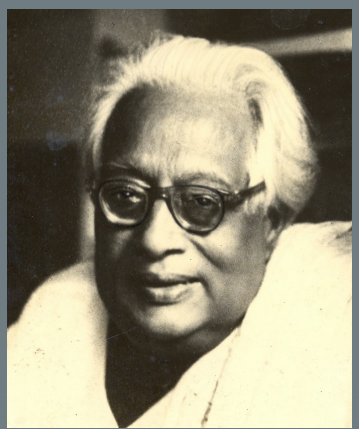
SATYENDRA NATH BOSE NATIONAL CENTRE FOR BASIC SCIENCES

Newsletter

Vol.13, Issue 2 (2023)

Editorial:

We are very happy to publish the second issue of Newsletter in 2023. Thanks to the great efforts made by the Newsletter support staff and members. We also sincerely thank all the contributors, who have promptly sent their interesting articles (scientific stories) and enriched the Newsletter immensely. The issue covers the academic as well as the non-academic events in the first half of the present year (January - June, 2023). We hope the readers would enjoy it.



Professor Satyendra Nath Bose

News and Events (Academic)

'Open Day' Programme at the Centre

Centre organised 'Open Day' on 2nd January, 2023 to comemmorate Prof. S N Bose's 129th birth anniversary celebrated on the preceding day (1st January, 2023).

Many science enthusiasts from schools and colleges participated in the Open Day programme. Prof. Tanusri Saha-Dasgupta, Director, SNBNCBS, gave the participants an overview of the diverse areas of research being carried out at the S. N. Bose Centre.

A popular science lecture on dark matter, black holes and unified field theory was delivered by Prof. Anirban Kundu, Department of Physics, C.U. Visitors watched documentaries and visited Bose Archive, based on Bose's life and works, visited various laboratories and also watched sky and planets through 8 inch telescope at the Centre.

Centre celebrates National Science Day

National Science Day 2023 was celebrated on 28.02.2023 at the Centre with great enthusiasm. The theme was "*Global Science for Global Wellbeing*". After inaugural session, a popular science talk on "*Living with Stars*" was delivered by Prof. Dibyendu Nandi, Indian Institutes of Science Education and Research Kolkata. Later the participants visited the S. N. Bose archive. Inter-college quiz contest and Inter-college poster competition were held on this occasion. Total 75 undergraduate students from different collages participated in the programme.

Bose Fest 2023

The Centre celebrated Bose Fest 2023 – the annual celebration of science during 1-3 March, 2023. Nominated research scholars and postdoctoral fellows came up with their presentations. There were 45 oral and 34 poster presentations. Muktangan organised PhotoFest and in-house cultural programme by the staff and students. A live music performance by folk band '*Dohar*' were also organized as part of the celebration.

Summer Research Programme

A total number of 37 students from different institutions/universities across the country have done their summer internship during the period. The interns include funding from the Centre as well as from INSPIRE and INSA-NASI-IAS.

Outreach programmes by the Centre

One-Day Program was organized at Ranaghat College

A One-Day Program was organized at Ranaghat College, Nadia, WB, on 26th may 2023. Around 150 participants (about 60 participants were from backward categories) from the departments of Physics, Chemistry and Mathematics of the said college participated in the program. After the inauguration, three talks were delivered by Profs. Ranjit Biswas, Manik Banik and Ramkrishna Das. In the afternoon, two experiments were demonstrated by Prof. Arijit Haldar and the students (Pritam Roy, Keshav Shaw, Dipyendu Dhar and Sourav Mandal) from SNBNCBS. The program ended with a sky-watching program by Prof. Ramkrishna Das and Mr. Avijit Mandal. The students were very excited and interacted with us to know more. Overall, the program was a great success.

Vidyasagar - Satyendra Nath Bose National Workshop

12th Vidyasagar Satyendra Nath Bose National Workshop on "Advances in Physics: Theories & Applications (APTA-2023)" was held at Vidyasagar University, Midnapore, West Bengal during 28th February to 2nd March, 2023.

Topical Research School at Cooch Behar

Topical Research School on "Quantum Foundation and Quantum Information 2023" was held at A. B. N. Seal College, Cooch Behar, West Bengal, during 14-16 March, 2023.

Topical Research School in Silchar

Topical Research School on "Current Trends in Theoretical and Experimental Physics" held at Gurucharan College, Silchar, Assam, during 20-23 March 2023.

Colloquium/Named Lectures

26th S. N. Bose Memorial Lecture

Prof. Deepak Dhar, the first Indian theoretical physicist, to be awarded the coveted Boltzmann Medal (the highest recognition in statistical physics) and a distinguished professor at the department of physics, Indian Institute of Science Education and Research, Pune, delivered the 26th S. N. Bose Memorial Lecture on the topic "Phase transition in hard rigid rods on a d-dimensional lattice" on 11.05.2023 at Silver Jubilee Hall, SNBNCBS.

