Book of Abstracts of Talks

1. Name of the speaker: Manik Banik

Affiliation: S.N. Bose National Centre for Basic Sciences, Kolkata

Title of the talk: Joint Measurability on Pair of Parallel vs Anti-Parallel State of Spin-1/2 Systems

Abstract: Bohr's Complementarity principle encapsulates a fundamental aspect of quantum theory, asserting that certain observables cannot be measured simultaneously. However, generalized measurements allow for joint measurement of such incompatible observables by considering their unsharp version. We explore this concept in a broader framework where multiple copies of a system's state are available per run. For a spin-1/2 system, we discuss some intriguing observations by considering ensembles of parallel and anti-parallel states.

2. Name of the speaker: Sibasish Ghosh

Affiliation: The Institute of Mathematical Sciences, Chennai

Title of the talk: Repeater-based optimal quantum teleportation in noisy scenario: the case of qubits

Abstract: When two distant labs shares an entangled two-qudit state, noisy in general, the optimal teleportation scheme — for sending (quantum) information about an arbitrary state of a d-level quantum system from the sender's (i.e. Alice's) lab to the receiver's (i.e., Bob's) lab — is known to exit in which Alice needs to perform measurement in the generalized Bell basis on her two-qudit system, followed by Bob's unitary operation on his qudit (based upon classical communication received from Alice regarding her measurement outcome). In a repeater-based quantum information transmission scenario (namely, 'entanglement swapping') — a fundamental scheme for establishing quantum communication channel between distant labs — will the same optimal teleportation protocol still work, in an optimal way, in the presence of noise in case this protocol is applied sequentially between each pair of consecutive nodes?
To answer this, we study [1] optimal quantum teleportation between two spatially separated labs, Alice and Charlie, with an intermediate lab, Bob, positioned in between them. Each pair of neighboring labs shares a bipartite quantum state with local dimension $d \geq 2$, and all parties are restricted to Local Operations and Classical Communication (LOCC). Our goal is to identify an unique LOCC protocol that enables Alice and Charlie to achieve the maximum possible teleportation fidelity. We propose general upper bounds for optimal teleportation fidelity achievable through separable

operations (SEP) for local dimension d ≥ 2. For d = 2, we observe that independent upper bounds exist which cannot be surpassed by LOCC. Also for d = 2, we find that no unique protocol universally maximizes fidelity; instead, the structure of the optimal protocols i.e., who starts the protocol and how many LOCC rounds are required between any two parties explicitly depend on the structure of the pre-1 shared states, and such protocols do not necessarily maximize the entanglement between Alice and Charlie, measured in terms of concurrence. Interestingly, the optimal protocol often diverges from the standard entanglement-swapping approach. We then discuss the increased complexity of extending these findings to larger linear network. In this connection, we propose [2] a more efficient protocol for a certain class of noisy states, achieving the same fidelity as the standard protocol while consuming less amount of entanglement. Our approach ensures optimal teleportation fidelity even when the end-to-end state gets noisier, and thus promises efficient utility of quantum resources in repeater-based distributed quantum protocols.

References:
[1] “Optimal quantum teleportation of collaboration” (by Arkaprabha Ghosal, Jatin Ghai, Tanmay Saha, Mir Alimuddin, and SG) arXiv:2401.17201 (quant-ph).

[2] “Repeater-Based Quantum Communication Protocol: Maximizing Teleportation Fidelity with Minimal Entanglement” (by Arkaprabha Ghosal, Jatin Ghai, Tanmay Saha, SG, and Mir Alimuddin) arXiv:2406.14216 (quant-ph).

3. Name of the speaker: Bhaskar Kanseri

Affiliation: Indian Institute of Technology, Delhi

Title of the talk: Entangled Qubit Sources for Quantum Secure Communication and Imaging

Abstract: Quantum entanglement is at the heart of quantum Physics. In communication, use of quantum entanglement offers an extra layer of security and simplifies the key analysis. In addition, it is useful in computing, imaging and sensing applications. This talk will begin with highlighting the development of entangled photon sources for both free-space and fibre based applications, and characterization of their quantum features. Partially coherent entangled qubit source containing multimode nature is found as an excellent choice for free-space quantum communication and imaging. We investigate the spatial and spectral properties, and polarization entanglement features of partially coherent biphotons generated using partially coherent pump through a quantum process, namely the spontaneous parametric down conversion (SPDC). We demonstrated both theoretically and experimentally that by reduction of their partial coherence, polarization entanglement of partially entangled qubits decreases, which can be recovered by performing few mode selection. This talk will also emphasize on fiber based QKD realizations made by our group at IIT Delhi in lab scale and in real field environment. Specifically, the practical aspects of entanglement enabled fibre QKD will be emphasized, focusing on the need of coexistence of classical and quantum signal on the same fibre. The need of multi-node quantum networks for realizing quantum internet would also be discussed.
References:

