SRI REU 2013 STUDENT PROJECTS AND PROGRAM ACTIVITIES

STUDENT RESEARCH PROJECTS AND ACCOMPLISHMENTS

Below is a summary of each student's project at the Molecular Physics Program at SRI International during the summer of 2013 in their own words with some editing of the text as appropriate.

Emma Regan (Wellesley College, Wellesley, MA)

Mentor: Dr. Gregory Faris

Project Title: New Nonlinear Optics Methods for Stimulated Rayleigh-Brillouin Scattering

This summer, Dr. Greg Faris and I used new optical techniques to create a system for stimulated Rayleigh-Brillouin scattering measurements that will evolve into a microscopy system for biological applications. The system consists of a pump and a probe beam, which are modulated to different frequencies, amplitudes, and pulse lengths by acousto-optic (AOM) and electro-optic modulators (EOM). The beams then overlap in a sample, producing a grating, causing the pump to scatter in the direction of the probe, and ultimately giving a detectable gain signal in the probe beam.

When I arrived, the AOMs, EOM, and accompanying electronics had just been set up, so I characterized the loss of each component to determine appropriate input power and attenuation to safely use the system. Once we were able to use the electronics, I tested the output of the EOM using the Fabry-Perot interferometer and determined that the sidebands followed the expected power spectrum defined by Bessel functions. About a month into our work, we revised many of the electronic components to reach higher frequencies more effectively, so I then re-characterized the electronics to determine a setup that would not damage any of the components. I then set up and learned to use two arbitrary function generators and wrote the code to make all necessary modulation waves and save them for the appropriate boards.

Once the electronics and arbitrary function generators were ready for use, we were able to monitor output signals from the EOM using a Fabry-Perot interferometer and determine how to reduce the power loss associated with sideband generation. To avoid distributing power among sideband frequencies, we forced most of the power into one sideband using the EOM. However, due to bandwidth limitations, this method is only viable for lower frequencies, so we simulated other methods for the Brillouin scattering. The first involved an amplitude modulator followed by an intensity modulator. I optimized this process to give 69% of the carrier power into one sideband, which is unfortunately not quite high enough to offset the technical difficulties of using hybrid modulation. We then simulated the effect of limited bandwidth using the first method, but it gave about the same result as the two modulators, and was still not useful for the Brillouin signal. While these simulations did not give us a perfect method for creating single sidebands for Brillouin scattering, I was able to rule out possible solutions while learning the mathematics behind the signal modulation and improve my coding skills.

After working with the EOM, we got the entire system online by connecting the modulation boxes to the appropriate amplifiers, lasers, and optical components. I characterized the output of the amplifiers and the frequency-dependent loss of the EOM and electronics, which allows us to generate a single-amplitude sweep. We also generated a single sideband with sidebands, which could be used for the Rayleigh signal. While there are still a few steps to be taken before

generating Rayleigh and Brillouin signals, we made significant progress in creating a functioning stimulated scattering system. My work at SRI exposed many wonderful and difficult aspects of research, and I am grateful for all of the advice that I received and knowledge that I gained while working here.

Kate Storey-Fisher (Brown University, Providence, Rhode Island)

Mentor: Drs. Konstantinos Kalogerakis and Oleg Kostko

Project Title: Laboratory Investigations of Excited O2 Emissions Relevant to CO_2 Atmospheres

My research this summer involved studying excited states of oxygen that contribute to airglow on Venus. The original goal of the project was very general: we wanted to study the energy transfer pathways of airglow processes. We decided to focus on the kinetics of oxygen atom recombination, intending to determine the speed of the process and the excited states of molecular oxygen produced. We studied this reaction in a CO_2 environment relevant to the atmosphere of Venus, which will contribute to the knowledge of the atmospheric dynamics of the planet.

The experimental apparatus had already been assembled when I arrived, so I just had to learn how to use it. We used an excimer laser to photodissociate the molecules, and a monochromator setup to measure the excited O_2 emissions at each wavelength. I learned how to run the laser, achieve the desired pressure conditions in the gas cell, and produce a spectrum and temporal evolution. I also worked on calculating the partial pressures of the gases and finding the degree of dissociation of CO_2 molecules into O atoms, as well as optimizing the spectral signal by adjusting the monochromator and photon counter.

