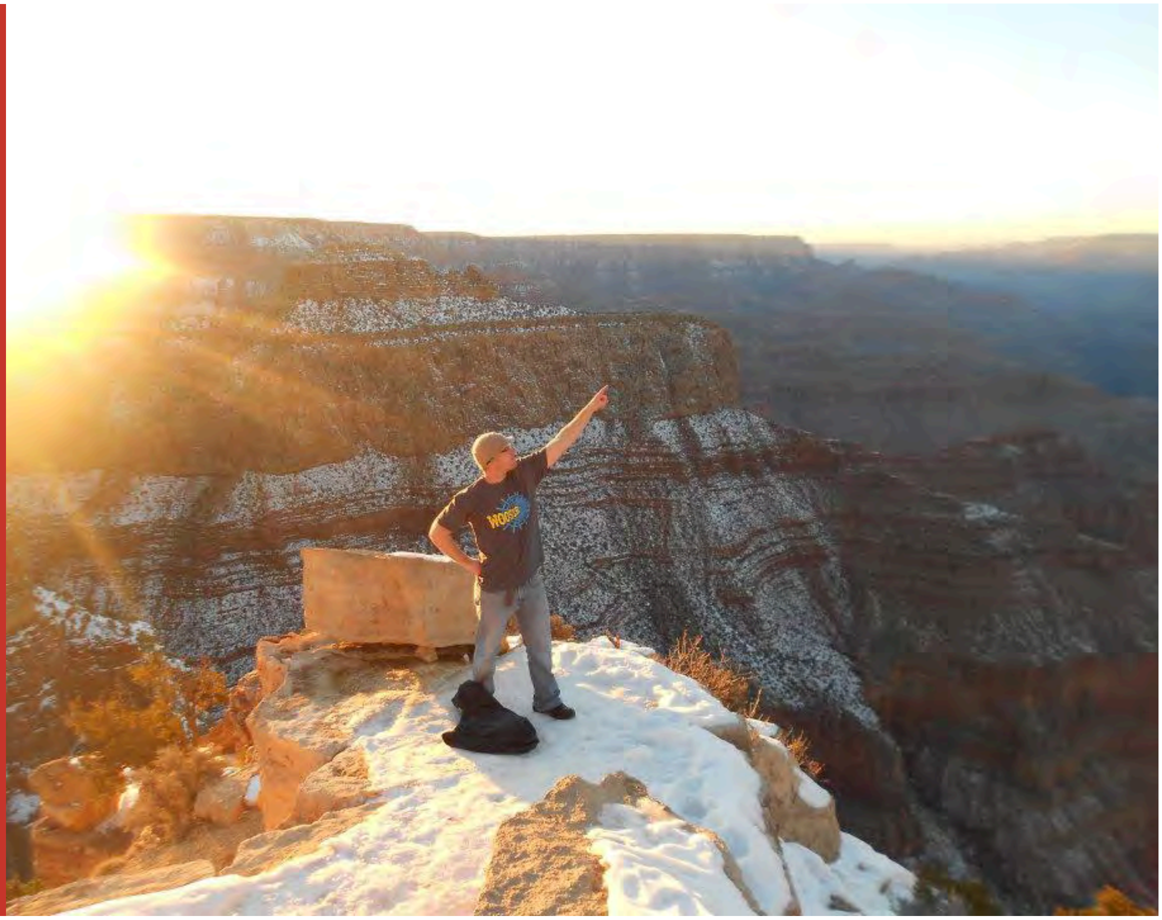
# WOOSTERPHYSICS





Tyler Rhoades '13 takes time from observing at the National Undergraduate Research Observatory in Flagstaff to enjoy some Arizona scenery.

## Greetings from the chair...

2012-13 was an exciting year for the physics department – with milestones for our students, faculty, and facilities. Like many of the other science departments, the enrollment in physics courses has been booming, and this year we set a new record of fifteen senior physics majors. They worked on IS topics ranging from entanglement of liquid crystal molecules to modeling the orbits of two line-shaped masses. At the small scale, students investigated electron tunneling into gallium nitride nanowires (with diameters of less than a millionth of a meter) and the transverse modes of massless photons, while other students investigated the transits of exoplanets orbiting massive stars thousands of light-years away.

We were delighted to welcome Shila Garg back into an active role within the department, as she returned to teaching after many years as Dean of the Faculty and ultimately Provost.

The Department saw a decades-long goal realized this fall with the construction of a simple observatory on the College golf course. The observatory allows longer-term tracking of celestial objects through the mounting of the College's 12-inch telescope and makes it much simpler to get groups of students together quickly for observing opportunities. The observatory is a wonderful resource both for classes and for the three-year-old Astronomy Club.

We hope you enjoy reading this annual report about the multitude of activities and accomplishments that took place in the Physics Department at Wooster during this past year!

*Susan Lehman*

# Class of 2013
## All 15 of them!

**Theresa Albon (Columbus OH)**
Physics and Math double major
(Physics Fellow, Taft School, Connecticut)

**Daniel Axe (Chillicothe OH)**
Physics major

**Andrew Blaikie (Allen Park MI)**
Physics and Math double major
(Grad school: University of Oregon)

**Lilianna Christman (Cambridge MA)**
Physics major
(Job in Palo Alto, CA,  US Geological Survey)

**Lorenzo Dumancas (Wellington FL)**
Physics major

**Thomas Gilliss (Towson MD)**
Physics major
(Grad school: University of North Carolina)

**Samuel Mermall (Chicago IL)**
Physics major

**Duncan Price (Nashville TN)**
Physics major
(Software Developer, Neurotargeting LLC)

**Tyler Rhoades (Guys Mills PA)**
Physics major
(Job at Kent Displays, Inc., Kent OH)

**Michael-Erik Ronlund (Medford MA)**
Physics major

**Syne Salem (Toledo OH)**
Physics and Philosophy double major

**Matthew Schmitthenner (Delaware OH)**
Physics and Math double major
(Job at Farmer's Insurance)

**Karl Smith (Nashville TN)**
Physics and Philosophy double major

**Andrew Sopher (New Philadelphia OH)**
Physics major
(Upper-class physics teacher, IMG Academy, Florida)

**Phillip Wales (Great Falls VA)**
Physics and Math double major

1st row, from left: Syne Salem, Phil Wales, Dan Axe, Theresa Albon, Karl Smith
2nd row: Michael-Erik Ronlund, Tyler Rhoades, Andrew Sopher, Lorenzo Dumancas
3rd rom: Tom Gilliss, Sam Mermall, Lily Christman, Matt Schmitthenner
Back row: Andrew Blaike, Duncan Price

# Faculty

## Susan Lehman, Chairperson

*Clare Boothe Luce Associate Professor of Physics*
*At Wooster since 2003*
*MS, PhD North Carolina 1996, 99; BA Goshen 1993*

Fresh from a productive research leave last year, Susan Lehman returned as department chair. Together with colleagues from Chemistry and Biology, she traveled to International Christian University in Tokyo, Japan to build relationships and explore potential collaborations between ICU and the College. She was also awarded a GLCA New Directions grant to expand her research in nanotechnology. In February she attended the Gordon Conference on Nanomaterials for Applications in Energy Technology in Ventura, CA. In May, Dr. Lehman returned to Vienna, Austria to do research with her collaborator there. Dr. Lehman published an article "Avalanches on a conical bead pile: scaling with tuning parameters" in *Granular Matter.* This publication was the result of a long-term collaboration with emeritus Professor of Physics Don Jacobs and included seven undergraduate researchers as co-authors.