[1] P. Sharma, N. K. Pathak and B. Kanseri, Controlling polarization entanglement in biphotons generated with partially spatially coherent pump beam, Results Phys. 27, 104506 (2021).
[2] N.K. Pathak, S. Chaudhary, Sangeeta and B. Kanseri, “Phase encoded quantum key distribution up to 380 km in standard telecom grade fiber enabled by baseline error optimization” Scientific Reports (Nature) 13, 15868 (2023).
[3] S. Rao, P. Sharma, and B. Kanseri, “Recovery of polarization entanglement in partially coherent photonic qubits”, Optics Letters 49, 1381-84 (2024).
[4] N. Pathak and B. Kanseri, “Simultaneous coexistence of polarization entangled photons and classical signal for quantum networks in C band”, Frontiers in Optics (FiO LS-2024), Sept 26-30, (2024).

4. Name of the speaker: Archan S. Majumdar

Affiliation: S.N. Bose National Centre for Basic Sciences, Kolkata

Title of the talk: Quantum measurements drive quantum communication

Abstract: We explore the role of quantum measurements in providing quantum-over classical advantage in information processing tasks useful for quantum communication. We show that measurement incompatibility is necessary for obtaining quantum advantage. We formulate operational witnesses for observing measurement incompatibility in the context of prepare and measure scenarios. We next show how measurement incompatibility can be demonstrated in experimental set-ups in the presence of imperfections such as environmental noise and finite precision of measurements. We finally show that quantum contextuality is responsible for communication complexity advantage in generic communication tasks such as quantum secret key generation.

5. Name of the speaker: Alok Kumar Pan

Affiliation: Indian Institute of Technology, Hyderabad

Title of the talk: Chained Bell inequality: Robust self-testing, certified randomness and secure key rate

Abstract: Self-testing is the strongest certification procedure that uniquely characterizes the physical system based on the observed statistics. The optimal quantum violation of a Bell inequality enables the device-independent self-testing of the states and measurement settings. One significant aspect of self-testing is robustness, ensuring the validity of certification in real experimental situations involving noise and imperfection leading to the deviation from the ideal scenario. In this work, we demonstrate the device-independent self-testing protocol based on the chained Bell inequality. We devise an elegant sum-of-square (SOS) technique enabling dimension-independent optimization of the quantum violation. This improves the previous methods of self-testing, which assume the state without deriving from the self-testing relation and is restricted to a two-qubit system. Our approach provides the derivation of state and further relationship between local observables in an arbitrary

dimension. We also provide a complete analytic technique for robust self-testing. As an application of our scheme, we demonstrate the certification of two-bit randomness using our self-testing protocol. Further, we derive the device-independent key rate and show that the key rate increases with the increment of measurement setting n and approaches to with sufficiently large value of n.

6. Name of the speaker: Anirban Pathak

Affiliation: Jaypee Institute of Information Technology, Noida, India

Title of the talk: Many facets of security in the post-quantum world

Abstract: The notion of security as it appeared in our works of the recent past will be summarized with a specific focus on the protocols designed, realized and analyzed by us. In the process, many facets of secure continuous variable and discrete variable quantum communication will be described. The discussion on secure quantum communication will not be restricted to quantum key distribution (QKD) only. Protocols for quantum identity authentication, quantum secure direct communication, and methodologies for modelling the environment for the satellite-assisted quantum communication will also be discussed. In addition, the talk will include short discussions on post-quantum cryptography, secure multiparty quantum computing and the removal of bottlenecks in the entanglement routing problem.

7. Name of the speaker: Prasanta K. Panigrahi

Affiliation: Siksha ‘O’ Anusandhan University, Bhubaneswar, India

Title of the talk: Multi-slit interference and discrimination of quantum states

Abstract: Multi-slit interference provides a beautiful playing ground to explore and quantify the wave-particle nature of quantum particles. Surprisingly it also provides a venue to quantify entanglement in its geometric form, I-Concurrence. An exact triality relation between coherence, entanglement and which path information has been recently experimentally verified. It involves measurement in non-orthogonal basis, which brings path entanglement into experimental observation. The role of distributed ancillary measurements in discriminating entangled states, which also has found recent experimental verification is illustrated.

