Channels
Abstract	Bosonic Gaussian channels are those CP maps or channels which produce a Gaussian state at the output every time the input is in a Gaussian state. The importance of Gaussian channels is due to their physical realizability with relative ease, particularly in the quantum optical scenario. That these channels are amenable to analytic study is due to the availability of [classical-looking, but quantum mechanically exact] phase phase representations in terms of quasiprobability distributions, and to the particularly elegant manner in which the symplectic group of linear canonical transformations act on the quasiprobabilities. The talk will review, from a quantum optical point of view, some developments contributing to our understanding of these channels, the untimate goal being to place in perspective the recent results of Solomon Ivan of Raman Research Institute, Bangalore and Krishnakumar Sabapathi of the Institute of Mathematical sciences, Chennai on the construction of operator-sum representation for all single-mode Bosonoc Gaussian channels. Several consequences of this representation will be explored.

Name	**Urbasi Sinha**
Affiliation	Waterloo, Canada
Title	Born Rule(s)
Abstract	As one of the postulates of quantum mechanics, Born's rule tells us how to get probabilities for experimental outcomes from the complex wave function of the system. It's quadratic nature entails that interference occurs in pairs of paths. An experiment was done in our laboratory that sets out to test the correctness of Born's rule by testing for the presence or absence of genuine three-path interference. This is done using single photons and a triple slit aperture.

	Although the Born rule has been indirectly verified to high accuracy in other experiments, the consequences of a detection of even a small three-way interference in the quantum mechanical null prediction are tremendous. If a nonzero result were to be obtained, it would mean that quantum mechanics is only approximate, in the same way that the double slit experiment proves that classical physics is only an approximation to the true law of nature. This would give us an important hint on how to generalize quantum mechanics and open a new window to the world. In this talk, I will show results that bound the possible violation of Born's rule and multi-path interference in quantum mechanics and will point out ways to obtain a tighter experimental bound.

Name	**R. Srikanth**
Affiliation	PPISR, Bangalore
Title	Entanglement, intractability and superluminal signaling
Abstract	We show that the no-signaling condition cannot be derived from the assumption that, as seen from a complexity theoretic perspective, the universe is not an exponential place. The reason is that there exist polynomial superluminal gates, hypothetical primitive operations that enable superluminal signaling but not the efficient solution of intractable problems. Therefore, if we adopt this assumption as an axiom of physics, we must either supplement it with an additional assumption to prohibit such gates, or, improbably, conclude that no-signaling is not a universal condition. We describe a simple experiment involving entangled light that appears to realize such a quantum gate. We believe that such operations arise because some practically measured quantum optical quantities are not describable as standard quantum mechanical observables.

Name	**A. Sudbery**
Affiliation	University of York
Title	The geometric measure of entanglement
Abstract	In this talk I will review the geometric measure, which, in a mathematical sense, is the most direct measure of multipartite entanglement. I will concentrate on the mathematical problem of calculating the geometric measure, which requires extending the concept of eigenvalue from matrices to tensors.

Name	**Jeff Tollaksen**
Affiliation	Chapman University
Title	Weak measurements and time-symmetry in quantum mechanics
Abstract	Quantum mechanics allows one to independently select both the initial and final states of a single system. Study of such pre- and post-selection has now led to a new approach to quantum mechanics, to the discovery of a number of new quantum effects such as weak measurements and a powerful amplification method, and to an admittedly controversial new view of the nature of time. In this talk, I briefly review some new results concerning multi-time states and contextuality.

