The Institute of Mathematical Sciences, Chennai

Quarterly Report

April - June 2023

Highlights: research and events

Condensed Matter Physics

Non-Abelian fractional quantum Hall states are of interest because they harbor quasiparticles with exotic non-Abelian statistics, which may be of use for fault-tolerant quantum computation. We propose a new mechanism for realizing non-Abelian fractional quantum Hall states via the hitherto unexplored route of Landau-level mixing. In particular, our calculations show that the composite-fermion Fermi seas at the half and quarter-filled Landau levels are unstable to paired fractional quantum Hall states with sufficient Landau level mixing.

This potentially opens a new avenue for creating and studying non-Abelian states. Reference: Composite Fermion Pairing Induced by Landau Level Mixing Tongzhou Zhao, Ajit C. Balram, and J.8201;K. Jain, Phys. Rev. Lett. 130, 186302 (2023)

In many-particle systems, certain exotic symmetries that are absent in the original Hamiltonian can emerge at low energies. One example, originally proposed in high-energy physics, is supersymmetry (SUSY) , an elusive symmetry relating to bosons and fermions. We show that SUSY can arise in a fractional quantum Hall state at filling factor 5/2, a well-known topological phase of matter. We construct wave functions for the collective excitations of this state based on SUSY and demonstrate that they are degenerate in energy for realistic models of the 5/2 state. Our work opens the door to the experimental exploration of SUSY in quantum materials.

Reference: Signatures of Supersymmetry in the 957;=5/2 Fractional Quantum Hall Effect, Songyang Pu, Ajit C. Balram, Mikael Fremling, Andrey Gromov, and Zlatko Papi263;, Phys. Rev. Lett. 130, 176501 (2023)

Foundations of Quantum Mechanics

Measurement incompatibility and the negativity of quasiprobability distribution functions are well-known non-classical aspects of quantum systems. Both of them are widely accepted resources in quantum information processing. We acquaint an approach [sibasish-2023.4] to establish a connection between the negativity of the Wigner function, a well-known phasespace quasiprobability distribution, of finite-dimensional Hermitian operators and incompatibility among them. We calculate the negativity of the Wigner distribution function

for noisy eigenprojectors of qubit Pauli operators as a function of the noise and observe that the amount of negativity increases with the decrease in noise vis-`a-vis the increase in the incompatibility. It becomes maximum for the set of maximally unbiased operators. Our results, although qualitatively, provide a direct comparison between relative degrees of incompatibility among a set of operators for different amounts of noise. We generalize our treatment for higher dimensional qudits for specific finite-dimensional Gell-Mann operators to observe that with an increase in the dimension of the operators, the negativity of their Wigner distribution, and hence incompatibility, decreases.

Quantum Computations

Weak values of product observables or higher moments of an observable are informationally significant because of their ability to solve some paradoxes, realize strange quantum effects, reconstruct density matrices, etc. In the present work [sibasish-2023.3], we demonstrate that pairwise orthogonal post-selections can be used to obtain higher moment weak values. By measuring only local weak values (defined as single system weak values in a multipartite scenario), product weak values can be obtained. As applications, we use product and higher moment weak values to reconstruct quantum states showing advantages over previous works in terms of number of required measurement operators and experimental feasibility. Additionally, a necessary separability criteria is given using product weak values to detect entanglement. For some classes of entangled states, positive partial transpose (PPT) criteria is achieved by cleverly choosing product observables and post selections. Robustness of our method against inappropriate choices of observables and noisy post-selections is also discussed.

Reference : Sohail Md., Subhrajit Modak, Sibasish Ghosh, and Arun K. Pati. Extraction of product and higher moment weak values: Applications in quantum state reconstruction and entanglement detection. Phys. Lett. A, 480, 128977, 2023.

India's giant metrewave radio telescope plays vital role in detecting universe's vibrations

India's Giant Metrewave Radio Telescope (GMRT) has emerged as a crucial player in the groundbreaking discovery of the universe's vibrations caused by ultra-low frequency gravitational waves. The GMRT, based in Pune, was one of the six large telescopes worldwide that contributed to this significant finding, announced by a team of international scientists, including the Indian Pulsar Timing Array (InPTA).

