Himanshu Sahu

Curriculum Vitæ

We have art in order not to die of the truth. – Nietzsche

Personal Information

Nome e Cognome	Himanshu Sahu
Gender	Male
Date of Birth	22-07-2002
Address	Department of Instrumental & Applied Physics, Indian Institute of Science, C.V. Raman Avenue, Bengaluru 560012, India
Nationality	Indian

Google Scholar • iNSPIRE-HEP • ORCiD • Linkedin • Github

Experience

06/2024-Present	**Junior Research Fellow**, Department of Instrumentation and Applied Physics, Indian Institute of Science, Bangalore, India.
03/2024-08/2024	**Quantum Intern**, IBM Quantum, IBM Research Lab, Bangalore, India.

Education

Fall 2024	**PhD in Quantum Information**, Perimeter Institute for Theoretical Physics and Institute for Quantum Computing, University of Waterloo, Waterloo, Ontario, Canada. • Perimeter Institute PhD Residency Fellow • Graduate program supervisors – Prof. Sisi Zhou and Ray Laflamme
07/2021–06/2024	**Masters (Research) in Physics**, Indian Institute of Science, Bangalore, India. • CGPA : 9.10/10 (max. typically $\sim$ 9.4) • On track for Distinction in the Major
06/2018-06/2021	**Bachelor in Physics**, Banaras Hindu University, Varanasi, India.. • CGPA : 9.15/10 • Passed in First Division with Distinction

Master thesis

Title	Quantum walk based simulations & algorithms
Supervisor	Prof. Subroto Mukerjee & Prof. CM Chandrashekar
Description	This dissertation details our research on a wide range of ideas from quantum computing – quantum simulation, quantum algorithms, and quantum complexity which are brought together under the umbrella of quantum walks.

Research activity

Brief description	I am a physicist broadly interested in the ideas at the intersection between condensed matter theory, quantum computing, and information theory.

Research Interests

Main interests Quantum optics, Quantum information, Quantum computation, Quantum simulation, Quantum error correction, Quantum algorithms, Quantum sensing, Quantum many-body physics, Open quantum systems, Quantum communication, Quantum chaos.

Research Experience

05/2022-05/2023 **Neutrino oscillations in a quantum walk framework**.
PI: Prof. CM Chandrashekar (Dept. of Instrumentation & Applied Physics, Indian Institute of Sciences)
Summary: By viewing the position space of a quantum walk as an environment, I've developed a novel approach to simulate neutrino flavor change dynamics within an open quantum system framework. This reduces the resource required for simulating quantum walk which include position space.

05/2022-03/2023 **Krylov complexity in open systems**.
PI: Dr. Aranya Bhattacharya (Centre for High Energy Physics, Indian Institute of Science)
Team/Collaborators: Pratik Nandy (Yukawa Institute for Theoretical Physics, Kyoto University), Pingal Pratyush Nath (Centre for High Energy Physics, Indian Institute of Science)
Summary: Our work extended the Krylov construction framework to dissipative open quantum systems coupled to a Markovian bath. This approach accommodates non-Hermitian effects due to the environment. Our investigation of the dissipative transverse-field Ising model and dissipative interacting XXZ chain reveals that initial Lanczos coefficients distinguish integrable and chaotic evolution during weak coupling. As dissipative effects intensify, higher Lanczos coefficients exhibit heightened fluctuations, culminating in similar late-time complexity saturation for both integrable and chaotic scenarios, casting doubt on the concept of late-time chaos.

06/2023-08/2023 **Quantum circuit complexity of quantum walk**.
PI: Dr. Kallol Sen (ICTP-South American Insitute of Fundamental Research) & Dr. Aranya Bhattacharya (Institute of Physics, Jagiellonian University)
Team/Collaborators: Dr. Ahmadullah Zahed (ICTP, Trieste)
Summary: We studied circuit complexity of quantum walk. Notably, we unveil that the Nielson complexity during unitary evolution oscillates, centering around an average circuit depth. Additionally, we reveal that the complexity of the step-wise evolution operator exhibits cumulative and linear growth in relation to the number of steps taken. This observation, from a quantum circuit perspective, implies a sequential application of (approximately) constant-depth circuits, contributing to the attainment of the final state. We explicitly constructed the quantum circuit, and verified the observation. This study contribute to our understanding of relation between quantum complexity and circuit complexity.