**Teaching 2012-2013**
- General Physics I Lab
- Physics Revolutions
- Modern Physics
- Foundations of Physics II
- Junior Independent Study
- Senior Independent Study (4 students, including 1 self-designed Art and Physics major)

## Shila Garg

*William F. Harn Professor of Physics*
*At Wooster since 1987*
*PhD Kent (UK) 1975; BS Madras (India) 1970; MS Sussex (UK) 1972*

Dr. Garg continues to lead a set of College initiatives building relationships in India, working to extend the College's successful practices of liberal education and creating international internship opportunities for Wooster students. She and Scott Friedhoff, VP for Enrollment and College Relations, spent two weeks in India building on an association that began decades ago when Presbyterian missionaries in India started sending their children to Wooster for a comprehensive liberal-arts education. Today, close to 100 Wooster alumni live and work in India.

**Teaching 2012-2013**
- Foundations of Physics I
- Mechanics
- Senior Independent Study (2 students)

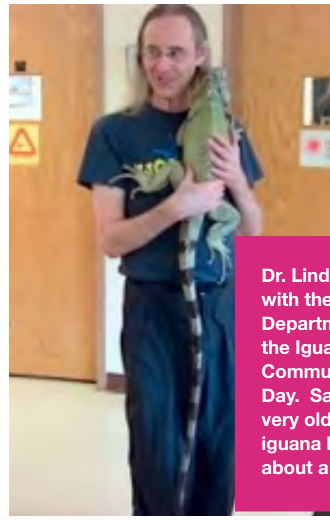
from left:
John Lindner,
Karen Lewis,
Susan Lehman,
Cody Leary,
Shila Garg

# Faculty

## John Lindner

*Professor of Physics, Moore Professor of Astronomy*
*At Wooster since 1988*
*PhD Cal Tech 1988; BS University of Vermont 1982*

With Norman Israel '12, Dr. Lindner published a paper on quantum gravity in Results in Physics. With Larry Markley '12, he published another paper on artificial gravity in Results in Physics. He described this work in an invited talk at John Carroll University. With Elliot Wainwright '15, he presented a poster on mechanical stochastic resonance at the March 2013 meeting of the American Physical Society in Baltimore.



Dr. Lindner cuddles with the Biology Department's Izzy the Iguana at Community Science Day. Sadly, Izzy was very old and went to iguana heaven about a week later.


In both astronomy classes and the computational physics classroom, Dr. Lindner made extensive use of a SMART podium interactive pen display as a replacement for chalkboards or whiteboards. This experiment is going well. Also, Dr. Lindner saw his decades-long goal realized this fall with the construction of a simple observatory on campus.

**Teaching 2012-2013**
Astronomy of Stars and Galaxies
Astronomy of the Solar System
Modern Physics lab
General Relativity
Computational Physics
Senior Independent Study (4 students)

## Karen Lewis

*Assistant Professor of Physics*
*At Wooster since 2010*
*PhD Penn State 2005; BS Physics & Mathematics, University of Wisconsin 1999*

**Teaching 2012-2013**
First Year Seminar
General Physics I and II
Thermal Physics (w/Cody Leary)
Foundations of Physics II Lab
Electricity and Magnetism
Senior Independent Study (3 students)

Dr. Lewis had an active year of travel and astronomical observations. In addition to continuing her research on Active Galaxies in the XMM Slew Survey (leading to a presentation co-authored by Kemal Ramic '12 at a conference in Alaska and an observing run at the Kitt Peak Observatory in Arizona with Vanessa Logan), Dr. Lewis is also observing transiting exoplanets. She and her students Tyler Rhoades and Vanessa Logan traveled to Flagstaff, AZ to conduct observations of exoplanets at the National Undergraduate Research Observatory. She also was instrumental in getting the new Wooster observatory into top performance so that similar observations can be conducted right here on campus. Dr. Lewis arranged to bring Dr. John Stolz from Duquense University to come to The College of Wooster to educate our students and community members about fracking. Over 150 people attended the public lecture, including many area residents. This talk was in conjunction with her First Year Seminar "Powering Our Future". She also participated on a faculty panel to discuss the presidential candidates' energy policies and their environmental impact.

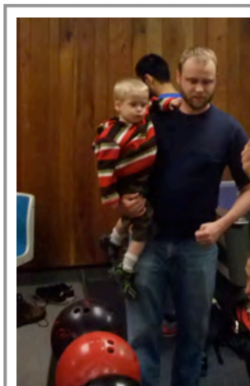
# Faculty

## Cody Leary

*Assistant Professor of Physics*
At Wooster since 2011
MS, PhD Oregon 2004, 2010; BS Puget Sound 2003

Together with students Deepika Sundarraman '14 and Tom Gilliss '13, Cody Leary has made some surprising predictions for a novel form of Hong-Ou-Mandel interference, a quantum effect in which two different events which would be indistinguishable are forbidden. This work forms the basis of Leary's paper "Bimodal Hong-Ou-Mandel Interference in Symmetric and Asymmetric Optical Systems" which was recently peer-reviewed and accepted for presentation at the 10th Conference on Coherence and Quantum Optics, a highly prestigious conference held at the University of Rochester every six years since the invention of the laser in 1960.

Teaching 2012-2013
Foundations of Physics I
Modern Physics
Thermal Physics (w/Karen Lewis)
Foundations of Physics II Lab
Math Methods for Scientists
Particle Physics
Senior Independent Study (3 students)



# Staff

## Lee Hothem

*Electronics and Instrumentation Technician*

Lee was recently recognized for **40 years** of service to the College. It's hard to imagine just how many pieces of equipment Lee has repaired in these 40 years. Whether it is a power supply for the physics department, a centrifuge for biology, hot plates for chemistry, or equipment for the radio station, Lee can track down the source of the problem. He doesn't just swap out the circuit board, but traces the issue to the precise component that has gone bad. Without Lee's skill, much of our older equipment would have been replaced with lower quality but higher priced models. Lee is a critical part of keeping all our labs running smoothly. We congratulate Lee on his many years of dedicated service.

## Ronald Tebbe

*Instrument Technician/Machinist*

Ron has been with the College as the instrument technician/machinist for the science departments for nine years. He received his degree in biochemistry at Wooster as a "returning" student in 1997 after several years working as a machinist. This past year, he machined projects for the 'bead dropper' apparatus and the 'Osorb vapor pressure' set-up, among others, in support of the Physics Department's Independent Study program.

## Manon Grugel-Watson

*Laboratory Manager and Adjunct Instructor*

Manon was recently recognized for five years of service to the College. This past year she taught laboratory sections for introductory physics. In July she attended the annual conference of the NAOSMM (National Association of Scientific Materials Managers) in Niagara Falls.

## Jackie Middleton

*Administrative Coordinator, Physics, Math & Computer Science*

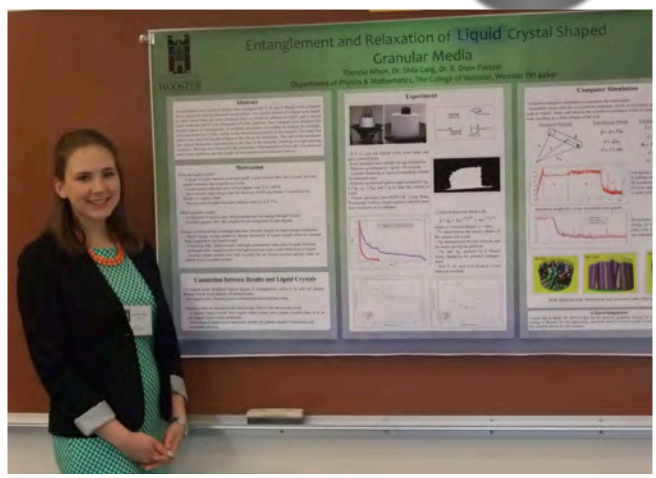
Jackie is in her 25th year in Taylor Hall, and she still loves to come to work every day. When she isn't at work, she keeps busy with her growing brood of grandchildren (currently at three, almost four!).

