University of Washington – Institute for Nuclear Theory

Professors – **Aurel Bulgac** (strongly-interacting many fermion systems, recently received very large grant for High Performance Computing in Low Energy Nuclear Physics, although it probably ran out a few years ago might indicate good grant-writing abilities), **Gerald Miller** (I have less understanding of what he does, but it sounds more analytical than computational, and very interesting; seems well-established and has a metric fuck-ton of publications, citations, and invited talks), **Martin Savage** (lattice QCD, massive computational challenges), **George Bertsch** (quantum many-particle theory, interested in applications to condensed matter, PI on large grant with Bulgac, won APS prize in nuclear physics), **David Kaplan** (seemingly has pretty diverse research interests in high-energy nuclear physics, from lattice QCD to alternatives to lattice QCD to unitary fermion limit / nuclear effective theory; is the director of INT, which may indicate that he is well-connected but may also indicate that he doesn’t have as much time for students and research. Was impressed by how dutifully he gave credit to his students and other researchers in his research summary)

**One page stating academic purpose and goals**

My greatest personal interests are on the boundary between physics and pure mathematics, and in the ways that modern computational resources can be employed to the end of solving open problems in theoretical physics and mathematics.

In my second semester at the university, I became fascinated by the bold and unfettered curiosity at the foundation of physics and research in particular. My change of major during this semester can be in large part attributed to a final project in Honors Physics II which was to select, solve, and present on a problem from the Rudolf Ortvay International Competition in Physics. I found this a fascinating challenge, and one in which I became deeply invested. I consider this my first exposure to the idea of research, and the thrill and dedication that it evoked in me at the time has followed me and grown through my research experiences since.

…The professor did this, that, and the other thing in this course which I found intriguing for these reasons, from which I determined that the kinds of conceptual problems that fascinated me were found in physics rather than engineering.

My goal is to contribute to the development of theoretical models and computational techniques for solving intractable problems in high energy physics. I have taken every available opportunity as an undergraduate to expand my horizons, try out new research areas, and develop an extensive foundation in research projects in engineering, experimental physics, and theoretical physics. I am therefore able to make a confident and informed statement about my research interests in graduate school, as well as about my passion for scientific research in general. I dabbled in several majors as a freshman at CU Boulder, but a few too many of “why is it that way?” and a persistent love of problem-solving found me in my second semester in a tiny honor’s section of freshman electricity and magnetism. Our professor challenged us throughout the course to push our abilities and to solve problems via logic and research rather than by facts and preparation. We received a course based in vector calculus and differential equations, remarkably similar to junior electricity and magnetism, before having these prerequisites and were expected to select, solve, and present on problems from an international competition in physics as freshmen. The approach resonated with my curiosity, drive, and love of problem-solving, and I was convinced that research was for me.

That spring I contacted an optics professor at Montana State University whose research I was interested in, and subsequently was awarded an REU grant to work in his group designing and building an optoelectronic system to detect the aurora borealis, and then writing a body of original microcontroller code (which is still used in the group) to control the electronics and reliably broadcast data over the network to our group’s servers, which sent aurora alerts to people across the state of Montana.

As a sophomore I was selected for a CU Boulder College of Engineering research apprenticeship with Dr. Ivan Smalyukh and the Liquid Crystal Materials Research Center. I learned many important experimental skills. I became involved, outside of my assigned project, in developing simulations of liquid crystal dynamics with a graduate student in the group. During this time I became aware of the unique and important contribution of simulations (computational physics) and theoretical (e.g. abstract) mathematics to experimental physics. Early in 2013, my interest in fluid dynamics in soft-matter systems, an interest in learning more about high-energy physics, and my new-found passion for computational and theoretical physics brought me to Dr. Paul Romatschke and the Nuclear Theory group at the University of Colorado. I became involved in writing and analyzing simulations of unitary Fermi gases. My work in the LCMRC, and particularly the central role of topology in governing the dynamics of structures and objects in the liquid crystal medium, sparked a fascination with pure mathematics which I have pursued in parallel with my physics curriculum ever since.