In some of our early simulations of Venus at higher pressures, we noticed an excited O_2 transition that had not been confirmed on the spectra taken from Venus, and I ended up spending much of my summer looking at this transition. We determined that this transition, from the ‘c’ state to the ‘a’ state (c-a), must be pressure dependent, using the strong c-X transition as a relative signal. I performed experiments over a range of pressures to determine the c-a/c-X pressure dependence. I also spent a while experimenting with different gas mixtures and found that these had varying enhancement effects. Fitting my pressure-dependence data revealed that three-body collisions had a strong enhancement effect, which explained why we see the c-a transition at higher pressures but not at the lower pressure of Venus’s atmosphere. I then used my data fit to extrapolate to the pressure on Venus and found that the peaks we expect to see for the c-a transition would be near the instrumental detection limit, which is why they are difficult to discern on the Venus spectra. Therefore, I was able to provide evidence for the existence of the c-a transition on Venus, adding to our understanding of excited O_2 emissions and the general dynamics of the atmosphere.

I completed my focus project, but there is still a lot to do to achieve our original goals. My research group intends to determine the rate constants for oxygen atom recombination and the energy transfer pathways for other airglow reactions, information that will eventually allow theorists to better model CO_2 atmospheres like that of Venus. While I mainly focused on a small phenomenon that is only a piece of our larger research goals, I was able to learn so much about aeronomy and physical chemistry, not to mention research in general. Immersing myself in this research environment has made me consider everything from the challenges of being a female

scientist to the fundamental nature of the quantum universe, and I plan on continuing to grapple with these ideas as I pursue further research in physics.

Gary Wan (Ithaca College, Ithaca, NY)

Mentors: Drs. Gregory Faris, Eric Hall, Chia Pin-Pan and Sanhita Dixit

Title: Optical Microfluidic Applications for Single-Cell PCR and Artificial Bilayers

So, this summer I made drops—many, many drops. If I had to put my whole research input at SRI this summer into one sentence, that would quite possibly summarize the bulk of it most accurately. My initial research project involved the continued development and improvement of two bio-analytical procedures: single-cell polymerase chain reaction (PCR) analysis, a process involving isolating a single cell in a droplet of fluid and running a quantitative PCR (qPCR), or the quantified amplification of DNA on the cell and, artificial bilayer analysis, a process in which artificial lipid bilayers are created with droplets to simulate cellular membranes with applications in testing drug compatibility. Both projects involved the formation and optical manipulation of droplets of fluid on the micron scale, usually less than 300 μm, and all the complications that went with it. So first, we needed good droplets.

Two-and-a-half months of drops later, we have improved the existing method of making micro-droplets, and have consistently produced droplets that were less than 100 microns. The two most important factors that we found in producing ideal droplets were: (i) high-quality, reproducible micropipettes with smaller diameters and with durable coatings; and (ii) adjustable parameters on the automated micropipette movement system that could adapt to different situations. In the end the complications were not in producing droplets, but in producing them *well*.

This summer has been a long, strange path, and this opportunity has been the first serious research project I have ever been involved in. There was definitely miscommunication, stumbling, and the occasional seething frustration. It was not easy to balance everything that was going on, but along the way I learned more than I ever could on my own—not just about the projects, but about research in general, communication, and nearly everything else in the universe. Literally, almost every topic would come up this summer in one way or another—and it was beautiful.

Nicholas Cothard (University of Rochester)

Mentor: Dr. Daniel Matsiev

Title: CESAR: The Compact Echelle Spectrograph for Aeronomical Research

CESAR was designed to be a high-throughput, high-resolution spectrograph for aeronomers to study airglow. This fall, CESAR will hopefully be deployed to Alaska, where it will collect airglow data throughout the winter. This summer, I worked with my mentor, Daniel, to construct and test CESAR. With most of the parts already ordered and in the lab, Daniel and I were able to build CESAR from the ground up so that we could understand how to assemble it in Alaska. We spent a lot of time examining each component and determining the best and most efficient method of installing it. We began with the struts, CESAR's structural support. We discovered that the majority of them were misthreaded, so we rethreaded them and installed them onto CESAR's frame. Next, we looked at the off-axis- parabolic mirror (OAP), which collimates light from the slit and passes it onto the optical gratings. We disassembled, cleaned and reassembled

the OAP before installing it, and its linear translation stage onto CESAR. The Echelle and cross-dispersing optical gratings needed similar examination, and I kept a log of our methods that will be used as an assembly manual in Alaska.