# Senior Independent Study
# Theresa Albon

**Mathematics and Physics, advised by Shila Garg (Physics) and Drew Pasteur (Mathematics)**

## The Entanglement and Relaxation of Liquid Crystal Shaped Granular Media

The intention of this research was to analyze properties of microscopic liquid crystal molecules. Since working with microscopic molecules can be difficult, a macroscopic model was made out of wires shaped like H, U, V, and rod shaped liquid crystal molecules. An experiment was done to analyze the collapse or relaxation of entangled wires of various shapes under sinusoidal relaxation accelerations. A *MATLAB* program was made to find the centroid and total pixel area of the entangled pile in every other frame of the video during the collapse. The centroid data was fitted with double exponential fits, which yielded two characteristic times for the collapse process. From this analysis, we concluded that the V and rod shaped wires behaved similarly, they did not display entanglement and would easily collapse. The U-shaped wires displayed the greatest amount of entanglement and would remain entangled together the longest out of all of the wires analyzed. A computer simulation was written to recreate the experiment. Only rods were analyzed and they varied in number: 50, 100, and 200. In addition to analyzing the relaxation height, the decrease in height due to entanglement from when the rods were first placed in an enclosure and accelerated was analyzed. Only the data runs with 100 rods displayed any decrease in height, due to their alignment within the enclosure. The decrease in height during the relaxations also were fitted with a double exponential fit. The V and rod wire shapes were easily untangled during the relaxation portion of the experimental research, this suggested that V and rod shaped liquid crystals have a low elastic energy. The rod wires would align parallel to one another in the experiment and computer simulation and form a layer of rods, suggesting that the rod shaped liquid crystal molecules have the greatest orientational and positional order. The ability to relax when the wires were free of their enclosure and subjected to an acceleration compares with a liquid crystal's molecular viscosity. Since the U-shaped wires displayed the greatest entanglement, this research suggests that they have the highest viscosity, while the rod shaped liquid crystal molecules would have the lowest viscosity.

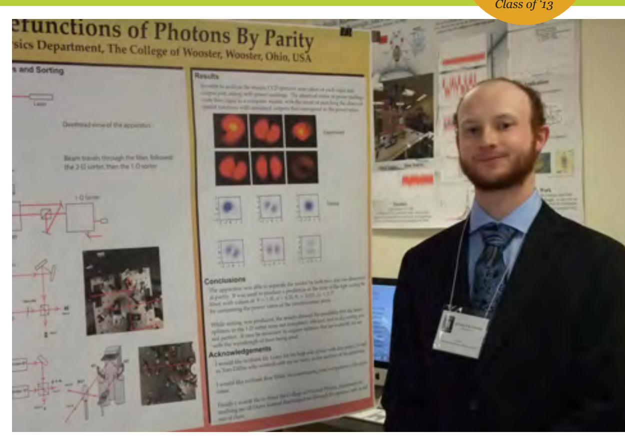



# Michael-Erik Ronlund

**Physics, advised by Cody Leary**

## Sorting Spatial Wavefunctions of Photons by Parity

An apparatus to sort the Hermite-Gauss modes produced when a laser passes through an optical fiber was connected from existing sorters, as well as augmented with new components. This apparatus involved a Sagnac interferometer which acted as a two-dimensional parity sorter combined with a Mach-Zender interferometer which acted as a one-dimensional parity sorter. In combination, the Sagnac first sorted modes with even and odd two-dimensional parity, and the odd two-dimensional modes were then sorted by one-dimensional parity in the Mach-Zender. The end result was to separate all modes produced by a three mode fiber, allowing for study of the fiber's effects on a laser beam passing through it, as well as other possibilities for the study of photons.

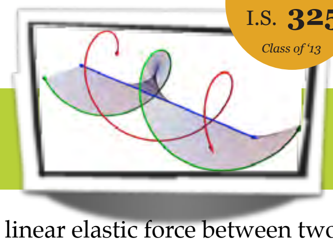


# Senior Independent Study

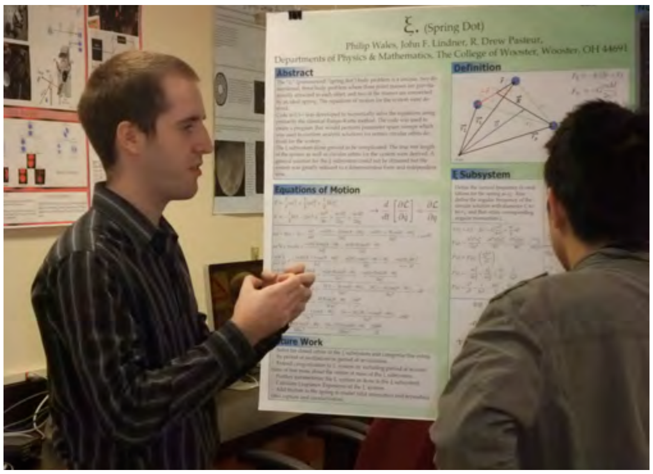
## Philip Wales

**Physics and Mathematics, advised by John Lindner (Physics) and Drew Pasteur (Mathematics)**

### ξ.



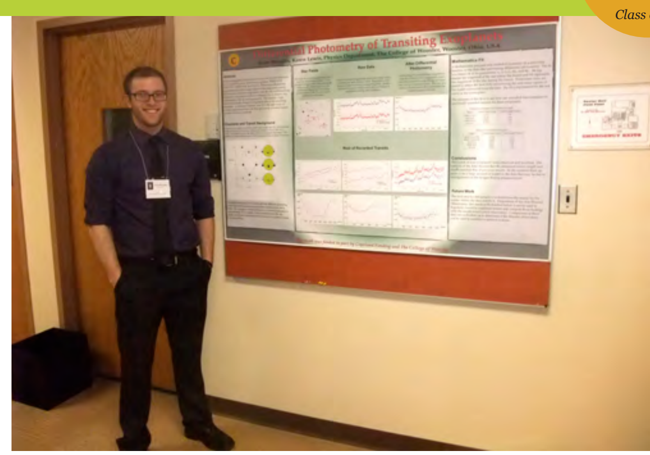
The ξ. (pronounced "spring dot") body problem is a unique, two dimensional, three body problem where three point masses are gravitationally attracted to each other. The uniqueness of the system is a linear elastic force between two of the point masses as though they were connected by an ideal spring. The two masses connected by the spring are denoted as the "ξ" subsystem, with the third free mass denoted as the ".". The equations of motion for the system were derived in multiple cartesian and polar form using both Newtonian analysis and the Euler-Lagrange equations. Code in *C++* was developed to numerically solve the equations using primarily the classical Runge- Kutta method. The code was used to create a program that would perform parameter space sweeps which was used to confirm analytic solutions for certain circular orbits derived for the system. Such circular orbits where when the spring was not stretched and the masses were either formed in a line or an equilateral triangle. The ξ subsystem alone proved to be complicated. The true rest length of the system as well as circular orbits for the system were derived. A general solution for the ξ subsystem could not be obtained but the system was greatly reduced to a dimensionless form and independent time.



## Tyler Rhoades

**Physics, advised by Karen Lewis**

### Differential Photometry of Transiting Exoplanets



A trip to Flagstaff, Arizona was taken to use Lowell Observatory to observe the transit of four extrasolar planets: WASP-12 b, HAT-P-9 b, WASP-50 b, and XO-2 b. IRAF was used to perform photometry on the images taken of the exoplanets during their transits. The data output from IRAF was then analyzed in *Igor Pro* where the magnitudes from the transiting exoplanet were subtracted from the average of the two reference stars to remove any fluctuations in the sky and equipment. This yielded a light curve showing the change in magnitude due to the transiting exoplanet. A *Mathematica* notebook was created to fit a piecewise function to the data from *Igor Pro* based on six fit parameters. The best representation of these parameters was found by minimizing the root mean square difference from the model and data. For all four objects, the transit depth and duration measured from the Lowell data was in good agreement with those published in literature.