8. Name of the speaker: Debasis Sarkar

Affiliation: University of Calcutta, Kolkata

Title of the talk: Quantum State Discrimination task- Some recent results

Abstract: The discovery of quantum entanglement is one of the most striking features in quantum information theory. It shows many counterintuitive results as well it acts as a useful resource in many quantum information processing tasks like energy in

classical physics. However, entanglement alone is not the sole responsible factor that reveals many fascinating ideas discovered in last thirty years. Local discrimination of set of orthogonal states in bipartite or multipartite quantum systems is one of the core research area where we find many counterintuitive results using or not using entanglement. In this lecture we want to illuminate some of our recent results in this topic.

9. Name of the speaker: Urbasi Sinha

Affiliation: Raman Research Institute, Bengaluru

Title of the talk: Secure Semi-Device-Independent Quantum Random Number Generation via Leggett-Garg Inequality Violations: From Photonic Systems to Superconducting Qubits

Abstract: We present a comprehensive investigation of secure semi-device-independent quantum random number generation (QRNG) through unambiguous violations of macrorealist inequalities, specifically the Leggett-Garg inequality (LGI). Our work spans two complementary experimental implementations: a heralded single-photon-based setup and an application on superconducting quantum processors.
In our photonic implementation, we employ a Mach-Zehnder interferometer followed by a displaced Sagnac interferometer, methodically addressing all relevant loopholes that have challenged previous macrorealism tests. The clumsiness loophole is closed through precision testing of classical invasiveness during negative result measurements, verified by maintaining quantum mechanically predicted two-time no-signalling in time (NSIT) conditions. We overcome the detection efficiency loophole through strategic measurement modifications, enabling LGI or WLGI violations for any nonzero detection efficiency. Additional loopholes— including multiphoton emission, coincidence, and preparation state loopholes—are systematically closed within our setup. This implementation demonstrates a significant LGI violation of 1.32±0.04 (8 times the error value), successfully generating 919,118 truly unpredictable bits at a rate of 3,865 bits/sec [1,2].
Extending these insights to superconducting quantum processors, we demonstrate how current quantum computers can be leveraged for practical random number generation despite limitations in qubit scaling and circuit depth. While traditional device-independent approaches require spatial separation through Bell inequality violations, our method employs temporal correlations through LGI violations, relying on the No-Signalling in Time condition to certify randomness. This approach enables implementation on a single quantum computer using low- depth circuits with single-qubit gates, overcoming spatial constraints that have previously limited practical quantum applications [3].
Through rigorous quantification of randomness using both analytical and numerical approaches in perfect agreement, our work opens an unexplored avenue toward empirically convenient, reliable random number generators across different quantum platforms, advancing practical quantum applications even with current technology limitations.

1. *Single system based generation of certified randomness using Leggett-Garg inequality,* P.P.Nath, Debashis Saha, Dipankar Home, U.Sinha, *Physical Review Letters*, **133**, 020802, 2024.

2. *Loophole free interferometric test of macrorealism using heralded single photons*, K.Joarder, D.Saha, D.Home, U.Sinha, *PRX Quantum,* **3**, 010307, 2022.
3. *Certified Random Number Generation using Quantum Computers*, P. P. Nath, A. Sinha, U. Sinha, arXiv: 2502.02973.

10. Name of the speaker: R. P. Singh

Affiliation: Physical Research Laboratory, Ahmedabad

Title of the talk: Experiments in Quantum Communication

Abstract: To provide unconditional security to the keys, and subsequently to the message, Quantum Key Distribution (QKD) comes to the rescue. QKD is one of the most ubiquitous applications of quantum mechanics in modern times. Though QKD provides unconditional security, its practical implementation deviates from the ideal one, affecting the security of key. In this talk, we will discuss the techniques to improve the key rates for BB84 and BBM92 QKD protocol and methods to characterize implementation loopholes that make it vulnerable against the side channel attacks. For increasing the key rate using weak coherent laser pulses, we introduce a novel quantum key distribution protocol, called coincidence detection quantum key distribution protocol (CD Protocol). We show that the Poissonian nature of weak coherent pulses instead of posing a security risk can be used to achieve a secure key rate higher than the standard GLLP and decoy state QKD protocols. Prepare and measure protocols such as BB84 consider the satellite as a trusted device, which is fraught with danger looking at the current trend for satellite based optical communication. Therefore, entanglement-based QKD (EB QKD) protocols must be preferred since, along with overcoming the distance limitation, one can take the satellite as an untrusted device. The most well-known EB QKD protocol is the E91 protocol, but the achieved key rate is less as maximum of the bits are sacrificed for measuring Bell parameter. This key rate can be increased without compromising the security provided by EB QKD, if one uses the BBM92 protocol with a pre-characterized relation between S and QBER. Thus, an estimate of QBER provides a simultaneous measurement of entanglement without sacrificing the bits used in proving the Bell's inequality violation. At the end, we will discuss the current international status of the field.

