Archan Subhra Majumdar

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Astrophysics and Cosmology
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Archan S. Majumdar is a theoretical physicist working in the dual fields of (i) gravitation and cosmology, and (ii) quantum information and foundations.

Supervision of Research / Students

Ph.D. Students

1. Subhadipa Das; Study of bipartite and multipartite quantum nonlocality; Thesis submitted.
2. Sovik Roy; Study on entanglement and its utility in information processing; Thesis submitted.
3. Shiladitya Mal; Interlinking fundamental quantum features to information theoretic resources; Thesis submitted.
4. Suchetana Goswami; Weak measurements and quantum steering; Ongoing.
5. Shounak Datta; Applications of uncertainty relations on information theoretic resources; Ongoing.
6. Riddhi Chatterjee; Relativistic quantum entanglement; Ongoing.
7. Arnab Sarkar; Cosmological probes with gravitational waves; Ongoing.
8. Ananda Gopal Maity; Quantum information theory; Ongoing.
9. Sourav Karar; Quantum information theory; Ongoing.

Projects of M.Sc./ M.Tech./ B.Tech./ Post B.Sc. students

1. Poulami Dutta Roy; IIT Kharagpur; An introduction to general theory of relativity and cosmology; Completed.
2. Riddhi Chatterjee; SNBNCBS; Study of general theory of relativity and cosmology; Completed.
3. Ananda Gopal Maity; SNBNCBS; Introduction to dark energy; Completed.
4. Shashank Gupta; SNBNCBS; Quantum Information theory; Completed.
5. Shantonu Mukherjee; SNBNCBS; A brief overview of cosmology; Completed.

Post Doctoral Research Scientists

1. Amna Ali
2. C. Jebaratnam

Teaching activities at the Centre

1. 2nd Semester; Summer project research (PHY 292); IPhD; 2
2. 3rd Semester; Advanced quantum mechanics and applications (PHY 303); IPhD; 7; shared with Biswajit Chakraborty
3. 3rd Semester; Project Research II (PHY 304); IPhD; 1
4. 5th Semester; Project Research Part – I (PHY 591); PhD; 1
5. 5th Semester; Relativity and cosmology (PHY 509); PhD; 3

Publications In journals

1. S. Mal, **A. S. Majumdar,** D. Home; Optimal violation of the Leggett-Garg inequality for arbitrary spin and emergence of classicality through unsharp measurements; Phys. Lett. A; 2016; **380**; 2265.
2. **A. S. Majumdar,** T. Pramanik; Some applications of uncertainty relations in quantum information; Int. J. Quant. Inf.; 2016; **14;** 1640022.
3. A. Ali, **A. S. Majumdar;** Future evolution in a backreaction model and the analogous scalar field cosmology; JCAP; 2017; **01**; 054.
4. S. Datta, S. Goswami, T. Pramanik, **A. S. Majumdar**; Preservation of a lower bound of quantum secret key rate in the presence of decoherence; Phys. Lett. A; 2017; **381**; 897.

Independent publications of students

1. S. Mal, D. Das, D. Home; Quantum mechanical violation of macrorealism for large spin and its robustness against coarse-grained measurements; 2016; Phys. Rev. A; **94**; 062117.
2. D. Adak, Amna Ali; Bounce and collapse in the slotheonic universe; Int. J. Mod. Phys. D; 2017; **26**; 1750089.
3. C. Jebaratnam, S. Aravinda, R. Srikanth; Nonclassicality of local bipartite correlations; 2017; Phys. Rev. A; 2017; **95**; 032120.
4. Sovik Roy, Biplab Ghosh; A revisit to non-maximally entangled mixed states: teleportation witness, noisy channel and discord; Quant. Inf. Process.; 2017; **16;** 108.