Name	**C. S. Unnikrishnan**
Affiliation	TIFR, Mumbai
Title	Quantum Mechanics of Spatially Separated Systems: Insights, Conflicts and New Results
Abstract	Quantum Entanglement of spatially distant physical systems on which classically independent measurements can be made is a source of continued debate, ever since the famous EPR query. The apparent conflict between the quantum mechanical description and our desire to reach a space-time picture of physical events appears in its most severe form in the correlations of such systems. I will outline a program of resolution [1] which has yielded some important and encouraging results. One of the results that I will highlight is the proof that the quantum correlation function emerges uniquely from the classical conservations laws assumed to be valid on the average over the quantum ensemble [2,3]. This will then imply that the local hidden variable theories are incompatible with fundamental conservation laws [3]. I will 'localize' the step in the proof of Bell's theorem that is crucial for its conclusion [4] and show how it is incompatible with the core idea of quantum theory and with any program of completing quantum theory by adding more to its structure. I will then show that Bell's theorem and experiments do not imply violation of Einstein locality in quantum mechanics, contrary to widespread belief. I will end with a summary of completed steps in a research program that hopes to show explicitly the validity of Einstein locality in the physics of spatially separated quantum entangled systems.

	References: [1] C. S. Unnikrishnan, *Quantum correlations from wave-particle unity and locality: Resolution of EPR puzzle,* Annales de la Fondation L. de Broglie (Paris), **25**, 363 (2000); *Is the quantum mechanical description of physical reality complete ? Resolution of the EPR puzzle*, Found. Phys. Lett., **15**, 1-25 (2002). [2] C. S. Unnikrishnan, *Conservation laws, Correlations functions and Bell's inequalities,* , Europhysics Letters **69**, 489-495 (2005). [3] C. S. Unnikrishnan, *The incompatibility between local hidden variable theories and the fundamental conservation laws,* Pramana – Jl. Phys. **65**, 359 (2005). [4] C. S. Unnikrishnan, *Light and the Observer: New Experiments and a Critique of Our Common Beliefs About Light,* Proc. SPIE conference 'The Nature of Light: What are Photons?' (Eds. C. Roychoudhuri, Al. F. Kracklauer and Katherine Creath), invited article 66640R (2007).

Name	**Andreas Winter**
Affiliation	University of Bristol & NUS, Singapore
Title	Communications between contextuality and non-locality
Abstract	When Bell started to think about no-go theorems for classical explanations of quantum observations, his fundamental understanding was based on non-contextuality (Gleason's theorem and what would later become the Kochen-Specker theorem), and it is clear that he introduced locality originally only as a means to make non-contextuality plausible. In this talk, rather than retracing the historical development, i want to elucidate in modern language how non-contextuality encompasses local realism, allowing for more general tests by "non-contextual inequalities". These reduce to Bell inequalities for certain context structures associated to local experiments, in such a way that also Tsirelson and no-signalling bounds are generalised as maximum quantum and abstract-probabilistic violations of the non-contextual inequality. As an aside, we find an apparently new semidefinite relaxation of the Tsirelson bound of arbitrary Bell inequalities. It remains to be determined how it relates to other methods of approximating it. Conversely, there are also ways of promoting a Kochen-Specker proof (and its associated non-contextual inequality) to a Bell inequality. Going even further, for each Kochen-Specker proof there is a zero-error communication game that can be won with suitable non-local resources, but not classically. Thus, non-contextuality is also behind a very measurable quantum communication advantage. [Based on work with A Cabello and S Severini, arXiv:1010.2163; and with T

	Cubitt et al., arXiv:1003.3195]

Name	**Ling-An Wu**
Affiliation	Chinese Academy of Science, Beijing
Title	Two-Photon Imaging with Entangled and Thermal Light
Abstract	Two-photon "ghost" imaging, based on the second-order intensity correlation, was first realized with entangled light, but has now been demonstrated with true thermal light. Following our work on lensless and high-order ghost imaging with thermal light, we have recently shown that both entangled and thermal light may be used to produce two-photon correlation Talbot effects. In the Talbot effect, first observed in 1836, a periodic object illuminated with coherent light can give rise to repeated self-images at specific positions within the Fresnel diffraction field without any lens. Using an incoherent thermal light source, we have experimentally observed second and higher order Talbot self-images, including fractional and phase-reversal images, at multiples of the Talbot length in a lensless setup containing two optical paths. Other interesting second-order correlation effects are also anticipated. It is expected that this type of imaging will find novel applications in both the microscopic and macroscopic regimes.