Alongside studying kinetic theory, numerical fluid dynamics, and the lattice Boltzmann equations by night, that summer I accepted a research position in the Optical Remote Sensing Laboratory pursuing my developing interest in computational sciences and algorithm development. The group had been involved in a zero-emissions research project aimed at doing a proof-of-concept of the effectiveness of airborne imaging of vegetation as a reliable method for detecting leaks at CO2 sequestration sites. I designed and wrote a set of algorithms to automate the analysis of data from balloon-borne imagers CO2 sequestration sites, for which I had to delve into the type of image processing and registration developed for robotics and computer vision.

I continued my research with the Nuclear Theory group upon my return to CU. I studying the hydrodynamics characteristics of the unitary Fermi gas through simulations that I wrote based on the lattice Boltzmann methods. In particular, we are studying elliptic flow in the unitary Fermi gas in hopes of placing theoretical bounds on the ratio of shear viscosity to entropy density for the unitary Fermi gas. Through this project I developed my interest in high-energy physics and became confident in my decision that computational and theoretical physics was my passion.

I also developed a strong and somewhat less-expected interest in hydrodynamics, kinetic theory, and fluids in general. To explore this interest in greater detail and to place my study of hydrodynamics for nuclear theory on a stronger fundamental basis, as a junior I enrolled in graduate Introductory Plasma Physics at CU Boulder, and subsequently elected to accept an 8-week summer program with Professor Dana Longcope at Montana State University simulating and studying shocks and magnetic reconnection in solar flares. In particular, we demonstrated the accuracy of Dana’s model of energy release in solar flares in the context of one specific flare which satisfied the constraints of the model.

Directly preceding my stay in Montana, I had the incredible opportunity to engage in an intensive week-long collaboration in Boulder with Dr. Miller Mendoza, a postdoctoral researcher from ETH Zurich and a colleague of Dr. Romatschke’s in lattice Boltzmann implementations of both relativistic and non-relativistic hydrodynamics. We continued to collaborate on how to effectively simulate hydrodynamics in strongly-coupled, thermal quantum fluids, particularly in the low density / high velocity tails of the expanding cloud at late times.

I am confident in my choice of theoretical research as a career path and in my preparation for pursuing it. My diverse set of research experiences as an undergraduate have given me an invaluable taste for several areas of research relevant to physics (electrical engineering, experimental and theoretical physics) and have prepared me to make informed and confident decisions about both my interests for graduate school and my future in scientific research.

I am interested in continuing work in Nuclear or High Energy theory. I would be interested in contributing to research into the implementation and results of lattice QCD, but am also interested in continuing studies of the role of hydrodynamics in nuclear systems and in relativistic hydrodynamics.

I would be interested in working with Professor Aurel Bulgac studying vorticity, quantum turbulence, and/or shear viscosity in the unitary Fermi gas.

*What special aspects of your personality, talents, interests and skills make you think that you will be a good physicist?* – I am exceptionally hard-working and dedicated, and am stubborn enough that I am very motivated by difficult problems, and have trouble putting them down until I have finished them. I am logical and an efficient and committed problem-solver. I really enjoy programming, computers, and algorithm development, which is an additional asset to my intended career as a theoretical physicist. Above all else, I am the type of person who seeks a good challenge and is motivated by “why”, by unanswered questions, and by problems I am having that I have not figured out yet.

**Things I want to talk about:**

Academic purpose: what do I want to do as a PhD student, including the experiences that motivated me to these desires and how the specific programs / professors at the university in question fit into my ideas of what I would like to do as a PhD student.

Goals: brief (?) discussion of long-term goals

1. Your interest in and motivation for doing research
2. Your experience in and preparation for doing research
3. Your short and long-term goals

Motivated by understanding WHY things do what they do, as opposed to just understanding what they do