Harshit Verma

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Current Location:
Sydney, Australia

Personal Details:

Nationality: Indian
Date of Birth: 12/06/1994

Pronoun: He/him
Gender: Male

Educational Qualifications:

- Doctor of Philosophy (Completed Thesis Examination) 2018 – 2023
  ARC Centre of Excellence for Engineered Quantum Systems (EQUS)
  School of Maths and Physics, University of Queensland, St Lucia, QLD 4072, Australia
  Doctoral thesis Topic: **"Quantum control in probing relativistic effects and thermodynamics"**
  Primary Supervisor: Dr. Fabio Costa
  Co-supervisors: Dr. Magdalena Zych and Prof. Tamara Davis
- Graduation and Post-Graduation 2012 – 2017
  5 year Integrated M. Tech in Engineering Physics, Indian Institute of Technology (BHU), Varanasi, India
  Masters' thesis Topic : "**Generalized Uncertainty Principle**"
  Supervisors: A/Prof. Sunil Kumar Mishra, and Prof. Bhabani Prasad Mandal
  CGPA : **8.73/10**

Research Interests:

Quantum process framework and thermodynamics, Many-body quantum spin systems, Quantum noise

Publications/ Preprints:

- Capela, M., **Verma, H,** Costa, F., & Céleri, L.C., ***Indefinite causal order is not always a resource for thermodynamic processes*.** Preprint : arXiv:2208.03205 (2022).
- Wood C.E., **Verma H.**, Costa F., Zych M. ***Operational models of temperature superpositions.*** Preprint : arXiv:2112.07860 (2021).
- **Verma, H.**, Zych, M., & Costa, F. ***Constraining the number of fundamental quantum degrees of freedom using gravity*.** Preprint : arXiv:2106.15164 (2021).
- **Verma, H.**, Zych, M., & Costa, F. ***Effect of environment on the interferometry of clocks*.** Quantum, 5(1), 525 (2021).
- **Verma, H.**, Chotorlishvili, L., Berakdar, J. et al. ***Quantum teleportation by utilizing helical spin chains for sharing entanglement***. Quantum Inf Process 20, 54 (2021).
- **Verma, H.**, Mitra, T., & Mandal, B.P. ***Schwinger's model of angular momentum with GUP***. Epl, 123(3) (2018).
- **Verma, H.**, Chotorlishvili, L., Berakdar, J. et al. ***Qubit(s) transfer in helical spin chains.*** *Epl, 119(3) (2017).*

Achievements/ Awards:

- Received amazing reviews for the video: "Finding elementary particles using gravity" in Visualize your thesis 2022.
- Awarded the **third prize** in ECA Pitchmasters, a pitching competition held at AIP congress 2021.
- Awarded the overall **first prize** (as a part of team of 4) in EQUS idea factory for proposal writing and presentation on *quantum thermal heat engines*.
- Awarded the **first prize** in 3-Minute thesis competition in the School of Maths and Physics, UQ.
- Awarded UQ research training scholarship for pursuing Ph.D.
- Awarded merit certificate for **second rank** in the Integrated M. Tech Engineering Physics 2017 batch at IIT-BHU.
- Poster awarded the best in research category at Departmental level (**First Position**) and Institute level (**Second position**) at Institute Day 2017, held at IIT-BHU.
- Awarded PG scholarship in the final year of Integrated M. Tech at IIT-BHU.
- Qualified Graduate Aptitude Test in Engineering (**GATE**), Joint entrance screening test (**JEST**), National Eligibility Test (**NET-LS**) held for Ph.D. admissions and Joint Admission test for M.Sc. (**JAM**).

Skills and scores:

- **Programming Languages: Matlab, Mathematica, Python**
- **Python Packages: Multi-processing, QuSpin, QuTip, Qiskit, Scipy optimize, CVXPY, Freqtrade**
- **GRE** Test Scores : **160** (Verbal), **166** (Quantitative), **3.5** (Analytical Writing), **860** (Physics) 2016
- **TOEFL** Score: Total **111** (IBT); **30** (Reading), **29** (Listening), **27** (Speaking), **25** (Writing) 2016

Academic Experience/ Positions of Responsibilities held:

- Member of EQUS Career Development and Mentorship committee (6 months).
- **Convenor :** Served as the **student Convener** of Jigyasa'16: A physics convention held at IIT-BHU in 2016.
- **Coordinator :** Served as the **student Coordinator** of Jigyasa'15: A physics convention held at IIT-BHU in 2015.