References:
[1] Sarika Mishra, et al., J. Optics 24, 074002 (2022).
[2] Ayan Biswas, et al., Optics Continuum 1.1, 68-79 (2022).
[3] Ayan Biswas, et al., IEEE J. of Quantum Electronics 57, 1-7 (2021).
[4] Ali Anwar et al., New J. of Physics 22, 113020 (2020).
[5] Ali Anwar, et al., J. Optical Society of America B 38, 2976-2983 (2021).

11. Name of the speaker: Usha Devi A.R.

Affiliation: Bangalore University

Title of the talk: Quantum heat exchange fluctuation

Abstract: It is well-known that Wigner distribution function approach exhibits a close resemblance to the classical phase-space trajectory description [1]. Using the fact that Wigner function is positive definite for Gaussian states [2] we discuss Jarzynski–Wojcik quantum heat exchange fluctuation theorem (XFT) [3] in two Gaussian thermal states at different temperatures. Our investigation results in a generalized Jarzynski–Wojcik XFT for Gaussian thermal states. The generalized heat XFT reduces to the Jarzynski– Wojcik heat XFT in the classical limit $\hbar\omega$ /kT $\rightarrow$ 0. Impact of measurements on heat-exchange statistics [4, 5] is outlined.

References:
[1] A. R. Usha Devi, Sudha, A. K. Rajagopal, A. M. Jayannavar, Heat exchange and fluctuation in Gaussian thermal states in the quantum realm, J. Stat. Mech. 2021, 023209 (2021).

[2] Arvind , B. Dutta, N. Mukunda, R. Simon, The real symplectic groups in quantum mechanics and optics, Pramana J. Phys. 45, 471 (1995).

[3] C. Jarzynski, D. K. Wojcik, Classical and Quantum Fluctuation Theorems for ´ Heat Exchange, Phys. Rev. Lett. 92, 230602, (2004).

[4] S. Jevtic, T. Rudolph, D. Jennings, Y. Hirano, S. Nakayama, M. Murao, Exchange fluctuation theorems for correlated quantum systems, Phys. Rev. E 92, 042113 (2015).

[5] K. Micadei, G. T., Landi, E. Lutz, Quantum fluctuation theorems beyond two-point measurements, Phys. Rev. Lett. 124, 090602 (2020).

12. Name of the speaker: Arpita Maitra

Affiliation: TCG CREST, Kolkata

Title of the talk: Quantum Secure Communication–Theory and Practices

Abstract: Theoretically, Quantum Secure Communication should guarantee unconditional security. However, in practice, this claim may not completely be viable if the devices are not flawless (ideal). Exploiting the inherent deviations of the devices from the ideal scenario, an adversary may extract significant amount of information regarding the final secret key. Thus, deployment of any QKD hardware in the network without proper security evaluation may cause potential security breach. In this talk, we will discuss how to evaluate a QKD device and what are the specifications that both the manufactures and the evaluators should maintain. In addition, we will also discuss black box testing issues related to a few methodologies for QKD devices and the inherent difficulties in performing such tests.

13. Name of the speaker: Joyee Ghosh

Affiliation: Indian Institute of Technology, Delhi

Title of the talk: All-fiber-integrated tunable polarization-entanglement distribution of 100-km for multiuser QKD over metro-area fiber-optic networks