The next component we worked on was the camera, which needed to be optically aligned before it could be installed. To do this, I designed a method of passing four parallel HeNe laser beams into the camera. This was a lot of work because the lasers needed to be parallel to the optical axis of the camera, and achieving such an alignment was not a trivial task. Once the alignment of the lasers was complete, we were able to adjust the alignment of the charge-coupled device (CCD) inside the camera by taking images of the four laser beams and observing where they converge. Once Daniel and I were satisfied with the alignment, we installed the camera with the rest of CESAR.

With CESAR fully assembled, we connected it to the computer and cooler and began to take images. We collected neon spectra and worked on correcting the focus of the images. A major issue that we faced was order overlap. The diffracted orders of light from the Echelle grating were very close together and overlapped in many regions. We eventually achieved an alignment without order overlap and very distinct spectral features. We estimate a resolution of 16,000-17,000. At the end of the summer, Daniel and I worked on improving the focus of the images and exploring methods of extracting spectra from the images.

Ernest Frimpong (Canada College)

Mentor: Drs. Jason White, Jochen Marschall, and Richard Copeland

Title: REMPI Measurement for O2 and N2

My experiment relates to the interaction between thermal protection systems (TPS) and atmospheric molecular species on the surface of hypersonic flight vehicle reentry. When hypersonic flight vehicles re-enter the atmosphere, they generate strong shock waves ahead of leading edges that can dissociate molecular species into atoms and radicals. The reactive species can diffuse into the boundary layer of the vehicle surface, where they react on or with the TPS. TPS materials catalyze the recombination of dissociated species back into molecules, a process that is exothermic and can contribute to the heat flux and overall heat that the TPS must withstand. Catalytic recombination is known to contribute to aerothermal heating for many different types of hypersonic vehicles. Unfortunately, very little is currently known about the molecular-level energy transfer mechanisms between vibrationally excited and electronically excited molecules and surfaces, either during formation or collision energy transfer.

My project laboratory experiments were designed to study the production and interaction of vibrationally excited and electronically excited oxygen with a silica surface. We used quartz as our model for the experiment. The oxygen-silica system is relevant to many hypersonic vehicles since most current high-temperature oxidation-protection systems for leading edges on hypersonic vehicles involve silica-based or phenolic materials.

When two oxygen atoms recombine they release about 5.1 eV of energy. The highly-energetic recombined molecule forms in one of the upper electronically-excited states (e.g., $X\ ^3\sum^-_g$, $a^1\Delta_g$, or $b^1\sum^+_g$) and settles into lower energy states through intermolecular collisions. From the potential energy diagram we can easily access $O_2\ a^1\ \Delta_g$. In a previous study by White, Marshall, and Copeland, they were able to detect ($O_2\ a^!\ \Delta_g$) (v=0). The goal of my experiment was to determine the amount of ($O_2\ a^!\ \Delta_g$) (v=1) that may be made.

Resonance enhanced multiphoton ionization (REMPI) is used to detect the electronic and vibrational product of small molecules on surfaces. The REMPI technique typically involves a resonant single or multiple photon absorption to an electronically excited intermediate state followed by absorption of another photon that ionizes the atom or molecule. In our experiment, we used a 2+1 REMPI scheme.

In this scheme, O-atoms travel downstream into the detection cell, where they are ionized with frequency doubled light from a dye laser pumped by an Nd:YAG laser. The ultraviolet (UV) light is focused on the REMPI cell, where the O_2 molecules absorb the photon from the beam and are ionized. The electrode in the cell attracts the ionized molecules, where they are collected and recorded by the computer.

TPS-relevant materials involve silica surfaces. To mimic these surfaces, we used a quartz tube. With a total cell pressure of ~ 1.000 Torr, a microwave discharge is used to generate oxygen atoms. These O-atoms recombine on a quartz surface travelling downstream into the detection cell and pick up energy, which can electronically excite O_2 molecules and vibrationally excite O_2. This procedure is also repeated for a nitrogen discharge to study the influence of excited nitrogen on our signal levels. A calibration procedure based on ozone photo-dissociation into $O + O_2$ is developed to quantify the O_2 ($a^1\ \Delta_g$) (v=0) and (v=1) REMPI signal followed by detection of vibrationally excited O_2 using a two laser technique.