Teaching Assistant

- Laboratory course **PHY 1002: Electromagnetism and Modern Physics** for one semester in 2021 (UQ).
- Theory course **PHY101: Classical, Quantum and Relativistic Mechanics** (for first year undergraduates) for three semesters during 2014-2015, 2015-2016 and 2016-2017 (IIT-BHU).
- Theory course **PHY201: Quantum Physics** (for sophomores and junior undergraduates) in the first semester of 2016-17 (IIT-BHU).

Posters/ Talks:

- 2022 | Poster on *"Estimating two temperatures using quantum processes, and Mach-Zehnder interferometer"* presented at the Quantum Thermodynamics (QTD) 2022 conference - online.
- 2022 | Talk on *"Using gravitational decoherence to constrain the number of extended quantum systems"* presented at the APS March Meeting - online.
- 2022 | Poster on *"Two-temperature estimation in the quantum regime: using Mach-Zehnder interferometer and quantum process framework"* presented at the Quantum Australia conference - online.
- 2021 | Oral pitch on *"Using gravity with quantum for fundamental physics"* presented at ECA Pitchmasters, AIP summer meeting at QUT Brisbane.
- 2021 | Talk on *"Using gravity to bound the number of fundamental quantum degrees of freedom"* presented in AIP summer meeting at QUT Brisbane.
- 2021 | Poster on *"Two-temperature estimation in the quantum regime: using Mach-Zehnder interferometer and quantum process framework"* presented in EQUS annual meeting at Noosa, QLD.
- 2021 | Poster on *"Two-temperature estimation in the quantum regime: using Mach-Zehnder interferometer and quantum process framework"* presented in SMP poster day at UQ.
- 2021 | EMCA 3 minute Talk on *"Q-ctrl, baths and their thermometry"* presented at SMP, UQ.
- 2021 | 3MT Talk on "Using gravity and quantum together for predicting fundamental particles" presented at SMP, UQ.
- 2021 | Poster on *"Two-temperature estimation in the quantum regime: using Mach-Zehnder interferometer and quantum process framework"* presented in Quantum Thermodynamics Summer School - online hosted by NCCR SwissMap and Squid.
- 2021 | Talk on *"Effect of environment on the interferometry of clocks"* presented at the RQI - online conference.
- 2020 | Talk on *"Effect of environment on the interferometry of clocks"* presented at QTURN - online conference.
- 2020 | Talk on *"Constraining the fundamental number of quantum degrees of freedom using gravity"* presented in Physics seminar series at UQ.
- 2020 | Poster on *"Constraining the fundamental number of quantum degrees of freedom using gravity"* presented in SMP poster day at UQ.
- 2020 | Poster on *"Effect of environment on the interferometry of clocks"* presented in Quantum Frontiers and Fundamentals conference at RRI, Bangalore.

- 2020 | Talk on *"Effect of environment on the interferometry of clocks"* presented in physics seminar series at IIT-BHU, Varanasi.
- 2019 | Poster on *"Effect of environment on the interferometry of clocks"* presented in EQUS annual meeting at Wollongong, NSW.
- 2019 | Participated in UQ pitch writing competition with my pitch on the topic: "Energy storage in a helical multiferroic quantum battery and its advantages".
- 2019 | Poster on *"Effect of environment on the interferometry of clocks"* presented in SMP poster day at UQ.
- 2019 | Talk on *"Effect of environment on the interferometry of clocks"* presented in Teach at the beach (students' meeting held at Gold Coast, QLD).
- 2017 | Poster on *"Qubit(s) Transfer through Multiferroic Spin Chain Systems"* presented on Institute Day at IIT-BHU.
- Others | Multiple talks and presentations in the quantum foundations and gravity meetings at UQ.

Research Experience:

- **Ph.D. projects**

  - **Project 1: Effect of environment on the interferometry of clocks**

  Quantum interference of *clocks* is a promising avenue to test genuine general relativistic effects in quantum systems. A clock acquires which path information while experiencing different proper times while traversing the arms of a Mach-Zehnder interferometer, leading to a drop in its path visibility. We developed a generalized formulation of interferometric visibility affected by quantum noise on the clock. We found that for small noise and a small proper time difference between the arms, the noise further reduces the visibility, while in more general situations it can either increase or reduce the visibility. As an example, we investigated the effect of a thermal environment constituted by a single field mode and showed that the visibility drops further as the temperature is increased. Additionally, by considering noise models based on standard quantum channels, we showed that interferometric visibility can increase or decrease depending on the type of noise and also the time scale and transition probabilities in the noise model.

