Statement of Purpose

I am captivated by the interplay between theory and experiment in quantum information science, condensed matter, and atomic, molecular, and optical physics. In particular, I am interested in quantum simulations as well as experiments with ultracold gases for quantum science and fundamental physics. In May 2021, I will complete my undergraduate studies at Colby College with two Honors Theses on experimental atomic physics and mathematical analysis. My next objective is to expand and subsequently apply my research training to address an important open problem in quantum science. To that end, the Physics Ph.D. program at Princeton University is a fantastic option.

My interest in quantum science originated with research experiences in ultracold atom experiments at the Joint Quantum Institute (JQI) and Colby College. In Summer 2019, I joined the Rolston group at JQI to study the long-range interaction between rubidium atoms magneto-optically trapped around an optical nanofiber. There, I built an imaging system for optimizing light polarization in optical nanofibers, which often introduce birefringence and undesirable longitudinal polarizations. I also developed a stand-alone Python program for controlling the entire experiment, removing the group's reliance on the less compatible LabView program. In January 2020, Dr. Hyok Sang Han and I observed a mysterious transient decay flash in the rubidium population that was much faster than even the fastest superradiance mode of the system. The group at JQI is developing a theory for this phenomenon, for it was only recently discovered and is not well-understood in the one-dimensional geometry of our nanofiber experiment.

Since my first year at Colby, I have been working on ultracold potassium experiments under Professor Charles Conover, my advisor and mentor. Applying the experimental techniques I learned at JQI, I am currently working towards a Physics Honors Thesis on lifetime measurements of quantum states in potassium by counting photons emitted from an excited, magneto-optically trapped, atomic cloud of this species. In previous years, I constructed a variety of laboratory apparatus from external-cavity diode lasers to electronics for laser frequency stabilization. I also carried out precision spectroscopy on potassium in Rydberg states to determine its quantum defects and absolute energy levels. At our level of precision, energy shifts due to the millimeter-wave source are significant and thus require data extrapolation to obtain unbiased measurements. Applying Ramsey's separated oscillatory field method, I eliminated this necessity and gave an alternative measurement scheme with comparable precision. I presented this work at the Colby Undergraduate Summer Research Retreat in 2018 and at DAMOP 19.

Besides thesis work, I am continuing the research started this summer with Dr. Timothy Hsieh at the Perimeter Institute for Theoretical Physics on efficient variational simulation of non-trivial quantum states that are not adiabatically connected to unentangled product states. Initially, we aimed to accelerate Dr. Hsieh's protocol, which according to numerical results could target the ground state of the uniform transverse-field Ising model with perfect fidelity via a variational ansatz based on the

Quantum Approximate Optimization Algorithm (QAOA). However, after I found that this protocol could also target the ground state of any non-uniform Ising model with random transverse field and couplings, our focus shifted towards understanding how QAOA provides such a reliable ansatz. Since then, I have obtained additional results related to targeting eigenstates of more general Ising Hamiltonians using similar schemes. I am now studying the free-fermion representation of the non-uniform transverse-field Ising model. Ultimately, we aim to prove that the QAOA-based ansatz can indeed target any eigenstate of this model with perfect fidelity, in accordance with numerical results.

I also enjoy exploring other areas of physics and mathematics. For four semesters with Professor Robert Bluhm, I studied general relativity and massive gravity and wrote detailed expositions of these topics on my website. Now, I am self-studying quantum field theory with an emphasis on applications in condensed matter physics. Last year, intrigued by their application in partial differential equations, I began research on mathematical analysis with Professor Evan Randles. Motivated by my numerical evidence, we developed a generalization of the polar-coordinate integration formula which aids in the understanding of convolution powers of complex functions. We will present this result at the Joint Mathematics Meeting in January 2021 and are preparing a manuscript for publication, part of which will become my Mathematics Honors Thesis. These projects, along with my role as a physics and mathematics teaching assistant in which I develop valuable pedagogical skills, enrich my academic experience outside of coursework and physics research.

At Princeton, I would like to focus my efforts on quantum science and expanding my teaching capacity. I have contacted Professor David Huse, whose research directly aligns with my current interest in quantum simulation. In addition, I am interested in Professor Waseem Bakr's work on ultracold quantum gases for condensed matter physics. Upon receiving my Ph.D., I aim to continue research in quantum science and eventually teach at a research-oriented university. Ultimately, I would like to make impactful contributions to the continually growing body of work in this field. I believe that admission to the Physics Ph.D. program at Princeton is an ideal step towards this goal.

Thank you for your consideration.

October 28, 2020