# Senior Independent Study

## Andrew Sopher

**Physics, advised by Karen Lewis**

I DID IT
THE COLLEGE OF WOOSTER
I.S. 198
*Class of '13*

### Head for Safety

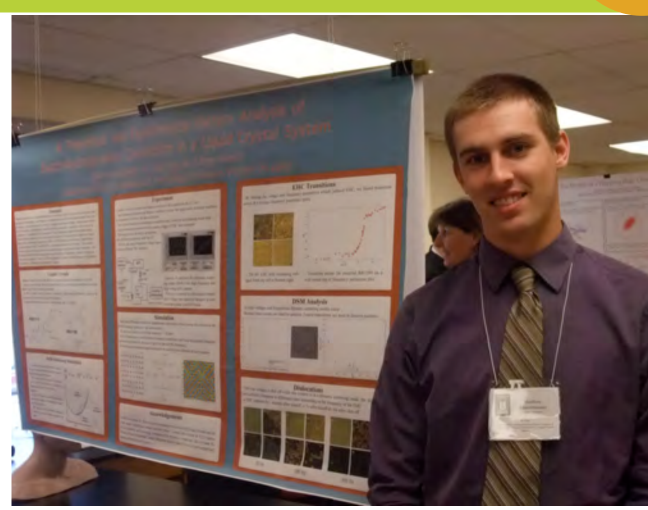
Soccer players of all ages put their body on the field for up to ninety minutes every game. Players run the risk of injury like any contact sport, but they also face damaging blows to their brains when heading soccer balls. Although protective headgear is available, it is seldom utilized. In this experiment, a soccer ball was launched at various angles and speeds at a ballistic dummy with and without headgear to measure the effectiveness of the headgear in reducing the acceleration that the head experiences upon impact with a soccer ball. An accelerometer placed within the dummy's skull measured the motion of its head upon collision with the ball. The motion was measured as voltages in the $x$, $y$, and $z$ directions. These voltages were combined and converted into accelerations in terms of $g$. Nine different configurations (three speeds and three angles) were tested and in all cases the acceleration was lower when the headgear was used.

## Matt Schmitthenner

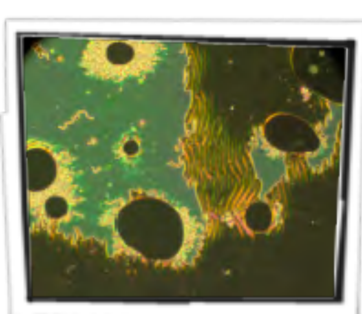
**Physics and Mathematics, advised by Shila Garg (Physics) and Drew Pasteur (Mathematics)**

### A Theoretical and Experimental Pattern Analysis of Electrohydrodynamic Convection in a Liquid Crystal System

I DID IT
THE COLLEGE OF WOOSTER
I.S. 72
*Class of '13*



Patterns formed by the electrohydrodynamic convection (EHC) of a liquid crystal system were analyzed experimentally and through a computational model. For the experimental liquid crystal system, a setup consisting of a circuit to supply and measure voltage, a microscope mounted with a camera, a temperature controlled heating stage and a computer to collect data was assembled. A simulation of the Generalized Swift-Hohenberg equation was created using a finite difference method to solve the partial derivatives. The liquid crystal experiment found the transition parameters between non EHC and EHC behavior for two novel shaped liquid crystal materials, RB1115 and RB1189, synthesized at Kent State University. The transition between dynamic scatter modes was also examined using discrete Fourier transforms. The Generalized Swift-Hohenberg equation was solved in two dimensions, and the resulting pattern was interpolated. These two different dynamical systems produced images with comparable patterns, validating the simulation to a degree.



# Senior Independent Study

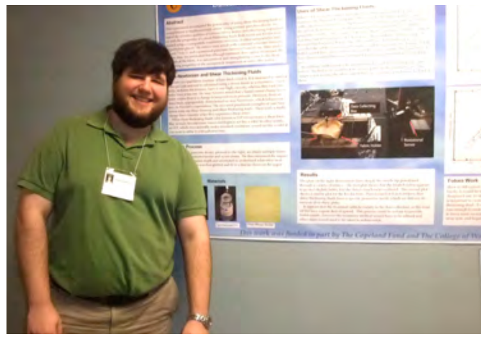
## Duncan Price

**Physics, advised by Karen Lewis**

### Liquid Body Armor and Shear Thickening Fluids

I DID IT THE COLLEGE OF WOOSTER I.S. 162 Class of '13

This experiment investigated the practicality of using shear thickening fluids as a supplement to traditional body armor. Using a rotary puncture device, we tested the resistive qualities of various fabrics before and after being impregnated with the properties of a shear thickening fluid. Both nylon and Kevlar were treated using a nanoparticle suspension consisting of silica nanoparticles and polyethylene glycol. The fabrics were struck with rotational velocities between 1.0 and 7.0 m/s, and experienced punctures between 0 and 10 cm. After analyzing the data, we concluded that although treatment does appear to increase the strength of the fabric, it is not certain if said strengthening is due to the shear thickening properties of the nanoparticle suspension or some other factor.

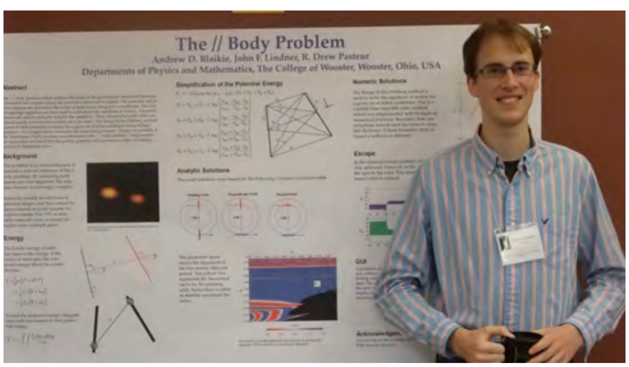


## Andrew Blaikie

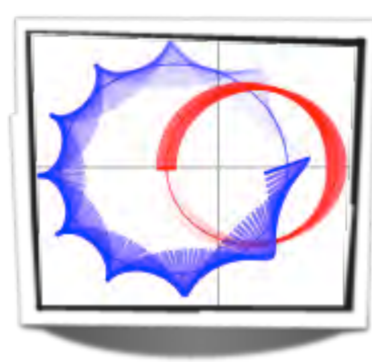
**Physics and Mathematics, advised by John Lindner (Physics) and Drew Pasteur (Mathematics)**

### //

I DID IT THE COLLEGE OF WOOSTER I.S. 122 Class of '13




The // body problem (slash-slash) is the study of the gravitational interaction between two extended line masses. The topic of this thesis is the study of the planar // body problem, where the universe is restricted to a plane. The analysis is performed using completely classical methods. The potential and kinetic energies are derived in the center of mass frame using polar coordinates. The Euler-Lagrange equations are then used to write down the equations of motion. Geometric vectors are used to radically simplify the equations. The equations of motion are shown to reduce to the planar /. body problem and the Newtonian 2 body problem in the appropriate limits. Three classes of periodic orbits are solved exactly and one class is believed to be stable. The Runge-Kutta-Fehlberg method is used to find numerical solutions for a given set of initial conditions using 64 digit precision. We describe a robust numerical mechanism to detect collisions before they occur. A GUI application automates the numerical processes. Retrograde spin was observed to stabilize orbits while prograde spin destabilized orbits. Escape not possible in the Newtonian 2 body problem was observed in the planar // body problem. Using parameter space plots we found that the gravity gradient orbit generates a valley of stability around its theoretical curve.



