Presidential Faculty/Student Collaboration and Publication Grant
Deadline Monday, February 20, 2017

Please use this checklist and budget. Include with your completed application. For more information about Presidential Faculty/Student Collaboration and Publication grants, please see https://gustavus.edu/kendallcenter/grant-opportunities/presidential-grant.php.

FACULTY INFORMATION

Name: Jessie Petricka

Email: jpetrick

Department: Physics

Rank: Associate

STUDENT INFORMATION

Name: Travis Boskowitz

Email: tboskowi

Major(s): Physics

Graduation Year: 2018

CHECKLIST

Project Details

- ☒ Brief description of the proposed project including its collaborative nature
- ☒ Clear statement of anticipated outcomes
- ☒ Likely placement for publication or performances
- ☒ Anticipated research completion date

Participant Details

- ☒ Names and brief biographies of all participants
- ☒ Explanation of how this project fits into the career of the faculty member
  Note: Applications from faculty at all career stages are encouraged
- ☒ Explanation of how this project fits into the educational trajectory of the student
  Note: Statement should be written by the student; include year of graduation; student eligibility is limited to full-time returning students

- ☒ **Presidential Budget Proposal Form**

- ☒ If successful, my proposal can be used as an example to assist future applications. Check to give permission. This decision will not influence the application evaluation.

Submit electronically as a PDF to cblaukat@gustavus.edu at the John S. Kendall Center for Engaged Learning.

Presidential Faculty/Student Collaboration Grant

Budget Information

Faculty Stipend ($300 per week, up to $3,000 for a maximum of 10 weeks)
Student Summer Stipend ($400 per week, up to $4,000 for a maximum of 10 weeks)
Student Summer Campus Housing ($60 per week, for a maximum of 10 weeks)
Budget Maximum ($8,100 for all categories)

Item		**Amount**
Equipment (e.g., transcription machine, camera, cassette recorder – but not to include computer hardware)		$ 500
1: Sputtering Target	Cost: 500	500
2:	Cost:	
3:	Cost:	
Materials (e.g., books, printing, software, lab supplies)		$
1:	Cost:	
2:	Cost:	
3:	Cost:	
Travel Costs (cannot include conference travel, see http://gustavus.edu/finance/travel.php for allowable travel expenses)		$
Airfare:		
Mileage: Number of miles_____ @ $0.53.5/mile		
Lodging:		
Meals:		
Stipends & Housing		$7,600
Faculty Stipend	$300 per week, up to $3,000 for a maximum of 10 weeks	3,000
Student Summer Stipend	$400 per week, up to $4,000 for a maximum of 10 weeks	4,000
Student Summer Campus Housing	$60 per week, up to 10 weeks	600
Total Expenses		$8,100
Amount Requested (Total Expenses + Requested Stipends + Housing)		$8,100

Have you applied for, or received funding from, another source to help support this project? (If no, skip a, b, and c below.)

☐ Yes ☒ No

a. Funding Source:
b. Amount:
c. Please explain how the Presidential grant will be used in addition to the other funding, and (if relevant), how the Presidential grant project would be impacted if external funding is not approved.

Molecular Ion Reaction Rates in a Linear Quadrupole Trap

Jessie Petricka
Travis Boskowitz

Brief description of the proposed project and its collaborative nature:

The overall goal of this study involves the measurement of reaction rates (charge exchange and other chemical reactions) between trapped molecular ions and a variety of other introduced gasses (either co-trapped ions or introduced neutral background). Over the course of this investigation Jessie and Travis will work closely together to conduct all stages of the scientific research. One additional student (funded likely either through the FYRE program or internal physics dept.) will also be sought to join the lab during this time, and together Jessie and Travis will first train then also collaborate with this student.

Travis Boskowitz has been a research student in the Petricka AMO lab since the fall of 2016. Since beginning, Travis has shown an ability to quickly learn the full apparatus and all its intricacies. Despite a steep learning curve on this task, Travis has already become proficient at using the apparatus with minimal supervision. In addition, Travis has demonstrated an inquisitive nature and experimental maturity, core requirements for the collaboration necessary to move this project forward. Travis has also shown the ability to work well with others (in lab, and classes) and the ability to teach/train (as a department TA) which will help in bringing a new person into lab.