Bose Colloquium

1. Prof. Puru Jena, Professor, Virginia Commonwealth University, Richmond, Virginia, delivered a lecture on the topic "Cluster-based Functional Materials – A Paradigm shift in Design and Synthesis" on 18.01.2023.
2. Prof. Kalachand Sain, FNA, FASc, FNASc, FTAS, J. C. Bose National Fellow, Director, Wadia Institute of Himalayan Geology delivered a lecture on the topic "Climate change induced Geohazards in the Himalaya and Plausible Mitigation" on 30.01.2023.
3. Dr. Jean Pascal Sutter, Research Director, CNRS (Centre national de la recherche scientifique), Toulouse, France, delivered a lecture on the topic "From magnetic anisotropy to molecular magnets: A journey into the coordination chemistry of pentagonal bipyramidal complexes" on 27.02.2023.
4. Prof. Uday Bandyopadhyay, Director, Bose Institute, Unified Academic Campus delivered a lecture on "Impact of acute mental stress on gastropathy/gastric ulcer: Mind–Mitochondria relation in stomach" on 28.04.2023.
5. Prof. Rupmanjari Ghosh, Former Vice Chancellor of Shiv Nadar University, Delhi-NCR, Former Professor of Physics and Dean, School of Physical Sciences at Jawaharlal Nehru University delivered a lecture on "The making of a private research university: Leadership challenges in higher education" on 16.06.2023.

Institute Colloquium

1. Prof. Satrajit Adhikari, Senior Professor, IACS & Adjunct Professor, IISER Kolkata, HOD CCRES delivered a lecture on "Role of Electron-Nuclear Coupling on Photoelectron Spectra, Reactive Scattering Processes and Phase Transition of Solids" on 07.02.2023.
2. Prof. Arun K Grover, Hony. Prof., Punjab Engineering College (Deemed to be University), Chandigarh and Ex-Vice Chancellor, Panjab University delivered a lecture on "Partnership between Meghnad Saha and Shanti Swarup Bhatnagar in the conception of plans in all domains in post-World War-II India" on 05.04.2023.
3. Prof. David Logan, Coulson Professor of Theoretical Chemistry and an Infosys Visiting Chair at the Indian Institute of Science, Bengaluru and is a Foreign Fellow of the National Academy of Sciences, India delivered a lecture on "Many-body localisation, multifractality and all that: a Fock-space perspective" on 10.04.2023.
4. Dr. Manoranjan Mohanty, Scientist-G and Head, Autonomous Institute Division delivered a lecture on "R&D support programs of DST" on 11.04.2023.
5. Dr. Angshuman Nag, Associate Professor, Department of Chemistry, Indian Institute of Science Education and Research (IISER) Pune, delivered a lecture on "Layered Hybrid Perovskites: Molecular Design and Optoelectronics" on 24.04.2023.
6. Prof. Supriyo Bandyopadhyay, Department of Electrical and Computer Engineering, Virginia Commonwealth University, Richmond, delivered a

lecture on "Energy-efficient information processing in our information hungry world" on 02.06.2023.

7. Prof. Kanishka Biswas, Ph.D, FRSC, FASc, Professor, New Chemistry Unit (NCU) & School of Advanced Materials (SAMat), International Centre of Materials Science (ICMS), Jawaharlal Nehru Centre for Advanced Scientific Research, delivered a lecture on "Metavalent chemical bond holds key to enhance the thermoelectric performance in quantum materials" on 05.06.2023.

Other Seminars

1. A departmental seminar (CMMP) was held on 03.01.2023. Dr. Somesh Chandra Ganguli, Postdoctoral Researcher, Department of Applied Physics, Aalto University School of Science, Espoo, Finland delivered a lecture on "Designer quantum matter in van der Waals heterostructures".

2. A departmental seminar (CMMP) was held on 06.01.2023. Dr. Ashish Arora, Assistant Professor of Physics, Indian Institute of Science Education and Research (IISER), Pune, delivered a lecture on "Magnetic fields and light for 2D investigations".

3. A departmental seminar (AHEP) was held on 06.01.2023. Dr. Anjasha Gangopadhyay, Assistant Professor, Hiroshima Astrophysical Science Center, Hiroshima University, Japan, delivered a lecture on "Investigation on a group of supernovae with diminishing hydrogen envelope".

4. A departmental seminar (PCS) was held on 09.01.2023. Dr. Suman G. Das, Research Associate, Institute for Biophysics, University of Cologne, Germany, delivered a lecture on "Biological evolution on a driven disordered fitness landscape".

5. A departmental seminar (AHEP) was held on 11.01.2023. Dr. Upamanyu Moitra, Postdoctoral Fellow, High Energy, Cosmology and Astroparticle Physics Section, The Abdus Salam International Centre for Theoretical Physics, Strada Costiera, Italy, delivered a lecture on "Self-Similar Gravitational Dynamics, Singularities and Criticality in 2D".

6. A departmental seminar (AHEP) was held on 13.01.2023. Dr. Sayantan Bhattacharya, Research Scholar, Physics Department at University of Massachusetts Lowell, delivered a lecture on "Blue Supergiant X-ray Binaries in The Starburst Galaxy IC 10".

7. A departmental seminar (AHEP) was held on 16.01.2023. Dr. Mukul Bhattacharya, Eberly Research Fellow at Penn State University, delivered a lecture on "Magnetised outflows as potential sites of heavy element nucleosynthesis and high-energy neutrinos".

8. A departmental seminar (CBS) was held on 17.01.2023. Dr. Bidyut Sarkar, Research Scientist, Molecular Spectroscopy Laboratory, RIKEN, Japan, delivered a lecture on "Chemistry and Material Physics Building, Investigation of structure-dynamics-function relationship of biomolecules with microsecond time resolution".

9. A departmental seminar (AHEP) was held on 19.01.2023. Dr. Swapnamay Mondal, Post-doc at Dublin Institute for Advanced Studies, Ireland, delivered a lecture on "Black hole microstates in String Theory".

10. A departmental seminar (PCS) was held on 19.01.2023. Dr. Avijit Misra, Post-doc research fellow, The Weizmann Institute of Science, delivered a lecture on "Work extraction from thermal noise by measurements and nonlinear interactions in quantum optical setups".

