Statement of Purpose

MIT Department of Physics · PhD Program · Fall 2024

Introduction

I am an aerospace engineer and scientific software developer who is passionate about computational dynamics. I have been fortunate to have had the opportunity to exercise this background to expand human space exploration at NASA. Now, I aspire to grow as a computational physicist, and expand astrophysical discovery through research.

As I continue to learn about open topics in astrophysics research, I am particularly drawn to research areas relating to galactic dynamics, large scale structure formation, and gravitational wave dynamics. I hope to be considered for graduate advisement by **Dr. Vogelsberger**, **Dr. Necib**, and **Dr. Hughes**. I am grateful for the opportunity to apply to the MIT Department of Physics' PhD program; thank you for your consideration.

Research Experience

My graduate research assistant experience under Dr. Dave Akin brought me into the weeds of constrained, performant software development. My final aerospace engineering course, Interplanetary Navigation & Guidance with Mr. Brent Barbee, introduced me to computational discovery and interdisciplinary research.

The University of Maryland's Space Systems Lab (**SSL**) develops and maintains an 8DOF serial manipulator (**Ranger**) for satellite servicing and dexterous manipulation research. I independently developed interfaces (`C++` templates) and implementations for kinematic solvers and Cartesian controllers. One **solver's** implementation introduced a small performance hurdle: the computation required several intermediate-Jacobian solutions, which I initially solved-for iteratively. After contributing the required **fixes**, I used Julia's `Symbolics.jl` to print analytical intermediate-Jacobian solutions to performant, non-allocating `C++` functions; as a result, each intermediate-Jacobian solve's performance improved by a factor of two. This experience at SSL, and others, taught me how to write performant software for high-speed computations. Graduate course projects, under Mr. Barbee's guidance, showed me how computation extends to discovery across fields.

For my final M.S. course's term project, I replicated halo orbit and invariant manifold computations as summarized by Megan Rund's **thesis** on low-cost interplanetary transfer techniques. Multiple flavors of the halo orbit solver algorithm existed in literature, but I found no guidance in selecting one flavor over another. My project delivered a decision tree for selecting which flavor of the differential correction algorithm to use, depending on the desired orbit characteristics, alongside **open source Julia packages**, and over 130k **initial conditions** for periodic orbits in three-body dynamics.

Computation had revealed true low-energy paths in the solar system; I was exhilarated, and I sought out more opportunities to learn about computational research. After **presenting** the foundations of my project at JuliaCon 2021, I was added to the `JuliaSpace` GitHub organization. I was later invited to a **seminar** on dynamical reachability. As I worked full-time at NASA, I continued to develop and release open source scientific software personally.

Scientific Computing

In 2021, I released all of my astrodynamics research, and much of the functionality covered by my astrodynamics coursework, in a single Julia package: `GeneralAstrodynamics.jl`. I have since corrected common beginner mistakes, such as over-relying on multiple dispatch. Throughout this effort, I have paused to develop new astrodynamics packages; of these, I have found `SPICEKernels.jl` to be the most useful. Professionally, scientific software has been critical to my role as an integrated GN&C analyst in the Artemis Program. I have developed several internal Python packages to assist with nonlinear analysis and verification, including a novel 6DOF kinematics simulator.

All of the scientific software I write personally is published on GitHub under the username `@cadojo`, and is linked-to and summarized by my personal website: `loopy.codes`. I have enjoyed applying scientific software to human space exploration projects, and I am excited to apply these skills to physical discovery.

Research Aspirations

Before my graduate astrodynamics coursework, I had not considered a career in astrophysics research. I was delighted to learn that astrophysical phenomena are studied in ways which align with my current technical skill set: dynamical analysis and scientific software development. Since graduation, I have missed formally learning about the universe through coursework and computation. I am eager to grow as a physicist, and work to advance discovery alongside scientists and research engineers.

Future Plans

I am exploring general astrophysical concepts through the **Big Orange Book**, and galactic dynamics specifically through Dr. Body's online **textbook** draft. Regardless of the path of my research career, I look forward to exploring concepts through computation, and sharing what I learn with others through open source scientific software.

I hope I have the opportunity to learn from the excellent scientists and software developers within MIT. Thank you for the opportunity to apply, your time, and your consideration.