We could see signals detected at v=0 and v=1 with ozone, and with oxygen we could see good signals at v=0; however, at v=1, the signal was difficult to identify. Also our nitrogen signal is flat or no signal at the range where scanning was performed. Since ozone photo dissociation occurs in the REMPI cell, it is easier to detect signal on the scan at both v=0 and v=1. But the oxygen signal is difficult to identify because it loses energy due to collisions as it travels downstream through the quartz surface as it recombines. Hence, nitrogen has no signal, just a flat spectrum.

The table below shows the ratio of detection at v=1 between ozone and oxygen molecule after integrating the signals.

Ozone (O_3)		Oxygen (O_2)	
v=0	0.85	v=0	1.43
v=1	0.30	v=1	0.03
Ratio (v1/v0)	0.35		0.02

The signal collected for nitrogen was flat; hence, it was not a contributing factor to the O_2 signal at v=1.

The overall impact of this project was that I had extensive hands-on experience with lasers, learning new skills in quantification and calibration of flow meters, laser operation and safety, ionization method using REMPI technique, and ozone generation and measurement. I have also acquired knowledge of gas-phase physics and computer software programs, i.e., PGOPHER and SciDavis.

Timothy Weber (Columbia University)

Mentor: Dr. Gregory Faris

Title: Fourier Transform Imaging Spectroscopy

My work this summer in the biomedical optics labs mainly involved building and testing a novel imaging device for fluorescence microscopy in small biological samples. As molecular biology experiments grow in complexity and automation, we anticipate a need for new high-channel imaging techniques. Such needs would be satisfied by a so-called “hyperspectral” imaging device, where a full spectrum of visible light is recorded for each pixel location in the image. A large number of closely colored, distinct fluorophores could be detected with a hyperspectral device and could be used to achieve needed high-channel imaging. Currently, multichannel microscopy is accomplished with the use of individual optical filters, each of which selects the specific wavelength of interest. Afterward, the images acquired from each filter are merged and a multichannel fluorescence image is recovered. This process becomes slow, cumbersome, and potentially damaging to the sample as the number of channels increases.

With my mentor, Dr. Gregory Faris, I worked to design and build a hyperspectral imaging device based on Fourier Transform imaging that addresses some of the inefficiencies in the current multichannel fluorescence imaging process. Fourier transform imaging does not directly record spectral information, but instead relies on the interfering properties of light. A 50:50 beam splitter first splits incoming light. Both split-light paths are reflected back toward the beam

splitter by mirrors placed at slightly different distances from the beam splitter. When the distance from the beam splitter to one of the mirrors is slowly changed, the recombined beam exhibits light interference effects, which can be recorded by a camera. The resulting signal as a function of light path difference between the two mirrors is called an interferogram. The interferogram can be mathematically transformed via the Fourier Transform to recover the original spectrum of the incoming light.

My task was expanding the concept of interference-based spectroscopy to imaging. I achieved this by focusing an image into infinity space, where it could be transmitted through a 1-inch cubic beam splitter and 1-inch diameter mirrors.

I built the system from scratch. First, I assembled all of the optics and spent a great deal of time working out techniques to align and properly interfere with a test He-Ne laser beam. Next I wrote a suite of software tools in LabVIEW, MATLAB, and ImageJ to control the displacement actuating devices, operate the camera, process recorded data, and view hyperspectral information in a meaningful way. During the summer, I ran into countless technical issues, but Dr. Faris and I were generally able to debug each one. Some of the issues involved phase correction, displacement velocity linearization, and wavelength calibration.

Toward the end of the summer when the system was nearing readiness for microscopy, I conducted a few successful performance tests. The first of these was a test of a mercury fluorescent lamp. With the system, I was able to record a crisp image with clear spectral lines that accurately corresponded to the spectra of the light source as verified by a commercial spectrometer. The second performance test involved the reflectance of a broadband light source on a multi-colored logo. In this test, I was able to clearly pick out colors in the hyperspectral image, which accurately represented the colors of the true logo.

During my last week, Dr. Faris and I worked very hard to connect the system to an existing florescence microscope. We were able to calibrate the system, but we were unable to obtain useful microscopy images. Dr. Faris will continue work with this system, and I plan to continue on the project by processing data remotely.

Overall, I really enjoyed my experience at SRI International. Just by virtue of being in the proximity of such great scientific research, I was able to soak up and learn a lot about many diverse topics, from aeronomy all the way to computer science. I enjoyed the handful of site visits we had to neighboring institutions and companies. I hope some day I will be able to return to the area where SRI is such an integral part of.

