Akhil Francis

Curriculum Vitae

Personal Information

Affiliation: Physics Graduate Student , North Carolina State University

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Education

2017 August - Present: **PhD, Physics Major**, *North Carolina State University*, North Carolina, United States, *CGPA 4.00/4.00*

2022 June - Present: **Visiting Scholar**, *Oak Ridge National Laboratory (ORNL)*, Tennessee
Performing a Machine learning project releted to entanglement witness and benchmarking quantum machines under the guidance of Dr. Kathleen Hamilton and Dr. Raphael Pooser as a part of PhD research.

2011 August - 2016 May: **BS-MS Dual Degree, Physics Major**, *Indian Institute of Science Education and Research Mohali*, Punjab, India, *CPI: 8.0/10*

Selected for INSPIRE SHE fellowship, of Department of Science and Technology, Govt. of India, to study five year integrated bachelors and masters.

Ph.D. Research

Topics: Condensed Matter Physics, Quantum Computation

Advisor: Dr. Alexander Kemper

Description: My research is about using quantum algorithms to study the physics of condensed matter systems, especially spin systems. I have completed three projects and I am working on other projects.

Project 1: *Machine learning for benchmarking of quantum machines*. Here we use supervised and unsupervised **machine learning** techniques to explore benchmarking of quantum machines. This is an ongoing project.
Project 2: *Fischer zeros to study Dynamical phase transitions*. We compute Fischer zeros using quantum computers to study **dynamical phase transitions**. This work is currently in progress.
Project 3: *Subspace Diagonalization on Quantum Computers using Eigenvector Continuation*. Here we use Eigenvector Continuation to perform **quantum subspace diagonalization**. We find the ground state and energy efficiently by solving a generalized eigenvalue equation in an appropriate subspace. We use low energy states at a few points of the parameter space as the basis vectors for the subspace.

We have demonstrated the method for interacting spin models and hydrogen molecule as a quantum chemistry example. This work is available in arxiv.

Project 4: *An entanglement-based volumetric benchmark for near-term quantum hardware*. Here we use **entanglement witnesses** of graph states to benchmark quantum machines. This work is available in arxiv.

Project 5: *Determining ground-state phase diagrams on quantum computers via a generalized application of adiabatic state preparation*. Here we are using generalized **adiabatic evolution** to find critical points of quantum phase transitions in a quantum computer. We have demonstrated the technique in XY model for small systems in IBM quantum machines. This work is published in Symmetry.

Project 6: *Many-Body Thermodynamics on Quantum Computers via Partition Function Zeros*. Here we have shown that Lee-Yang zeros and Fisher zeros can be measured using a quantum algorithm. This gives us information about the partition function which in turn is used to compute **thermodynamic** quantities. The qualitative nature of Lee-Yang zeros has been used to signal quantum phase transitions in the 1-D XXZ spin model. This is relevant for the present-day noisy machines and has been demonstrated in the ion-trap quantum machine for a two site system. This work is published in Science Advances.

Project 7: *Quantum Computation of Magnon Spectra*. Here we tailored a known algorithm to compute spin-spin **correlators** of one dimensional (1-D) Heisenberg model and simulated it in IBM quantum machines. We analyzed the noisy data and obtained the magnon spectra for the 4 site chain. This work is published in Physical Review B.

Technical Skills

Programming	Python, C, C++
Quantum Computing	QISKIT | search-compiler, QISKIT-Nature
Data Analysis	Pandas, NumPy, Scipy, Matplotlib
Machine Learning	Scikit-learn, Keras
Math	Mathematica
Writing	LaTeX, MS Office
Softwares	Git, Tmux | Inkscape, Gnuplot

Publications

2022 September 21 **Subspace Diagonalization on Quantum Computers using Eigenvector Continuation**, Akhil Francis, Anjali A. Agrawal, Jack H. Howard, Efekan Kökcü, Alexander F. Kemper, arXiv:2209.10571 (2022).
Citations count as of December 2, 2022, | Google scholar: 1

2022 September 1 **An entanglement-based volumetric benchmark for near-term quantum hardware**, Kathleen E. Hamilton, Nouamane Laanait, Akhil Francis, Sophia E. Economou, George S. Barron, Kübra Yeter-Aydeniz, Titus Morris, Harrison Cooley, Muhun Kang, Alexander F. Kemper, and Raphael Pooser, arXiv:2209.00678 (2022).
Citations count as of December 2, 2022, | Google scholar: 0

