# Prem Kumar

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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

- Analytical derivation of the 4th-order Time-Convolutionless (TCL4) generator for Spin-Boson models, benchmarking it against exact numerical methods. We also studied the corrections to the steady state and non-Markovianity of the dynamics. [1, 2]
- Analytical extension of the ultra-strong coupling quantum mean force Gibbs state (the generalization of the Gibbs state when the system-environment coupling is non-negligible) for a large class of anharmonic environments. [3]

## Research Interests

My main research interest is open quantum systems. This includes its theoretical study as well 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.

## 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.

[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.

[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.

***Pedagogical Reviews***

[4] Prem Kumar. "Local harmonic approximation to quantum mean force Gibbs state". In: (2024). arXiv: 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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