Executive Summary: Computational Physics at the Physics and Astronomy Department, Michigan State University

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Motivation

Modern scientists increasingly rely on computational modeling and data analysis to explore and to understand the natural world. Given its ubiquitous use in science and its critical importance to the future of engineering, computational modeling has been called the "third leg" of 21st century science, next to theory and experiment. This is particularly true in physics, where many important recent advances in our understanding of the physical world have been driven by large-scale computational modeling and data analysis - for example, the 2012 discovery of the Higgs boson, the 2013 Nobel Prize in chemistry for computational modeling of molecules (received by biophysicists), and the 2016 discovery of gravitational waves. It has become clear that a large fraction of theoretical and experimental physicists require a high level of computational sophistication to competently pursue many aspects of their work - a trend that is likely to grow with time as computers increase in power and experimental datasets grow exponentially.

Beyond its increasing centrality in research, the use of computational modeling in the classroom setting provides students with insights that are complementary to those resulting from pencil-and-paper manipulation of equations. In particular, the ability to closely examine the behavior of systems that are too complex to be easily analytically tractable, or that have no analytic solutions (i.e., many systems of practical interest), helps to develop intuition that is unavailable to many students from analytic calculation.

More broadly, computational modeling and data analysis is core to a variety of non-academic career paths that are often pursued by physics students following the receipt of their Bachelor's degree. A 2012 AIP survey of almost 5,000 recent physics bachelor's degree recipients indicated that roughly 50% of chose to enter the workforce immediately after receiving their undergraduate degree. Of these, roughly 75% go into STEM-related fields including engineering, software development, or information technology. Depending on the specific sub-field, between 60% and 80% of these individuals regularly need to engage in computer programming or simulation/modeling tasks, and many respondents to the survey stressed the importance of computer skills, including programming, in increasing their marketability to potential employers.

Despite the ubiquity of computational modeling and data analysis by physicists in both academia and industry and its utility as a means of building physical intuition, the MSU undergraduate physics curriculum does not require its majors to learn these crucial skills (although there is optional coursework in computational methods in PHY 102 and PHY 480). In recent years, individual faculty have integrated computation into various upper-division courses targeted at physics majors, which is an important step forward - however, these efforts are highly dependent on the individual faculty teaching the course, and are largely uncoordinated.

For all of the reasons outlined above, it is critical to ensure that students graduating from MSU with a physics degree have mastery of a range of skills relating to computational modeling, data analysis, and visualization, as well as computer programming and software development. Furthermore, to ensure that students have a consistent and positive experience learning these subjects, it is important that computation is integrated into the undergraduate physics curriculum in a way that is consistent over time and between courses, and which facilitates a gradual progression in students' computational skill sets.

Proposal

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