Project description:

The field of atomic physics has seen an explosion of interest, activity and results in the last 15 years due to the AMO (atomic, molecular, and optical) community's ability to control both the internal and external degrees of freedom of matter. Such control has allowed for the creation of ultra-cold and ultra-pure quantum samples with which to do experiments. By far the bulk of the results have been with a few specific neutral atoms, where the internal structures of those atoms allow for specific cooling and trapping techniques[1]. Yet the achievements of the ultracold atom field with this small set are remarkable. From basic quantum science with Bose-Einstein Condensation and degenerate Fermion gases[2,3], to fundamental precision measurements of constants and spectroscopy[4], even practical atomic sensors and ultra-precise atomic clocks[5], ultracold atoms have revolutionized the field of AMO. Unfortunately, these techniques fail for more complex atoms and especially for molecular samples, samples whose complexity would lead to vast increases in scientific understanding and practical utility.

General molecular experiments follow the same basic routine as atomic experiments, sample production, followed by manipulation and then detection. As alluded to, the first step, production is the enabler that allows a host of other study.

Much of the current focus for production is on producing ultracold neutral molecules, as neutral molecules can be brought into close proximity to one another, achieving a density where quantum effects are important and bring the atoms to where short range forces will cause the molecules to interact. Even though the field is making progress toward this goal, the growing number of competing techniques is neither general nor able to produce the high density and cold temperatures that applications and scientific study require[6].

The study of molecular ions, on the other hand, has seen less attention for a couple of reasons. One is because a clear production method (as for neutrals) is yet to be found. Another is that ions interact via the long range Coulomb force. Coulombic repulsion pushes ions apart, reducing the density of the sample and dwarfing any short range interactions. Their study, though, is interesting for several reasons. The trapping of ions is a well established and straightforward field, working generally for any charged object[1]. While certain applications and studies with ultracold molecules would not work with ions, several of the most interesting remain, including the study of cold chemistry[7], ultra-precise measurement of molecular transitions, and implementation of a scalable quantum computer[8].

Upon trapping, ions can be cooled a number of different ways. Laser cooling, the staple of neutral atom research, can cool simple ions but again fails for molecules due to their internal structure. The simplest method for cooling those with complex structure is collisional cooling, where an introduced cryogenic gas (such as a simple ion[10] or noble buffer gas[9]) is brought into thermal contact with the molecular ions. To date the choice of refrigerant has been successful in cooling either only the external degrees of freedom (motion) or, to a very limited extent, both. It is clear that further research in the methods for producing ultracold ions, if successful, would be a boon to further scientific research. What is limiting progress is experience with molecule ion / refrigerant reactions and interactions.

We plan to study these reaction for a variety of molecular ions and potential refrigerants (other introduced gasses). By measuring the reactions such as charge exchange rates, and interactions such as cooling efficiency[10], we believe that suitable choices can be found that allow cooling both external and internal degrees of freedom to the ultra cold regime. This data will be invaluable to the field as it continues its quest for the production of ultra cold molecular ions.

Previous work:

With strong summer students and independent studies during the school year, a number of milestones have been reached in the ion trapping project. The entire design, construction, testing, revision, and use of this apparatus has been collaboration with former and current research students. Several components, including control electronics, vacuum, optics and lasers, ion detectors and data collection systems, and trapping hardware have all been successfully implemented to complete a useable and useful ion trap. Most recently, a 2017 IEX project with two students implemented an automated software control for the measurement of the number of ions in the trap over time. This measurement ability is directly applicable to the measurement of reaction rates for the proposed project.

Anticipated outcomes and research goals by the end of summer 2017:

- We will design and implement a method for the introduction and measurement of background gasses into the trapping environment.

- We will develop a reaction rate experiment protocol.

- We will measure the trapping lifetimes of a variety of trapped species with a variety of introduced gasses.

- We will explore the possibility of optical detection of the ions.

- We will create and present a project poster for presentation at the 2018 American Physical Society Division of Atomic Physics meeting.

Participant details and career trajectories:

Jessie Petricka

Jessie Petricka is an associate professor of Physics. He has been teaching and researching at Gustavus since 2009. The focus of his Ph.D, postdoc, and current research is on atomic, molecular and optical physics where he studies the interactions between molecular gasses.