2021 December 8 **Determining ground-state phase diagrams on quantum computers via a generalized application of adiabatic state preparation**, A. Francis, E. Zelleke, Z. Zhang, A. Kemper, and J. Freericks, Symmetry 14(4): 809 (2022).
Citations count as of December 2, 2022, | Google scholar: 6

2021 August 18 **Many Body Thermodynamics on Quantum Computers via Partition Function Zeros**, Akhil Francis, D. Zhu, C. Huerta Alderete, Sonika Johri, Xiao Xiao, J.K. Freericks, C. Monroe, N. M. Linke, A.F. Kemper, Science Advances 7, 2447 (2021).
Citations count as of December 2, 2022, | Google scholar: 15

2020 January 9 **Quantum computation of magnon spectra**, A. Francis, J. Freericks, and A. Kemper, Phys. Rev. B 101, 014411 (2020).
Citations count as of December 2, 2022, | Google scholar: 36

Presentations

2022 April 6 **Graduate Student Research Symposium**, poster presentation on "Many-Body Thermodynamics on Quantum Computers via Partition Function Zeros" during the Graduate Student Research Symposium at North Carolina State university.

2022 March 14-18 **March Meeting, APS**, oral presentation on "Determining ground-state phase diagrams on quantum computers via a generalized application of adiabatic state preparation" during the APS march meeting at Chicago

2021 October 21 **Quantum Information class**, virtual oral presentation on "Quantum Computation of Spin Systems" at Quantum Information class North Carolina State University.

2021 March 15-19 **March Meeting, APS**, virtual oral presentation on "Many-Body Thermodynamics on Quantum Computers via Partition Function Zeros" during the virtual APS march meeting.

2020 November 5-6 **South Eastern Section American Physical Society (SESAPS)**, virtual oral presentation on "Many-Body Thermodynamics on Quantum Computers via Partition Function Zeros" during the virtual SESAPS meeting.

2020 October 24 **Quantum Information class**, virtual oral presentation on "Quantum Computation of Spin Systems" at Quantum Information class North Carolina State University.

2020 October 6 **Kwek group meeting**, invited virtual oral presentation on "Quantum Computation of Spin Systems" at Kwek group meeting, National University of Singapore.

2020 July 7 **Preliminary Exam Talk**, virtual oral presentation on "Quantum Computation of Spin Systems" at North Carolina State University as a part of my Preliminary exam for my Ph.D. candidacy.

2020 March **March Meeting, APS**, uploaded a talk on "Magnon Spectra using Quantum Computers" as a part of virtual march meeting
http://meetings.aps.org/Meeting/MAR20/Session/D07.5

2019 November 7-9 **South Eastern Section American Physical Society (SESAPS)**, oral presentation on "Magnon Spectra using Quantum Computers" on the 86th annual meeting of SESAPS at Wrightsville Beach, North Carolina.

2019 August 9 **Quantum Friday**, oral presentation on "Magnon Spectra using Quantum Computers" during the "Quantum Friday" meeting at North Carolina State University.

2019 June 6-7 **NISQ**, poster presentation on "Evaluating Many-Body Correlation Functions using Quantum Computation" during NISQ conference at University of Maryland.

Code

2022 PhD **Eigenvector Continuation**, Contributed to the published code for Eigenvector Continuation project.

Computational Projects

2019 PhD **Density Matrix Renormalisation Group (DMRG)**, The project was done as a part of the Advanced Computational Physics course. In this project, I studied the single particle version of DMRG as well as the standard many-body DMRG algorithm. For the single-particle case, the ground state energy and wave function of the particle in a box were calculated. For the many body version, ground state energy of one dimensional Heisenberg model was computed using both infinite size and finite size version algorithm.

2018 PhD **Entanglement Entropy of One Dimensional Ising Model**, The project was done as a part of the Computational Physics course. In this project, I reproduced the results of the paper on the 'Exact Ising model simulation on a quantum computer' and computed the entanglement entropy of the ground state of a bipartite system using the SWAP method.

2015 BS-MS **Relativistic orbits**, A group computational project on 'Relativistic orbits' was done as a part of the 'Computational methods in Physics' course. In this project using the Runge-Kutta methods for solving partial differential equations, different kinds of relativistic orbits were simulated. Also, the relativistic correction of the precision angle of mercury was estimated.

