Statement of Objectives

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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 MIT would help make it a reality.

Eager to go beyond courses and start contributing to science directly, I took an internship during the first summer of my undergraduate. I joined Prof. Jeffrey Quilliam's group to conceive 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 tainted my theorist view of physics with an appreciation of the work behind data.

With the reality of experimentalists in mind, my theoretical physics 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 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 providing a semi-classical description of 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. Having more independence, I produced animations of the numerical evolution of charge densities through time and found a way to decouple the equations using Ampère's law. In the end, we identified the presence of photoinduced plasma oscillations which lead 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 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 revolution, I will participate in a winter research project

on a new qubit implementation relying on the stimulated Unruh effect.

I am currently studying at Perimeter Institute as a Perimeter Scholars International master's student. The coursework portion of the program has shown me excellence in education through its world-class teachers and its exceptional physics students from 17 different countries. My classmate's unique experiences and sets of skills have strengthened my view of physics as an international endeavor. Every day, I grow from cultural exchange and collaborative problem solving where I give my all to embody the values of inclusivity and collaboration of the institute. My peers selected me to receive the Marsland Family PSI award highlighting my contribution to the learning environment of the program and alignment with the values of the institutes. As for the research portion of the program, I will work on a novel way to study emergent conformal symmetry called the "Fuzzy Sphere" method under the supervision of its inventor Prof. Yin-Chen He. MIT feels like the natural next step for me because it provides a continuation of the excellence in education and research I am growing with at Perimeter Institute.

In light of all my past experiences, I can say I have a strong desire to explore the uses of quantum information methods in many-body physics and non-equilibrium dynamics. I am fascinated by the multidisciplinary aspects of this research direction and its concrete implications for understanding and controlling quantum phenomena at the origin of familiar and mysterious thermodynamical behavior. At MIT, I would be thrilled to join Prof. Soonwon Choi's group because of the diversity of his methods, their proximity to quantum technology, and their alignment with my interests. As a result of my project on chaotic-driven cat qubits, I am particularly curious about his work on ergodicity in time-dependent quantum systems. I am also curious about the criticality aspects of Rydberg quantum simulators. Going in a different direction, I see myself joining Prof. Senthil Todadri's group to expand on my research about non-fermi liquids and quantum criticality in cuprates. 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 MIT. I would be honored to take part in the cutting-edge research happening at MIT 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