Lectures Delivered

1. Effect of backreaction on the future evolution of the accelerating universe; Recent developments in Gravity; Hellenic Society of Relativity, Gravitation and Cosmology; Mikonos, Greece; September; 2016.
2. Witnesses in quantum information theory; S. N. Bose Lecture at "International Conference on applications of mathematics in topological dynamics, physical, biological and chemical sciences"; Calcutta Mathematical Society; December; 2016.
3. Uncertainty relations and their application in quantum information; UGC-DSA-SAP Program; University of Calcutta; February; 2017; 2 lectures.
4. Fine-grained steering inequalities; "Recent trends in quantum theory"; Deptt. Applied Maths.; Univ. Calcutta; March; 2017.
5. Witnesses in quantum information processing; "Physics and Applied Mathematics Researchers Meet"; ISI Kolkata; March; 2017.
6. A backreaction model and the analogous scalar field cosmology; "Recent advances in astrophysics and cosmology"; Physics Department, North Bengal University; Siliguri; March; 2017.

Membership of Committees

Internal Committee

CEWP; FSC

Sponsored Projects

1. Fundamental aspects of quantum theory and quantum information; DST; 2014-2017.

Conference / Symposia / Workshops / Seminars etc. organized

1. Discussion meeting on quantum mechanics; 19.01.2017; SNBNCBS; Convener.

Collaborations including publications (Sl. No. of paper/s listed in 'Publications in Journals' jointly published with collaborators)

National

1. D. Home, Bose Institute, Kolkata (Sl. No. 1)

International

1. T. Pramanik, LTCI, Telecom ParisTech, France (Sl. No. 2)

Significant research output / development during last one year

General research areas and problems worked on

(A) Gravitation & Cosmology: dark energy from various perspectives

(B) Quantum Information & Foundations: entanglement, nonlocality and uncertainty relations

Interesting results obtained

We investigate the future evolution of the universe using the Buchert framework for averaged back reaction in the context of a two-domain partition of the universe. We show that this approach allows for the possibility of the global acceleration vanishing at a finite future time, provided that none of the sub-domains accelerate individually. The model at large scales is analogously described in terms of a homogeneous scalar field emerging with a potential that is fixed and free from phenomenological parametrization. The dynamics of this scalar field is explored in the analogous FLRW cosmology. We use observational data from Type Ia Supernovae, Baryon Acoustic Oscillations, and Cosmic Microwave Background to constrain the parameters of the model for a viable cosmology, providing the corresponding likelihood contours.

We discuss some applications of various versions of uncertainty relations for both discrete and continuous variables in the context of quantum information theory. The Heisenberg uncertainty relation enables demonstration of the EPR paradox. Entropic uncertainty relations are used to reveal quantum steering for non-Gaussian continuous variable states. Entropic uncertainty relations for discrete variables are studied in the context of quantum memory where fine-graining yields the optimum lower bound of uncertainty. The fine-grained uncertainty relation is used to obtain connections between uncertainty and the nonlocality of retrieval games for bipartite and tipartite systems. The Robertson Schrodinger uncertainty relation is applied for distinguishing pure and mixed states of discrete variables. In the context of temporal correlations of particles with arbitrary spin, we obtain optimal violation of the Leggett-Garg inequality (LGI), improving upon an earlier result [Phys. Rev. Lett. \textbf{99}, 180403 (2007)]. Our proof is accomplished through a suitable adaptation of a measurement scheme, previously employed for studying spatial correlations. We next consider unsharp measurements as a method of coarse graining, and show that LGI can not be violated below a precise value of the sharpness parameter. We then apply Fine's theorem in the context of LGI and derive a sufficient condition for emergence of classicality.