# Senior Independent Study

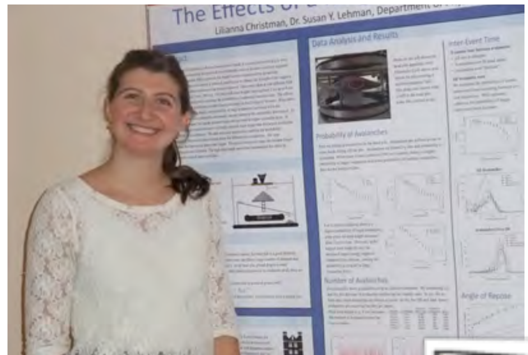
## Lilianna Christman

**Physics, advised by Susan Lehman**

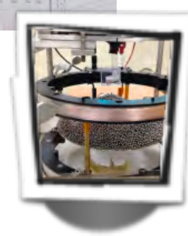
### The Effects of a Magnetic Field on a Conical Bead Pile

I DID IT THE COLLEGE OF WOOSTER I.S. 121 Class of '13

The effects of increasing cohesion between steel beads in a slowly-driven bead pile were investigated by surrounding the pile with two Helmholtz coils to produce a uniform magnetic field. When a magnetic field is present, the beads become magnetized but do not stay magnetized when the coil current is reduced, enabling us to change the strength of the magnetic field and thus the cohesion between the beads as desired. Data were taken at four different field strengths (currents of 0 mA, 500 mA, 750 mA) with drop heights varying from 2 cm up to 8 cm.



The data were analyzed to examine the probability of avalanches based on size. The effects of cohesion matched preliminary results found previously at The College of Wooster. When there was cohesion among the beads, the probability of large avalanches increased while the probability of mid-sized avalanches decreased, causing humps in the probability distribution. As the cohesion increased, the humps became larger and occurred at higher avalanche sizes. In addition, the largest avalanches seen with high cohesion were larger than the largest avalanches seen with low or no cohesion. The data were also analyzed to examine the probability distribution of inter-event times in bead drops for different size avalanches. For large avalanches, the inter-event times were longer. The typical inter-event time also became longer when cohesion was increased. The high drop height somewhat counteracted this effect by shortening the typical inter-event time.



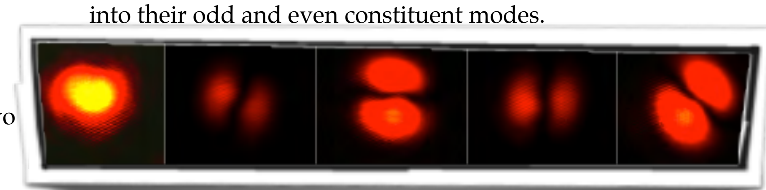
## Thomas Gilliss

**Physics, advised by Cody Leary**

### Manipulation of Transverse Photonic Degrees of Freedom via Classical and Hong-Ou-Mandel Interference

I DID IT THE COLLEGE OF WOOSTER I.S. 161 Class of '13

We demonstrate theoretical and experimental techniques for manipulating the transverse spatial photonic degrees of freedom. Exploration of three interferometric systems, including a single beam-splitter and two distinct setups of the Mach-Zehnder type, reveals conditions necessary for observing Hong-Ou-Mandel interference between two photons, each in an arbitrary linear superposition of the two first-order Hermite-Gaussian modes. For a Mach-Zehnder interferometer arranged to discriminate between modes of odd and even one-dimensional parity, we predict that if both input photons are in a balanced, in-phase superposition of the first-order modes, the resulting interference will alter the transverse wavefunctions of the photons to be of Laguerre-Gaussian form. For a balanced Mach-Zehnder interferometer, we find that HOMI can be observed for input photons in distinguishable transverse spatial modes. We experimentally test the one-dimensional parity-based Mach-Zehnder for inputs of classical coherent laser beams and find that perfect constructive and destructive interference, at either output port, occurs under HOMI conditions. In addition, we demonstrate the ability of this interferometer to sort inputs of arbitrary spatial modes into their odd and even constituent modes.



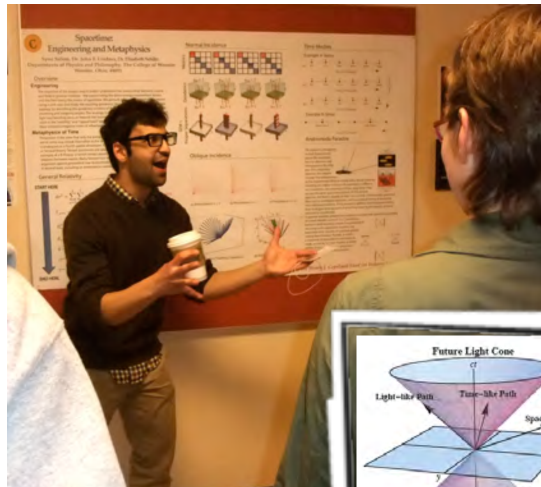
# Senior Independent Study
## Syne Salem

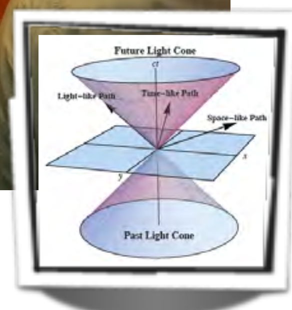
**Physics and Philosophy, advised by John Lindner (Physics) and Elizabeth Schiltz (Philosophy)**

I DID IT
THE COLLEGE OF WOOSTER
I.S. 311
*Class of '13*

## Spacetime: Engineering and Metaphysics

This thesis will deal with two topics, both clearly related, but also clearly distinct. The first three chapters deal with what we have chosen to call 'spacetime engineering'. It involves the systematic testing of basic perturbations of the spacetime metric, followed by observations of the way these perturbations affect the geodesics, the paths of extremal length. Part of this is visualization–general relativity is a highly complex theory based on four-dimensional spacetime structures. Another part is trying to determine what those visualizations mean. The last part is applying them to create exotic custom spacetimes–a sort of tradition for general relativists. We don't really get into the applications here; that is left for future work. We do begin to build the opto-mechanical analogy with the way light rays bend as they pass through spacetime steps.






The second half deals with metaphysics of time, primarily the debate between the positions known as presentism and eternalism. Chapter 4 introduces the debate and builds up the compatible positions from a primarily metaphysics perspective. Chapter 5 introduces what is considered to be the best argument against presentism and in favor of eternalism: the argument from special relativity. In the course of the chapter we introduce spacetime models as they are typically built in the philosophy of physics (simplified, of course). Chapter 6 examines five arguments one can make to try to lessen the impact of special relativity on presentism. Of those arguments the first three fail, and the fourth inconclusively softens the blow. The fifth, however, genuinely opens the door to a metaphysics of time that could be both presentist and compatible with quantum gravity.

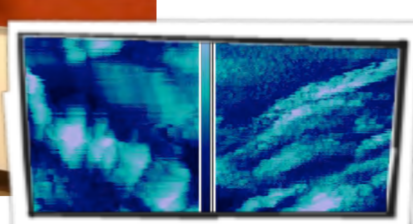
The motivation that drives each of these projects is the unifying factor–that is, the desire to better understand what our most up-to-date physical theories mean for us. General relativity is highly counterintuitive, and physics will probably only get more complicated in the future. Hopefully a reader of this thesis will be able to come away with both a better grasp of the formal theory, its empirical implications, and its metaphysical ones.