Poster Presentations

Name	**Satyabrata Adhikari**, A. S. Majumdar, D. Home, A. K. Pan
Affiliation	IOP, Bhubaneswar
Title	Swapping path-spin intraparticle entanglement onto spin-spin mixed interparticle entanglement involving amplitude damping channel
Abstract	Based on a scheme that produces pure entanglement between the spin and the path variables of a single spin-1/2 particle (qubit) using a beam-splitter and a spin flipper, we formulate a procedure for transferring this intraparticle hybrid entanglement to an interparticle pure entanglement between the spin variables of two other spatially separated spin-1/2 particles which never interact with each other during the entire process. We extend the above procedure to the case of mixed states. The mixed state is generated when path-spin entanglement in a particle passes through a noisy channel such as an amplitude damping channel. We then show that the spin-spin entanglement at the output can be made useful for quantum information processing if one applies suitable filtering operation.

Name	**Satyabrata Adhikari**, D. Home, A. S. Majumdar, A. K. Pan
Affiliation	IOP, Bhubaneswar
Title	Quantum contextuality as security check in quantum cryptography using intraparticle entanglement
Abstract	In this work we present a quantum key distribution scheme which exploits the quantum mechanical violation of noncontextuality for checking the security of the protocol. In this scheme, the sender encodes the key using path-spin intraparticle entanglement of a single particle. The receiver decodes the information using a combination of beam splitters, phase shifters in conjunction with the Stern-Gerlach measuring devices. Distinctive features of this protocol as compared to the BB84 and E91 protocols are discussed.

Name	**Veena Adiga** and Swarnamala Sirsi
Affiliation	Yuvaraja's College, University of Mysore

Title	Bounds on the parameters of some entangled three qubit symmetric states
Abstract	Here we study entanglement of three qubit symmetric states (equivalent to spin 3/2) by employing a new representation for the corresponding density matrix. The fifteen parameters which characterize the density matrix are real and provide physical interpretation as they are related to first, second and third order moments of spin operators J_x, J_y and J_z. Bounds on these parameters for some well known entangled states are studied in detail.

Name	**Md. Manirul Ali**, Po-Wen Chen, and Hsi-Sheng Goan
Affiliation	Academica Sinica, Taiwan
Title	Decoherence-free subspace, disentanglement dynamics and Quantum zeno subspace for two-level systems in a non-Markovian squeezed reservoir
Abstract	We study the non-Markovian entanglement dynamics of two qubits in a common squeezed bath. We see remarkable difference between the non-Markovian entanglement dynamics with its Markovian counterpart. We show that a non-Markovian decoherence free state is also decoherence free in the Markovian regime, but all the Markovian decoherence free states are not necessarily decoherence free in the non-Markovian domain. We then study the non-Markovian Zeno dynamics of a two-level quantum system interacting with a squeezed bath. It was shown that, by frequent measurements of adequately chosen observables, a complete suppression of the decay in an exponentially decaying two-level system (interacting with a squeezed bath) can occur. The observables and the initial states (Zeno subspace) for which the effect is observed depend on the squeezing parametrs of the bath. We show interesting differences between the non-Markovian Zeno subspace with its Markovian counterpart. We extend our calculation from squeezed vacuum bath to squeezed thermal bath, where we see the effects of finite bath temperatures on the dynamics.

Name	**S. Balakrishnan** and R. Sankaranarayanan
Affiliation	National Institute of Technology, Tiruchirappalli

Title	Schmidt strength of the geometrical edges of two-qubit gates
Abstract	Nonlocal two-qubit gates are represented by canonical decomposition or equivalently by operator-Schmidt decomposition. The former decomposition results in geometrical representation such that all the two-qubit gates form tetrahedron within which perfect entanglers form a polyhedron. On the other hand, it is known from the later decomposition that Schmidt number of nonlocal gates can be either 2 or 4. In this work, all the edges of tetrahedron and polyhedron are characterized using Schmidt strength, a measure of operator entanglement. It is found that one edge of the tetrahedron, which includes SWAP and Double-CNOT, possesses the maximum Schmidt strength. It implies that all the gates in the edge are maximally entangled.