For multilevel spin systems, robustness of the quantum mechanical (QM) violation of macrorealism (MR) with respect to coarse-grained measurements is investigated using three different necessary conditions of MR, namely, the Leggett-Garg inequality (LGI), Wigner's form of the Leggett-Garg inequality (WLGI), and the condition of no-signaling in time (NSIT). It is shown that for dichotomic sharp measurements, in the asymptotic limit of spin, the algebraic maxima of the QM violations of all these three necessary conditions of MR are attained. Importantly, the QM violations of all these persist in that limit even for arbitrary unsharp measurements, i.e., for any nonzero value of the sharpness parameter characterizing the degree of fuzziness of the relevant measurements. The results clearly demonstrate that classicality does not emerge in the asymptotic limit of spin, whatever be the unsharpness and degree of coarse graining of the measurements.

Simulating quantum nonlocality and steering requires augmenting preshared randomness with nonvanishing communication cost. This prompts the question of how one may provide such an operational characterization for the quantumness of correlations due to even unentangled states. We show that for a certain class of states, such quantumness can be pointed out by superlocality, the requirement for a larger dimension of the preshared randomness to simulate the correlations than that of the quantum state that generates them. This provides an approach to define the nonclassicality of local multipartite correlations in convex operational theories.

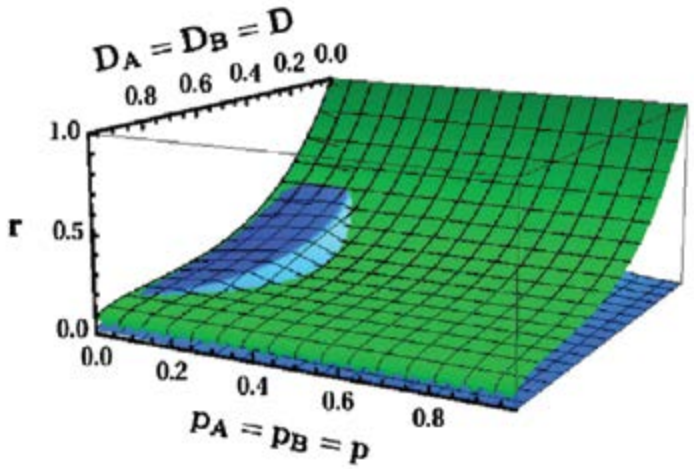
It is well known that the interaction of quantum systems with the environment reduces the inherent quantum correlations. Under special circumstances the effect of decoherence can be reversed, for example, the interaction modelled by an amplitude damping channel can boost the teleportation fidelity from the classical to the quantum region for a bipartite quantum state. Here, we first show that this phenomenon fails to preserve the quantum secret key rate derived under individual attack. We further show that the technique of weak measurement can be used to slow down the process of decoherence, thereby helping to preserve the quantum secret key rate when one or both systems are interacting with the environment via an amplitude damping channel. Most interestingly, in certain cases weak measurement with post-selection where one considers both success and failure of the technique is shown to be more useful than without it when both systems interact with the environment.