11. A departmental seminar (AHEP) was held on 20.01.2023. Dr. Chandan Datta, Postdoctoral Researcher, Dr. Alexander Streltsov at the Centre of New Technologies, University of Warsaw, delivered a lecture on "Entanglement catalysis for quantum states and noisy channels".

12. A departmental seminar (CMMP) was held on 31.01.2023. Prof. Ashwani K. Tiwari, Professor, FRSC, Dean of International Relations and Outreach, Department of Chemical Sciences, Indian Institute of Science Education and Research (IISER), Kolkata delivered a lecture on "Dynamics of H2O Dissociation on Metal Surfaces".

13. A departmental seminar (AHEP) was held on 01.02.2023. Dr. Soumyakanti Bose, Postdoctoral Research Fellow, Seoul National University, delivered a lecture on "Quantum teleportation of optical qubits using Gaussian resources".

14. A departmental seminar (AHEP) was held on 02.02.2023. Mr. Chandramouli Chowdhury, A PhD student at ICTS-TIFR, delivered a lecture on "Principle of Holography of Information".

15. A departmental seminar (CMMP) was held on 03.02.2023. Dr. Rajib Sarkar, Scientist, Technische Universität Dresden, Institut für Festkörper-und Materialphysik, Dresden, Germany, delivered a lecture on "Competing orders and spin dynamics: Nuclear probes".

16. A departmental seminar (CMMP) was held on 10.02.2023. Dr. Subhasish Mandal, Assistant Professor, Department of Physics & Astronomy,

West Virginia University, delivered a lecture on "First-principles investigation on strongly correlated materials with chemical accuracy using beyond-DFT methods".

17. A departmental seminar (CMMP) was held on 14.02.2023. Dr. Shishir Kumar Pandey, AI for Science Institute, Beijing, delivered a lecture on "A Route to Access the Quantum Spin Liquid State In Spin-orbit Coupling Assisted Mott Insulators".

18. A departmental seminar (CMMP) was held on 15.02.2023. Dr. Subhayan Roychoudhury, Postdoctoral Researcher, The Molecular Foundry, Lawrence Berkeley National Laboratory, delivered a lecture on "Computational Electronic Structure and X-Ray Spectroscopy: A Symbiotic Friendship".

19. A departmental seminar (CBS) was held on 21.02.2023. Dr. Andreas Schneemann, Assistant Professor. Technical University Dresden. Dresden, Germany, delivered a lecture on "Side Chain Functionalized Covalent Organic Frameworks – From Facilitated Delamination to Property Engineering".

20. A departmental seminar (PCS) was held on 24.02.2023. Prof. Soumya Bera, Professor, Dept. of Physics, IIT – Bombay, delivered a lecture on "Many-body delocalization".

21. A departmental seminar (AHEP) was held on 01.03.2023. Dr. Rajesh Mondal, Postdoctoral Fellow, Tel Aviv University, Tel Aviv-Yafo, Israel, delivered a lecture on "The 21-cm cosmology".

22. A departmental seminar (AHEP) was held on 22.03.2023. Dr. Anindita Bera, Post-Doctoral Fellow at Institute of Physics, Astronomy and Informatics, Nicolaus Copernicus University, Poland, delivered a lecture on "A class of Bell diagonal entanglement witnesses in C^4 ⊗ C^4 : optimization and the spanning property".

23. A departmental seminar (AHEP) was held on 24.03.2023. Dr. Debarshi Das, Royal Society - Newton International Fellow & Honorary Research Fellow, Department of Physics and Astronomy, University College London, UK, delivered a lecture on "Mass-independent test of genuine quantumness of massive objects".

24. A departmental seminar (CMMP) was held on 30.03.2023. Dr. Rajeswari Roy Chowdhury, DST INSPIRE Faculty, Department of Physics, IISER Bhopal, delivered a lecture on "Unconventional magneto resistive behaviour in layered magnets".

25. A departmental seminar (PCS) was held on 31.03.2023. Prof. Shankar P. Das, Professor of Physics, School of Physical Sciences, Jawaharlal Nehru University, New Delhi, delivered a lecture on Dynamic density functional theory for a Brownian fluid".

26. A departmental seminar (AHEP) was held on 06.04.2023. Mr. Indranil Chakraborty, Ph. D student from IIT, Kharagpur, delivered a lecture on "A study of gravitational wave memory effects in radiative geometries and wormholes."

27. A departmental seminar (CBS) was held on 13.04.2023. Dr. Rajesh Dutta, Postdoctoral Fellow, Department of Chemical and Biological Physics, Weizmann Institute of Science, Israel, delivered a lecture on "Understanding transition path dynamics for protein folding and unfolding".

28. A departmental seminar (AHEP) was held on 13.04.2023. Prof. M. Sivakumar, Professor, School of Physics, University of Hyderabad, delivered a lecture on "How effective, field theory is?"

29. A departmental seminar (AHEP) was held on20.04.2023. Dr. Chiranjeeb Singha, Research Associate Theory Division, Saha Institute of Nuclear, Physics, delivered a lecture on "Strong cosmic censorship conjecture for a charged BTZ black hole"

30. A departmental seminar (AHEP) was held on 24.04.2023. Dr. Jayanta Dutta, Post-Doctoral Fellow, Harish-Chandra Research Institute (HRI) delivered a lecture on "Formation of the very First Stars (primordial stars) in the Universe, and their survival possibility".

31. A departmental seminar (CMMP) was held on 24.04.2023. Dr. Kausik Majumdar, Associate Professor, Department of Electrical Communication Engineering, Indian Institute of Science, Bangalore, delivered a lecture on "Van der Waals heterojunctions for quantum device applications".

