

Prem Kumar

Ph.D. Student

The Institute of Mathematical Sciences (IMSc), Chennai, India

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Education and Training

Ph.D. in Theoretical Physics	2021-Present
Institute of Mathematical Sciences (IMSc), Chennai, India	
PhD supervisor: Prof. Sibasish Ghosh	
M.Sc. in Physics	2019-2021
Institute of Mathematical Sciences (IMSc), Chennai, India	
MSc project supervisor: Prof. Sibasish Ghosh	
B.Sc. in Physics, Maths, Electronics	2016 - 2019
Christ (Deemed to be University), Bangalore, India	

Research Highlights

- **Corrections to quantum dissipative dynamics at higher order in the noise strength:**
 - Analytical derivation of the 4th-order Time-Convolutionless (TCL4) generator for Spin-Boson models for a very large class of model parameters [1].
 - Analytical proof that the higher order corrections to steady state match exactly with the corresponding generalized Gibbs state [1].
 - Study of the corrections to the non-Markovianity of the dynamics, application to a solid state double quantum dot and benchmarking against exact numerical methods (HEOM) [2].
 - This work resulted in an open-source package that can be found on my GitHub: [spin-boson-tcl4](#).
- **Analytical extension of large coupling generalized equilibrium state to anharmonic environments:**
 - Analytical derivation of the strong coupling generalized Gibbs state for a large class of anharmonic environments [3].
 - The harmonic environment assumption, although widely successful, is known to fail in some systems of physical relevance.

Research Interests

My main research interest is open quantum systems. This includes its theoretical study as well as application to physically/experimentally relevant models like those found in chemical, biological or other many-body systems. I am interested in studying both analytical and numerical techniques useful in studying these systems. I am also interested in related topics like non-Markovianity, Quantum Thermodynamics and other topics in quantum information theory.

Other than this, I am keen on exploring systems with indistinguishable particles and many body quantum systems. I am also open to exploring other interesting topics in theoretical physics.

Research Statement

I am currently focusing on expanding the scope of research in the following directions:

- Application of open quantum system techniques to study systems of physical interest. For example, I am studying the phenomenon of Chirality induced spin selectivity (CISS), specifically focusing on the temperature dependence of the phenomenon. I am also investigating some mechanism through which CISS can be observed in the absence of phonons.
- Higher order TCL master equation has been recently reported to have long time divergence if the bath correlator has an algebraic tail. I am performing a detailed study of the origin of this divergence using exactly solvable models and trying to find techniques to mitigate it and exploring other computationally efficient master equations that can circumvent this issue.
- Deriving an ultrastrong coupling master equation for anharmonic environments and studying its consistency with the corresponding generalized Gibbs state derived in my work [3].
- Recent research has revealed some general results on various constraints on the state space of a symmetric molecule with indistinguishable Fermionic nuclei. This opens up an avenue for physical effects in large molecular systems originating directly from a purely quantum mechanical effect. I am studying the physical implications of these results, for example in certain chemical reactions. I am also interested in the generalization of these results to more complicated molecules with higher degrees of freedom.

Publications

Refereed Journal Publications

- [1] Prem Kumar, K. P. Athulya, and Sibasish Ghosh. “Equivalence between the second order steady state for the spin-boson model and its quantum mean force Gibbs state”. In: *Physical Review B* 111.11 (2025), p. 115423. DOI: [10.1103/PhysRevB.111.115423](https://doi.org/10.1103/PhysRevB.111.115423).
- [2] Prem Kumar, K. P. Athulya, and Sibasish Ghosh. “Asymptotic TCL4 Generator for the Spin-Boson Model: Analytical Derivation and Benchmarking”. In: *Physical Review B* (2025). DOI: [10.1103/69y3-x6vh](https://doi.org/10.1103/69y3-x6vh).
- [3] Prem Kumar and Sibasish Ghosh. “Ultrastrong coupling limit to quantum mean force Gibbs state for anharmonic environment”. In: *The Journal of Chemical Physics* 161.17 (2024). DOI: [10.1063/5.0223734](https://doi.org/10.1063/5.0223734).

Pedagogical Reviews

- [4] Prem Kumar. *Local harmonic approximation to quantum mean force Gibbs state*. 2024. arXiv: [2401.11595](https://arxiv.org/abs/2401.11595).

Technical Skills

• Computational Physics & ML:

- **Tensor Networks:** Implementation of algorithms for simulating open quantum system dynamics using Feynman-Vernon influence functional formalism and tensor network framework.
- **Machine Learning:** **PyTorch** for machine learning and designing transformer models.
- **Languages:** Python (QuTiP, NumPy, SciPy).

• Symbolic Computing (Mathematica):

- Developed **spin-boson-tcl4**: An open-source package for the symbolic derivation and implementation of 4th-order Time-Convolutionless (TCL) master equations.

List of presentations and participations at conferences

1. Poster presentation on “*Equivalence between the second order steady state for the spin-boson model and its quantum mean force Gibbs state*”, [29th Annual Quantum Information Processing Conference \(QIP 2026\)](#), Riga, Latvia, 24–30 January 2026.
2. Poster presentation on “*Asymptotic TCL4 Generator for the Spin-Boson Model: Analytical Derivation and Benchmarking*”, Quantum Foundations Technology and Applications (QFTA-2025), IISER Mohali, India, 4–8 December 2025.
3. Poster presentation on “*Ultrastrong coupling limit to quantum mean force Gibbs state for anharmonic environment*”, [Second DPG Fall Meeting: 100 Years of Quantum Physics](#), Georg-August-Universität Göttingen, Germany, 8–12 September 2025.
4. Poster presentation on “*Equivalence between the second order steady state for the spin-boson model and its quantum mean force Gibbs state*”, [“100 Years of Quantum Mechanics”](#), IISER Kolkata, India, 18–21 December 2024.
5. Poster presentation on “*Ultrastrong coupling limit to quantum mean force Gibbs state for anharmonic environment*”, [QCMC-24: International Conference on Quantum Communication, Measurement and Computing](#), IIT Madras, Chennai, India, 26–30 August 2024.

Talks and Seminars

1. “*Quantum mean force Gibbs state in weak and ultra-strong coupling limits*”, Academic visit, “Department of Mathematical Physics, Nicolaus Copernicus University, Torun, Poland”, Sept 15-19,
2. Seminar on “*Equilibrium state and dynamics of an open quantum system in weak and strong coupling limits*”, Academic visit, IIT-H, May 7-9 2025.
3. Seminar on “*The Approximate Thermal State for a Quantum System*”, Institute Seminar Days 2024, IMSc, Chennai, India, Jan 23 & 31, 2024.

Achievements

- JEST 2019: [All India Rank 75](#), Percentile: 98.89
- JAM 2019: [All India Rank 146](#), Percentile: 99.06
- During BSc, won 1st prize in State level Inter-Collegiate Fest, Jyoti Nivas College, Bangalore, February 2018 for building a [20-bit programmable computer on breadboard](#).

Professional References

Dr. Sibasish Ghosh

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