

# STATEMENT OF PURPOSE

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The interaction between quantum matter and quantum computing has sparked countless ideas, shaping a second quantum revolution. From high-temperature superconductors to superconducting qubits, these ideas reached me as my journey through academia started and they showed me how modern technology can build on the full elegant machinery of theoretical physics. I aim to become a leader participating in the second quantum revolution with no compromise between concrete application and theoretical sophistication. At the age of 14, I won a writing contest about career ambitions by describing a future where I would play an important role in the development of physics. This dream stayed with me and, at the dawn of specialization, working at Caltech would help make it a reality.

While outreach projects fostered my interest in the foundations of modern physics, internships helped me explore and refine my aspirations. Eager to go beyond courses and start contributing to science directly, I took an internship in Prof. Jeffrey Quillian's group during the first summer of my undergraduate studies. The project revolved around the conception of an interface treating nuclear magnetic resonance data generated by experiments on frustrated Kagome crystals at high pressure. Throughout the summer, I developed a rigorous work ethic as I implemented Fourier analysis of spin echos, curve fitting tools, and efficient data storage. Along the way, interactions with experimentalists complemented my theorist view of physics with an appreciation of the work behind data.

With the reality of experimentalists in mind, my theoretical research journey started in Prof. André-Marie Tremblay's group. My role was to produce and analyze data from two-particle self-consistent approach simulations of electron-doped cuprates. At the beginning of the project, I demonstrated efficient self-learning by rapidly gaining a working understanding of Matsubara frequencies and their role in the evaluation of many-body functions. Meticulously exploring simulation data, I devised a procedure to locate the quantum critical point of the electron-doped phase diagram by approximating temperature for antiferromagnetic pseudogap appearance. My analysis allowed me to qualify the effect of a simple implementation of disorder on the quantum critical point and on the Vilk criterion for hot spots appearance. These results helped orient further research that would lead to a publication in Physical Review B. Looking back, I see this internship as the origin of my current ambitions in the material sciences. It is the idea that my work could lead to new superconductivity-related technologies that made it so engaging for me.

The thrill of material sciences became even more vivid with my next internship project. This time, I was working with Prof. Ion Garate on an adaptation of the Van Roosbroeck system of partial differential equations to describe Weyl semimetals interacting with light. The goal of the project was to solve the equations to gain insight into the semi-classical role of the chiral anomaly. Independently, I found a way to decouple the equations further using an adaptation of Ampère's law and animated the evolution of charge densities through time. In the end, we identified the presence of photoinduced plasma oscillations, leading to a publication in Physical Review B. This internship introduced me to the intricacies of non-equilibrium phenomena and the challenging task of bringing a theoretical model closer to an experiment.

As a second exposition to non-equilibrium phenomena, I collaborated with a student from Prof. Alexandre Blais's group on a small project about the mixed regular/chaotic dynamics of a driven superconducting cat qubit and its classical limit. The fact we were working with the sophisticated ideas of chaos theory to ultimately improve quantum gates was fulfilling and laid the basis of my current career ambitions. Following my objective to play a role in the second quantum revolution, I will participate in a Perimeter Institute winter research project on a new qubit implementation relying on the stimulated Unruh effect with Dr. Barbara Soda.

I am currently studying at Perimeter Institute as a Perimeter Scholars International (PSI) master's student. The coursework portion of the program has shown me excellence in education through its world-class teachers and its exceptional students. With exposition to a broad range of advanced topics, I realized how challenging and stimulating studying theoretical physics truly is. I am eager to continue taking on this challenge with the diverse PhD courses offered at Caltech. For the research portion of the PSI program, I will work under the supervision of Prof. Yin-Chen He on a novel way to study emergent conformal symmetry associated with critical phenomena called the "Fuzzy Sphere" method. Caltech provides a continuation of the excellence in education and research I am growing with at Perimeter Institute while giving me access to a bigger community working closer to technology.

For my Ph.D. research, I have a strong desire to work at the interface of quantum information and many-body physics to increase our control of complex quantum systems. Following this goal, I would be thrilled to join Prof. Fernando Brandão's group because his methods involve hardware and quantum algorithms aspects of quantum information. Under his supervision, I could improve superconducting qubits and explore the role of entanglement in complex systems. I am also curious about his work on the second law of quantum thermodynamics. Going in a different direction, my internship on Weyl semimetals has given me an appreciation for the technological prospects of topological materials and I see myself pursuing this interest by working with Prof. Alexei Kitaev. A Ph.D. with either of these professors would build on my experience and satisfy my ambitions.

In a general sense, I look forward to making meaningful connections with the great minds of Caltech. I would be honored to take part in the cutting-edge research happening at Caltech and I am convinced the institute's professors and students will allow me to reach my full potential in this century of great scientific opportunities.

Sincerely,  
Pierre-Antoine Graham