## Lorenzo Dumancas

**Physics, advised by Susan Lehman**

I DID IT
THE COLLEGE OF WOOSTER
I.S. 177
*Class of '13*

## Optimization of BEEM Techniques



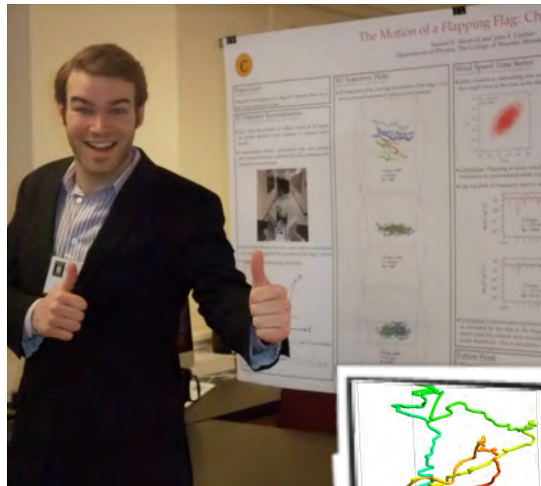
The primary topic of this thesis is the analysis of the Schottky barrier height of samples of Au: GaAs and GaN nanowires. This was accomplished through the use of a ballistic electron emission microscope. The ballistic electron emission microscope was adapted from a scanning tunneling microscope through the addition of extra base and BEEM current terminals in order that BEEM spectra may be collected. During this experiment the Schottky barrier height of Au: GaAs was characterized and compared to previous data taken at the Vienna University of Technology (TU-Wien). This data compared favorably to the data at TU-Wien thus showing that the adapted BEEM system was functioning properly. Some preliminary data was also taken for GaN nanowire samples.

# Senior Independent Study
# Sam Mermall

**Physics, advised by John Lindner**

## The Motion of a Flapping Flag: Chaos or Noise?

I DID IT
THE COLLEGE OF WOOSTER
I.S. 146
*Class of '13*



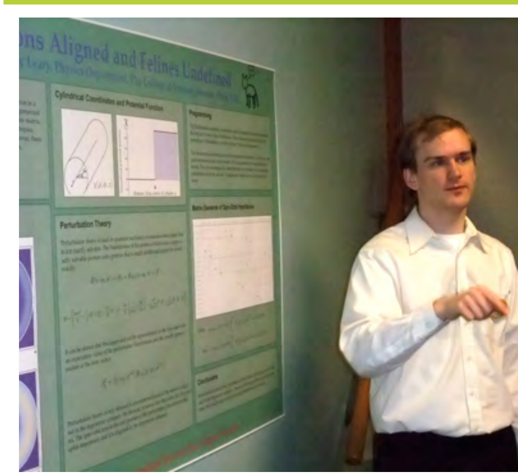
Observing a flag flapping in a passing breeze is so commonplace that the rich dynamical behavior it exhibits is often overlooked. This experiment sought to observe and categorize the motion of a flag in a fluid flow to be either that of a chaotic system or a noisy system. A jet fan plugged into a variac autotransformer allowed precise wind speed control, which was used to produce laminar airflow. Time series were collected for the speed of air leaving the trailing end of the flag and the drag force experienced by the flag. Several minutes of time series data were analyzed numerically using delay coordinate embedding, Fourier analysis, and three dimensional trajectory reconstruction. This data indicates that the motion of a flapping flag is dominated by weakly colored noise at lower wind speeds and white noise at higher wind speeds. The three dimensional trajectory reconstructions were done using a stereoscopic triangulation system. It was designed to use a single high speed camera and a series of mirrors configured so that the camera can see the flag from two different vantage points. The apparent shift of a point on the flag between the two perspectives, or parallax, provides the means to triangulate the point's position in three dimensional space. The point's position was tracked in two dimensions over a couple of seconds from both perspectives. This position data was read and interpreted using Wolfram *Mathematica*, which produced three dimensional trajectory plots of this motion over time. These plots show how the flag's fluttering patterns change qualitatively with increases in wind speed.

# Karl Smith

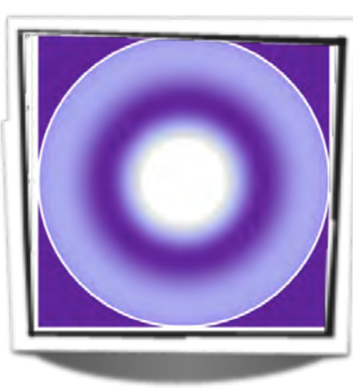
**Physics and Philosophy, advised by Cody Leary (Physics) and Elizabeth Schiltz (Philosophy)**

## Electrons Aligned and Felines Undefined: Interpretations of Quantum Mechanics and Perturbing the Spin-Orbit Interaction in Electrons

I DID IT
THE COLLEGE OF WOOSTER
I.S. 333
*Class of '13*



This thesis contains an exploration of various questions about quantum mechanical interpretations as well as an examination of the spin-orbit interaction using perturbation theory. Does consciousness change reality through measurement? Can we come to know things about reality? Do we infer our understanding of reality indirectly, or can we perceive things as they are? Can we even speak meaningfully about the external physical world? Does the notion of language and translation cause problems for our understanding of a quantum reality? In the physics chapters I explore perturbation theory and create a *Mathematica* program to solve for the perturbation matrix.

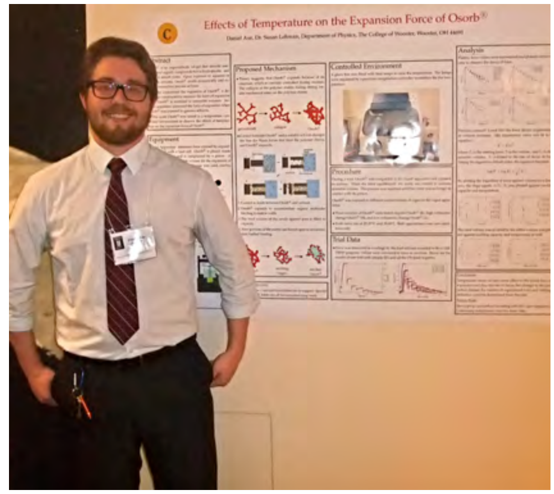


# Senior Independent Study
## Daniel Axe

**Physics, advised by Susan Lehman**

### Temperature's Effects on Expansion Force of Osorb®

Osorb® is an organosilicate material that displays unique properties. It absorbs non-polar and organic compounds but does not absorb water. During absorption, Osorb® has been shown to swell up to eight times its original size while exerting tremendous forces that have been measured over 500 N. In this work, the force of expanding Osorb® was tested at different temperatures to observe the effects on relationships found in previous work. An apparatus that measures the expansion force at controlled volumes was improved upon to reduce sample loss and increase sample saturation. Another apparatus was found to test Osorb® reaction to organic compounds diffused in gas phase, but required replacement parts and needed to be reconstructed. The two apparatuses were tested at ~22°C C and 40°C. Three varieties of Osorb® were tested. No usable data could be collected from the vapor apparatus, but results form the liquid apparatus were analyzed. Due to an unforeseen extra variable, there are no doubly reproduced trials.




# Junior Independent Study
## Self-Designed Projects

### Modeling Earthquake Seismology
**Benjamin Harris**

Earthquakes result from plate tectonic behavior just below Earth's crust. Seismology is the study of earthquake dynamics. We modeled earthquake seismology by studying stick-slip friction with three spring-block models. The first was a one-dimensional three block system pulled by a driving motor. The second was a two-dimensional, nine block system pulled from the center. The third was a two-dimensional, nine block system pulled more evenly. Earthquakes follow a power law known as the Gutenberg-Richter law with a power of $n = 1$. Our three models seemed to tend toward behavior in accordance with the Gutenberg-Richter law. For our three systems, we measured powers of $-1.0\pm0.3$, $-0.7\pm0.2$, and $-1.3\pm0.2$ respectively. With more data collection and a more significant number of events, it may be possible to show a more strong correlation to the power law behavior.