Name	**Abir Bandyopadhyay**, Shashi Prabhakar and Ravindra Pratap Singh
Affiliation	Hooghly Engineering and Technology College; Quantum Optics & Quantum Information Group
Title	Wigner function and entanglement of generalized quantum optical vortex
Abstract	A rigorous quantum mechanical treatment is provided for a spin-polarized plane wave passing through a region of uniform magnetic field, leading to a modified formula for Larmor precession. This new formula matches with the standard expression in certain regimes of the experimental parameters. We pointed out that there are experimentally verifiable regimes of departure from the standard formula. The treatment is then extended to the case of a spin-polarized wave packet passing through a uniform magnetic field.

Name	**Arka Banerjee**
Affiliation	TIFR, Mumbai
Title	Larmor precession reexamined: Testable correction and ramifications
Abstract	A rigorous quantum mechanical treatment is provided for a spin-polarized plane wave passing through a region of uniform magnetic field, leading to a modified formula for Larmor precession. This new formula matches with the standard expression in certain regimes of the experimental parameters. We pointed out that there are experimentally verifiable regimes of departure from the standard formula. The treatment is then extended to the case of a spin-

	polarized wave packet passing through a uniform magnetic field.

Name	**Kinshuk Banerjee**
Affiliation	S. N. Bose National Centre for Basic Sciences, Kolkata
Title	Magnetically induced variation of tunneling current and its relation to nonclassicality and entanglement in the coupled quantum dot systems
Abstract	We have studied the intradot mixing of three states in a quantum dot in presence of an external magnetic field with a suitable Hamiltonian that can give rise to avoided crossing of the energy levels and the subsequent variation of the tunneling current. The connection between the current variation and the symmetry of the composite wavefunction of the dot is explored. We have provided a measure of the nonclassicality of the states involved in terms of the negative volume of the Wigner function corresponding to the vibrational degrees of freedom of the two-dimensional confinement potential of the quantum dot system. It is explicitly shown that a quantitative variation of nonclassicality with the variation of magnetic field directly corresponds to the variation of tunneling current with the magnetic field. As a nonclassical state can act as a rich source of entanglement, the measure of nonclassicality and the entanglement it can generate in terms of the experimentally measurable current can be very important.

Name	**Priyanka Chowhury**, S. Das, D. Home, A. S. Majumdar, V. Mousavi
Affiliation	S. N. Bose National Centre for Basic Sciences, Kolkata
Title	On the quantum analogue of Galileo's leaning tower experiment for Gaussian and Non-Gaussian wave packets
Abstract	The quantum analogue of Galileo's leaning tower experiment is revisited using Gaussian and Non-Gaussian wave packets evolving under the gravitational potential. We first calculate the position detection probabilities for particles projected upwards against gravity around the classical turning point and also around the point of initial projection, which exhibit mass dependence at both these points. We then compute the mean arrival time of freely falling particles using the quantum probability current, which also turns out to be mass dependent. The mass dependence of both the position detection probabilities and the mean arrival time vanish in the limit of large mass. Thus, compatibility between the weak equivalence principle and quantum mechanics

	is recovered in the macroscopic limit for both Gaussian and non-Gaussian wave packets. For non-Gaussian wave packet, the amount of violation of WEQ increases with the non-Gaussian parameter.

Name	**Sayan Chouhury** and Prasanta K. Panigrahi
Affiliation	IISER, Kolkata
Title	A proposal to generate entangled compass states with sub-Planck structure
Abstract	We illustrate a procedure to generate a bipartite, entangled compass state, which shows sub-Planck structure. The proposed method uses the interaction of a standing wave laser field, with two, two-level atoms and relies on the ability of this system to choose certain mesoscopic bipartite states to couple with the internal degrees of freedom. An appropriate measurement on the internal degrees of freedom then leads to the entangled state, which shows sub-Planck structures, desired for quantum metrology.