Abstract: The scalability of quantum communication networks requires compact, fiber-integrated, easy-to-deploy, and efficient wavelength-division multiplexed (WDM) sources for *multi-user secure quantum key distribution*. In the Quantum Photonics group of IIT Delhi, we have demonstrated such a multi-channel source of polarization-entangled photon pairs in the low-loss telecom C-band based on spontaneous parametric down-conversion in an all-fiber-integrated PPLN waveguide in the Sagnac configuration. The source can be easily tuned to generate two different entangled Bell states, measured in 14 channel pairs of the International Telecommunication Union dense WDM grid around 1550-nm with a maximum raw fidelity of ≳94%. The raw concurrence is ≳0.8 for both Bell states in all channel pairs, and the observed S-parameter (>2.56± 0.04 in all 14-channel pairs) shows a strong violation of CHSH-Bell's inequality. The source's suitability for long-distance entanglement transmission is also demonstrated by the successful transfer of entangled photons up to 100 km while maintaining a raw fidelity >85% and quantum bit error rate <9%. The effect of polarization mode dispersion on entanglement distribution among remote users is also studied in detail. All these performance metrics are measured using conventional room-temperature semiconductor-based single-photon avalanche detectors with merely 10-20% quantum efficiency, and these metrics are the best reported with these detectors. Our highly flexible source can support up to ~40 user pairs to communicate simultaneously, and it can be easily deployed into the current metro-area fiber-optic telecom infrastructure to form a complete WDM-based quantum communication network.

Relevant publications/reads:

1. *Telecom source of tunable polarization-entanglement distribution up to 100-km for multi-user QKD over*
metro-area fiber-optic networks -- Vikash Kumar Yadav, Vivek Venkataraman, Joyee Ghosh; **[**Applied
Physics Letters- Quantum]: **APL Quantum 2,** 016102 **(2025)**.
2. *High-brightness fiber-coupled source of polarization-entangled photon pairs spanning the telecom C-*
and L-bands -- Vikash Kumar Yadav, Vivek Venkataraman, Joyee Ghosh;
Optics and Laser Technology 175, 110774, (**2024**).
3. *Fully-guided polarization-correlated photon pairs at 1560-nm from a type-II SPDC-based source* -- A
Angural and Joyee Ghosh, **Optics Letters 49**, No. 3, 442 (**2024**).
4. *Broadband telecom photon pairs from a fiber-integrated PPLN ridge waveguide* -- Vikash K Yadav, V
Venkataraman, Joyee Ghosh, **Optics Letters 47**(19) 5132-5135 (**2022**).

14. Name of the speaker: Karol Horodecki

Affiliation: University of Gdańsk, Poland

Title of the talk: Upper bounds on secret key rate in various quantum and beyond-quantum cryptographic scenarios

Abstract: Quantum cryptography enables secure communication at a distance by, among others, providing methods for the distribution of keys for one-time pad encryption. Depending on the power of the adversary, the resources at the disposal of the honest parties, and the allowed class of operations that the honest parties can perform, one can consider different cryptographic scenarios for distributing key for one-time pad encryption secure against the adversary. These include but are not limited to (i) device-dependent quantum cryptography, (ii) device-independent quantum cryptography, (iii) supra-quantum cryptography secure against the non-signaling adversary and related to the last one, traditional (non-quantum), (iv) scenario of the secure key agreement. In the following talk, I will provide insight into the history and methods for providing the upper bounds on the amount of secret key achievable in these scenarios and some of the recent bounds, showing the similarities and differences between these four cryptographic scenarios and related challenges.

15. Name of the speaker: Prem Kumar

Affiliation: Northwestern University, USA

Title of the talk: Engineering Challenges for the Emerging Quantum Networks

Abstract: Future quantum photonic networks will require device functionalities that implicitly respect fundamental facts such as quantum information cannot be copied and cannot be measured precisely. A quantum repeater, for example—analog of an optical amplifier that enabled global reach of the ubiquitous Internet connectivity we enjoy today—is yet to be demonstrated, although recent years have seen tremendous progress. Many other device functionalities—switches, routers, format converters, etc.—would also be needed that do not unnecessarily disturb or corrupt the quantum information as it flows from one node of the internet to another. In recent years, my group has engineered many quantum-optical tools and techniques that fulfil the requirements for distributing quantum photonic information in a networked environment. In this talk, I will present our motivation, design, construction, characterization, and utilization of some example techniques for near-term networked quantum applications.

16. Name of the speaker: Lorenzo Maccone

Affiliation: University of Pavia, Italy

Title of the talk: Quantum time and quantum spacetime

Abstract: In textbook quantum mechanics, time is an external parameter and not a dynamical variable. Instead, in this talk I will review two different approaches to internalize time and treat it as a fully quantum degree of freedom. The first "quantum time" is suitable for non-relativistic quantum mechanics. We detail its consequences and show how this proposal can bypass all conventional criticisms against the

quantization of time, e.g. the Pauli objection. The second, a Geometric Event-Based quantum mechanics, is suited to the relativistic case. This is still a partial proposal which is being worked out, but some of the results of quantum field theory can be recovered in this context.