32. A departmental seminar (CBS) was held on 25.04.2023. Dr. Rajeswari Basu, Postdoctoral Scientist Boehringer Ingelheim, PhD, Chemistry, Stony Brook University, delivered a lecture on "Drug Discovery: The use of Mass spectrometry and other analytical tools".

33. A departmental seminar (CMMP) was held on 27.04.2023. Dr. Dhiman Bhowmick, Postdoc at Nanyang Technological University, Singapore, delivered a lecture on "Discrete time crystal made of topological edge magnons in Kagome ferromagnet".

34. A departmental seminar (CMMP) was held on 27.04.2023. Dr. Poulami Chakraborty, Postdoctoral

Researcher, Basque Center for Applied Mathematics, Bilbao, Spain, delivered a lecture on "Hydrogen interplay with defects in Al alloys".

35. A departmental seminar (PCS) was held on 01.05.2023. Dr. Himadri Shekhar Dhar, Assistant Professor, IIT Bombay, delivered a lecture on "Transfer and protection of quantum information in hybrid systems".

36. A departmental seminar (PCS) was held on 04.05.2023. Kanchan Meena, Ph. D student, SNBNCBS, delivered a lecture on "Time Reversed States in Barrier Tunneling".

37. A departmental seminar (PCS) was held on 18.05.2023. Dr. Raj Kumar Manna, Postdoctoral Research Associate at the Department of Physics at Syracuse University, delivered a lecture on "Shape morphing of chemically active elastic sheets, and tissues".

38. A departmental seminar (CMMP) was held on 19.05.2023. Dr. Abhishek Samanta, Postdoctoral Researcher, Ohio State University, delivered a lecture on "Hall coefficient of multi-band and interacting systems".

39. A departmental seminar (AHEP) was held on 25.05.2023. Dr. Piyali Saha, Project Researcher, ALMA Project, East Asian ALMA Regional Center (EA-ARC),National Astronomical Observatory of Japan, delivered a lecture on "Magnetic Fields in Massive Star-forming Regions (MagMaR)".

40. A departmental seminar (AHEP) was held on 29.05.2023. Prof. Rukmini Dey, Professor, ICTS-TIFR, Bengaluru, delivered a lecture on "Berezin-type quantization on compact even dimensional manifolds and pullback coherent states".

41. A departmental seminar (PCS) was held on 06.06.2023. Mr. Anjishnu Bose, Ph. D student, University of Toronto, delivered a lecture on "Field-induced Quantum Spin Liquids in honeycomb J 1 -J 3 XY models".

42. A departmental seminar (PCS) was held on 15.06.2023. Dr. Indranil Paul, Research Director at CNRS, Laboratoire MPQ, Université Paris Cité, delivered a lecture on "Pseudogap and Exceptional Van Hove Singularity in the Cuprates".

43. A departmental seminar (CBS) was held on 20.06.2023. Dr. Prabir Khatua, Postdoctoral Research Associate, Department of Chemistry, College of Staten Island, City University of New York, delivered a lecture on "Exploring Nucleosome Dynamics and Protein Folding/Aggregation Mechanism through Molecular Simulations".

44. A departmental seminar (AHEP) was held on 22.06.2023. Prof. Rabin Banerjee, Raja Ramanna Fellow, SNBNCBS delivered a lecture on "From Lorentz to non-Lorentz theories".

45. A departmental seminar (PCS) was held on 26.06.2023. Prof. Parthanil Roy, Professor, Theoretical Statistics and Mathematics Division, ISI Bengaluru, delivered a lecture on "Branching Random Walks: Two Conjectures and a Theorem".

46. A departmental seminar (AHEP) was held on 27.06.2023. Dr. Debashis Saha, Assistant Professor, IISER TVM, delivered a lecture on "Quantum correlations that are incompatible with absoluteness of measurement".

47. A departmental seminar (AHEP) was held on 28.06.2023. Dr. Chayan Mondal, Post-Doctoral Fellow, IUCAA, Pune, delivered a lecture on "AstroSat UV Deep Field - A unique view of the distant galaxies".

48. A departmental seminar (PCS) was held on 28.06.2023. Dr. Manabendra Nath Bera, Assistant Professor, Physical Sciences, IISER- Mohali delivered a lecture on "Quantum Bayes' Rule Affirms Consistency in Measurement Inferences in Quantum Mechanics".

Special Lectures / Conferences

Conference & Workshop

1. A conference on "Focused meet on Quantum Materials" was held on 24.01.2023. Convener: Prof. Priya Mahadevan, SNBNCBS.

2. A conference on Steady state phenomena in soft matter, active and biological systems was held during 16.03.2023 – 18.03.2023. Conveners: Dr. Urna Basu, Dr. Sakuntala Chatterjee, Prof. Punyabrata Pradhan and Prof. Jaydeb Chakrabarti, SNBNCBS.

Webiner Series on Statistical Mechanics

Prof. Uriel Frisch, The French National Centre for Scientific Research delivered a lecture on *Leonardo da Vinci, Andrei Kolmogorov and Giorgio Parisi. The energy decay of turbulence from Leonardo to multifractal theory on 30.1.2023 as a part of VASP Webinar Series on "Statistical Mechanics".*

Scientific Story

Harnessing Entanglements

A futuristic vision sprouting from the marriage of an old and profound theory with an upstart counter intuitive theory

Manik Banik

Thermodynamics is an old, time tested theory of physics with four inviolable laws (Including the 0^{th} Law) formulated on the basis of phenomenological observations. Quantum mechanics, on the other hand, is still evolving and grappling with new ideas. Dr. Manik Banik and his team at the S.N. Bose National Centre for Basic Sciences are exploring the deep-rooted connections between the laws of thermodynamics and Quantum Information Theory (QIT). QIT promises advanced information, communication and computation protocols that are not possible with classical resources. The quantum systems under their scrutiny are 'entangled' systems.