Name	**Shubhadipa Das** and Guruprasad Kar
Affiliation	S. N. Bose National Centre for Basic Sciences, Kolkata
Title	Simulation of singlet for unsharp measurement with free cost of communication
Abstract	Simulation of singlet for all projective measurements with nonlocal correlation is well known. There is no requirement of communication cost for this type of simulation. Here we prescribe a protocol to simulate singlet for more general measurement(POVM).The simulation of singlet for projective measurements appear as a special case of our model.

Name	**Nirman Ganguly,** S. Adhikari, G. Kar, A. S. Majumdar
Affiliation	Heritage Institute, Kolkata
Title	Characterization of entangled states with positive partial transpose through witness operators
Abstract	Edge states lying at the edge of positive partial transpose (PPT) entangled states have a very intriguing existence and their detection is equally interesting. We present here a witness for detection of edge states and

	compare it with the one proposed by Lewenstein *et al* [Phys. Rev. A 62, 052310(2000)] in terms of being finer. In this regard we show that this operator is finer than the operator of Lewenstein *et. al.* in some restrictions. We discuss its experimental relevance via Gell-Mann matrices. We then propose methods to find common entanglement witnesses. We also discuss how a common decomposable witness differs from a common non-decomposable one.

Name	**MD. RAJJAK GAZI** and Guruprasad Kar
Affiliation	ISI, Kolkata
Title	Local randomness in Hardy's correlations: Implications from information causality principle
Abstract	Study of nonlocal correlations in term of Hardy's argument has been quite popular in quantum mechanics. Recently Hardy's argument of non-locality has been studied in the context of generalized non-signaling theory as well as theory respecting information causality. Information causality condition significantly reduces the success probability for Hardy's argument when compared to the result based on non-signaling condition. Here motivated by the fact that maximally entangled state in quantum mechanics does not exhibit Hardy's non-local correlation, we do a qualitative study of the property of local randomness of measured observable on each side reproducing Hardy's non-locality correlation, in the context of information causality condition. On applying the necessary condition for respecting the principle of information causality, we find that there are severe restrictions on the local randomness of measured observable in contrast to results obtained from no-signaling condition. Still, there are some restrictions imposed by quantum mechanics that are not obtained from information causality condition.

Name	**Yang Tzyh Haur**
Affiliation	NUS, Singapore
Title	Quantum Bell Inequalities from Macroscopic Locality
Abstract	We propose a method to generate analytical quantum Bell inequalities based on the principle of Macroscopic Locality. By imposing locality over binary processings of virtual macroscopic intensities, we establish a correspondence between Bell inequalities and quantum Bell inequalities in bipartite scenarios with dichotomic observables. We discuss how to improve the latter approximation and how to extend our ideas to scenarios with more than two

	outcomes per setting.

Name	**Deepak Jalla** and Tanumoy Pramanik
Affiliation	S. N. Bose National Centre for Basic Sciences, Kolkata
Title	Teleportation of two qubit mixed states and quantum discord
Abstract	We consider the teleportation of two-qubit mixed states using four-qubit entangled states such as the GHZ state as resource. We study how the quantum discord of the state to be teleported gets modified in the process. Interesting comparisons of the concurrence and discord of the teleported state with that of the initial state are made for various teleportation schemes.

Name	**Mikhail M Kucherov**
Affiliation	Siberian Federal University
Title	Thermal entanglement in terms of pulse NMR
Abstract	There has been a growing interest in using nuclear magnetic resonance (NMR) in quantum computation and in-formation processing. Many approaches have been realized by using NMR in liquid and solid state samples because of the weak environmental interaction and thus long spin decoherence time [1]. The physical manipulation of spin state can be realized by sequences of electromagnetic pulses with resonant frequencies. Nuclear spin systems can be perspective candidates for implementing quantum logic gates and quantum computing. In the present paper several questions of quantum entanglement are discussed, in particular how entanglement can be related to the nuclear enhanced spin polari-zation under the low temperature and high magnetic field [2]. After introducing briefly the basic notations and defini-tions conditions for concurrence are found, and the question of teleportation is considered.

