

Mahadevan Subramanian

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Education

- Indian Institute of Technology, Bombay
- Third year undergraduate, Engineering Physics

CGPA: 9.68/10

Jul 2019 – Present

Pursuing Honors in Physics and a Minor in Computer Science and Engineering

Research Experience & Key Projects

Qudits for efficiently generating higher moments of Hermitian operators [report]

Guide: Professor Sai Vinjanampathy, IIT Bombay

Jul 2021 – Present

- Examined the methods of **block-encoding** matrices, **qubitization** and the **quantum SWAP test** for realizing non-unitary quantum operations and finding their state overlaps and extending to higher powers of these non-unitary operations.
- Analyzing error propagation in generalized qudits using more than 2 quantum levels using **mixed state circuits**. Controlled versions of arbitrary qubit unitary gates have been demonstrated using internal swap gates for 4 level qudits with $\mathcal{O}(n)$ gates.
- Studied **quantum error correction** theory along with crucial bounds such as the Hamming bound and Knill-Laflamme bound. Analyzed concatenation success probabilities for the 5-qubit code and an encoding of the code for arbitrary qudits.

State population transfers using Rabi Oscillations [report, code]

Guide: Professor Barak Dayan, Weizmann Institute of Science

Mar 2021 – Jul 2021

- Examined the **Jaynes-Cumming Hamiltonian** and simulated **Rabi oscillations** and **Collapse and revival** using QuTip.
- Obtained accurate proportionality constant values for modelling intensity of electromagnetic waves required for a certain Rabi frequency for **hyperfine levels** of **Rubidium 87** using calculations and reviewing literature on existing experiments.
- Studied the **stimulated Raman adiabatic passage** for population transfer using coherent electromagnetic pulses. Additionally noted the necessity of two photon detuning caused by **Autler Townes shifts** for unequal Rabi peaks.
- Simulated an adiabatic state population transfer with an efficiency of 99.5% with coherent Rabi pulses with peaks of 100 MHz and 10 MHz with single photon detuning of 1 GHz and two photon detuning of 2.18 MHz over $25\mu\text{s}$.
- Prepared a framework to simulate and optimize parameter choices for a N -level **chain STIRAP** and **cavity-STIRAP**.

Reading Project on Quantum Simulations [report]

Guide: Professor Alok Shukla, IIT Bombay

Oct 2020 – May 2021

- Studied the problem of quantum simulation and some implementations of **analog and digital quantum simulation**.
- Studied **Hartree-Fock theory** along with its canonical transformations with an implementation using **Given's rotations**.
- Explored physical implementations of **Bose Hubbard** hamiltonian using atoms and ions to observe phase transitions and **NMR spectroscopy** for ground state energy calculation of the hydrogen molecule.
- Reviewed **Variational Quantum Eigensolvers** and their applications in simulations of molecules and quantum magnets. Reviewed a modified version of VQE called **ctrl-VQE** which optimizes pulse shapes instead of circuit parameters.
- Studied **Configuration Interaction** theory, methods for reducing the CI space and vectorized algorithms for Full CI.

Measurement Theory in Quantum Mechanics [report]

Guide: Professor Amber Jain, IIT Bombay

Apr 2020 – Aug 2020

- Reviewed the different interpretations of quantum mechanics including **Bohmian Mechanics**, **Many Worlds Interpretation** and the **Ghirardi-Rimini-Weber** theory to appreciate their different approaches to measurement.
- Inspected the possible breaking points for each of these theories and also understanding their respective advantages.
- Investigated papers on experimental methods aimed at bringing out differences between these multiple interpretations.
- Examined certain experiments which aimed to find the quantum to classical transition point according to the **Ghirardi-Rimini-Weber** and **Continuous Spontaneous Localization** models.