The idea of 'entanglement' was first manifested in the EPR Paradox in 1935. In their paper Einstein, Podolsky and Rosen brought out a paradoxical situation for two particles born out of a quantum of energy. Supposing a gamma ray transforms into an electron positron pair that move in two opposite directions with their spin vectors pointing in opposite directions. According to Copenhagen Interpretation, the two particles will have a shared wave function. Schrodinger called these particles 'entangled' as the fate of these two particles are peculiarly interconnected. The two subatomic particles separated at birth would perpetually be in knowledge of the fate of its twin - as if there was instantaneous communication between the two particles howsoever far apart they drifted. But Einstein's special theory of relativity forbids instantaneous communication. No signal can travel faster than light. Hence a tension arises. EPR use this to establish the fact that description of nature by wave function must be incomplete.

The idea of 'hidden variables' was suggested as a way out of the paradoxical situation. The particles have information embedded within them such that they always act in complementary fashion, following the laws of quantum mechanics. In 1964 J.S. Bell designed a thought experiment with photons and polarisers to prove the existence of hidden variables. He come up with an inequality involving experimental statistics which should be satisfied by any local realistic theory. Experiment, carried out in the laboratory by Alan Aspect group in 1982 show violation of this inequality establishing that quantum predictions do not allow a local realistic, i.e. classical, description.

Theoretical bafflement notwithstanding, it has been proved experimentally that entanglement does exist among subatomic particles. Thus a practical question is what use can entanglement be put to?

"Harnessing this resource has been the key to the invention of groundbreaking protocols such as quantum teleportation, dense coding and secure quantum key distribution whose implications deeply impacted physics and computer science", wrote Giulio Chiribella and Carlo Maria Scandolo in their paper titled **"**Entanglement and thermodynamics in general probabilistic theories" (*New Journal of Physics,* October 14, 2015)

The first non trivial use of entanglement was suggested by Charles Bennett and colleagues in 1993 in a paper published in Physical Review Letters. It was a blueprint for quantum teleportation - a technique for transferring quantum information from a sender at one location to a receiver at some distance away. The quantum information or qubit is transferred through two classical bits sent to the receiver, provided both sender and receiver share an entangled pair.

The protocol of super dense coding depicts another nontrivial use of quantum entanglement. Applying this protocol two bits of classical information can be communicated by transmitting a single qubit, provided sender and receiver already share an entangled resource. Super dense coding was first experimentally achieved in 1996 by Zeilinger and colleagues using entangled photon pairs. Entanglement also plays a crucial role in secret communication by eliminating the possibilities of eavesdropping the transmitted messages.

Another useful utility of entanglement would be to extract work out of the quantum systems - and that is where the relation between entanglement and thermodynamics comes in. Prof. Banik along with his collaborators Dr. Mir Alimuddin (a Chanakya Post-Doctoral Fellow) and Mr. Samgeeth Puliyil (a Project Student from IISER TVM) get motivation of their work from the already known connections between entanglement and thermodynamics. Like the second law of thermodynamics that prohibits the complete conversion of heat (disordered form

of energy) to work (ordered form of energy) in a cyclic process, the theory of entanglement is also governed by a no-go that forbids the creation of entanglement among spatially separated quantum systems under local operations

and classical communication (LOCC). The analogy goes even deeper as the von Neumann entropy plays a crucial role in quantifying entanglement.

According to thermodynamics, we can extract work from a non passive system. If no work can be extracted from a system, we call it passive. However, several copies of passive states can become non passive - except for thermal systems, that is, systems in thermal equilibrium with the surroundings. That is why, thermal states are called completely passive states.

But the situation changes when the states are entangled. For such an ensemble, even if the local states are thermal, work can be extracted from the global state. Therefore, work extraction can be seen in two different ways - local work extraction arising from the individual subsystems and global work extraction originating from the whole state. If the local systems are thermal systems, then, the local work will be zero while the global work can be positive. In general, global work is always greater or equal than the local work= (W_g -W_l) >= 0. The correlation in state sometimes helps to give global work more than the local work and the advantage is more if we consider quantum correlation or entanglement. For those cases this extra work gain in global operation can be a fruitful quantity to measure the entanglement.

Without any restriction on the global state, the maximum amount of work extracted from the system is when the system comes to the ground state or thermal state.

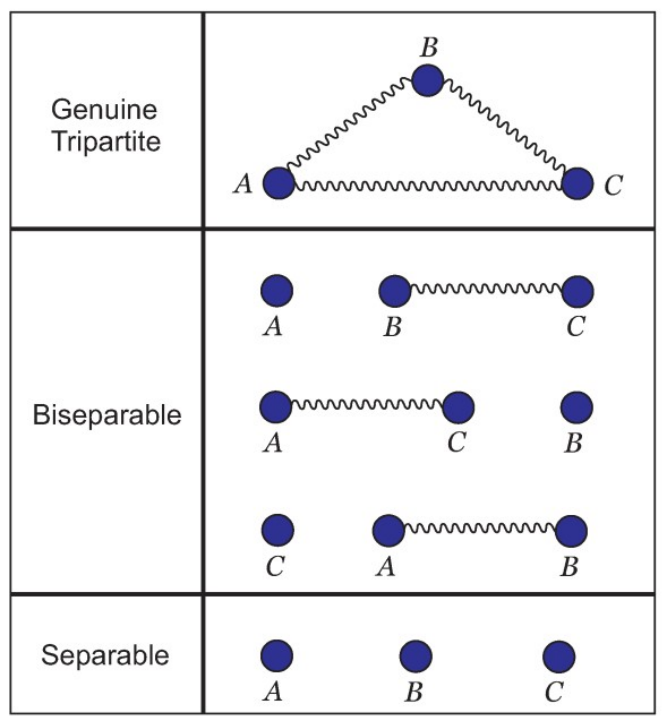
Work and quantum correlations are two fundamental resources in thermodynamics and quantum information theory. In a paper titled "Extractable Work from Correlations", published in the *Physical Review* in October 2015, the authors Marti Perarnau-Llobet et al have shown that:

