Shihabul Haque

Integrated Bachelor's-Master's in Science (2020-2025) Physics major
Indian Association for the Cultivation of Science (IACS), Kolkata, India
Mail: shihabul1312@gmail.com | ug2020sh2371@iacs.res.in || ***Personal page:*** psihq.github.io

RESEARCH INTERESTS

I am interested in **theoretical high energy physics**, specifically **quantum field theory**, **elementary particle physics** and **cosmology**. I am interested in BSM phenomenology - specific topics where I have hands-on experience include **ALPs**, **Higgs sector**, **electroweak symmetry breaking**, **neutrinos**, **dark matter**. In the future, I would like to study phenomenological models and their consequences with an emphasis on model-building.

EDUCATION

1. The International School for Advanced Studies (SISSA), Trieste, Italy Expected start: October 2025
Incoming PhD student in the Theoretical Particle Physics (TPP) group

2. Indian Association for the Cultivation of Science, Kolkata, India October 2020 – July 2025 (Expected)
Integrated Bachelor's - Master's in Physics **CGPA: 9.61/10.00** (as of semester 9)

Relevant coursework: Classical and Quantum Mechanics, Statistical Mechanics, Quantum field theory, Statistical field theory, General Relativity.

3. South Point High School, Kolkata, India
CBSE XII (2020): **95%**, CBSE X (2018): **96.6%**

SKILLS

- **Programming languages:** Julia (advanced), Python (intermediate), C/C++ (basic)
- **Software:** LaTeX, Mathematica

PREVIOUS EXPERIENCE

ALP/photon mixing and related phenomena in astrophysical scenarios **August 2023 – Present**
School of Physical Sciences, Indian Association for the Cultivation of Science 2 years BS - MS project
Supervisor: *Sourov Roy, Senior Professor; Soumitra SenGupta, Senior Professor (co-supervised RS model work)*

- For my BS-MS project, I initially focused on the astrophysical consequences of ALP/photon oscillations, specifically targeting polarisation-based studies, writing codes, numerically solving differential equations and estimating Stokes parameters. Following this, I extended these ideas graviton/photon mixing scenarios and explored ways to apply the theoretical/computational results to actual observations. My first semester report can be found here (Google Drive).
- I later worked on the link between axions and Randall-Sundrum (RS) models, using current observational data on the ALP/photon mixing strength to impose bounds on the model, which has interesting consequences for the RS model's solution of the hierarchy problem. An arXiv preprint is available online and the manuscript is under review. For my current semester, I am focusing on a study on axion echoes and some related ideas.

Collider and GW signals of electroweak phase transition in the THDM **July 2024 – August 2024**
Department of Physics, Osaka University, Japan International Summer Program (ISP) 2024
Supervisor: *Shinya Kanemura, Senior Professor*

- As an ISP 2024 student, I explored the Higgs sector in SM and BSM scenarios. Specifically, I looked into the two Higgs doublet model (THDM) and the baryon asymmetry issue. I explored how finite temperature effects in field theory, in the context of the THDM, can be employed to explain the problem through a strong 1st order phase transition. I considered two approaches to probing such models - loop corrections to the Higgs self-coupling using effective potentials that can be observed in colliders and detecting GWs generated due to bubble collisions during the electroweak phase transition. A report summarising the main aspects of the project can be found here.

Nonlinear oscillators and resonant responses **December 2021 – January 2024**
School of Physical Sciences, Indian Association for the Cultivation of Science Long term project
Supervisor: *Jayanta K. Bhattacharjee, Emeritus Professor*

- Under Prof. Jayanta Bhattacharjee (now at IIT, Kanpur), I learnt about different approximating techniques, perturbative techniques, diverging quantities and applied these ideas to physical systems. For my first major project, I worked on

parametric resonances in a double spring pendulum. I presented our work at **NODYCON, 2023**, in Rome (virtually, due to financial constraints). Specifically, we derived multiple parametric resonance conditions for the system, looked into its numerical solutions and estimated Lyapunov exponents.
- I also worked on the resonant forced oscillator, specifically in the context of its finite response. For smaller drives, we characterised two drive-dependent scaling laws and showed that the finiteness of the resonant response can be attributed to a destructive interference like effect. At larger drive values, we numerically showed that the oscillator undergoes a first-order transition. This work was published in *J. Phys. A*.

Weak measurements in simple quantum mechanical systems **June 2023 – July 2023**
Department of Physics, Chennai Mathematical Institute, Chennai, India Summer project
Supervisor: *H. S. Mani, Adjunct Professor*

- As a summer student at CMI, I looked at projective measurements, weak values and how our understanding evolved over time, initially working on a simple spin 1 system. I explored the relation between weak measurements and interference, replicating the results in *Sokolovski et. al. (2018)* (here) in general settings and explicitly calculating weak values in a few simple quantum systems. A brief report on some parts of the project can be accessed here.

Basic overview of the Dirac equation and related ideas **May 2022 – August 2022**
Department of Physics, Rajabazar Science College, Kolkata, India Summer project
Supervisor: *Amitava Raychaudhuri, Professor Emeritus*

- A brief summer project in which I learnt a bit about neutrinos starting from the covariant formulation of the Dirac equation and looking into SU(2), spinors and their transformation properties, and neutrino mass models.

PRESENTATIONS, PUBLICATIONS & PREPRINTS

Presentations:

- "*Testing the electroweak phase transition with future collider experiments and gravitational wave observations.*" ISP 2024, Osaka University (non-technical due to audience background; slides available here)
- **Haque, S.**, Sasmal, N. & Bhattacharjee, J. K. (2023). "*An extensible double pendulum and multiple parametric resonances.*" NODYCON 2023, Rome (abstract available here)

Publications/Preprints:

- **Haque, S.**, Roy, S., & SenGupta, S. (2024). "Translating current ALP photon coupling strength bounds to the Randall-Sundrum model". arxiv:2411.08396 [hep-ph] (under review)
- **Haque, S.**, & Bhattacharjee, J. K. (2024). "Interference aided finite resonant response in an undamped forced oscillator". *J. Phys. A: Math. Theor.* **57** 325701 (10.1088/1751-8121/ad6412)
- **Haque, S.**, Sasmal, N. & Bhattacharjee, J. K. (2024). "An extensible double pendulum and multiple parametric resonances.", *Advances in Nonlinear Dynamics*, Volume I, ICNDA 2023, NODYCON Conference Proceedings Series, Springer, Cham. (10.1007/978-3-031-50631-4_12) (published after peer-review)

AWARDS

Scholarship for Super Short Term Study, Osaka University July 2024 – August 2024
I was nominated for and selected as a recipient of the competitive *Scholarship for Super Short Term Study* at the Graduate School of Science, Osaka University, which supported my stay in Japan for the duration of the ISP, 2024.

KVPY 2019 (SX) Fellow 2020 – 2025
I am funded by the KVPY fellowship provided by the Department of Science and Technology, Government of India, for selected students pursuing basic sciences. The fellowship is awarded to around 2000 candidates after a written exam followed by an interview from an initial pool of 200,000 - 300,000 candidates.

ADDITIONAL ACADEMIC EXPERIENCES

- Completed an astronomy course organized by the **Breakthrough Science Society, Kerala Chapter**.
- Zonal Toppers (Kolkata), **Mimamsa 2022**, a national level open book team-based science competition.

EXTRACURRICULAR EXPERIENCES

- Ranked 6^{th} in the Young Ruskin Bond competition (2019), a national level short story competition.
- Won the gold medal in the Don Bosco Jubilee Quiz (2015). Represented school in the Bournvita Quiz (2015).

Last updated: June 13, 2025