06/2023-01/2024 **Out-of-Time-Ordered Correlator's Growth Rate in a $\mathcal{PT}$-symmetric Chaotic System**.
PI: Prof. Subroto Mukerjee (Department of Physics, Indian Institute of Science)
Team/Collaborators: Kshitij Vijay Sharma (Department of Physics, Indian Institute of Science)
Summary: In ongoing work, we studied OTOC as well as complex level-spacing ratio as a diagnose of quantum chaos for the $\mathcal{PT}$-symmetric quantum kicked rotor – a textbook driven chaotic system. The analysis based on complex level-spacing ratio shows that phase space consists of unbroken integrable and chaotic phases, and broken chaotic phase while broken integrable phase is absent. The OTOC shows exponential growth at early time in chaotic phase, as well as at late time in broken $\mathcal{PT}$-symmetric phase.

07/2023-10/2023 **Quantum search algorithm**.
PI: Dr. Kallol Sen (ICTP-South American Insitute of Fundamental Research)
Summary: Building upon the quantum search algorithms, we have extended their applicability to a diverse range of problems spanning multiple fields, such as real-time object tracking, network management, and routing. Our approach involves expanding the database by introducing an additional dimension, similar to error-correction codes, which provides supplementary information, including the category of the search data points. We have applied this method to develop an algorithm for tracking moving particles, but its potential reaches far beyond this specific problem.

08/2023-12/2023 **Krylov complexity in non-local systems**.
PI: Dr. Aranya Bhattacharya (Institute of Physics, Jagiellonian University)
Team/Collaborators: Pingal Pratyush Nath (Centre for High Energy Physics, Indian Institute of Science)
Summary: Motivated by recent works in spin systems with nonlocal interactions, this study investigates operator growth using the Lanczos algorithm in various versions of the Ising model. We find that the non-locality results in a faster scrambling of the operator to all sites. The corresponding Krylov complexities still carry the distinguishability between integrable and chaotic theories in a suppressed way than the local Hamiltonian, which is a result of the faster scrambling for nonlocal Hamiltonian at early times. We investigate behavior of level statistics and spectral form factor as a probe of quantum chaos to study the integrability breaking due to non-local interactions.

11/2023-Present	**Spready Complexity of Random Unitary Circuits**. **Team/Collaborators:** Dr. Aranya Bhattacharya (Institute of Physics, Jagiellonian University), Pingal Pratyush Nath (Centre for High Energy Physics, Indian Institute of Science) **Summary:** In ongoing work, I devised the formulation for evaluating the spread complexity of random unitary circuits. Using this formulation, we studied the complexity in random-haar unitary circuits as well as monitored RUCs.
12/2023-Present	**Information scrambling in Time Crystals**. **Team/Collaborators:** Fernando Iemini (Universidade Federal Fluminense), Pingal Pratyush Nath (Centre for High Energy Physics, Indian Institute of Science) **Summary:** In ongoing work, We are studying information scrambling in Time crystals

Publications

Peer-reviewed journals

[1] A. Bhattacharya, P.P. Nath & H. Sahu, Speed limits to the growth of Krylov complexity in open quantum systems, (2024). Phys. Rev. D 109, L121902 (2024) Letter .
All authors contributed equally to this work.

[2] A. Bhattacharya, P.P. Nath & H. Sahu, Krylov complexity for non-local spin chains. Phys. Rev. D 109, 066010 (2024) .
All authors contributed equally to this work.

[3] A. Bhattacharya, H. Sahu, A. Zahed, and K. Sen, Complexity for one-dimensional Discrete Time Quantum Walk Circuits. Phys. Rev. A 109, 022223 (2024).

