ADITHYA A RAO

adithyarao3132001@gmail.com adithyarao3103.github.io github.com/adithyarao3103

Education

5-year Integrated MSc | ***Physics***

National Institute of Technology, Surat, India 2019 - 2024

- Masters Thesis - *Gribov Problem and Stochastic Quantization*
- Advisors - Prof. Laurent Baulieu & Dr. Vikash K. Ojha
- CGPA - 9.77 /10 ($\equiv$ 97.7%)
- **University Gold Medalist**

Publications

V. K. Ojha, **A. A. Rao**, and S. D. Pathak, "Estimating the Age of Universe via Scalar Field," in Proceedings of the XXV DAE-BRNS High Energy Physics (HEP) Symposium 2022, 12-16 December, Mohali, India, vol. 304, S. Jena, A. Shivaji, V. Bhardwaj, K. Lochan, H. K. Jassal, A. Joseph, and P. Khuswaha, Eds., Singapore: Springer Nature Singapore, 2024, pp. 1015-1016. doi:10.1007/978-981-97-0289-3_272.

V. K. Ojha, **A. A. Rao**, and S. D. Pathak, "Interacting tachyonic scalar field II," 2023, doi: 10.48550/ARXIV.2305.00277. (**arXiv Preprint**)

Conference Presentations

V. K. Ojha, **A. A. Rao**, and S. D. Pathak. (2022), *"Estimating the Age of Universe via Interacting Tachyonic Scalar Field"*. XXV DAE-BRNS High Energy Physics Symposium 2022. Poster presentation.

Honors and Awards

2024 Young Scientist Participant, 73rd Lindau Nobel Laureate Meeting in Physics, selected as a part of the Indian Delegation, one of 640 international young scientists.

2023 DAAD-WISE award, fully funded research project at FSU Jena, one of 130 Indian students.

2021 IASc, INSA, NASI - SRFP award, fully funded research project at PRL Ahmedabad, one of 100 Indian students.

2019 Department of Science and Technology, Government of India - INSPIRE award, for exceptional performance in high school examinations. Awarded to top 1% students of the country.

Relevant Technical Skills

Programming Languages: C++, C, MATLAB, FORTRAN, Python (ML/DL using PyTorch, NumPy, TensorFlow)

Data Analysis Tools: ROOT

Computer Algebra Systems: Mathematica, SymPy

Typesetting Tools: LaTeX, Microsoft Office

Version Control: Git, GitHub

Research Projects

Gribov Ambiguity and Stochastic Quantization (Master's Thesis) [Aug 2023 - May 2024]

Supervisors: Prof. Dr. Laurent Baulieu, Sorbonne University, Paris & Dr. Vikash K. Ojha, SVNIT, Surat.

Links: [Thesis][Certificate]

Overview:

- Conducted a non-perturbative analysis of the Gribov problem in Quantum Yang-Mills theory, examining Gribov copies' impact and the path integral restriction to the Gribov region, with implications for gluon confinement.
- Presented stochastic quantization formalism as an alternative to quantizing field theories. Explicitly quantized scalar field theory and pure gauge field theory, demonstrating what 'gauge fixing' translates to in stochastic quantization.
- Further, displayed, following Zwanziger, that the gauge fixing can also be done by introducing a non-conservative drift force along the gauge orbits and that such a force implicitly constraints the theory to the Gribov region, therefore leading to a theory free of Gribov Problem.

Spanning Trees on a Lattice [Dec 2023 - Jan 2024]

Supervisor: Prof. Dr. Sourendu Gupta, TIFR, Mumbai

Links: [Report][GitHub]

Overview:

- Demonstrated that imposing a spanning tree on a lattice will map the local gauge transformed configurations to global gauge transformed configurations.
- Discussed Kirchoff's Matrix Tree Theorem and its application to counting the spanning trees on a lattice.
- Developed a general algorithm to generate all the spanning trees of a lattice and to find the local gauge transformation that transforms one spanning tree to another.
- Implemented the counting algorithm, generating algorithm, and the algorithm to find the gauge transformation between the trees in Mathematica, and discussed the computational challenges and possible improvements.

BFSS Model on the Lattice (DAAD-WISE project) [May 2023 - Jul 2023]

Supervisor: Dr. habil. Georg Bergner, Friedrich-Schiller-Universität Jena, Germany

Links: [Report][GitHub]

Overview:

- Extended the C++ implementation of the lattice BFSS model by writing observables for Energy, R^2, and gauge-invariant 4-point correlator in the Bosonic sector of the theory, and the total energy in the complete (Bosonic + Fermionic) theory.
- Developed statistical analysis pipelines for the simulation data to verify the model's behavior and the codebase's integrity.
- To quantify the origin of the observed anomalous behavior in the 4-point correlator, developed tests and also implemented the correlators in the FORTRAN code. Observed that the anomalous behavior is characteristic of the Bosonic sector of the theory and not a programming artefact, and that it vanishes when interactions are turned off, and also in the complete theory (Bosonic + Fermionic) with interactions.