> *"The amount of work that can be stored in unentangled states is always lower than the amount that can be stored in entangled states. Moreover, in the limit of a large number of systems, this gain vanishes, and one recovers the classical limit."*

This simply means that as far as extraction of work is concerned, entangled states are at an advantage as long as the number of quantum states are finite. For the number of states tending to infinite, the work extracted tends to the classical thermodynamic limit.

Dr. Manik Banik and his colleagues at the S.N. Bose National Centre for Basic Sciences have turned their attention to multipartite entangled systems. With more than two particles, entanglement has more drastic manifestations. In their Letter titled "Thermodynamic signatures of genuinely multipartite entanglement" (*Physical Review Letters,* August 9, 2022) they write:

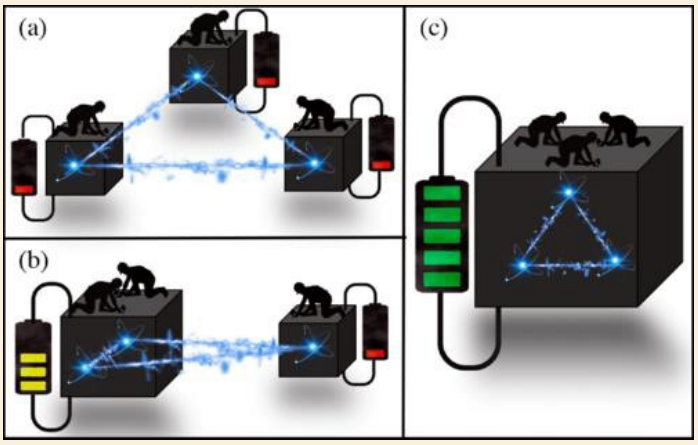
> *Depending on how different subsystems are correlated with each other, qualitatively different classes of entangled states are possible when more than two subsystems are involved. Among these, the most exotic one is the genuinely entangled state that first appears in the seminal Greenberger–Horne–Zeilinger (GHZ) Version of the Bel ltest. Subsequently, it has been shown that genuinely entangled states can also be of different types.*



In their Letter Prof. Banik and colleagues have proposed thermodynamic quantities that capture a signature or genuineness in multipartite entangled states. Their proposed quantities are defined in terms of energy instead of entropy. The works extractable under local and global operations keeping the entropy of the system unchanged like in the adiabatic process, is termed as ergotropic work. So one can have local ergotropic work applying product unitaries on their subsystems, biseparable ergotropic work by some biseparable unitaries, and global ergotropic by some global unitaries.

In general $W_e^{\ l} <= W_e^{X/Xc} <= W_e^{\ g}$. For genuinely entangled states, local ergotropy is always less that bipartite ergotropy, which in turn is always less than global ergotropy. Now one can define various functions over this ergotropic gaps which can capture the genuine entanglement. Prof. Banik and co-authors argue:

> *Suitably defined functions of this quantity—minimum ergotropic gap, average ergotropic gap, ergotropic fill and ergotropic volume—can serve as good measures of genuineness for multipartite systems. In fact, one can come up with measures that capture the notion of k separability for arbitrary multipartite systems.*



(a) Local ergotropic work; (b)Biseparable ergotropic work; (c) Global ergotropic work

Identification, characterization and quantification of genuine entanglement are of extreme practical relevance. When the laboratories will be able to harness the ergotropic gap, pathways will open for putting quantum batteries to use, that will never run out of charge. The consequences will be far reaching in terms of mitigating climate change.

Reference:

1. Samgeeth Puliyil, Manik Banik, and Mir Alimuddin,"Thermodynamic Signatures of Genuinely Multipartite Entanglement", *Physical Review Letter,* August 9, 2022

2. Marti Perarnau-Llobet et al, "Extractable Work from Correlations", *Phys. Rev. X 5, 041011, 22 October 2015*

3. Giulio Chiribella and Carlo Maria Scandolo, "Entanglement and thermodynamics in general probabilistic theories", *New Journal of Physics,* October 14, 2015

4. https://youtu.be/0x9AgZASQ4k (EPR Paradox by DrPhysicsA)

5. https://youtu.be/qd-tKr0LJTM (Bell's Inequality by DrPhysicsA)

