Archan Subhra Majumdar

Senior Professor
Astrophysics & Cosmology
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Guidance of Students/Post-Docs/Scientists

a) Ph.D. Students

1. Suchetana Goswami; Quantum Information; Awarded
2. Shounak Datta; Quantum Information; Under progress
3. Riddhi Chatterjee; Relativistic Quantum Mechanics; Under progress
4. Arnab Sarkar; Gravitation & Cosmology; Under progress; K. R. Nayak (IISER Kolkata) (Co-supervisor)
5. Ananda Gopal Maity; Quantum Information; Under progress
6. Shashank Gupta; Quantum Information; Under progress
7. Bihalan Bhattacharya; Quantum Information; Under progress
8. Arun Kumar Das; Quantum Information; Under progress
9. Subhankar Bera; Quantum Information; Under progress
10. Shashank Sekhar Pandey; Gravitation and Cosmology; Under progress

b) Post-Docs

1. Arup Roy; Quantum Information
2. Amit Mukherjee; Quantum Information
3. Debarshi Das; Quantum Information

Teaching

1. Autumn semester; Advanced Quantum Mechanics; Integrated PhD; 12 students; with 1 (Sunandan Gangopadhyay) co-teacher
2. Autumn semester; Quantum Physics; PhD; 3 students; with 1 (Sunandan Gangopadhyay) co-teacher

Publications

a) In journals

1. Ananda G. Maity, Debarshi Das, Arkaprabha Ghosal, Arup Roy, and **A. S. Majumdar**, *Detection of genuine tripartite entanglement by multiple sequential observers*, Physical Review A, 101, 042340, 2020
2. Ananda G Maity, Samyadeb Bhattacharya and **A S Majumdar**, *Detecting non-Markovianity via uncertainty relations*, Journal of Physics A: Mathematical and Theoretical, 53, 175301, 2020
3. Samyadeb Bhattacharya, Bihalan Bhattacharya and **A S Majumdar**, *Thermodynamic utility of non-Markovianity from the perspective of resource interconversion*, Journal of Physics A: Mathematical and Theoretical, 53, 335301, 2020
4. Samyadeb Bhattacharya, Bihalan Bhattacharya and **A S Majumdar**, *Convex resource theory of non-Markovianity*, Journal of Physics A: Mathematical and Theoretical, 54, 035302, 2021
5. Suchetana Goswami, Sibasish Ghosh and **A S Majumdar**, *Protecting quantum correlations in presence of generalised amplitude damping*

channel: the two-qubit case, Journal of Physics A: Mathematical and Theoretical, 54, 045302, 2021

6. Shashank Gupta, Ananda G. Maity, Debarshi Das, Arup Roy, and **A. S. Majumdar**, *Genuine Einstein-Podolsky-Rosen steering of three-qubit states by multiple sequential observers*, Physical Review A, 103, 022421, 2021

Independent publication of student/post-doc

7. Biswajit Paul, Kaushiki Mukherjee, Ajoy Sen, Debasis Sarkar, Amit Mukherjee, Arup Roy, and Some Sankar Bhattacharya, *Persistency of genuine correlations under particle loss*, Physical Review A, 102, 022401, 2020

8. Biswajit Paul, Kaushiki Mukherjee, Sumana Karmakar, Debasis Sarkar, Amit Mukherjee, Arup Roy & Some Sankar Bhattacharya, *Detection of genuine tripartite entanglement in quantum network scenario*, Quantum Information Processing, 19, 246, 2020

9. Sagnik Dutta, Amit Mukherjee, and Manik Banik, *Operational characterization of multipartite nonlocal correlations*, Physical Review A, 102, 052218, 2020

10. Pratapaditya Bej, Arkaprabha Ghosal, Debarshi Das, Arup Roy, and Somshubhro Bandyopadhyay, *Information-disturbance trade-off in generalized entanglement swapping*, Physical Review A, 102, 052416, 2020

11. Rivu Gupta, Shashank Gupta, Shiladitya Mal, and Aditi Sen (De), *Performance of dense coding and teleportation for random states: Augmentation via preprocessing*, Physical Review A, 103, 032608, 2021

Talks / Seminars Delivered in reputed conference / institutions

1. Online Symposium on Quantum Information & Computation; Jun 29, 2020; IIIT Hyderabad; 1 hr
2. International Physics Webinar; Sep 30, 2020; Pabna University; 1 hr

Administrative duties

1. Dean (Faculty)

Extramural Projects (DST, CSIR, DAE, UNDP, etc.)