Scholastic Achievements

- Awarded the **Institute Academic Prize** IIT Bombay, for exemplary academic performance. Aug 2021
- Secured **Department Rank 3** (of 51 students) after 5th Semester of B.Tech (Department of Physics) Dec 2021
- Joint Entrance Exam**
 - Achieved **99.58 percentile** in **JEE Advanced** among **200,000 participants** for entrance to IITs. May 2019
 - Among **top 0.09 percentile** in **JEE Main Paper 1** amongst **1.5 million students** across India. Apr 2019
- SAT Scores**
 - SAT I: Scored 800/800 in Mathematics section, and a total score of 1460/1600. May 2018

- SAT Subject Test: Scored 800/800 in Mathematics II and Physics tests. Oct 2018
- o Recipient of the esteemed **Kishore Vaigyanik Protsahan Yojana (KVPY) Fellowship** from IISc. May 2018

Other Projects

Bell's measure of classical optical coherence [executable paper]

Prof: Anshuman Kumar, Course Project, Waves, Oscillations and Optics

Mar 2021 – Apr 2021

- o Using python, demonstrated how Bell's measure can be used as a metric to quantify coupling of degrees of freedom in a beam of light hence demonstrating a classical analogue of quantum entanglement using polarization and parity.
- o Studied **Jones calculus** and optical devices such as half and quarter wave plates and the **Mach-Zender interferometer**.
- o Proposed a **parity sensitive polarization modifying** device using a combination of a PS-MZI and a half wave plate.
- o Proved **two qubit universality** for the system of the two DOFs of polarization and parity of the light beam.

Quantum Field Theory [report]

Reading Project, Summer of Science, Maths and Physics Club, IIT Bombay

May 2021 - Jul 2021

- o Studied variational calculus, manifolds and Lagrangian mechanics on them, symmetries and symmetry breaking, Klein-Gordon field, Feynman diagrams, Dirac field and the hole theory under the guidance of a senior student mentor.

Resynchronization of circadian oscillators, east-west asymmetry of jet-lag [report, code]

Prof: Amithabha Nandi, Course Project, Non-linear Dynamics

Sep 2020 – Nov 2020

- o Modelled **suprachiasmatic nucleus** cells which are responsible for circadian rhythms to understand jet-lag.
- o Making use of the **Forced Kuramoto model** and studying the east-west asymmetry of jet-lag by simulating this model.
- o Extended the model to account for continuous travel instead of instantaneous and observed slightly varying dynamics.

Higher moments of average of transverse momentum of p-p collisions [report, code]

Prof: Sadhana Dash, Course Project, Data Analysis and Interpretation

Oct 2020 – Nov 2020

- o Analysed data of transverse momentum of proton-proton collisions at 13 TeV obtained using Pythia Generator 8.
- o Calculated higher moments of the average transverse momentum for different multiplicity classes using **ROOT** macros.
- o Observed the changing values of standardized variance, intensive and standardized skewness for different multiplicities.

Quantum Information and Computing [report]

Reading Project, Summer of Science, Maths and Physics Club, IIT Bombay

Apr 2020 - Jun 2020

- o Studied reversible computation, quantum teleportation, superdense coding, quantum measurement, quantum circuits, Grover's algorithm, quantum fourier transform, quantum phase estimation and the hidden subgroup problem.
- o Implemented unitary decompositions, phase estimation, discrete logarithms and the BB84 protocol using **Qiskit** and **Q#**.

Deep Learning for Leaf Disease Detection [website, code]

Institute Technical Summer Project, Institute Technical Council

Apr 2020 - Jun 2020

- o Developed a **DenseNet** model in **TensorFlow** which diagnoses diseases in apple leaves with over **95%** accuracy.
- o The aforementioned model could classify any given image of apple leaf as healthy or having rust or scab disease or both.
- o Built and deployed a **website** where one can upload images of apple leaves and obtain the results predicted by the model. The backend of the website was developed on Django, and HTML, CSS and JS were used for the frontend.

Presentations

The Quantum Measurement Problem [presentation]

Maths and Physics Club, IIT Bombay

March 2021

- o Discussed the quantum measurement problem by introducing **Wigner's friend paradox** and it's extended version. Also explained the no-go theorem proposed on the extended version which was disproven using **Bohmian mechanics**.

