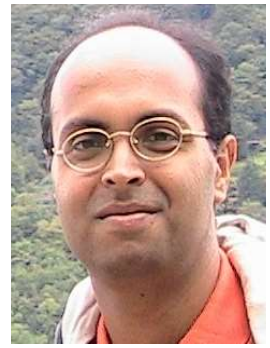
Curriculum Vitae



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Date and Place of Birth: 4th January, 1974; Kolkata, West Bengal

Gender: Male

Category: General

Whether differently abled: No

Summary of educational qualifications

Sl . No	Name of the Board /University / Institution and Department	Examination / Degree passed	Discipline/ Specialization	Year of Passing	Distinction / Class / Division and CPI / Percentage
1	Calcutta University	Bachelor of Science	Physics (Honours)	1995	First Class
2	Indian Institute of Science, Bangalore	Master of Science	Physics	1997	First Class
3	Indian Institute of Science	PhD	Physical Sciences	2003	-

Recognitions and Honours : Awarded Ramanujan Fellowship from DST-SERB (Govt. of India), October 2010 – September 2015 .

Thesis details:
Title --- "Interacting Quantum Spin and Fermionic Systems in One Dimension: Variations on a Theme"
Advisor --- Prof. Diptiman Sen
Institution --- IISc, Bangalore
Year --- 2003

Work Experience

Sl. No.	Organisation / Institute	Position held	Nature of duties / work	Date of joining	Date of leaving
1	Indian Institute of Science Education and Research-Kolkata	Associate Professor	Teaching and Research	September 12, 2019	-
2	Indian Institute of Science Education and Research-Kolkata	Assistant Professor	Teaching and Research	July 22, 2010	September 12, 2019
3	University of Illinois at Urbana-Champaign, USA	Postdoctoral Fellow	Research	April 2008	May 2010
4	Abdus Salam ICTP, Trieste, Italy	Postdoctoral Fellow	Research	October 2006	March 2008
5	ITP, Univ. of Koeln, Germany	Postdoctoral Fellow	Research	August 2002	May 2006

Mentoring

Ph.D Thesis: 3 completed, 3 in process

M. S. Thesis projects: 10 completed

Postdoctoral Fellows mentored: 1

Teaching: At the level of the BS-MS, Int. Ph.D and Ph.D programmes at IISER Kolkata.

Courses (Theory): Basic Quantum Mechanics, Advanced Quantum Mechanics, Advanced Statistical Mechanics, Advanced Condensed Matter Physics

Courses (Lab): 1st year UG Physics Lab., 2nd year UG Physics Lab., Advanced Condensed Matter Physics Lab.

Ongoing Funded Projects:

1. "Exploring the many-particle entanglement and quantum criticality of quantum matter", SERB Core Research Grant (CRG), February 2022 – February 2025

2. "Holographic geometry of quantum matter", SERB MATRICS Research Grant, February 2022 – February 2025

Completed Funded Projects:

1. Ramanujan Fellowship Research Grant: "Emergent Phenomena and quantum criticality in low-dimensional quantum systems" from the DST-SERB, 2010-2015

Research Interests (keywords) : Theoretical quantum condensed matter physics, with emphasis on (i) strongly correlated electron systems, (ii) quantum magnetism, (iii) non-Fermi liquids, (iv) unconventional superconductivity, (v) topological states of matter and topological order, (vi) fermionic criticality, (vii) many-particle entanglement, (viii) low-dimensional quantum systems, (ix) quantum transport and (x) search for quantum materials.

Complete List of Refereed Publications (in reverse chronological order):