17. Name of the speaker: Alexander Streltsov

Affiliation: IPPT PAN, Warsaw, Poland

Title of the talk: Entanglement catalysis and the second law of entanglement manipulation

Abstract: Entanglement is a fundamental resource in quantum information processing, yet understanding its manipulation and transformation remains a challenge. When it comes to manipulating entangled quantum systems on a single copy level, using entangled states as catalysts can significantly broaden the range of achievable transformations. Similar to the concept of catalysis in chemistry, the entangled catalyst is returned unchanged at the end of the state manipulation procedure. In this talk we discuss recent progress on entanglement catalysis, and also consider the more general framework of entanglement batteries. An entanglement battery is an auxiliary quantum system that facilitates quantum state transformations without a net loss of entanglement. We establish that reversible manipulation of entangled states is achievable through local operations when augmented with an entanglement battery. Different entanglement quantifiers give rise to unique principles governing state transformations, effectively constituting diverse manifestations of a "second law" of entanglement manipulation.

18. Name of the speaker: Paolo Villoresi

Affiliation: University of Padua, Italy
Title of the talk: Quantum communications as a global resource for fundamental studies and applications

Abstract: The exchange of quantum states is the most fundamental level of communications. Notwithstanding the difficulties due to the weak signal, it enables protocols that goes beyond the classical ones.
Current realizations of quantum communication systems allow for very important test of quantum physics, recently extended also to include affected due to relativity.
The applications of quantum communications are also exploited in many continents, supported with important investments.
We shall address both areas with the focus on the development of these sectors seems that its inception for the quantum channels in space and on the ground. The evolution of quantum random number generation will also be addressed.
1. Villoresi, P. et al. Experimental verification of the feasibility of a quantum channel between space and Earth. New J. Phys. 10, 033038 (2008).
2. Vallone, G. et al. Experimental Satellite Quantum Communications. Phys. Rev. Lett. 115, 040502 (2015).

3. Vallone, G. et al. Interference at the Single Photon Level Along Satellite-Ground Channels. Phys. Rev. Lett. 116, 253601 (2016).
4. Vedovato, F. et al. Extending Wheeler's delayed-choice experiment to space. Sci. Adv. 3, e1701180 (2017).
5. Agnesi, C. et al. Sub-ns timing accuracy for satellite quantum communications. J. Opt. Soc. Am. B 36, B59 (2019).
6. Mohageg, M. et al. The deep space quantum link: prospective fundamental physics experiments using long-baseline quantum optics. EPJ Quantum Technol. 9, 25 (2022).
7. Terno, D. R. et al. Proposal for an optical interferometric measurement of the gravitational redshift with satellite systems. Phys. Rev. D 108, 084063 (2023).

19. Name of the speaker: Jonathan Oppenheim

Affiliation: University College London, UK

Title of the talk: Decoherence vs diffusion: testing the quantum nature of spacetime

Abstract: We consider two interacting systems when one is treated classically while the other remains quantum. The most general form of such dynamics can be derived and has implications for the foundations of quantum theory, and to the problem of understanding gravity when spacetime is treated classically. If any system is treated as fundamentally classical, the dynamics necessarily results in decoherence of quantum systems, and a breakdown in predictability in classical phase space. We prove that a trade-off between the rate of decoherence and the degree of diffusion induced in the classical system is a general feature of all classical-quantum dynamics. Applying the trade-off to general relativity provides an experimental signature of theories in which spacetime is fundamentally classical. Bounds on decoherence rates arising from current interferometry experiments, combined with precision acceleration measurements, squeezes the theory from both sides and can be used to probe the nature of spacetime.

20. Name of the speaker: Giulio Chiribella

Affiliation: University of Hong Kong, HK

Title of the talk: Quantum indeterminism vs classical determinism, and a toy theory that challenges the divide

Abstract: Quantum theory is often contrasted with classical theory on the ground that the latter is a deterministic theory while the former is not. This comparison is based on the standard, realistic interpretation of classical theory, in which every system is assumed to have well-defined properties, pre-existing the act of measurement. Here we show that, in fact, the contrast between quantum and classical theory is not as sharp as it might seem at first sight. In particular, we show that the standard realistic interpretation of classical theory can, in principle, be falsified if classical systems coexist with other types of physical systems that interact with classical systems in a non-trivial way. To make this point, we construct a toy theory that (i) includes classical theory as a sub theory and (ii) allows classical systems to be entangled with another

type of systems, called anti-classical. We show that our toy theory allows for the violation of Bell inequalities in two-party scenarios where one of the settings corresponds to a local measurement performed on a classical system alone. Building on this fact, we show that measurement outcomes in classical theory cannot, in general, be regarded as predetermined by the state of an underlying reality. While our toy theory is just a toy theory, it makes a conceptually important point, by showing that the status of probabilities in classical and quantum theory is not necessarily different. This observation suggests that certain interpretational problems of quantum mechanics, such as the emergence of definite outcomes through the act of measurement, may have analogues also in a classical context, which in turn suggests that their solution may require a change of paradigm in the interpretation of probability itself.