1. Applications of Quantum Information; DST; 3 years; PI
2. Free space quantum communication: road to satellite quantum communication; DST; 3 years; Co-PI
3. Quantum heat engines; DST; 3 years; Co-PI

Scientific collaborations with other national / international institutions (based on joint publications)

1. Bose Institute, Kolkata; Sl. No. 1, 10; National
2. IMSc, Chennai; Sl. No. 5; National
3. Calcutta University; Sl. No. 7; National
4. IISER Kolkata, IISER Thiruvanathapuram; Sl. No. 9; National
5. HRI, Allahabad; Sl. No. 11; National
6. University of Hong Kong; Sl. No. 7, 8; International

Outreach program organized / participated

1. Online seminars (2) TEQUIP-III, NIT Sikkim, 3-17 October, 2020

Areas of Research

Quantum Information Science; Cosmology

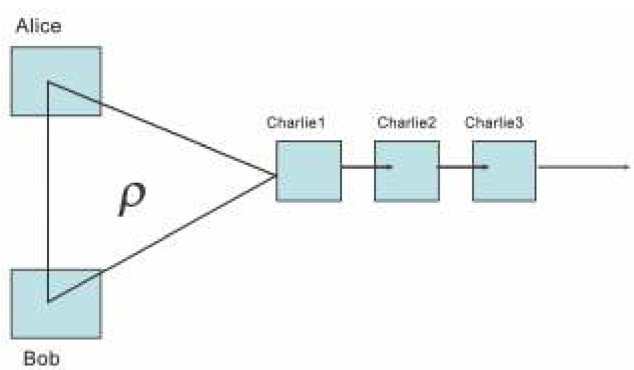

Fig. 1. Sequential detection of genuine tripartite entanglement.

We explore the possibility of multiple usage of a single genuine entangled state by considering a scenario consisting of three spin-1/2 particles shared between Alice, Bob and multiple Charlies. Alice performs measurements on the first particle, Bob performs measurements on the second particle and multiple Charlies perform measurements on the third particle sequentially. Here the choice of measurement settings of each Charlie is independent and uncorrelated with the choices of measurement settings and outcomes of the previous Charlies. In this scenario, we investigate whether more than one Charlie can detect genuine tripartite entanglement, and we answer this question affirmatively. In order to probe genuine entanglement, we use correlation inequalities whose violations certify genuine tripartite entanglement in a device-independent way. We extend our investigation by using appropriate genuine tripartite entanglement witness operators. Using each of these different tools for detecting genuine tripartite entanglement, we find out the maximum number of Charlies who can detect genuine entanglement in the above scenario.

We investigate the possibility of multiple use of a single copy of three-qubit states for genuine tripartite Einstein-Podolsky-Rosen (EPR) steering. A pure three-qubit state of either the Greenberger-Horne-Zeilinger (GHZ)-type or W-type is shared between two fixed observers in two wings and a sequence of multiple observers in the third wing who perform unsharp or non-projective measurements acting independently of each other. The choice of measurement settings for each sequence is independent and uncorrelated with the measurement settings and outcomes of the previous observers. We investigate all possible types of genuine tripartite steering in the above set-up. For each case we obtain an upper limit on the number of observers on the third wing who can demonstrate genuine EPR steering through violation of a tripartite steering inequality. We show that the GHZ allows for a higher number of observers compared to that for W states.

We present a formalism for detection of non-Markovianity through uncertainty relations. We show that when there is an information back-flow to the system from its environment through CP-divisibility breaking, the Choi-states corresponding to the reduced system evolution contain at least one negative eigenvalue. The consequent break down of uncertainty relations for such states can be used to witness non-Markovian dynamics. We present some relevant examples of the phenomenon for qubit channels. We further prove that square of the variance of a suitable hermitian operator can act as a non-linear witness of non-Markovianity. We finally show that non-Markovianity is necessary in order to decrease the uncertainty of the states undergoing unital dynamics for qubits. This provides another method of certifying non-Markovianity.

