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 for me to pursue a successful research career. In this regard, I am convinced that the University of Chicago 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. 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 machine 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 working with Dr. Rebecca Willet and study the mathematical foundations of machine learning.

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. 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. In the long term, I am interested in leveraging AI and Machine Learning for this and build systems to make scientific simulations cheaper and simpler. I am extremely interested in the work carried out in the Machine Learning group, especially in the Jonas Lab. I believe Dr. Eric Jonas' interests in physical sciences and leveraging ML for scientific measurements align seamlessly with my own. I wish to work with him on integrating my knowledge of computer science and physical sciences. In addition to Dr. Jonas, Dr. Risi Kondor's interests in machine learning for physics and chemistry albeit with a more fundamental methodological approach resonates with my interests in developing ML algorithms in these domains. I would be extremely interested in collaborating with him.

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, hence, it is important to study their optimization landscape and convergence guarantees. 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 coursework in "Introduction to the Theory of Machine Learning" and "Mathematical Foundations of 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 eventually work in an academic setting as a professor. The vibrant community of students and researchers at the University of Chicago 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.