### Physics of Swimming: Conditions that Affect the Passive Drag on a Swimmer in Streamline Position
**Evan Hagedorn**

The purpose of this experiment is to explore the variables that affect the efficiency of a swimmer in the streamline position. There are various factors that affect the drag of a swimmer such as: the type of suit, wearing a cap or not, and the depth of the push off. The hydrophobicity of a fast suit and a regular suit was measured to show which one will be the most effective in the water. The contact angle of the fast suit was 20° less that that of the regular suit, meaning it is more hydrophobic and will produce better times in competition. The effects of suit and cap were tested by having the swimmer push off of the wall wearing two different types of suits and wearing a dome cap versus not wearing a cap at all. The depth was tested by having the swimmer push off deeper than one normally would to see the effects of pressure drag. The results showed a 44% decrease in drag while wearing a fast suit and cap compared to wearing a regular suit without, and the push off at a deeper depth yielded a 49% increase in drag compared to the original push off depth.

### Causal Dynamical Triangulation in Three Dimensions: Tiling Spacetime with Tetrahedrons
**Prakrit Shrestha**

In this paper, a new approach to quantizing gravity is explored called Causal Dynamical Triangulation (CDT). This paper talks very briefly about the theory necessary to build a computer simulation to investigate Quantum Gravity with 2 spatial dimensions and 1 temporal dimension. Furthermore, we have successfully built the initial structure of the universe and filled all of vacuum spacetime in 3 dimensions with 3-simplices (tetrahedrons). The next immediate step is to investigate CDT in 2+1 dimensions by performing combinatorial moves and anti moves along the topology of spacetime.

# Junior Independent Study

## Self-Designed Projects

### Drivers Start Your Engines: A Comparison of the Forces on Race Cars and Toy Cars

**Danielle Shepherd**

The purpose of this work was to experimentally determine whether toy cars accurately model the behavior of race cars, like NASCAR or IndyCar cars, with respect to their movement around a banked curve and the resulting drag coefficient. For a professional race car team's engineers, it is important to understand the forces that act on an individual car so that they can provide the driver with a mechanical set up that will help lead to victory. Through the use of a banked curve track and photogates, the velocity of a toy car was monitored to determine whether its behavior mimics that of an actual race car traveling around a banked curve. In addition, the drag coefficient was calculated for the toy cars to determine if a correlation exists between the toy cars and the actual race cars they model. After data were collected regarding the three cars, it was determined that there exist some correlations between the toy cars and the actual race cars; however, discrepancies still exist between the predicted and actual results. Two of the toy cars' data results match the predicted results for speed on a banked curve and there is some correlation between the drag coefficients of the toy cars and the race cars.

### Space-Time Curvature of Unusual Metrics

**Min Sung Kim**

This research is an attempt to further develop cloaking through stress energy momentum that has been studied in The College of Wooster Physics Department by specifically exploring the behaviors of swirling space-time. A program was developed which calculates a specific space-time geometry according to the given metric. The strength of this program is that it accepts any diagonally symmetric metric. However, there is the downfall of such general input, as it only provides mathematical boundaries, disregarding physical boundaries. Moreover, the visualizations that were generated have their limits in specifying what exactly is happening. Randomly generated metrics were put through the programs, which led to a very unusual space-time curvature. However, unfortunately, attempts to further understand only led us to incomprehensible results.

### The Manipulation of Photon Spatial Wave Function by Polarization and Parity

**Deepika Sundarraman**

We investigate interference of light in classical optics based on a one-dimensional parity transformation. The manipulation of the photon spatial wave function is used to predict Hong Ou Mandel Interference (HOMI), which has applications to quantum information processing. This effect is achieved by manipulating two degrees of freedom, namely, the parity and polarization of the photon spatial wave function. Plots for the interferometer outputs in the case of classical interference are studied in the form of density plot of intensity distributions, and plots of polarization ellipses. Inferences are drawn to predict the relationship between these two degrees of freedom and whether they are relevant to HOMI and quantum computing. Theoretical predictions are made for both single and two input cases, the latter of which can then be extrapolated to HOMI. HOMI is predicted to occur for any case where completely destructive interference is present in one output port in the corresponding classical situation. A special case to keep both degrees of freedom independent of each other during transmission was found, when two identical inputs of $HG_{01}$ modes with $\hat{x} + \hat{y}$ polarization are introduced in the interferometer. Further, another means to mix polarization and parity are found when two $HG_{+45}$ spatial modes with $\hat{x} + \hat{y}$ polarization are introduced as inputs. These cases have been modeled using a simulation in *Mathematica*. The results from various predictions for classical beams thus help us gather intuition for the behavior of photons.

### The Effect of Surface Roughness on the Magnus Force

**Ian Wilson**

The fur on a tennis ball is one of the more peculiar aspects of any piece of sports equipment. Although aesthetically pleasing, how much of an effect does it have on the way the game of tennis is played? In this experiment, three different tennis balls with varying amounts of fuzz were investigated to see how much the surface roughness affects the flight path of the ball. By creating an apparatus that simulated the motion of a spinning tennis ball traveling through air, I was able to investigate the effect of the surface roughness on the Magnus force. It is this force that creates the effects of topspin and backspin in tennis. The results depicted that the fuzzier the ball was, the greater its Magnus force. However, the difference in forces was less than 0.01 N, so the effect seems to be quite small at the velocity at which the balls were tested.

### Weight and Strength Dependency in Cheerleading Stunts

**Vanessa Logan**

Cheerleading is one of the most dangerous sports for young women and produces the highest rate of catastrophic injuries in female athletes. Because of the increased difficulty in stunts over the last fifteen years, the rate of cheerleading injuries has significantly increased. Often, the bases of the stunts are the ones who are injured. In this study, the dismounts from prep or elevator level stunts were tested in relation to the strength of the stunt group and the weight of the flyer. A group of collegiate cheerleaders participated in performance tests to gauge their strength. Seven combinations of stunt groups and flyers performing elevator stunts were video recorded. The dismounts from the stunts were tracked and then analyzed based off of the flight of the flyer. From this data, it was concluded that increasing the mass of the flyer decreases her acceleration into the air. Additionally, it was concluded that a stronger stunt group retains more consistent results during the entire study. Therefore, it was concluded a strong stunt group is essential for consistent stunts, however a lighter flyer will result in faster stunt sequences.