21. Name of the speaker: Andreas Winter

Affiliation: Universitat Autonoma de Barcelona, Spain

Title of the talk: Hidden Markov models - classical and quantum mechanisms, and beyond

Abstract: Among the stationary time series of events (in discrete time steps and with signals from a discrete alphabet), those generated as a function of a hidden Markov chain have a special place. Here, we are studying the case that the hidden system is quantum mechanical, giving rise to C*-finitely correlated states [Fannes / Nachtergaele / Werner, CMP 1992] on a commutative chain algebra, which we call hidden quantum Markov models; and even more generally finitely correlated states, corresponding to a general probabilistic theory (GPT) memory. The latter case is entirely described in terms of the rank of the so-called Hankel matrix of the process, and equivalently an associated canonical finite dimensional vector space with associated positive cone preserved under the hidden dynamics of the model. For the quantum case, we describe the structure of the possible GPTs via semidefinite representable (SDR) cones. It turns out that these GPTs are all finitely presented operator systems, i.e. induced subspaces of quotients of B(H) for a finite-dimensional Hilbert space H. Unlike operator systems, for which complete positivity can be very hard to decide, the SDR models come with a subset of the completely positive maps, which is itself an SDR cone. I will describe a geometric approach, through the study of the positive cone of any GPT giving rise to a given process, which can sometimes show that certain processes with hidden quantum Markov model have no finite classical memory model. I will then describe the first known example of a process generated via a finite-dimensional GPT as the hidden system, which however cannot be reproduced by any hidden classical or quantum Markov model with finite state space, answering a question posed by Fannes, Nachtergaele and Werner. Processes generated via a finite-dimensional GPT which cannot be reproduced by a hidden classical Markov chain had been known before, but the examples exhibited there turn out to be generated by hidden quantum Markov models.

22. Name of the speaker: Markus P. Müller

Affiliation: IQOQI, Vienna, Austria

Title of the talk: Space, time and quantum probabilities: from fundamental insights to protocols

Abstract: Quantum theory (QT) is just one probabilistic theory among many others, and recent years have seen a wave of research that explores how QT compares to other theories in terms of Bell nonlocality. In this talk, I describe several recent results that explore a different but somewhat related direction of research, which is motivated by the following questions: how does the structure of space and time constrain the probabilities we observe in experiments? Does relativistic spacetime admit more general probabilistic theories than QT, or are QT and its sub theories essentially the only ones that “fit onto space and time”? While versions of this question can be traced back to people like von Weizsäcker and Wootters, I present a new approach to tackling it, relating it to the classification of correlations in prepare-and-measure scenarios and semi-device-independent randomness generation. In [1,2], we analyze the question of how detector click probabilities can respond to rotations around a fixed axis, in any possible “covariant” physical theory. It is natural to ask this while bounding the “spin” (representation label) of the system, upper-bounding the degree of the trigonometric polynomials that yield the probabilities as a function of the angle. We prove that quantum theory admits the most general rotational correlations for spins 0, 1/2, and 1, but we describe a metrological game where beyond-quantum resources of spin 3/2 outperform all quantum resources of the same spin. We prove a multitude of fundamental results about these correlations, including an exact convex characterization of the spin-1 correlations, a Tsirelson-type inequality for spins 3/2 and higher, and a proof that the general spin-J correlations provide an efficient outer SDP approximation to the quantum set. We also show how these results can be used for a semi-device-independent protocol for the generation of random numbers which does not rely on the validity of QT.

23. Name of the speaker: Nicolas Brunner

Affiliation: University of Geneva, Switzerland

Title of the talk: Bell nonlocality in quantum networks

Abstract: Quantum networks enable novel forms of Bell nonlocality. This talk will present recent progress in this direction.