  - **Project 2: Constraining the number of quantum degrees of freedom using gravity**

  Fundamental particles are quantization of omnipresent fields which can be visualized as a product of interacting quantum degrees of freedom spread over space. In the low energy scenario, we analyzed the effect of gravity on such extended quantum systems (EQSs) by devising a differential red-shift factor of the system Hamiltonian which depends on the relative position of a nearby massive particle. At zero temperature, by the mere dependence of the ground state of the EQS on the position of the gravitating particle (via the differential red-shift), we established the gravitational decoherence of the massive particle prepared in a spatial superposition. Taking a spin chain as a toy model for an EQS, we identified the number of independent spin chains that can cause reasonable decoherence in the spatial superposition of the massive particle.

  - **Project 3: Measuring two temperatures using a single thermometer**

  Recently, there were efforts to incorporate quantum processes in parameter estimation and channel discrimination tasks leading to the development of a general framework of metrology in the quantum process framework. However, the prospect of simultaneous estimation tasks – that of estimating two or more parameters has not been considered. If used with thermalizing quantum channels corresponding to distinct bath temperatures, the framework of quantum processes constitutes an interesting scenario with the possibility of multi-parameter estimation, specifically multi-temperature estimation using a single thermometer. We have calculated the bounds on the covariance of temperatures, and their attainability for this simultaneous estimation task, using established methods of multiparameter estimation.

- **Collaborative Projects during Ph.D.:**

  - **Making sense of a quantum superposition of temperatures** (with Dr. Carolyn E. Wood, Ph.D. student at EQUS, SMP, UQ)

  In this project, using the interferometric setup with composite particles, and environment(s) defined by two temperatures, we propounded two novel ways in which one could attribute a quantum nature to an inherently fundamental thermodynamic quantity – temperature. In our work, the aforesaid superposition is achieved by

introducing a quantum control DoF in a Mach-Zehnder type interferometer with the quantum controlled evolution of probe exposing it to baths at two different temperatures or a quantum-controlled state of a bath. Apart from putting together the basic framework of this project, my primary contribution was in modelling the pre-thermalization regime, whereby the composite particle does not fully thermalize in a single interaction with the environment, rather, only thermalizes partially. This involved simulating a collisional model for thermalization and obtaining the interferometric visibility for the external DoF associated with the probe, or the control in the relevant cases.

- **Indefinite causal order is not always a resource for thermodynamic processes** (with Dr.Matheus Capela, visiting Ph.D. student from Federal University of Goiás, Brazil)

We analysed the utility of processes in performing thermodynamic tasks (modelled as a system undergoing CPTP maps), which usually result in monotones such as that of free energy. We showed that though a quantum switch leads to the non-trivial effect of an increased free energy over a simple composition of two thermal operations, the same cannot be generalized to all the classes of processes. In this project, my primary contribution was calculating the thermodynamic quantity – *Ergotropy*, with such nontrivial setups in the background playing a role in the evolution of a qubit, thus, adding another dimension to this study. Broadly, ergotropy represents the maximum work that can be extracted from a system using an optimal cyclic unitary. Since our model had many free parameters in the underlying processes – essentially leading to many novel possibilities for the evolution of the qubit – the calculation of (Daemonic) ergotropy involved the usage of methods from classical optimization techniques in combination with the analytical formulae.

- **Generalized Uncertainty Principle** **(M.TECH PROJECT (THESIS))**

I studied the Generalized Uncertainty Principle (GUP) arising out of quantum gravity theories and its implications on quantum mechanical models. Further taking cues from a previous internship, we extended the discussion to PT-symmetric systems particularly Hartmann-Fletcher effect in complex barriers. We developed the creation/annihilation operator formalism of simple harmonic oscillator subject to GUP corrections and used it to obtain angular momentum algebra by Schwinger's Model of angular momentum.

Supervisors: Dr. Sunil Kumar Mishra (Assistant Professor, Department of Physics, IIT-BHU) & Dr. Bhabani Prasad Mandal (Professor, Department of Physics, Institute of Science, BHU).

- **Quantum Spin systems for Quantum Information transfer** **(PROJECT)**

This project entailed a study and simulation of Quantum spin systems (1D) for their application in Quantum information Processing. I successfully tested many such systems having varied interactions (Dzyaloshinskii-Moriya, magnetic field and impurities etc.) for their properties viz. chirality, correlation, magnetization, entropy, and fidelity of spin transfer (one and two qubits). We successfully developed a transfer protocol involving kicking helical spin chains with electric field for achieving a better transmission fidelity, including in sharing entanglement.

Supervisor: Dr. Sunil Kumar Mishra (Assistant Professor, Department of Physics, IIT-BHU).

References:

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