The InPTA experiment involved researchers from several institutions in India, including NCRA (Pune), TIFR (Mumbai), IIT (Roorkee), IISER (Bhopal), IIT (Hyderabad), IMSc (Chennai), and RRI (Bengaluru), as well as their counterparts from Kumamoto University in Japan.

Observations were conducted using the 100-m Effelsberg radio telescope in Germany, the Lovell Telescope of the Jodrell Bank Observatory in the United Kingdom, the Nancay Radio Telescope in France, the Sardinia Radio Telescope in Italy, and the Westerbork Synthesis Radio Telescope in the Netherlands.

Source **:** https://www.theweek.in/news/sci-tech/2023/06/30/india-giant-metrewave-radio-telescope-plays-vital-role-in-detect.html

Inaugural meeting of Asian-Oceanian Women in Mathematics during Apr 24 – Apr 28, 2023.

This was the first meeting of recently formed AOWM under the auspices of CWM of IMU. The meeting was funded by ICTS, IMSc and CWM. Details of the meeting can be found at https://www.icts.res.in/discussion-meeting/AOWM In addition to the lectures and the panel discussions, we also had the first hybrid meeting of EC members of AOWM.

Participation in conferences

Coimbatore Balram, Ajit

Visited International Centre for Theoretical Sciences (ICTS) during Dec 24, 2022 – Dec 1, 2023. attended the lectures of Ganpathy Murthy and had discussions with him

Visited Indian Institute of Science (IISc), Bengaluru during Apr 17 – Apr 18, 2023. invited seminar

Visited Raman Research Institute (RRI), Bengaluru during Apr 20 – Apr 21, 2023. invited seminar

Participated in Quantum Information, Quantum Matter, and Quantum Gravity held at Center for Quantum and Topological Systems (CQTS), New York University, Abu Dhabi (NYUAD) during May 22 – May 26, 2023. invited talk

Visited IISER Kolkata during Jun 21 – Jun 22, 2023. invited seminar

Visited Harish-Chandra Research Institute, Prayagraj during Jul 24 – Jul 28, 2023. invited seminar

Participated in Discussion Meeting on Non-Equilibrium Correlated Systems held at HarishChandra Research Institute, Prayagraj during Jul 24 – Jul 26, 2023. invited talk

Participated in Fractionalization and Emergent Gauge Fields in Quantum Matter held at International Centre for Theoretical Physics (ICTP), Trieste, Italy during Dec 4 – Dec 8, 2023. invited talk

Ghosh, Sibasish

Visited Indian Statistical Institute, Kolkata during May 8 – May 12, 2023. I visited the Physics and Applied Mathematics Unit (PAMU), interacted with the members in the group of Prof. Guruprasad Kar of PAMU, and gave a talk there on 11th May, 2023 on linear optics based local discrimination of quantum states.

Participated in Quantum Information and Quantum Technology (QIQT-2023) [online mode] held at IISER-Kolkata during May 8 – Jun 15, 2023. I gave an invited (online) talk entitled, "Quantum homogenization in Marovian and non-Markovian collisional models" (on 2nd June, 2023).

Mahajan, Meena B.

Visited Simons Institute for the Theory of Computing during Mar 18 – May 12, 2023. Participant, Extended Reunion on Satisfiability 13 March - 12 May. Participant: Workshop on Proof Complexity and Meta-Mathematics 20-24 Mar, Workshop ToniCS 27-29 Mar, and workshop Satisfiability: Theory, Practice, and Beyond 17-21 Apr.

Participated in a Workshop on "Satisfiability: Theory, Practice, and Beyond" held at Simons Institute for the Theory of Computing, Berkeley, USA. during Apr 17 – Apr 21, 2023. Gave an invited talk titled "Beyond SAT - Proofs for QBF, and more".

IMSc Outreach

Azadi Ka Amrit Mahotsav

Title : Nuclear architecture and the structural basis of cellular memory

Speaker : Prof. Rakesh Mishra, Director, Tata Institute for Genetics and Society, Bengaluru

Date : 5 April 2023

URL of the Talk : https://www.youtube.com/watch?v=gM3jD57tdFg