Madeleine Lu (St. Mary's University) (Student Visiting Fellow)

Mentor: Drs. Hua Lin and Thomas Shaler

Title: Isomerization and Autolysis of Specific Amino Acid Residues of Tau Protein and its Relation with Alzheimer's disease

Alzheimer’s disease is the most common form of dementia that more than 5 million Americans suffer from. It is the 6th leading cause of death in the United States. With no known cure and no known cause, Alzheimer’s disease is an urgent matter that researchers are attempting to tackle. Alzheimer’s disease is clinically characterized by memory loss and histopathologically characterized by the high prevalence of amyloid plaques and neurofibrillary tangles (tau tangles). In a healthy brain, the tau protein performs the role of stabilizing microtubules in healthy neurons. However, due to their long turnover rates, they are susceptible to many non-enzymatic,

post-translational protein modifications, including racemization. While many non-enzymatic protein modifications can be repaired or replaced, damaged extracellular proteins can accumulate in a time-dependent manner if the protein has a long turnover rate. Racemization is the spontaneous transformation of an entiomerically pure mixture into a mixture with more than one enantiomer present. Racemization of an asparagine residue transforms an asparagine to a rare and possibly toxic D-form from its common L-form via succinimide intermediate. The rate of racemization can be determined as levels of racemization increase linearly with time. Thus, racemized tau protein fragments can be used as a biomarker for Alzheimer's disease. This research focuses on determining the turnover rate and the rate of racemization of asparagine residues in the Tau protein.

My project goals were to isolate and identify any asparagine residues that were isomerizing into the non-native D-form. Then, if we could corroborate that this indeed occurred, our next goal was to find the rate of racemization for the specific asparagine in the Tau peptide. We were able to identify exactly where asparagine was racemizing within the Tau peptide fragment; however, we were not able to find the rate of racemization. More testing and more data are certainly needed if we hope to find it. I am confident though that finding estimates are feasible using the data from the triplicate I was able to do. Although we did not find the rate of racemization by the time the summer REU program concluded for me, we did find some surprising results. We found that the Tau peptide actually naturally cleaves at a certain fragment and forms four different isomers. We were able to come up with a possible mechanism that was occurring and leading to the formation of D-isoasparagine, D-asparagine, L-asparagine, and L-isoasparagine. Previous research shows that a similar mechanism happens naturally in certain bacteria. It was also noted that higher temperature and higher pH favors this cleavage. The location of a specific nitrogen along the asparagine side chain is ideal for the mechanism that we came up with, further strengthening the possibility of its accuracy.

SRI 2013 REU PROGRAM ACTIVITIES

Regular meetings with the REU students were scheduled to gauge student progress and address any concerns. In addition, several activities were included in the 12-week program to provide a well-rounded REU experience.

Seminars

Several opportunities exist for the REU students to attend seminars on the SRI campus. Besides the staff in the Molecular Physics Program (MPP), staff members from across the campus routinely give seminars. In addition, there are invited speakers visiting the campus as well. For example, SRI is the venue for seminars hosted under the Café Scientifique Silicon Valley initiative (http://www.cafescipa.org). Below, is a list of seminars attended by the REU students during the summer of 2013.

Date	Time	Seminar Title and Speaker
5-28-2013	3:00 - 4:00 pm	*Systems biology at the Cellular Scale using Light Microscopy* Jan Ellenberg, Ph.D. EMBL Heidelberg. Seminar Presented at Stanford University
5-31-2013	11:00 am - noon	*Translational Neuroimaging Studies: From Rats to Man* Natalie Zahr, Ph.D. SRI International
6-17-2013	1:30-2:30 pm	*A Dish Among Dishes-The 150ft Dish at Stanford* Mike Cousins, Ph.D. Stanford University
6-21-2013	11:00 am-noon	*Cubic Mile of Oil* Ripudaman Malhotra, Ph.D. Associate Director of the Chemical Science and Technology Laboratory SRI International
7-23-2013	7:30 - 8:30 pm	*The Dark Universe Through Einstein's Lens* Debbie Bard, Ph.D. SLAC Public Lecture
8-15-2013	11:00 am-noon	*To the Stratosphere and Beyond: the Unusual Isotopic Connection Between O_3 and CO_2* Aaron Wiegel, Ph.D. UC-Berkeley
8-16-2013	10:30 -11:30 am	*Microfluidic Heating Calibration via Thermal Dissociation of Contact-Quenched DNA Oligomers* Eric Hall, Ph.D. SRI International