24. Name of the speaker: Siddhartha Das

Affiliation: IIIT Hyderabad, Hyderabad

Title of the talk: Conditional entropy and information of quantum processes

Abstract: What would be a reasonable definition of the conditional entropy of bipartite quantum processes, and what novel insight would it provide? We develop this notion using desirable information-theoretic axioms and define the corresponding

quantitative formulas based on the generalized channel divergences, e.g., quantum relative entropy and max-relative entropy. We show that the conditional entropy of a bipartite quantum channel provides insight into the underlying causal structure of the channel. We realize a necessary and sufficient condition for the (von Neumann) conditional entropy of a quantum channel, for which the channel shows no causal influence from the non-conditioning input system to the conditioning output system. Additionally, our definition of conditional entropy establishes the strong subadditivity of the entropy for quantum channels. Furthermore, we extend our approach behind the definition of conditional entropy to quantify the total amount of correlations due to quantum processes by defining the mutual information and conditional mutual information of quantum channels.

25. Name of the speaker: Analabha Roy

Affiliation: The University of Burdwan, Burdwan

Title of the talk: Dynamical Many Body Localization in Floquet Spin Chains: From Simple Quantum Magnets to Discrete Time Crystals

Abstract: Dynamical Many Body Localization (DMBL) is a fascinating phenomenon involving quantum interference, characterized by hysteresis that prevents a periodically driven quantum system from reaching the expected infinite-temperature thermal equilibrium. The principle revolves around Floquet Engineering, where a time-periodically driven system becomes "Dynamically Localized" because its instantaneous relaxation rate falls below the driving rate. The localization criteria lead to the creation of approximate Noether charges based on symmetries, independent of disorder or the local properties of observables, rendering it more robust than prethermal Many Body Localization (MBL).
We illustrate that DMBL can manifest in periodically driven Ising spins with nearest neighbour interactions [1]. The ubiquity of the DMBL effect is further verified in quantum many-body systems with reduced symmetries, like the disordered Ising model [2] and systems with long-range interactions [3]. Moreover, we delve into ongoing studies of DMBL in long-range spin systems, showcasing analysis and numerical findings for the periodically driven Lipkin-Meshkov-Glick (LMG) model [3, 4]. At low driving frequencies, classical chaos induces thermodynamic characteristics, but within the Floquet modes, there is a mobility edge within drive-frequency space, prompting a shift from a thermal to a DMBL phase at high frequencies. This mobility edge is absent in integrable systems, where a fully thermalized phase doesn’t exist. Lastly, we explore a practical application of DMBL in replacing disorder-induced MBL for designing Floquet Time Crystals, where a chimera-like state emerges, featuring discrete spatial separation between subharmonic response and localized areas [5].
REFERENCES
[1] A. Das, Phys. Rev. B 82 (2010) 172402.
[2] A. Roy and A. Das, Phys. Rev. B 91 (2015) 121106.
[3] M. Rahaman, T. Mori, and A. Roy, Phys. Rev. B 109 (2024) 104311. [4] T. Mori, J. Phys. A: Math. Theor. 52 (2019) 054001.
[5] M. Rahaman, A. Sakurai, and A. Roy, New J. Phys. 26 (2024) 063035.

26. Name of the speaker: Soumya Das

Affiliation: Eindhoven University of Technology

Title of the talk: Entanglement monogamy in indistinguishable particle systems

Abstract: Recently, it has been realized that indistinguishability is a resource for quantum information processing. A new method to represent the indistinguishable particles by Franco et al. (Sci Rep 6:20603, 2016, https://doi.org/10.1038/srep20603) and measure the concurrence is developed by Nosrati et al. (npj Quantum Inf 6:39, 2020, https://doi.org/10.1038/s41534-020-0271-7). The monogamy property says that quantum entanglement cannot be shared freely between more than two particles. For three distinguishable particles, the monogamy of entanglement was first expressed as an inequality using squared concurrence where each particle has a single degree of freedom (for pure or mixed states). Using multiple degrees of freedom, similar inequality was shown to be held between two distinguishable particles. However, for two indistinguishable particles, where each particle cannot be addressed individually, the monogamy inequality was shown to be violated maximally for a specific state. Thus a question naturally arises: what happens to the monogamy of entanglement in the case of three or more indistinguishable particles? We prove that monogamy holds in this scenario and the inequality becomes equality for all pure indistinguishable states. Further, we provide three major operational meanings of our result. Finally, we present an experimental schematic using photons to observe our result.
Reference: Das, Soumya, Goutam Paul, and Ritabrata Sengupta. "Entanglement monogamy in indistinguishable particle systems." *Scientific Reports* 13.1 (2023): 21972.