# Statement of Academic Purpose

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My research interests lie in uncovering the mathematics that drives Machine Learning and deep learning and their theoretical nature. What are the theoretical foundations explaining the success of deep networks? Are there inherent limits to their expressiveness? What are the potential applications of learned representations in various domains, such as computer vision, natural language processing, and speech recognition? How do we address the challenges of interpretability and explainability in these learned representations? I aim to explore these problems to develop an understanding of the theoretical limits of Machine Learning. I am particularly interested in understanding and applying these algorithms across engineering and natural sciences to build intelligent systems and conduct research in physics and mathematics to solve problems such as approximating numerical computations using neural networks, astronomical simulations, assisted theorem proving, etc. My unwavering passion for engineering and research is evident in my academic achievements during my undergraduate years, reflected in my transcripts and my active involvement in extracurricular activities. My journey has underscored the importance of further specialization and enrichment, which I believe a master's program can provide, laying the foundation for a future Ph.D. pursuit. In this regard, I am convinced that Princeton University is the ideal place to nurture my potential.

During my bachelor's I was extremely fascinated by astrophysics and its intersection with computer science. In my junior year, I led a team of three and delved into the research on neural network applications in galaxy morphology classification. Identifying galaxy morphologies has important implications in many astronomical tasks, e.g., studying galaxy evolution, probing dark matter distribution, etc. The recent data influx in astronomy necessitates a robust and automated system for processing large amounts of images. We aimed to set up a 7-class classification system that classified galaxy images using CNNs, which can surpass existing benchmarks. I was responsible for establishing a robust training pipeline and optimizing various neural network architectures from the ground up. Our collective efforts outperformed the second-best submission on the Kaggle Public Leaderboard. I gained a profound understanding of the intricacies of applying deep learning to various tasks and explored aspects such as hyperparameter tuning, debugging, troubleshooting, and custom model design—each underscored by a need for a profound grasp of the underlying theory. Consequently, I eagerly anticipate the advanced topics in coursework such as *'Fundamentals of Deep Learning'* by Dr. Sanjeev Arora, offering a more in-depth exploration of the core principles of deep learning and rigorous mathematics compared to my prior senior-year coursework.

The Galaxy Morphology Classification project proved to be a stepping stone in connecting astrophysics to computer science. Soon after that project, I began contributing to *EinsteinPy*, an open-source Python package designed to address issues in General Relativity and gravitational physics. My work specifically involved incorporating various symbolic computations, such as the Reissner–Nordström metric and calculations for the event horizon and ergosphere of a Kerr-Newmann black hole. While symbolic computations are valuable in controlled environments, real-world problems often necessitate approximate rather than exact solutions. This led me to investigate the processes used for various physical simulations where numerical methods are widely popular. The potential for deep learning in simulating complex system behaviors is vast, e.g., in surrogate modeling where we can use deep learning to approximate behaviors in complex systems allowing for faster evaluations when original simulation using numerical methods is computationally expensive. I am interested in leveraging AI and Machine Learning for this task in the long term. Dr. Ryan Adam's interests in computational statistics align extremely well with mine. Moreover, his *'Mathematics for Numerical Computing and Machine Learning'* course seems extremely fascinating and promises a comprehensive exploration of various mathematical concepts that extend beyond my previous academic coursework.

For my bachelor's thesis, I worked on utilizing Conditional GANs for astronomical image colorization. Space archives are filled with large amounts of low-quality, greyscale images, many of which go unnoticed. I was interested in utilizing generative models for creating aesthetically pleasing representations of celestial scenes. Generative models are attractive because they enable us to better understand, create, and work with data, having many practical and theoretical implications. In my work, I focused on tasks like image-to-image translation and style transfer, where I realized the need for distributional robustness in my application to maintain quality in my output images, even in varying conditions. GANs often deal with high-dimensional data and are used for various conditional image generation tasks. In my ongoing academic journey, I'm equally interested in gaining a theoretical understanding of how various neural network models generalize, especially in complex, high-dimensional spaces when provided with different conditions or inputs. Undergraduate studies seldom comprehensively cover advanced machine learning theory. In this regard, I see the coursework in *'Theoretical Machine Learning'* as an exhilarating opportunity to immerse myself in these concepts more formally than ever. It promises a more profound understanding and a pathway to engaging with these fundamental theories at a higher level.

For the past two years, I have been working as an ML consultant at Relfor Labs, an AI startup. My professional experience in Machine Learning has further motivated me to pursue graduate studies to kick-start a research career. The scientific landscape has been consistently evolving, but many longstanding problems have eluded complete solutions for many years. Looking into the future, I wish to make a difference in this significant era. My determination to pursue a research career is unwavering, and I aspire to work in an academic setting and eventually pursue a Ph.D. The vibrant community of students and researchers at Princeton is the perfect place for me to nurture myself and further my commitment to help expedite this scientific advancement. Thank you for considering me as a prospective student at your university.