2011 10+2 **Graphiti**, This software was developed in C++ as a part of a 10+2 computer science project with two other group members. It is used for geometric calculations like finding the area of any polygon, finding the best fit line for a set of points.

Master's Thesis

Title *CP violation in Quark and Leptonic sectors*

Supervisor Prof. Manmohan Gupta, Department of Physics, Punjab University

Description The project was about studying CP violation and estimating Jarlskog invariant and the corresponding CP violating phase, in leptonic sector using unitarity triangles taking analogy from quark sector.

Conferences and Workshops

2021 June 14-18 **Quantum Error Correction course**, attended the one week online lectures organised by IBM.

2021 January 11-15 **Quantum Foundry Winter School**, attended the one week online winter school organised by the UCSB NSF Quantum Foundry.

2020 January 28-30 **VQE course**, attended the workshop on Variational Quantum Eigensolver at TJ Watson Research Lab in Yorktown Heights, New York organised by IBM.

2019 June 3-5 **TQC**, attended the Theory of Quantum Computation conference held at University of Maryland.

2019 April 24-25 **Quantum Computing User Forum**, attended a half day software training session on QISKIT and then a one day talks about quantum computing held at Oak Ridge National Laboratory, Tennessee.

2019 February 26 - March 1 **Qiskit Camp**, attended the talks, training session on QISKIT held at IBM Thomas J. Watson Research Center at Yorktown Heights, NY. Also attended the hackathon held at Killington, VT. The hackathon project was to emulate braiding of Majorana fermions using tranverse Ising chain in a quantum computer.

2016 April 6-9 **PHENO1@IISERM**, attended workshop on Beyond Standard Model Physics at IISER Mohali.

Internships

2012 Summer **Summer Project (BS-MS)**, *Indian Institute of Science Education and Research (IISER)*, Mohali
Studied Special Theory of Relativity mainly from books, 'Essential Relativity' by W.Rindler and 'Introduction to Special Relativity' by Robert Resnick under the guidance of Dr. Jasjeet Singh Bagla.

2011 Summer **Summer Project (BS-MS)**, *Indian Institute of Space Science and Technology (IIST)*, Thiruvananthapuram
Studied basic principles of Quantum Mechanics mainly from the book, 'Introduction to Quantum Mechanics' by David J. Griffiths, under the guidance of Dr. Sudheesh C.

Teaching and Mentoring

2020 Summer - 2021 Summer Mentored two undergraduate students as part of a research project. The project is about using generalized adiabatic evolution in finding quantum phase transitions in a quantum computer. This work is published in Symmetry.

2017 Fall, 2017 Spring, 2018 Fall Teaching Assistant (TA) for the Problems Solving Session of course PY 205, Physics for Engineers and Scientists I. Mostly guiding students to solve Classical Mechanics Problems.

2017 Summer Aided in designing and upgrading laboratory experiments for undergraduate students in 'WebAssign' and performed captioning of video lectures.

Relevant Courses

2019 PhD **Advanced Computational Physics**, *3 credit*, main topics were Travelling Salesman and simulated annealing, Diffusion Monte Carlo and ground state energy, Variational Monte Carlo and ground state energy, Machine Learning. I used Python for this course, grade: A+.

2018 PhD **Physics of Quantum Computing and Information Science**, *1 credit*, main topics were Jordan Wigner Transformation, Quantum Fourier Transformation, Bogoliubov Transformation and physics of different types of quantum computers, grade: Satisfactory.

2018 PhD **Computational Physics**, *3 credit*, main topics were Random Walks and Diffusion, Monte Carlo simulations, Molecular Dynamics, solving partial differential equation using greens function. I mainly used Python for this course, grade: A.

2017, 2018 PhD **Quantum Mechanics I, Quantum Mechanics II**, *3 credit, 3 credit*, together in both courses, mainly covered Modern Quantum Mechanics by J.J. Sakurai, grade: A,A.

2015 BS-MS **Computational Methods in Physics**, *4 credit*, covered some numerical techniques like Runge-Kutta approximations, interpolation etc.. I used C language for this course, grade: A.

2014 BS-MS **Quantum Computation and Quantum Information**, *4 credit*, covered topics from the book Quantum Computation and Quantum Information by Isaac Chuang and Michael Nielsen. Some topics covered were quantum gates, quantum algorithms, quantum cryptography, grade: C.

2013 BS-MS **Quantum Mechanics**, *4 credit*, covered topics from the book Modern Quantum Mechanics by J.J. Sakurai, grade: B.

References

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