Ph.D. Awarded/Submitted

Ph.D. degree awarded

1. Shashank Gupta, Thesis title: Certification And Preservation Of Quantum Correlations. Supervisor: Archan S Majumdar
2. Ruchi Pandey, Thesis title: Study of Novae Properties. Supervisor: Ramkrishna Das
3. Saikat Pal, Thesis title: Some Studies On The Effects Of Crowding Agents On The Structure, Functionality And Activity of Biomolecules. Supervisor: Rajib Kumar Mitra
4. Partha Pyne, Thesis title: Studies of Some Biophysical Processes Using Ultrafast Spectroscopic Techniques. Supervisor: Rajib Kumar Mitra
5. Sumanti Patra, Thesis title: Electronic, structural and optical properties of transition metal dichalcogenides heterostructures. Supervisor: Priya Mahadevan
6. Dipanjan Maity, Thesis title: Solar Energy Harvesting In A Photoelectrochemical Cell: Development Of Photoanodes Based on Earth Abundant Materials. Supervisor: Kalyan Mandal
7. Priyanka Saha, Thesis title: Improvement in Rheological Response of Transition Metal Oxide Based Magnetic Fluids. Supervisor: Kalyan Mandal
8. Ankan Pandey, Thesis title: Study of Dynamical Aspects of Some Class of ODEs and PDEs. Supervisor: Partha Guha

Ph.D. thesis submitted

1. Shantonu Mukherjee, Thesis title: Some Applications of Quantum Field Theoretic Dualities to Superconducting Systems. Supervisor: Amitabha Lahiri
2. Arnab Sarkar, Thesis title: A Study Of Cosmology With Gravitational Waves And Primordial Black Holes. Supervisors: Archan S Majumdar & Rajesh Kumble Nayak (IISER-K)
3. Md Nur Hasan, Thesis title: Optical Spectroscopy and Ab-Initio Study on Biocompatible Nanohybrids for Their Potential Biomedical and Environmental Applications. Supervisors: Samir Kumar Pal & Debjani Karmakar (BARC)
4. Biswajit Panda, Thesis title: High-Resolution Spectroscopic Investigations of Various Trace Gases and Their Isotopologues using Cavity Ring-Down Spectroscopy. Supervisor: Manik Pradhan
5. Saheli Samanta, Thesis title: Large Magneto-functional responses in transition metal-based alloys: Protocol dependence across martensitic phase transition. Supervisor: Kalyan Mandal
6. Snehamoyee Hazra, Thesis title: Investigation on Nanostructured Piezoelectric Materials for Energy Harvesting. Supervisor: Barnali Ghosh (Saha)
7. Parushottam Majhi, Thesis title: Growth, Structure and Physical Properties of Strained NdNiO3 Films. Supervisor: Barnali Ghosh (Saha) & Arup K Raychaudhuri

8. Amrit Kumar Mondal, Thesis title: Ultrafast Spin Dynamics in Continuous and Confined Magnetic Thin Film. Supervisor: Anjan Barman
9. Koustuv Dutta, Thesis title: Femto and Picosecond Spin Dynamics of Low Dimensional Magnetic Structures. Supervisor: Anjan Barman
10. Biswajit Pabi, Thesis title: Influence of molecular orientation on the electronic transport of a metal-molecular-metal junction. Supervisor: Atindra Nath Pal
11. Shubhrasish Mukherjee, Thesis title: Investigation of Hybrid Opto-electronic Devices Based on Graphene-Transition Metal Dichalcogenides Heterostructures. Supervisors: Samit Kumar Ray & Atindra Nath Pal
12. Abhik Ghosh Moulick, Thesis Title: Microscopic insights to relaxation phenomena in proteins. Supervisor: Jaydeb Chakrabarti
13. Rahul Karmakar, Thesis title: Manipulation Of Soft Matter System ln Nonequilibrium Conditions. Supervisor: Jaydeb Chakrabarti

News and Events (Administrative)

Celebration of Republic Day

The Centre celebrated the 74th Republic Day at its premises on 26th January, 2023. Prof. Tanusri Saha Dasgupta, Director of the Centre hoisted the National Flag at 8.00 a.m. and addressed the faculty, staff and students of the Centre. The security personnel deployed at Centre exhibited the march-past.

Hindi Workshops

On 17th March, 2023 a Hindi Workshop was held at Fermion Hall of the Centre at 3.15 p.m. In this workshop Mr. Rajesh Kumar Shaw, Deputy Manager (Rajbhasha), Coal India Ltd., Kolkata conducted the training. The administrative staff and officers of the Centre participated in the programme.

On 22nd June, 2023, another Hindi Workshop was held at Silver Jubilee Hall of the Centre. Shri Manindra Nath Biswakarma, Assistant Director (Rajbhasha) from All India Institute of Hygiene and Public Health, Kolkata conducted the training to the administrative staff and officers of the Centre.

Centre observed Swachchata Pakhwada

As per directives received from the AI Division of Department of Science & Technology, New Delhi, the Centre observed "Swachchata Pakhwada" from 1st May to 15th May, 2023. On 1st May, 2023 the Swachchata Pakhwada was inaugurated and mass "Swachchata Pledge" was taken by the employees and students. On this day, mass cleaning of the Centre premises, pavement areas and outside pavement areas, awareness campaign for proper disposal of wastes and no use of plastics were held. Posters titled "Zero Plastic, Green Campus" were pasted in all Notice Boards. Trilingual banners titled "Swachchata Pakhwada, 01-15 May, 2023" were displayed at Main Gate and other prominent places of the Centre for wider publicity. On 02.05.2023, weeding out of old records were done. On 03.05.2023 cleanliness drive at Administrative Block, Laboratories and Canteen of the Centre were carried out. On 04.05.2023, an essay writing competition on "E-waste Se Raksha, Swachchata hi Suraksha" was carried out. A "Waste Compactor Facility" was inaugurated at Centre on 08.05.2023. On 09.05.2023 a poster competition on "E-waste Se Raksha, Swachchata hi Suraksha"