Particle Dark Matter: Existence And Constraints [May 2022 - Jul 2022]

Supervisor: Dr. Ranjan Laha, Center for High Energy Physics, Indian Institute of Science, Bangalore, India.

Links: [Report][Certificate]

Overview:

- Explored the necessity of Dark Matter in Cosmological Models.
- Examined the constraints on the properties of Particle Dark Matter from cosmological observations.

Lepton Oscillations (IASc, INSA, NASI - SRFP project) [Jun 2021 - Dec 2021]

Supervisor: Prof. Srubabati Goswami, Senior Professor, Physical Research Laboratory (PRL), Ahmedabad, India.

Links: [Report][Certificate]

Overview:

- Addressed the question "Why do charged leptons not oscillate?" in connection to the oscillations observed in the neutrinos.
- In connection with the above question, quantified the coherence distance of the flavor superpositions, which turn out to be very small for the charged leptons, thus ruling out the possibility of experimental observation of oscillations.

Statistical and Thermodynamic properties of Quark Gluon Plasma [Apr 2021 - Jun 2021]

Supervisor: Dr. Arvind Kumar, Dr. B R Ambedkar National Institute of Technology, Jalandhar, India.

Links: [Report]

Overview:

- Obtained a crude bound on the phase boundaries of the quark-gluon plasma via its statistical and thermodynamic properties.
- Addressed the question of the possibility of producing quark-gluon plasma in the laboratory, based on the thermodynamic phase diagram.

Mini-projects (as a part of the Integrated MSc curriculum)

Interacting Tachyonic Scalar Field as Dark Energy Candidate [Aug 2022 - Dec 2022]

Supervisor: Dr. Vikash K Ojha, Sardar Vallabhbhai National Institute of Technology, Surat, India.

Links: [Preprint]

Overview:
- Modeled the dark energy as a Tachyonic Scalar Field that interacts with the matter content of the universe.
- Calculated the evolution of the various parameters, especially the functional form of scale factor and the Age of Universe.
- Obtained the constraints on the interaction term from the age of the universe calculations.

Magnetic Monopoles [Jan 2022 - Apr 2022]

Supervisor: Dr. Vikash K Ojha, Sardar Vallabhbhai National Institute of Technology, Surat, India.

Links: [Report]

Overview:
- Modeled a classically consistent two-potential formulation for classical electrodynamics with magnetic charges.
- Constructed the Lagrangian for the two-potential theory and derived Maxwell's equations with magnetic sources and Lorentz force equations for dyons using Euler-Lagrange equations.

Dynamical Symmetries of the Kepler System [Aug 2021 - Dec 2021]

Supervisor: Prof. K N Pathak, Sardar Vallabhbhai National Institute of Technology, Surat, India.

Links: [Report]

Overview:
- Studied the $SO(4)$ symmetry group of the Kepler system.
- Examined the observation that the nontrivial symmetry operations that modify the eccentricity of the elliptic orbit keeping the energy constant translate to simple rotations in a 4D space with non-trivially reparameterized time.

Independent Projects

Numerical Simulations of the Schwinger Model

Links: [Github]
- Obtained, numerically, the real-time dynamics of particle density and entanglement entropies for the Schwinger model mapped to a spin-lattice model. [Reproduced numerically the experimental results of Muschik et al. (2023)]
- To obtain the ground state of the Schwinger Hamiltonian
  - Developed a variational quantum solver that implements the gradient descent, stochastic gradient, and ADAM method to obtain the *separable product state* best approximating the ground state.
  - Developed and implemented a gradient descent algorithm for finding the Matrix Product State approximation.
  - Further employed quantum adiabatic evolution, and Physics Informed Neural Network to prepare the ground state.

Physics Informed Neural Networks (PINNs)

Links:[GitHub]
- Implemented Physics Informed Neural Networks (PINNs) for solving PDEs using both TensorFlow and PyTorch.
- Used PINNs to first solve, as a benchmark, simple one-variable differential equations, and then used it to solve the Heat Equation, Burgers Equation and Wave Equation in 2D. Further extended the methods to solve coupled differential equations.
- Presently working on solving the Lotka-Volterra equations, to verify if the equation invariants are preserved.

Outreach Activities

2021-22 Head, Physics Club of NIT Surat (Member 2020-24), a club actively conducting events to impart knowledge and inculcate interest in physics in the young minds and the general public. (I also created the website for the club)

2020- Author, thehavok.com, writing science articles to make the scientific jargon accessible to even a non-academic.

References

Prof. Dr. Laurent Baulieu
baulieu@lpthe.jussieu.fr
Sorbonne University, Paris, France

Dr. habil. Georg Bergner
georg.bergner@uni-jena.de
Friedrich Schiller Universität Jena, Germany

Dr. Vikash K. Ojha
vko@phy.svnit.ac.in
Sardar Vallabhbhai National Institute of Technology, Surat