Name	**Chiranjib Mitra,** Diptaranjan Das, Tanmoy Chakraborty, Harkirat Singh, Swadhin Mandal and Tamal Sen
Affiliation	IISER, Kolkata
Title	Entanglement in Spin Chains
Abstract	Entanglement has been extensively studied from the perspective of Quantum

	Information Processing for the last decade and various measures of entanglement, to quantify it are now available. Experimentally also it has been possible to measure entanglement in pure state, mostly in optics. However, in recent years there has been significant development in Quantum Condensed Matter systems, especially spin chains, where extraction of entanglement has been made possible through macroscopic witness operators like magnetic susceptibility. In this work, we have made some spin chains, where the exchange interaction can be tuned by preparation technique and we have extracted a magnetic field and temperature dependence of entanglement from susceptibility and magnetization data taken at various temperatures and fields. We have also checked the previously conjectured result of complementarity between Susceptibility and Magnetization as a function of magnetic field and temperature. We have also obtatained signatures of Quantum Phase Transitions through our witness operators.

Name	**Soumya Debabrata Pani** and C. Behera
Affiliation	NIST, Behrampore
Title	MEASURES TO EMPOWER QUANTUM FINITE AUTOMATA (QFA)
Abstract	After the rendezvous of quantum physics and automata theory we got a new and highly developed field in the science of computing that is "QUANTUM AUTOMATA". The first developed quantum automaton is 1-way quantum finite automata (1-QFA). Though exponentially space efficient it is strictly less powerful than its classical counterpart. Then 2-way quantum finite automaton (2-QFA) was developed. It can recognize context free languages but number of states depends upon the input. To remove the drawbacks of 1-QFA and 2-QFA many development measures are taken. We can add multiple counters to 1-QFA so that it can recognize more complex languages like $L_{product} = \{a^m b^n c^{mn} \mid$ m and n are real numbers$\}$. Here by reading each alphabet the automaton has to do modification on the counters and when the end of string ($) is read along with 'zero' value of a counter then the input string is accepted. We can also operate two automatons like classical finite 1-counter automata (CF1-CA) and 2-way quantum finite automata (2-QFA) recognize the language $L_{product}$. The language $L_{product}$ cannot be recognized by either CF1-CA or 2-QFA alone. But when we apply them together the 2-QFA uses the output of CF1-CA to recognize the language. This symbiotic alliance of two automatons improves the power of both the automata.

Name	**Tanumoy Pramanik**, S. Adhikari, A. S. Majumdar, D. Home
Affiliation	S. N. Bose National Centre for Basic Sciences, Kolkata
Title	Proposal for testing non-locality of single photons in cavities
Abstract	We present a proposal for testing nonlocality of single photons by considering the state of a single photon that could located within one of the two spatially separated cavities. The outcomes of four experiments using this state involving the resonant interactions of two-level atoms with these cavities and a couple of auxiliary cavities are shown to lead to a contradiction with the condition of locality.

Name	**Ramji Rahaman**
Affiliation	Bergen, Norway
Title	Local cloning of CAT states
Abstract	In this paper we analyze the (im)possibility of the exact cloning of orthogonal three-qubit CAT states under local operation and classical communication(LOCC) with the help of restricted entangled state. We also provide the classification of the three-qubit CAT states that can (not) be cloned under the LOCC restrictions and then extend the results in n-qubit case.

Name	**Ashutosh Rai**, D. Home and A. S. Majumdar
Affiliation	S. N. Bose National Centre for Basic Sciences, Kolkata
Title	A generalized crypto-nonlocal realist inequality without any constraint on measurement settings
Abstract	Quantum mechanical violation of an inequality derived for a type of nonlocal realist model (known as crypto-nonlocal model) was pointed out by Leggett [Found. Phys. **33**, 1469 (2003)], and has been subsequently reformulated and tested in recent experiments. However, the crypto-nonlocal inequalities derived and tested so far are limited by certain constraints on the measurement settings. Here we derive a generalized form of crypto-nonlocal inequality by relaxing the constraint on the measurement settings. Such an inequality could

	be helpful in analyzing the experimental results, pertaining to which any strict constraint on measurement settings is very difficult to maintain in practice.