During my eight years at Gustavus, I have supervised a total of nine summer students, most on the ion trapping project. This project is a long term effort that provides challenging and interesting directions to both students and myself alike. As mentioned above, all phases of the project have been and will continue to be collaborative with students. Due to the nature of the undergraduate research environment, and to the steep learning curve with the apparatus, summer is the time where by far the bulk of progress is made. The ion trapping project is entering an interesting phase where it is on the cusp of producing publishable data interesting and relevant to the field. Such a milestone would be extremely beneficial to the project, as it would raise my competitiveness for external funding of this project.

Travis O. Boskowitz

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Education

Gustavus Adolphus College, St. Peter, Minnesota
Bachelor of Science: Physics, May 2018

Accomplishments

Programming

- C, Python, Matlab, and LabVIEW

Testing, Evaluation and Analysis

- Tested equipment to ensure compliance
- Analyzed data and provided and received recommendations in developing new research solutions given our experimental setup
- Performed data collection and statistical analysis

Engineering

- Created a burglar alarm circuit to warn when a laser tripwire was clipped with a secret code to stop the alarm
- Created a LabVIEW VI to communicate with equipment, moving a stepper motor and collecting data. Data was written to a file
- Built pieces of a deer stand, then created a way to place them upon a platform 10 feet in the air and assemble them into the final product

Related Experience

Research assistant: Petricka Lab, Gustavus, September 2016-Present

- Familiarity with the equipment, programs and procedures
- Understanding of the goals, and ideas on how to accomplish them
- Ability to reflect on previous work and see ways to improve

Skills

- Experience with sophisticated equipment
- Advanced analytical and applied mathematical skills
- Inventiveness and ability to think outside the box in attempts to fix errors
- Ability to learn new technologies quickly

Leadership and Student Involvement

- Society of Physics Students
- Physics Demos for Youth

After college, I plan on attending graduate school for a PhD in physics with a focus on Atomic, Molecular and Optical (AMO) physics, condensed matter physics or particle physics. This research experience would help me prepare for graduate school, because all of these are experimental disciplines, and it will allow me to get a better understanding of sustained research in AMO physics, allowing me to observe the nature of research at the professional level, full time. At the same time, I am interested to continue learning new lab techniques and be able to incorporate the skills I have learned in the classroom and lab setting to a practical research setting. I've always been interested in the intersection between chemistry and physics, and one of the long-term goals of the experiment is to study the way chemical reactions occur in a changing electromagnetic field, allowing me to have that experience as well. In conclusion, this research experience could help me gain the confidence and experience needed to become a graduate student at a competitive university and pursue my career.

References:

1. Foot, C. *Atomic Physics*. (Oxford University Press: Oxford, 2005).
2. O'Hara, K.M., Hemmer, S.L., Gehm, M.E., Granade, S.R. & Thomas, J.E. Observation of a Strongly Interacting Degenerate Fermi Gas of Atoms. *Science* 1079107 (2002).doi:10.1126/science.1079107
3. Anderson, M.H., Ensher, J.R., Matthews, M.R., Wieman, C.E. & Cornell, E.A. Observation of Bose-Einstein Condensation in a Dilute Atomic Vapor. *Science* **269**, 198-201 (1995).
4. DeMille, D. et al. Enhanced Sensitivity to Variation of m_ ${$e$}$/m_ ${$p$}$ in Molecular Spectra. *Physical review letters* **100**, 43202 (2008).
5. Rosenband, T. et al. Frequency Ratio of Al+ and Hg+ Single-Ion Optical Clocks; Metrology at the 17th Decimal Place. *Science* **319**, 1808-1812 (2008).
6. Carr, L.D., DeMille, D., Krems, R.V. & Ye, J. Cold and ultracold molecules: science, technology and applications. *New Journal of Physics* **11**, 055049 (2009).
7. Hudson, E.R. et al. Production of cold formaldehyde molecules for study and control of chemical reaction dynamics with hydroxyl radicals. *Phys. Rev. A* **73**, 063404 (2006).
8. DeMille, D. Quantum Computation with Trapped Polar Molecules. *Phys. Rev. Lett.* **88**, 067901 (2002).
9. Petricka, J. A New Cold Molecule Source: The Buffer Gas Cooled Molecular Beam. (2007).
10. Hudson, E.R. Method for producing ultracold molecular ions. *Phys. Rev. A* **79**, 032716 (2009).