[4] H. Sahu & K. Sen, Quantum-walk search in motion. Scientific Reports 14, 2815 (2024) .

[5] H. Sahu & C.M. Chandrashekar, Open system approach to Neutrino oscillations in a quantum walk framework. Quantum Information Processing 23, 7 (2024) .

[6] A. Bhattacharya, P. Nandy, P.P. Nath & H. Sahu, On Krylov complexity in open systems: an approach via bi-Lanczos algorithm. Journal of High Energy Physics 2023, 66 (2023) .
All authors contributed equally to this work.

[7] A. Bhattacharya, P. Nandy, P.P. Nath & H. Sahu, H. Operator growth and Krylov construction in dissipative open quantum systems. Journal of High Energy Physics 2022, 81 (2022).
All authors contributed equally to this work.

Pre-prints under review

[1] H. Sahu, Information scrambling in quantum walks, (2024). arXiv:2406.05865 [quant-ph] .

[2] K.V. Sharma, H. Sahu & S. Mukerjee, Quantum chaos in $\mathcal{PT}$-symmetric Quantum Kicked Rotor, (2023). arXiv:2401.07215 [quant-ph].

In-preparation

[1] H. Sahu, A. Bhattacharya, and P.P. Nath, Spready Complexity in Random Unitary Circuits.
The order of the author and article title may vary in bibliographic citations.

Bibliometric parameters

Indices	h-index 3 total citations 148 (July 2024), iNSPIRE-HEP
	h-index 3 total citations 122 (July 2024), Google-Scholar

Conferences, Seminars, and Schools

Talks

2023	Quantum Information Scrambling in non-local systems. CHEP In-House Symposium, Centre for High Energy Physics, Indian Institute of Science, Bangalore, India 18-19 November 2023

Posters

2023 Simulating Neutrino Oscillations Using Quantum-walk .
Quantum Information Processing and Applications, Harish-Chandra Research Institute, Prayagraj, India 04-10 December 2023.

2023 Quantum Information Scrambling in Dissipative Open Quantum Systems.
Emerging Topics in Quantum Technology, Indian Institute of Technology, Palakkad, India 02-04 November 2023.

2023 Operator Complexity in Open Quantum System.
Condensed Matter meets Quantum Information, International Centre for Theoretical Sciences (ICTS), Bengaluru, India 25 Sep-06 Oct 2023.

2023 Neutrino oscillations in discrete-time quantum walk framework.
Student Conference in Optics and Photonics, Physical Research Laboratory, Ahmedabad, India 27-29 September 2023.

2023 Exploring Operator Growth and Krylov Complexity in Dissipative Open Quantum Systems.
It from Qubit, Perimeter Institute for Theoretical Physics, Waterloo, Ontario, Canada 31 July-4 August 2023 (Online)

Attended Conferences

2023 Quantum Information Processing and Applications.
Harish-Chandra Research Institute, Prayagraj, India 04-10 December 2023.

2023 Emerging Topics in Quantum Technology.
Indian Institute of Technology, Palakkad, India 02-04 November 2023.

2023 Student Conference in Optics and Photonics.
Physical Research Laboratory, Ahmedabad, India 27-29 September 2023.

2023 Photonics 2023.
Indian Institute of Science, India 05-08 July 2023.

Virtually Attended Conferences

2023 It from Qubit.
Perimeter Institute for Theoretical Physics, Waterloo, Ontario, Canada 31 July-4 August 2023.

2023 Machine Learning for Quantum Many-Body Systems .
Perimeter Institute for Theoretical Physics, Waterloo, Ontario, Canada 12-17 June 2023.

2023 Quantum Simulators of Fundamental Physics .
Perimeter Institute for Theoretical Physics, Waterloo, Ontario, Canada 05-10 June 2023.