Name	**Shibdas Roy**
Affiliation	IISc, Bangalore
Title	A Compositional Characterization of Multipartite Quantum States
Abstract	Quantum entanglement is at the root of the most surprising quantum phenomena and plays a crucial role in the usage of quantum systems for processing information in tasks including but not limited to quantum teleportation, quantum key distribution, quantum communication and super-dense coding, that are impossible for classical systems. However, obtaining a generic, structural understanding of entanglement in arbitrary N-qubit systems is a long-standing open problem in quantum computer science. Multipartite quantum entanglement can be shown to admit a well-behaved compositional structure, such that it is subject to modern computer science methods. Such a compositional structure is observed in an abstract setting of commutative Frobenius algebras expressed internal to symmetric monoidal categories. Categorical quantum mechanics was originally formulated by Prof. Samson Abramsky and Dr. Bob Coecke at the Oxford University Computing Laboratory. A more intuitive graphical approach to studying categorical algebra, originally laid down by Penrose-Joyal-Street, was exploited to study quantum phenomena and various protocols in the graphical paradigm by Dr. Bob Coecke. A powerful GHZ/W graphical calculus has now been established by Bob Coecke and Aleks Kissinger that is expressive enough to generate and reason about representatives of arbitrary N-qubit quantum states. Based on the basic set of axioms satisfied by a GHZ/W pair, we arrived at certain normal forms that provide us with a toolkit for reasoning about interacting GHZ and W states in composing SLOCC-superclasses of multipartite quantum states. We hope that such a calculus would further help to gain much deeper and more intuitive insights into the nature of quantum multipartite entanglement, as also categorical algebra in general useful for other various fields.

Name	**Papri Saha**, N. Nayak and A. S. Majumdar
Affiliation	Derozio College, Kolkata
Title	Atomic entanglement mediated by various non-classical cavity fields

Abstract	In this work several non-classical properties of the interaction of atoms with cavity modes are described such as the entanglement of bipartite system in the multimode cavities. We first study the dynamics of a single Rydberg atom in an n-mode cavity. The dynamics are described by oscillations at the rate of the interaction strength of the atom-field interaction, which are popularly known as Rabi oscillations. We proceed to study the entanglement of two mutually non-interacting atoms growing out of the interactions with the cavity modes, described by the Tavis-Cummings model. The recently proposed phenomenon of "entanglement sudden death" in atomic systems is also investigated in the context of the Tavis-Cummings model. For all these schemes we analyze and discuss the quantitatively distinct fall of entanglement as the cavity photon number increases. Effects such as the growth of the magnitude of atomic entanglement with the increase of the cavity photon number, arising out of the intensity dependent atom-cavity coupling lead to interesting dissimilarities from the case of entanglement generated by the standard Jaynes-Cummings interaction. We also consider a system consisting of a pair of two-level atoms passing one after another through a cavity in the framework of multiphoton Jaynes-Cummings model. We consider the cavity field in a Fock state, coherent and thermal states, and the squeezed states, respectively. The entanglement of formation of the joint two-atom state is studied as a function of the Rabi angle gt and of the number of photons m required by the atoms to make transitions between its two states. It is shown that, under certain values of gt and average photon numbers in the cavity field considered, the entanglement could be enhanced with m.

Name	**Sujit Sarkar**
Affiliation	PPISR, Bangalore
Title	Perfect Entanglement Transport in a Quantum Spin Chain
Abstract	We propose a mechanism for perfect entanglement transport in anti-ferromagnetic (AFM) quantum spin chain systems with modulated exchange coupling and also for the modulation of on-site magnetic field. We use the principle of adiabatic quantum pumping process for entanglement transfer in the spin chain systems. We achieve perfect entanglement transfer over an arbitraly long distance and a better entanglement transport for longer AFM spin chain system than for the Ferromagnetic one. We explain analytically and physically why the entanglement hops in alternate sites. We find the condition for blocking of entanglement transport even in the erfect pumping condition. Our analytical solution interconnects quantum any body physics and quantum information science.

