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)

I am interested in theoretical and computational nuclear and high energy physics, particularly in the dynamics of relevant fluids (e.g. ultra-cold quantum gases, QGP). I have taken every available opportunity as an undergraduate to explore a diverse set of research disciplines including theoretical and experimental physics and engineering, and therefore am confident in my choice of graduate research area and in my commitment to a career in research.

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 our problem-solving skills – he taught us to break down our own boundaries by expecting us to figure out how to solve problems of types we had never seen before, and encouraged my confidence in my ability to reason my way through unfamiliar problems.

That spring I contacted optics professor Joe Shaw at Montana State University, and was subsequently invited to work in his group that summer under an NSF REU grant. I designed and built an electronic system to optically detect the aurora borealis, and wrote a microcontroller interface to control the electronics and broadcast data to our servers.

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 using video microscopy and fluorescence imaging to study the interactions between particles suspended in liquid crystal fields. 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. 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. 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.

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 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.

An interest in applications of physics to atmospheric modelling and climatology led me to an REU in the summer after my freshman year with Dr. Joseph Shaw’s Optical Remote Sensing group at Montana State University designing and building an optoelectronic system to detect the aurora borealis. Upon my return to CU, I began a research assistantship with Dr. Ivan Smalyukh’s experimental soft matter group studying interactions between particles in liquid crystal (LC) fields. The central role of topology in governing the dynamics of structures in the LC medium sparked a fascination with the relevance of pure mathematics in physics, and I have physics and mathematics curricula in parallel ever since. I became involved in writing simulations of LC dynamics, and found my interest in fluid dynamics and my passion for computational physics, alongside a curiosity about high-energy physics, that led me to become involved in Dr. Paul Romatschke’s Nuclear Theory group at the University of Colorado in early 2013. Alongside studying kinetic theory for Dr. Romatschke by night, I returned to the Optical Remote Sensing Laboratory in summer 2013 to work on a project tailored to my new interest in computational physics and algorithm development; to write a set of algorithms to automate the image analysis for a blimp-borne CO2 imaging system. As my research with Dr. Romatschke picked up in 2013, I was hooked and knew I had found what I wanted to do. To further broaden my horizons in the realm of kinetic theory, I enrolled in introductory graduate plasma physics in my junior year and subsequently elected to spend 8 weeks of the following summer again in Bozeman, Montana simulating shocks in flare loops and studying the total energy release in magnetic reconnection events and solar flares with Dr. Dana Longcope.

Describe how Joe’s, Ivan’s convinced me that I wanted to pursue a career in research, but make clear how and why it was Paul’s project where I found what I really wanted to do.