Attended Schools

2023 Condensed Matter meets Quantum Information.
International Centre for Theoretical Sciences (ICTS), Bengaluru, India 25 Sep-06 Oct 2023

2021 Introductory Summer School in Astronomy and Astrophysics.
Inter-University Centre for Astronomy and Astrophysics, India 10 May-11 June 2021.

Seminars and Panels

2023 Climate Change and Disaster Risk Reduction : Making Sustainability a Way of Life.
Y20 Panel Discussion, Indian Institute of Science, Bangalore, India 12 August 2023.

Teaching Activity

Teaching Assistant

Spring 2023 UP 204 - Intermediate Thermal Physics.
• Undergraduate Course Grader • Organized exams, graded exam sheets, and provided students with detailed feedback.

Honors, Awards & Scholarships

2023	Semi-Finalist, Rhodes Scholarship. • A semi-finalist for the prestigious Rhodes Scholarship, representing the STEM category. • Acknowledged for exceptional academic and leadership qualities during the Rhodes Scholarship application process
2021-2024	IISC MS scholarship. • Beneficiary of the academic and financial provisions provided to Integrated PhD scholars at IISc Bangalore.
2018-2021	INSPIRE Scholarship Awardee (SHE Program). • Awarded the prestigious INSPIRE Scholarship for Higher Education, a selective grant awarded to top 1% performers in XII standard supported by the Department of Science and Technology, Government of India
2017	State Government Academic Excellence Award. • Acknowledged by the State Government for academic achievements in Class X

Other skills

Computer skills

OS	Windows, Linux, HPC
Languages	Python, Processing3, JavaScript, CSS, HTML
Software	Mathematica, LaTeX, Matlab, Microsoft office, Origin, . . .
Libraries	Numpy, Scipy, Qiskit, QuSpin, QuTip, Sympy, Open Fermion, joblib, p5.js, . . .

Linguistic skills

Hindi	Mother tongue
English	Fluent : TOEFL iBT Score - 99/120 (L:28-R:25-W:25-S:21)

Volunteering

2020-Present	Contributor on Physics Stack Exchange. • Top 2% overall • 11K+ Reputation • ~ 284K people reached
2023-Present	IISC Nature Club Coordinator. • Raising awareness towards the need to protect environment • Organize walks in the forest and treks
2023 & 2024	IISC Annual Open Day. • On 4th March 2023 • Presented experiments and counselled youths for a career in science.
2023	Waste Collector in GOA Monsoon Trekking 2023
2023	Behavioral Experiment Test Subject Volunteer : Vision Lab IISC.
2023	EEG Experiment Test Subject Volunteer : MILE Lab IISC
2023	Functional MRI Experiment Test Subject Volunteer : Centre for Neuroscience IISC

Extracurricular

2023	National Monsoon Trekking cum Training Expedition- Goa, 2023. Youth Hostels Association of India Goa State Brach, July-August 2023.

References

Prof. **CM Chandrashekar**, Adjunt Faculty at Instrumentation and Applied Physics, Indian Institute of Sciences, Bengaluru, India.
Email: chandracm@iisc.ac.in

Prof. **Subroto Mukerjee**, Associate Professor, Indian Institute of Science, Bengaluru, India.
Email: smukerjee@iisc.ac.in

Dr. **Aranya Bhattacharya**, Postdoc at Institute of Physics, Jagiellonian University, Krakow, Poland.
Email: aranya.bhattacharya@uj.edu.pl

Prof. **Sumilan Banerjee**, Associate Professor, Indian Institute of Science, Bengaluru, India.
Email: sumilan@iisc.ac.in

Dr. **Kallol Sen**, Postdoc at ICTP-SAIFR, Sao Paulo, Brazil.
Email: kallolmax@gmail.com

Github Directories

pyhobo
: PyHOBO allows to construct Hamiltonian for Variation Quantum Algorithms based on Higher-Order Binary Optimization.

q-complexity
: The directory contains code files related to work done in finding the quantum circuit complexity of quantum walk.

q-search
: The directory contains code files related to work done in quantum-walk search in motion.