Name	**Surajit Sen**, Mihir Ranjan Nath and Tushar Kanti Dey
Affiliation	GC College, Silchar, India
Title	Bloch space structure, qutrit wave function and atom-field entanglement in three-level system
Abstract	The Bloch space structure of the three-level configuration is studied by solving the semiclassical Bloch equations of the lambda, vee and cascade configuration, respectively. It is shown that at resonance, the eight-dimensional Bloch sphere is broken into two distinct subspaces due to the existence of a pair of quadratic non-linear constants and they are different for different systems. We propose a possible representation of the qutrit wave function and show its equivalence with the three-level system. Finally following Phoenix-Knight formalism, the interrelation between the atom-field entanglement and the population inversion of all threelevel configurations is studied and the existence of an inversion symmetry is pointed out particularly for the equidistant cascade system.

Name	**Siddhartha Sinha**, A. S. Majumdar, D. Home
Affiliation	S. N. Bose National Centre for Basic Sciences, Kolkata
Title	Quantum Entanglement and Dark Energy of the Universe
Abstract	We explore two observable consequences of quantum entanglement in the paradigm of cosmology. For both of these, the respective mechanisms lead to the emergence of Dark Energy of the Universe, a form of energy which dominates the energy density of our present Universe and whose negative pressure ensures the observed acceleration. Our first approach stems from dynamical wave function collapse models in which a fluctuating background scalar field interacting with the matter wave-function causes the collapse of the latter through non-linear stochastic terms in the Schrodinger equation. This process is accompanied by a continuous liberation of energy by the scalar field at a specified rate. The wave-function collapse of dark matter particles, results in the liberated accumulated energy to constitute the requisite amount of dark energy around the time of galaxy formation and can cause the Universe to accelerate at later times. The second approach concerns possible relics of the QCD phase transition, which are the so-called strange quark nuggets (SQNs). The fact that the colour degrees of freedom are inaccessible to any observer outside the SQN surface leads to an entanglement entropy. By the holographic mechanism, this leads to the formation of entanglement energy.

	We show that this entanglement energy could constitute the required amount of dark energy which dominates the current energy density of the universe leading to the observed late-time acceleration of the universe. Observational results are used to place constraints on our model parameters.

Name	**R. Srikanth**
Affiliation	PPISR, Bangalore
Title	**Entanglement, intractability and superluminal signaling**
Abstract	We show that the no-signaling condition cannot be derived from the assumption that, as seen from a complexity theoretic perspective, the universe is not an exponential place. The reason is that there exist polynomial superluminal gates, hypothetical primitive operations that enable superluminal signaling but not the efficient solution of intractable problems. Therefore, if we adopt this assumption as an axiom of physics, we must either supplement it with an additional assumption to prohibit such gates, or, improbably, conclude that no-signaling is not a universal condition. We describe a simple experiment involving entangled light that appears to realize such a quantum gate. We believe that such operations arise because some practically measured quantum optical quantities are not describable as standard quantum mechanical observables.

Name	**Roman Sverdlov**
Affiliation	Raman Research Institute
Title	Can superluminal locality be a basis for Pilot Wave model?
Abstract	I would like to come up with Pilot Wave model that is based on very fast, but finite, speeds of signal propagation. In particular, these signals can circle the universe within small but finite period of time. Furthermore, I would like to propose that different point-like "classical" particles are tuned into different frequencies of these signals. Any group of particles that is tuned to the same frequency is "superluminally correlated". These correlated groups of particles acts as elements of a position-based Fock space. Probability amplitude, ψ, represents internal degree of freedom of each particle; therefore, it is "local". However, due to the above correlation, it happens to be approximately the same for different particles within the same "group". This is what makes it "look like" a function on Fock space. The main point of my work is to "convert" the key elements of quantum field theory as

	well as D\"urr's Pilot Wave model into this particular framework. The end product is a deterministic theory ran by "local" (although superluminal) signals.