Academic/Industrial Visits, Seminars and Presentations

1. On July 11th 2013, the REU students participated in a lab tour of the Materials Research Laboratory at SRI International. Their host, Dr. Jordi Perez, introduced them to research involving carbon dioxide capture and showed them facilities on campus that include the microchip research and production lab and silicon reactors.
2. On August 7th 2013, the REU students visited the Stanford dish along with Dr. Gregory Faris, our REU program's co-director. They were hosted by Dr. Mike Cousins at Stanford University.
3. On August 9th 2013, the REU students visited Intel Laboratories in Santa Clara, CA. They were accompanied by Dr. Sanhita Dixit and Dr. Gregory Faris (co-directors of the REU program) and were hosted by Dr. Juthika Basak at Intel Laboratories.

Student Presentations

Around the 11th week of the program, each REU student is required to give a presentation outlining the research they conducted over the summer. The lab director and other associated or interested staff attend. Presentations last approximately 20 minutes with an additional 10 minutes reserved for questions and discussion. The 2013 REU students gave the following presentations on August 7 and 8, 2012.

Student	Seminar Title
Emma Regan (REU Intern)	*New Nonlinear Optics Methods for Stimulated Rayleigh-Brillouin Scattering*
Kate Storey-Fisher (REU Intern)	*Laboratory Investigations of Excited O_2 Emissions Relevant to CO_2 Atmospheres*
Gary Wan (REU Intern)	*Optical Microfluidic Applications for Single-Cell PCR and Artificial Bilayers*
Nicholas Cothard (REU Intern)	*The Compact Echelle Spectrograph for Aeronomical Research*
Ernest Frimpong (REU Intern)	*REMPI Measurement for O_2 and N_2*
Timothy Weber (REU Intern)	*Fourier Transform Imaging Spectroscopy*
Madeleine Lu (Student Visiting Fellow)	*Isomerization and Autolysis of Specific Amino Acid Residues of Tau Protein and its Relation with Alzheimer's Disease*

Ethics Training

A formal mechanism to train the students in the ethics of scientific research was put in place in the summer of 2010. As part of this training, the students were required to take an online course to educate themselves about ethics in a research environment. The online course is free and available at: http://ori.dhhs.gov/education/products/montana_round1/issues.html#intro. The study of the following three sections was mandatory; Section One: Ethical issues in Research, Section Two: Interpersonal Responsibility, and Section Four: Professional Responsibility. At the

end of their study of each section, this website provided a test. The students were asked to take the test and furnish copies of their scores to Dr. Sanhita Dixit or Jacqueline Kritzer (REU administrative assistant).

Social Events

Students were invited to attend SRI and Laboratory events during the course of the REU program. The laboratory hosted bi-weekly payday meetings for students to learn about current news from the group and enjoy bagels/donuts in a congenial atmosphere with other lab scientists. They also attended farewell celebrations for staff, seminar presentations given by prospective postdoctoral research candidates and any group meetings that were of interest or relevant to their research. An SRI "All-Hands Meeting" given by company President and CEO, Dr. Curtis R. Carlson, provided the students an opportunity to learn about SRI staff and their research activities. Before the REU students left at the end of the program, a farewell celebration was given in their honor.

James R. Peterson Award for Excellence in Undergraduate Research

During its 50th anniversary reunion in 2006, the Molecular Physics Program announced the creation of the James R. Peterson Award for Excellence in Undergraduate Research. This award is given to the summer undergraduate student participating in the laboratory's NSF-supported REU program that best combines Jim Peterson's technical excellence and spirit of friendliness and cooperation.

REU student nominations determine the winner of the Peterson Award. The 2013 winner was Timothy Weber of Columbia University. Previous winners include Anand Oza, Princeton University (2006), Zachary Geballe, University of Michigan (2007), Brad Hartl, University of Wisconsin, LaCrosse, (2008), Aya Eid, Illinois Institute of Technology (2009), Alejandro Ceballos, Northern Arizona University (2010), Michael Rodriguez, California Lutheran University (2011), and Stefan Mellem of St. Olaf College (2012).