1. **Unveiling topological order through multipartite entanglement.** S. Patra, S. Basu and **S. Lal**. Physical Review A **105**, 052428 (2022).
2. **Holographic entanglement renormalisation of a topologically ordered quantum liquid.** A. Mukherjee and **S. Lal**. J. Phys.: Condens. Matter **34,** 275601 (2022).
3. **Unveiling the Kondo cloud: unitary RG study of the Kondo model.** Anirban Mukherjee, Abhirup Mukherjee, N. S. Vidhyadhiraja, A. Taraphder and **S. Lal**. Physical Review B **105**, 085119 (2022).
4. **Origin of topological order in a Cooper-pair insulator.** Siddhartha Patra and **S. Lal**. Phys. Rev. B **104**, 144514 (2021).
5. **Fermionic Criticality is shaped by Fermi Surface Topology: a case study of the Tomonaga-Luttinger liquid.** Anirban Mukherjee, Siddhartha Patra and **S. Lal**. Journal of High Energy Physics 2021, 148 (2021).
6. **Holographic unitary renormalization group for correlated electrons - II: Insights on fermionic criticality.** A. Mukherjee and **S. Lal.** Nucl. Phys. B **960**, 115163 (2020).
7. **Holographic unitary renormalization group for correlated electrons - I: A tensor network approach.** A. Mukherjee and **S. Lal.** Nucl. Phys. B **960**, 115170 (2020).
8. **Scaling theory for Mott-Hubbard transitions – I: T=0 phase diagram of the ½-filled Hubbard model.** A. Mukherjee and **S. Lal.** New Journal of Physics. **22**, 063007 (2020).
9. **Scaling theory for Mott-Hubbard transitions – II: Quantum Criticality of the doped Mott insulator.** A. Mukherjee and **S. Lal.** New Journal of Physics. **22**, 063008 (2020).
10. **Topological approach to quantum liquid ground states on geometrically frustrated Heisenberg antiferromagnets.** S. Pal, A. Mukherjee and **S. Lal.** J. Phys. Condens. Matter **32**, 165805 (2020).
11. **Magnetisation plateaux of the quantum pyrochlore Heisenberg antiferromagnet.** S. Pal and **S. Lal.** Phys. Rev. B **100**, 104421 (2019).
12. **Correlated spin liquids in the quantum kagome antiferromagnet at finite field: a renormalisation group study.** S. Pal, A. Mukherjee and **S. Lal**. New Journal of Physics **21**, 023019 (2019).
13. **Orbital and Spin Ordering physics of the Mn_3O_4 spinel.** S. Pal and **S. Lal**, Physical Review B **96**, 075139 (2017).
14. **Charge Fractionalization in a Mesoscopic Ring.** W. deGottardi, **S. Lal** and S. Vishveshwara. Phys. Rev. Lett. **110**, 026402 (2013).
15. **Inelastic Light Scattering Measurements of a Pressure-Induced Quantum Liquid in $KCuF_3$.** S. Yuan, M. Kim, J. T. Seeley, J. C. T. Lee, **S. Lal**, P. Abbamonte and S. L. Cooper. Phys. Rev. Lett., **109**, 217402 (2012).
16. **Two-step stabilization of orbital order and the dynamical frustration of spin in the model charge-transfer insulator $KCuF_3$**. J. C. T. Lee, S. Yuan, **S. Lal**, Y. I. Joe, Y. Gan, S. Smadici, K. Finkelstein, Y. Feng, A. Rusydi, P. M. Goldbart, S. L. Cooper, P. Abbamonte. Nature Physics **8**, 63-66 (2012).

17. **Andreev Bound State Spectroscopy in a Graphene Quantum Dot.** T. Dirks, T. L. Hughes, **S. Lal**, B. Uchoa, Yung-Fu Chen, C. Chialvo, P. M. Goldbart, N. Mason. Nature Physics **7**, 386-390 (2011).
18. **Charge-Density-Wave and Superconductor Competition in Stripe Phases of High Temperature Superconductors.** A. Jaefari, **S. Lal** and E. Fradkin. Physical Review B **82**, 144531 (2010).
19. **Approaching multichannel Kondo physics using correlated bosons: Quantum phases and how to realize them. S. Lal**, S. Gopalakrishnan and P. M. Goldbart. Physical Review B **81**, 245314 (2010).
20. **Ordering from Frustration in a strongly correlated one-dimensional system. S. Lal** and M. S. Laad. Int. J. Mod. Phys. B **23**, 3485 (2009).
21. **Transport through constricted quantum Hall edge systems: beyond the quantum point contact. S. Lal**. Physical Review B **77**, 035331 (2008).
22. **From frustrated insulators to correlated anisotropic metals: charge ordering and quantum criticality in coupled chain systems. S. Lal** and M. S. Laad. J. Phys. (Condens. Matt.) **20**, 235213 (2008).
23. **On transport in quantum Hall systems with constrictions. S. Lal**. Europhys. Lett. **80**, 17003 (2007).
24. **Junction of several weakly interacting quantum wires: a renormalisation group study**. S. Lal, S. Rao and D. Sen. Physical Review B **66**, 165327 (2002).
25. **Transport in quantum wires. S. Lal**, S. Rao and D. Sen. Pramana **58**, 205 (2002).
26. **Conductance through contact barriers of a finite-length quantum wire. S. Lal**, S. Rao and D. Sen. Phys. Rev. B **65**, 195304 (2002).
27. **Transport through Quasiballistic Quantum Wires: The Role of Contacts. S. Lal**, S. Rao and D. Sen. Phys. Rev. Lett. **87**, 026801 (2001).
28. **Electron transport through ballistic quantum channels. S. Lal**, S. Rao and D. Sen. Applied Surface Science **182**, 377 (2001).
29. **One dimensional Fermions with incommensuration.** D. Sen and **S. Lal**. Physical Review B **61**, 9001 (2000).
30. **One-dimensional fermions with incommensuration close to dimerization.** D. Sen and **S. Lal**. Europhys. Lett., **52**, 337 (2000).
31. **Magnetisation Properties of Some Quantum Spin Ladders.** K. Tandon, **S. Lal**, S. K. Pati, S. Ramasesha and D. Sen. Physical Review B **59**, 396 (1999).

