Beyond the Standard model (BSM) theories pack a real punch – not only are they intriguing as standalone theoretical models, but they also offer a tangible way to test for new physics beyond what we already know. My research in particle physics, particularly axion-like particles (ALPs) and Randall–Sundrum (RS) models, has allowed me to engage with both and has informed my decision to look for graduate positions with similar goals.

Despite being interested in particle physics, my research began with nonlinear physics. As a greenhorn undergraduate, I worked with Prof. [] on nonlinear oscillators - I learnt analytic and computational techniques (for example, solving systems of differential equations). I also learnt to collaborate effectively – initially, I worked with a classmate, while for the second project, I collaborated with Prof. [] online after his relocation. Ultimately, my work led to a presentation at [] (I personally presented online because of financial constraints) and a first-author paper in *J. Phys. A*.

I was, however, always interested particle physics - my group theory and quantum field theory courses only made my conviction stronger. So, I joined Prof. []'s group for my Master's thesis, focusing on the mixing between axion-like particles (ALPs) and photons. I focused on estimating Stokes parameters since they give us an observational signal to look for - photon polarization. Having gained a solid background, I wanted to explore how additional smaller turbulent magnetic fields in a helical model would affect the conversion probability - and whether the changes would be observationally significant. The motivation for this was a discussion with a graduate student in our group who had recently worked on a similar idea and found significant enhancement in results. I wrote the relevant codes and generated the smaller fields, but, unfortunately, since the intergalactic magnetic field (IGMF) is weak, the even weaker turbulent components led to no discernible change. While there were no significant observational changes, the project sharpened my skills and deepened my understanding of the limitations inherent in our models. It also reinforced the need to be adaptable in research, leading me to explore RS models, later.

After investigating axion/photon mixing, I was intrigued by the possibility of extending the formalism to the less discussed graviton/photon scenario, drawing on my General Relativity course. I found that, analytically, it was more interesting and verified my analytical results numerically. Initially, there were some discrepancies, but I resolved them after revisiting the assumptions behind the calculations. While the analytical results were cool, I wanted to figure out a way to use them in a real physical system – this proved difficult as the coupling strength was too weak, rendering most systems futile. I worked on this for several days, however – tinkering with domain sizes to see how they affect probabilities. I found that even though the probabilities do get enhanced, the effect was not strong enough to provide any stringent constraints.

After discussing these issues with my supervisor, we decided to tackle the problem by looking into RS models which include a 5-dimensional spacetime with an exponential warp factor that could provide the boost we needed. I worked through the formalism – it turns out that in the RS model, the axion/photon coupling is directly related to the size of the extra dimension. I realized that current observational bounds on the axion/photon coupling could be directly translated to the size of the extra dimension – this would enable us to correlate RS models, axions and actual experimental data together. This work is being modified for future publication and I plan to extend my graviton calculations to RS models.

Outside of this, I participated in the [summer program] 2024 at [foreign country], where I worked with Prof. [] on the baryon asymmetry problem. I explored the possibility of a 1st order electroweak phase transition in the two Higgs doublet model (THDM). I calculated the finite temperature contributions to the effective potential and corrections due to the heavier Higgs particles, finding significant deviations in the parameter space that could be probed by colliders. I also explored gravitational wave generation by such phase transitions - a direct connection to my Master's project. This experience was invaluable as it introduced me to new areas of particle physics and a whole different culture – I adapted to the change well and enjoyed my stay in Japan. At Osaka, I engaged in thought-provoking discussions on BSM phenomenology with Prof.

[] and his group while gaining insights into the current frontiers of particle physics through the group meetings, seminars and arXiv club talks. Academically, I broadened my exposure and gained a solid background in the Higgs mechanism, THDM, electroweak symmetry breaking, and learnt about Coleman - Weinberg corrections, effective potential calculations and how to derive higher-order corrections from such potentials.

My work with axions, RS models and electroweak phase transitions has made me more interested in the various approaches used to resolve open problems in physics. The question of massive neutrinos, on top of this, provides further motivation to focus on BSM approaches and their connection to observations. Axions, in particular, are also dark matter candidates while the THDM and electroweak phase transition scenarios often incorporate additional CP violating contributions. In the end, these theories connect different problems to each other and these connections can reveal more questions. I am interested in these questions, since they might lead to potential experimental signatures. We are entering an age of GW astronomy along with upgrades for the HL – LHC and proposals for a muon collider and the ILC. Experimental observations in the coming decades will point out more disagreements with the standard model and I want to be a part of a theoretical effort to identify these shortcomings and look for solutions.

Throughout my research, I have encountered setbacks, for instance, in connecting theory to observations, like for gravitons. This has taught me the importance of bridging theory to physical observations - something I had not given much thought earlier. This understanding will guide my future work, where I aim to relate BSM theories to experimental signatures, ensuring that the results remain impactful both theoretically and phenomenologically. Along the way, I have also learnt to work independently and challenge myself. I enjoy working independently – it gives me the freedom to try out different things and the flexibility to work at my own pace. However, I do not work alone - my work is actively shaped by discussions with my supervisor, group members and the valuable feedback they provide. I have also learnt to keep an open mind – even though my primary interests are theoretical, I have learnt the importance of being informed on experimental techniques. On a similar theme, I actively discuss ideas with my peers from different backgrounds – condensed matter or pure math – and incorporate new techniques and ideas in my own work. This openness to cross-disciplinary techniques will inform my future work as well, especially as BSM theories often require innovative approaches that span different fields of physics, math and even computer science.

I feel that XYZ university is a great fit for me because of the perfect blend of theoretical and phenomenological research carried out in the particle physics group in the university. I feel that it is the perfect place to hone my mathematical interests while focusing on real world observations and phenomenological techniques. I wish to work more on BSM theories – specifically, on electroweak symmetry breaking, the Higgs sector, axions, neutrinos and the nature of dark matter. XYZ has some of the best people working on these areas – Prof. [...] on [...] and Prof. [...] on [...]. I have gone through some of the recent publications from the department and I came upon several interesting ideas - for example, [...]. My specific interests seem to be at the forefront of the kind of work being actively carried out at XYZ. This is why I believe that the graduate program at XYZ would be an amazing fit for me.