Proposed research activities for the coming year

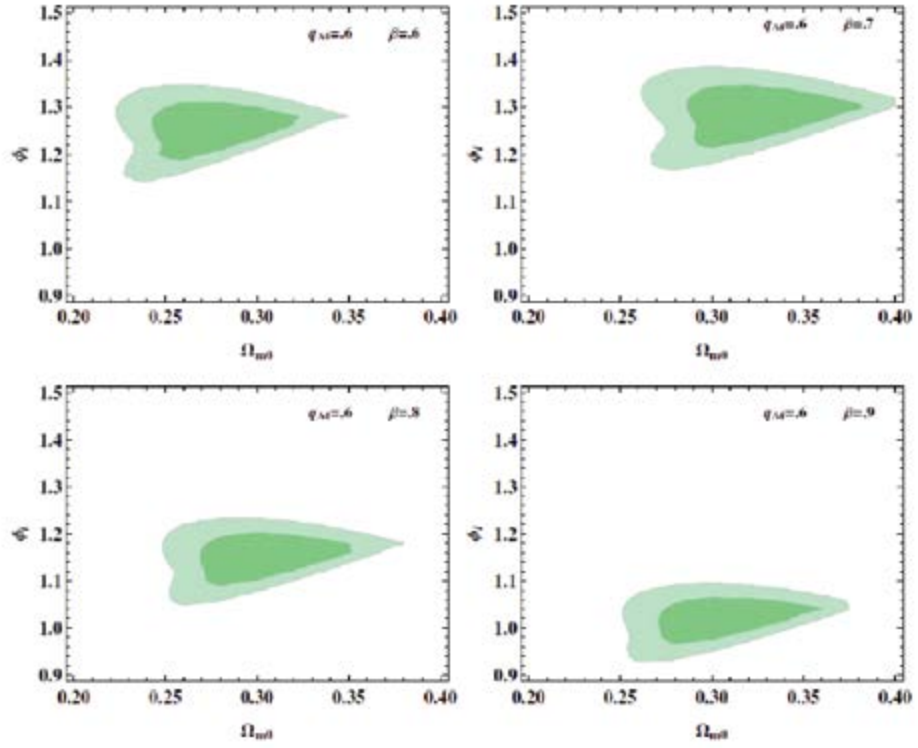
We will investigate the effect of backreaction due to inhomogeneities on the evolution of the present Universe by considering the Universe to be partitioned into multiple domains within the Buchert framework. Taking the observed present acceleration of the universe as an essential input, we will study the effect of inhomogeneities on the future evolution. We will investigate whether the backreaction from inhomogeneities causes the acceleration to slow down in the future for a range of initial configurations and model parameters, and even lead in certain cases to the emergence of a future decelerating epoch. We will consider various different partitioning of the Universe and perform a comparative analysis for the separate cases on the behaviour of the acceleration and backreaction of the Universe. The dynamics will be explored in the analogous FLRW cosmology. We will use observational data from Type Ia Supernovae, Baryon Acoustic Oscillations, and Cosmic Microwave Background to constrain the parameters of the model for a viable cosmology, providing the corresponding likelihood contours.

For a bipartite local quantum correlation, superlocality refers to the requirement of a larger dimension of the random variable in the classical simulation protocol than that of the quantum states that generate the correlations. We will consider the classical simulation of local tripartite correlations in the protocol where one of the parties pre-share a random variable with the other parties who may also share arbitrary randomness in case of fully local correlations or arbitrary nonsignaling boxes in case of partially local correlations. In this context, we define superlocality and super-bi-locality for fully local and partially local tripartite correlations, respectively. A tripartite fully local (partially local) quantum correlation is genuinely superlocal} (genuinely super-bi-local) if it is superlocal (super-bi-local) across all bipartitions. We will present specific examples of genuine superlocality and super-bi-locality for tripartite correlations derived from three-qubit states. It will be argued that genuine quantumness as captured by the notion of genuine discord is necessary for demonstrating genuine superlocality.

It is known that the coherence of the input state is an upper bound of the entanglement generated in the two qubit state by incoherent operations. In general, the coherence of the reduced single qubit output state obtained by partial trace of either of the qubits decreases. We will show that the entanglement of formation is the upper bound of the sum of the coherence in the reduced output state. We will further show that there exists a cloning operation which can be regarded as an incoherent three qubit quantum operation that does not generate an entanglement in the two qubit reduced state when the cloning machine state vector is traced out. We will construct a coherent quantum operation which makes the coherence of the reduced two qubit output state free from input state parameters. We will study the entanglement generated under coherent three qubit quantum operations.



The average of secret key rate, r_{AV} is plotted against the strength of decoherence D_A=D_B=D(x-axis) and the strength of weak measurement PA=PB=P (y-axis). It is seen that the improvement of the average of secret key rate is possible for a range of values of the strength of decoherence and weak measurement.



The 1σ(dark) and 2σ(light) likelihood contours in the (Ω_{m0}, ϕ_i) phase plane for the total $\chi^2_{SN+BAO+CMB}$ for different values of β.