We establish a convex resource theory of non-Markovianity inducing information backflow under the constraint of small time intervals within the temporal evolution. We identify the free operations and a generalized bona-fide measure of non-Markovian information backflow. The framework satisfies the basic properties of a consistent resource theory. The proposed resource quantifier is lower bounded by the optimization free Rivas-Huelga-Plenio (RHP) measure of non-Markovianity. We next define the robustness of non-Markovianity and show that it can directly linked with the RHP measure of non-Markovianity through a lower bound. This enables a physical interpretation of the RHP measure. We further relate robustness of non-Markovianity with the quantum capacity of dephasing channels.

Any kind of quantum resource useful in different information processing tasks is vulnerable to several types of environmental noise. Here we study the behaviour of quantum correlations such as entanglement and steering in two-qubit systems under the application of the generalised amplitude damping channel and propose two protocols towards preserving them under this type of noise. First, we employ the technique of weak measurement and reversal for the purpose of preservation of correlations. We then show how the evolution under the channel action can be seen as an unitary process. We use the technique of weak measurement and most general form of selective positive operator valued measure (POVM) to achieve preservation of correlations for a significantly large range of parameter values.

Plan of Future Work Including Project

1. Characterization of quantum devices received from unknown providers is a significant primary task for any quantum information processing protocol. Self-testing protocols are designed for this purpose of certifying quantum components from the observed statistics under a set of minimal

assumptions. Here we propose a self-testing protocol for certifying binary Pauli measurements employing the violation of a Leggett-Garg inequality. The scenario based on temporal correlations does not require entanglement, a costly and fragile resource. Moreover, unlike previously proposed self-testing protocols in the prepare and measure scenario, our approach requires neither dimensional restrictions, nor other stringent assumptions on the type of measurements. We further analyse the robustness of this hitherto unexplored domain of self-testing of measurements.

2. We study the resonance interaction between two entangled identical atoms coupled to a quantized scalar field vacuum, and accelerating between two mirrors. We show how radiative processes of the two-atom entangled state can be manipulated by the atomic configuration undergoing noninertial motion. Incorporating the Heisenberg picture with symmetric operator ordering, the vacuum fluctuation and the self-reaction contributions are distinguished. We evaluate the resonance energy shift and the relaxation rate of energy of the two atom system from the self-reaction contribution in the Heisenberg equation of motion. We investigate the variation of these two quantities with relevant parameters such as atomic entanglement, acceleration, interatomic distance and position with respect to the boundaries. We show that both the energy level shift and the relaxation rate can be controlled by tuning the above parameters. It is observed that the relaxation rate can be enhanced or diminished by a more significant amount compared to the energy level shift.

3. We study the spontaneous excitation of a two-level atom in the presence of a perfectly reflecting mirror, when the atom, or the mirror, is uniformly accelerating in the framework of the generalised uncertainty principle (GUP). The quantized scalar field obeys a modified dispersion relation leading to a GUP deformed Klein-Gordon equation. The solutions of this equation with suitable boundary conditions are obtained to calculate the spontaneous excitation probability of the atom for the two separate cases. We show that in the case when the mirror is accelerating, the GUP modulates the spatial oscillation of the excitation probability of the atom, thus breaking the symmetry between the excitation of an atom accelerating relative to a stationary mirror, and a stationary atom excited by an accelerating mirror. An explicit violation of the equivalence principle is demonstrated. We further obtain an upper bound on the GUP parameter using standard values of the system parameters.

4. The problem of bound entanglement detection is a challenging aspect of quantum information theory for higher dimensional systems. Here, we propose an indecomposable positive map for two-qutrit systems, which is shown to detect a class of positive partial transposed (PPT) states. A corresponding witness operator is constructed and shown to be weakly optimal and locally implementable. Further, we perform a structural physical approximation of the indecomposable map to make it a completely positive one, and find a new PPT-entangled state which is not detectable by certain other well-known entanglement detection criteria.