amongst the members of the Centre was held. On 10.05.2023, eco-friendly compostable garbage bags were distributed to housekeeping staff of the Centre. On 10.05.2023 an invited lecture on "E-waste Management" was organized at Silver Jubilee Hall of the Centre. Shri Sisir Mondal, Assistant Environmental Engineer, West Bengal Pollution Control Board delivered a lecture. On the occasion of "National Technology Day" on 11.05.2023, an in-house talk was delivered by Prof. Samir Kr. Pal, Senior Professor, SNBNCBS on the topic "Cleanliness Must Start with Yourself". On 13.05.2023, sanitization was done at Centre. On 15.05.2023 deep cleaning of overhead tanks were carried out. The concluding ceremony of "Swachchata Pakhwada" was held on 19.05.2023 at Silver Jubilee Hall of the Centre. Prizes were distributed amongst the staff of the Centre who contributed the maximum to the cause of maintaining health and hygiene on rating and ranking. A short audio drama "Aartanaad" by Centre's staff and students on the theme "Awareness of Cleanliness" was presented. Also, a short drama titled "Trapped as a slave in E-waste Empire" was presented by the students of the Centre on the theme "E-waste Se Rakha, Swachchata Hi Suraksha".

Health Camp organised at the Centre

A Special Cardiac Clinic and Health Talk was organized by the Medical Cell of the Centre with the help of Desun Hospital, Kolkata on 09.05.2023. The programme started at 10.45 a.m. at Basundhara Building Ground Floor of the Centre. Total 9 (nine) persons from Desun Hospital were present. Two Technicians measured the Weight, Blood Pressure, Random Blood Sugar (RBS) and Pulse Oximeter test of the staffs and students. Those who required ECG/ECHO tests were undergone the tests as recommended by the Doctors. Total 118 (one hundred and eighteen) permanent staffs, contractual staffs, students and the manpower deployed through agencies at Centre participated in this programme. At 3.30 p.m. a Cardiac Health Talk on Lifestyle Awareness was delivered by Dr. Saptarshi Bhattacharyya, MBBS, MD & In-charge Critical Care Unit, Desun Hospital at Silver Jubilee Hall of the Centre. Total 47 (forty-seven) staffs and students were present and many of them interacted with the Doctor after the talk.

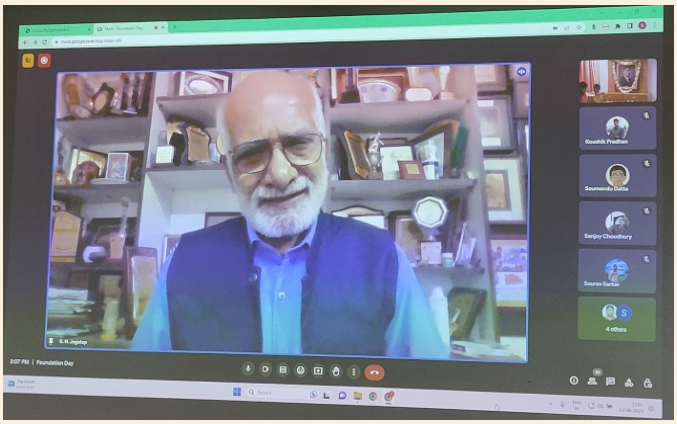
Blood Donation Camp organised by the Centre

The Social Outreach Activities Group of Muktangan of the Centre with the help of Calcutta Medical College and Hospital, Kolkata organized a Blood Donation Camp at Centre on 09.06.2023 from 10.30 a.m. onwards. A team of Doctors and technicians comprising of Dr. Sayan Biswas and Dr. Shyam Mundra from Calcutta Medical College and Hospital conducted the Blood Donation Camp at Basundhara Building Ground Floor of Centre. Total 42 (forty-two) staff and students participated and donated blood. The State Blood Transfusion Council, Govt. of West Bengal provided a Certificate of Appreciation to the Centre. The Blood Donation Camp was concluded at 2.00 p.m. as there were no more donors.

Foundation Day Celebrated at the Centre

The Centre celebrated its 37th Foundation Day on 13th June, 2023. The programme was inaugurated by Prof. B. N. Jagatap, IIT Bombay and Chairman, Governing Body, SNBNCBS followed by the

welcome address by Prof. Tanusri Saha-Dasgupta, Director, SNBNCBS.



On this auspicious occasion, the virtual tour of the Bose Archive and Museum was inaugurated (link: *https://www.bose.res.in/bosearchive).*

Dr. Manik Banik, Associate Professor delivered scientific talk on "*The Nature is Nonlocal Ultimately*". The toppers of last 5 years Integrated PhD (M.Sc.) were awarded with medals and two best teachers were awarded with memento and book grant. The programme ended with classical musical performance by external artist.

International Day of Yoga observed

The Centre observed the International Day of Yoga (IDY-2023) on 21.06.2023. An interactive yoga session was organized in the Dining Hall of the Basundhara Building of the Centre. The theme for this year was "Yoga for Vasudhaiva Kutumbakam". Total 66 employees and students including the Director and Registrar of the Centre actively participated and performed various yoga postures. Mr. Pradyut Das, Principal and Yoga consultant, Prachin Yog & Physiotherapy Research Institute, Kolkata conducted the programme. The event was organized as per the directive of the Ministry of Ayush, Govt. of India and directions from Department of Science & Technology.

Editorial Board: Saumen Adhikari, Jaydeb Chakrabarti, Sanjoy Choudhury, Ramkrishna Das, Gurudas Ghosh, Manoranjan Kumar, Rajib Kumar Mitra, Punyabrata Pradhan.

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