Positions of Responsibility

Manager, Maths and Physics Club, IIT Bombay

Institute Technical Council, IIT Bombay

May 2021 – Present

- o **Leading** a team of **5 conveners** towards fostering the enthusiasm of **500+ students** in Physics and Math and having an outreach of **10,000+ enthusiasts** online.
- o Responsible for organising several institute-wide competitions, scientific documentary screenings, group discussions and lectures to promote interest in and maintain an enthusiastic community for Mathematics and Sciences.
- o Supervised the Conduction of Summer Of Science 2021, a novel initiative through which nearly **600 students** got an opportunity to pursue reading project in a topic of their interest, under the Guidance of over **200 student senior mentors**.

Department Academic Mentor

Department Academic Mentorship Program, IIT Bombay

Jun 2021 – Present

- Mentoring 8 sophomores in the department, providing academic guidance and general counselling.
- Involved in bridging the student-faculty gap and taking up activities promoting student interaction.

Teaching Assistant, PH 107 (Quantum Physics and Application)

Instructor: Prof. CV Tomy, Department of Physics, IIT Bombay

Dec 2020 – Mar 2021

- Responsible for conducting tutorials for a class of 40 students, guiding and mentoring them with their coursework.
- Conducted and evaluated quizzes for the course and held doubt sessions when necessary.

Moderator, Quantum Computing Workshop [workshop material]

Maths and Physics Club, IIT Bombay

Jul 2020 – Aug 2020

- Developed course-content to moderate an 8-day **Quantum Computing Workshop** for introducing **Qiskit** and basic concepts of Quantum Computing which attracted **500+** students from multiple universities across India.
- Designed questions involving coding to supplement theoretical understanding of topics such as **BB84 protocol**, **Grover's algorithm** and **Quantum Fourier transform** and their applications such as period finding and discrete logarithms.
- Conducted live hands-on-sessions and created presentations for guiding the participants to understand the underlying concepts and clearing doubts and moderated a forum with 200+ active participants for clearing doubts.

Technical Skills

- **Languages:** C++, Python, Q#
- **Packages & Softwares:** Qiskit, QuTip, NumPy, SciPy, Matplotlib, SymPy, Pandas, TensorFlow, ROOT
- **Others:** HTML, CSS, AutoCAD, Solidworks, Arduino IDE

Relevant Courses

- **Physics :** Quantum Information & Computing*, Introduction to Condensed Matter Physics*, Electromagnetic Theory*, Statistical Physics*, Quantum Mechanics I & II, Photonics, Group Theory Methods, Waves & Oscillations & Optics, General Relativity, Classical Mechanics, Introduction to Special Theory of Relativity, Non-linear Dynamics, Thermal Physics
- **Math :** Numerical Analysis, Complex Analysis, Partial Differential Equations, Linear Algebra, Calculus
- **Computer Science :** Introduction to Machine Learning*, Design and Analysis of Algorithms, Data Structures & Algorithms, Logic for Computer Science, Computer Programming and Utilization
- **MOOCs :** Completed **Deep Learning Specialization** offered by **deeplearning.ai** (Coursera)
- **Other :** Quantum Transport in Nanoelectronic Devices*, Electronic labs - Digital, Microprocessors & Analog, Data Analysis and Interpretation, Digital Systems, Economics, Physical Chemistry

Courses marked with a * will be completed in Spring 2022

Extracurricular Activities

Core and Technical.....

- Completed the **IBM Quantum Challenge**, a quantum programming challenge based on **Qiskit**. May 2020
- Built a bluetooth controlled four wheeled bot which was later modified to be a line-follower bot. Oct 2019
- Secured **1st** place in the **Observation Planning GC** (inter-hostel astronomy competition). Oct 2019

Culturals.....

- Composed an original score for IIT Bombay's first Radio-play - "Atithi", released on Spotify. Jan 2021
- **Institute Cultural Summer Project** Aug 2020
 - Composed two original songs using a digital audio workstation which have been released on various streaming platforms under **Symphony**, music club of IIT Bombay.
- **Goonj GC, Music Arcade GC** (inter-hostel music competitions) Feb, Mar 2020
 - Performed keyboard in **Goonj GC** and arranged an original piece that was performed by our band.
 - Secured **2nd** position in **Music Arcade GC** and was awarded best keyboardist.
- Performed keyboard in **Surbahaar**, an annual musical event in IIT Bombay with an audience of 2,000 people