Exploring the Impact of a Three-Body Interaction Added to the Gravitational Potential Function in the Restricted Three-Body Problem

Consider a binary star system (e.g., pulsar-white dwarf, pulsar-pulsar) with a significantly smaller companion, such as an exoplanet, in orbit about the binary. Given the absence of experimental data gathered within the vicinity of the binary, it is possible that the gravitational field within this system might not be accurately modeled by well-known pairwise gravitational forces. In this research, the presence of an additional three-body interaction is considered. Many-body forces are not an entirely new concept; in fact, the importance of three-body interactions in accurately modeling force fields on the atomic scale is well established in nuclear physics. On a much larger scale, the motion of a small body orbiting a binary star system serves as a new and interesting application for determining the characteristics of a three-body interaction. In this investigation, frequency analysis is used to study its effect on possible orbits of the exoplanet. When weighted appropriately, the three-body force contribution is found to significantly alter the stability, form and existence of periodic and quasi-periodic orbits available at various energy levels. Physically, this means that exoplanets could follow orbits that cannot be accurately recovered using traditional inverse-square gravitational forces.

This interdisciplinary research is the result of a collaborative effort involving myself, Professor Kathleen Howell (my advisor in Aeronautical and Astronautical Engineering) and Professor Ephraim Fischbach (Physics). Initially, the question underlying this research was posed and constructed by Professors Fischbach and Howell; in fact, Professor Fischbach has published numerous papers exploring many-body forces in the context of nuclear physics. Given this initial question, I numerically modeled and analyzed the dynamics of the exoplanet by constructing “maps” of the solution space and performing both frequency and stability analyses of a subset of trajectories. Under their guidance, I have interpreted these numerical results to explain the characteristics of the proposed three-body interaction in binary star systems.

To our knowledge, the application of many-body forces to orbital dynamics has not yet been explored. Thus, presenting this research at the 23rd AAS/AIAA Space Flight Mechanics Conference would provide a crucial forum for sharing this new and exciting problem with the astrodynamics community. Since this will be the first time that this research question is documented and presented publicly, it is anticipated that attending this conference will further Purdue University’s name as a well-renowned research institution, always at the forefront of interdisciplinary innovation. In addition, attending this conference will prove beneficial to the advancement and success of my intended career in academia; primarily because it is the culmination of original research performed during my Masters degree. Active participation in the Space Flight Mechanics conference will allow me to network with other astrodynamicists, introducing me to alternative methodologies that can be developed and used to explore the characteristics of this new, modified force model as I move forward into the PhD program at Purdue University.
A Protein Kinase Assay Linked with Phosphoproteomics (ProKALIP) Method To Identify Direct Kinase Substrates

The involvement of protein kinases in disease has been extensively studied in cancer, diabetes, cardiovascular diseases, and central nervous system pathologies. Therefore, to understand the disease pathology requires the identification of protein kinase substrates. However, the method used to screen kinase substrates has been challenging. To address this issue, I developed a novel proteomics strategy suitable for identifying the potential substrates of any protein kinase. Identifying substrates by this method would provide critical insights into how the biological system is regulated and our understanding of such a mechanism will eventually benefit drug discovery in the pharmaceutical industry.

In my experimental design, a pool of proteins is extracted from cellular lysates. After in vitro kinase reaction, the phosphorylated proteins are identified by mass spectrometry. A comparison of consensus sequences of the phosphoproteins reveals the specificity of the kinase and identifies putative substrates. At the same time, I profile the whole endogenous phosphopeptides derived from cells in which the specific kinase is active or inhibited. Overlapping this data with the in vitro reaction results further enhances the identification of protein kinase substrates.

Using spleen tyrosine kinase (SYK) as a proof of principle, I identified more than half of known substrates and several novel substrates that were further confirmed by in vitro kinase assay, demonstrating the sensitivity and accuracy of this method. Bioinformatics annotation identified several major signaling pathways, such as the immune response and signaling transductions. Some uncharacterized pathways like transcription regulation and cell morphology were also elucidated from our study, indicating the power of this method to identify new biological pathways. These results demonstrate that this experimental design should be well adaptable for the substrate screening for any protein kinases.

I have been working on this project since I started at Purdue in 2008 and some preliminary work has been published in Proceedings of the National Academy of Sciences. I single handedly initiated this project, designed and conducted all the experiments, analyzed the data, and prepared the manuscript with my advisor.

I will present this research at the annual conference of American Society for Mass Spectrometry (ASMS). Considering the high demand of methods to identify kinase substrates, this presentation is a precious chance to introduce this valuable proteomics method to the ASMS society, which is the largest professional association that supports the scientific field of mass spectrometry around the world. I expect such novel technique would expand and benefit phosphoproteomics research. Meanwhile, as the only group that focuses on the mass spectrometry based proteomics at Purdue, only my group can raise the reputation of Purdue on the proteomics field through such encouraging work. Moreover, I will be able to learn about the most recent advances in my field which can be shared with other group members, and I will be able to network with academics and professionals for my career development and Purdue’s visibility.
Examining the skills and methods of graduate mentors in an undergraduate research settings

Previous studies have shown that graduate student mentors have great impact on the education of undergraduate researchers in various undergraduate research (UR) settings. Graduate mentors’ roles can vary from initiating and maintaining regular contacts to providing research guidance and encouragement to undergraduate researchers. The relationship between graduate students and UR students, however, is not without challenges. Some of the challenges in the relationship are due to graduate mentors’ lack of skills in training undergraduates as future researchers. Studies show that a positive relationship between undergraduates and graduates in UR settings increases UR students’ understanding of how to conduct research, as well as UR students’ enrollment in graduate schools. For these reasons research that purposefully examines ways to build and sustain positive mentor-mentee relationships is clearly warranted. Therefore, the purpose of my study is to identify practices and skills that (1) graduate mentors have successfully employed in a research setting and (2) undergraduate students have found to be beneficial. The study will determine the number of recurring methods employed by graduate mentors and appreciated by undergraduate researchers in the UR program.

To identify exceptional mentoring practices and skills of graduate mentors, UR students were asked to complete a form assessing their mentor’s abilities and describing their relationship. Twenty-two nomination forms were submitted, and I am responsible for analyzing these forms. I will use a constant comparative analysis procedure, which means categorizing similar skills and abilities under a common construct. I am responsible for developing assertions about graduate students’ mentoring practices and skills and synthesizing the findings with existing literature. Using the results from this study, I will spearhead the creation of seminars and professional development workshops that educate graduate students on how to effectively address the challenges associated with mentoring undergraduate researchers.

Attending the conference is a chance for me to share my work and receive feedback from researchers outside Purdue. It is an occasion for me to convince my audiences of the importance of my research and generate a wave of interest for future research opportunities. Furthermore, meeting researchers and administrators from the conference can help me examine the current research trends, and postulate future research areas that are going to be of great importance in my field. I will share this knowledge with my colleagues in my department to help us broaden our perspective and pursue research areas of great potential.

I have worked with researchers from China, India, Korea, Turkey, Mexico, and Saudi Arabia all of whom are interested in my current research. This international network will be present at the conference, and I am excited to share my work with them, especially projects like Developing Leadership Capacity in Undergraduate Students and Professional Practices of PhD Students. I want to help implement workshops based on the projects mentioned above at other universities around the world to help them better educate future scholars. Furthermore, as a representative for Engineering Education department and for Purdue University, I will pursue future collaboration with international researchers to advance knowledge in engineering education.