Manuscripts in review or on arXiv:

1. **Holographic entanglement renormalization of fermionic quantum matter: geometric and topological aspects.** A. Mukherjee, S. Patra and **S. Lal**. arXiv:2302.10590.
2. **Kondo frustration via charge fluctuations: a route to Mott localisation.** A. Mukherjee, N. S. Vidhyadhiraja, A. Taraphder and **S. Lal**. arXiv:2302.02328.
3. **Universal entanglement signatures of quantum liquids as a guide to fermionic criticality.** S. Patra, A. Mukherjee and **S. Lal**. arXiv:2205.11123.
4. **Frustration shapes multi-channel Kondo physics: a star graph perspective.** S. Patra, Abhirup Mukherjee, Anirban Mukherjee, N. S. Vidhyadhiraja, A. Taraphder and **S. Lal**. arXiv:2205.00790.

5. **Graph Polynomial for Colored Embedded Graphs: A Topological Approach.** S. Basu, D. Bhasin, **S. Lal** and S. Patra. arXiv:2204.13876.
6. **Topological transitions in Ising models.** S. Jalal, R. Khare and **S. Lal**. arXiv:1610.09845.
7. **Emergent Spin Hall phase at a Lifshitz transition from competing orders.** N. Mohanta, S. Bandopadhyay and **S. Lal**. arXiv:1407.6539.

Brief description of Research Interests :

My interests lie in exploring the interplay of low dimensionality, strong correlations and quantum fluctuations leading to novel emergent collective behaviour in quantum condensed matter systems. The theoretical analysis of such phenomena is often made challenging by the absence of any obvious small coupling constant in the problem. In addition, critical phenomena in low-dimensional systems are often at zero-temperature and driven by quantum fluctuations arising from the competition between different quantum orders. I have, over the years, investigated emergent phenomena in a wide variety of systems. These include, for instance, inhomogeneous quantum Hall states, graphene-based quantum dots, orbital-spin liquid states in transition-metal compounds, charge-transfer organic salts, stripe phases of a high-T_C superconductor and cold bosonic condensates. These works have often been either in direct collaboration with experimental groups or strongly motivated by their findings.

My recent work has focused on the understanding of fermionic quantum criticality lying beyond the Ginzburg-Landau-Wilson paradigm. I am keenly looking at how such criticality may be responsible for the appearance of topological states of matter in strongly correlated electronic systems, quantum spin liquids etc. Very recently, for instance, my group has developed a renormalization group method (two works in Nucl. Phys. B, 2020) that offers non-perturbative insight into the nature of gapped as well as gapless spin liquid ground states in the two-dimensional quantum Kagome antiferromagnet at finite field (New J.Phy., 2019). We have also developed a spectral flow technique that provides a criterion for the existence of gapped topological spin liquid phases at finite field (corresponding to magnetization plateaux states) in geometrically frustrated quantum Heisenberg antiferromagnets in the two-dimensional kagome and triangular lattices (JPCM, 2020), as well as in the three-dimensional pyrochlore lattice (PRB, 2019). We have furthered our understanding of frustrated magnetism in quantum materials by developing an understanding of the complex phenomenology of the Mn_3O_4 spinel by formulating a model that incorporates the interplay of orbital, spin and lattice degrees of freedom. This has helped us in proposing Mn_3O_4 as a candidate in the search for materials that can host orbital-spin liquid states of matter (PRB, 2017).

Ongoing research in my group includes extending our novel renormalization group method to the study of Mott transitions in the two-dimensional Hubbard on the square lattice at, and away from, half-filling (two works in New J. Phys., 2020). These works offer insight into how superconductivity emerges from purely repulsive strong inter-electronic correlations. Several other prototypical models have been studied as well (two works in Nucl. Phys. B, 2020). We have also developed a novel entanglement renormalization approach that has been applied to the Hubbard model (JPCM, 2022), reduced BCS pairing model (PRB, 2021) and models of strongly correlated electrons in 1D (JHEP, 2021). We have also developed a low-energy theory for the Kondo cloud (PRB, 2022) for the very first time, as well as obtained exact results for how many-particle quantum information measures can capture the topological entanglement entropy of a topologically ordered quantum system by using a graph topology based approach (PRA, 2022).

Future goals include (i) furthering the development of a theory for topological order, (ii) working towards a classification scheme for quantum matter based on insights learnt from fermionic criticality,

(iii) connecting measures of multipartite entanglement with experimental observables, and (iv) developing an analytic understanding of the inner workings of auxiliary model approaches for strongly correlated electronic systems (e.g., dynamical mean-field theory).