# Awards and Honors (awarded to Physics Majors)

## Latin Honors

***Summa cum laude***
Andrew Douglas Blaikie

***Magna cum laude***
Thomas Ferguson Gilliss

***Cum laude***
Lilianna Elizabeth Christman
Syne Omar Salem

## Departmental Honors

Andrew Douglas Blaikie
Thomas Ferguson Gilliss
Lilianna Elizabeth Christman
Syne Omar Salem

## The Arthur H. Compton Prize in Physics

Andrew Douglas Blaikie

## Phi Beta Kappa

Andrew Douglas Blaikie

## The Mahesh K. Garg Prize in Physics

Andrew Douglas Blaikie and Lilianna Christman

## The Vivien Chan Prize in Interdisciplinary Sciences

Andrew Douglas Blaikie

## The Joseph Albertus Culler Prize in Physics

Joseph Smith '15

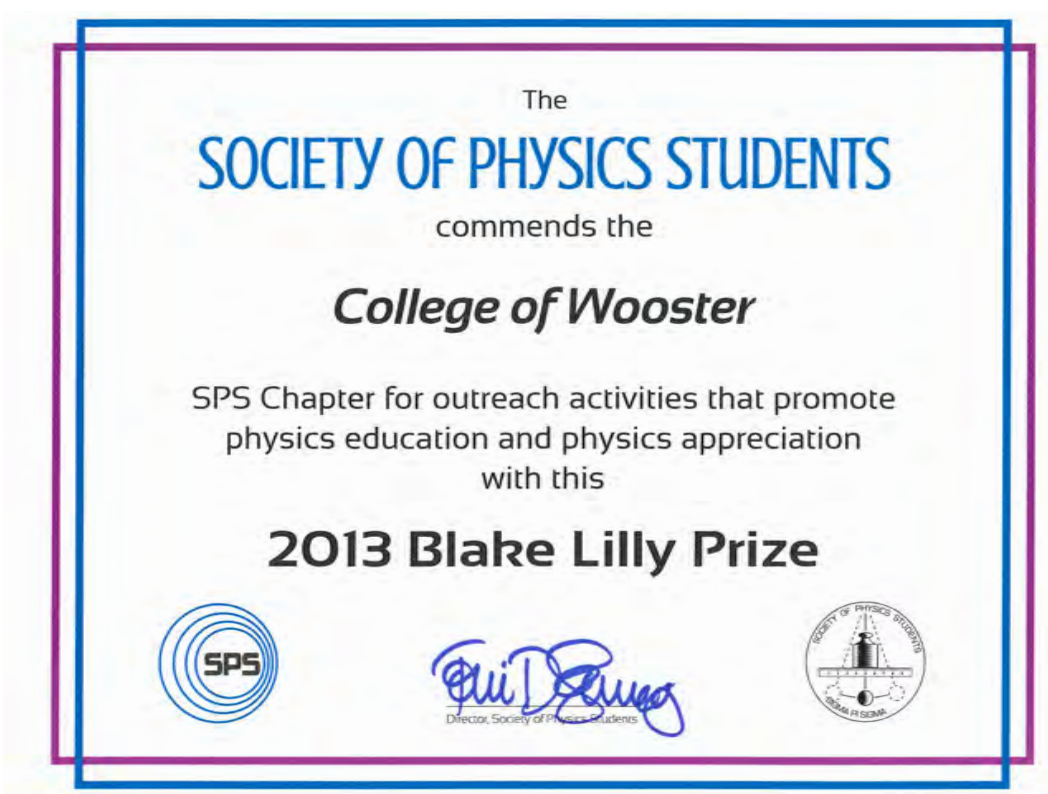
## The Endowed Faculty Scholarship

Andrew Douglas Blaikie

## The Elias Compton Freshman Prize

Amanda Steinhebel '15

## More kudos to our outreach program...



# Physics Colloquium Series 2012-2013

Wooster Physics Juniors, *Junior Independent Study Progress Reports*, 30 May

Peifang Tian, John Carroll University, *Shedding light on brain function: imaging 3D spatiotemporal hemodynamics of single cortical vessels in vivo using two-photon laser scanning microscopy*, 3 April

Yumi Ijiri, Oberlin College, *Probing magnetic nanoparticles for data storage, biomedical and other devices*, 28 February

Karen Lewis and Cody Leary, *Wooster Physics Research*, 14 February

Wooster Physics Seniors, *Senior Independent Study Progress Reports Round III*, 4 December

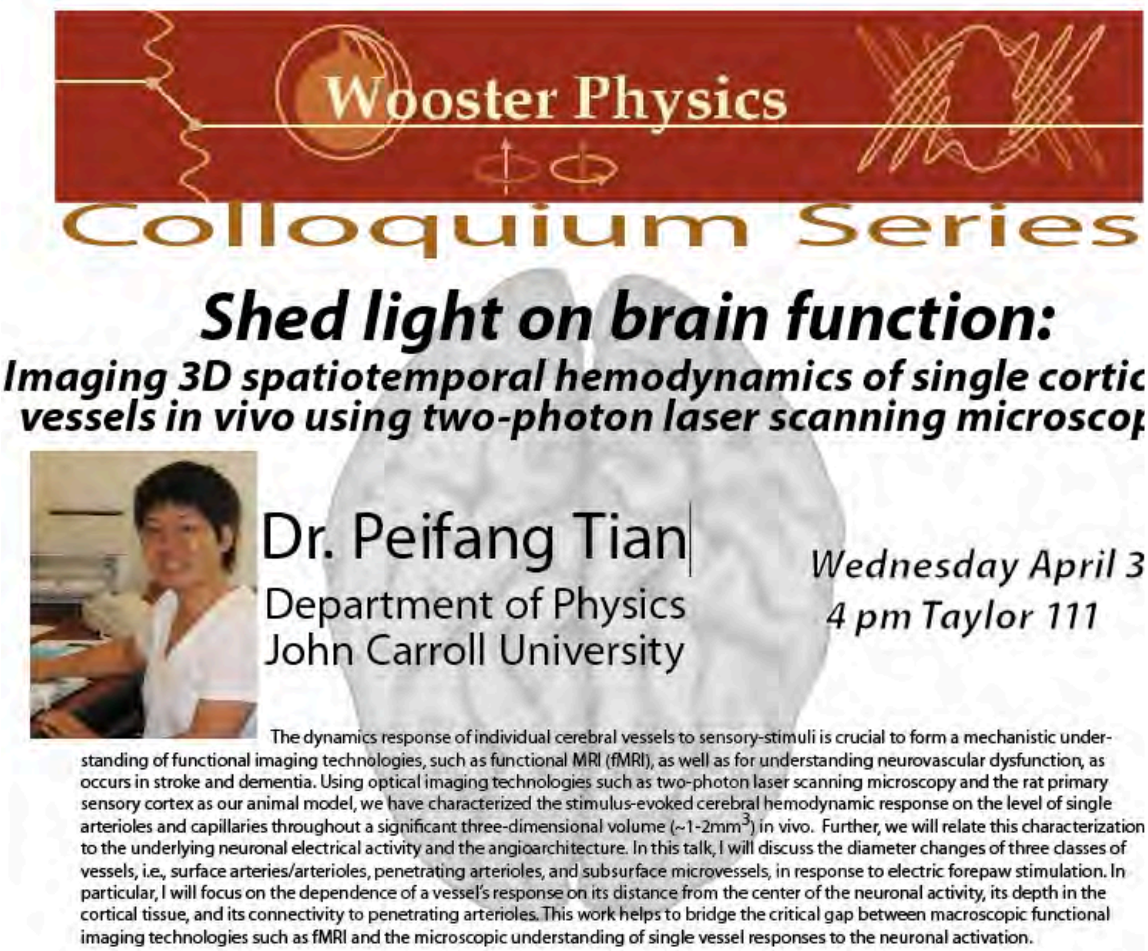
Wooster Physics Seniors, *Senior Independent Study Progress Reports Round II*, 29 November

Wooster Physics Seniors, *Senior Independent Study Progress Reports Round I*, 27 November

T.E. Sheridan, Professor Physics, Ohio Northern University, *Arrangement Phases of Small Clusters*, 8 November

Jim Gleeson, Professor of Physics, Kent State University, *Liquid Crystals in Every Shape and Size*, 4 October

Andrew Blaikie '13, Lily Christman '13, Tom Gilliss '13 and Duncan Price '13, *Summer Research Experiences*, 6 September



# Physics Club

2012 August 31: Scot Spirit Day
2012 September 6: Summer Research Experiences
2012 September 13: Physics Grad School Information Session
2012 September 13: Luce Pizza and Dessert Night
2012 September 26: General Meeting
2012 October 3: Outreach Training: Forces & Motion
2012 October 5: Video Game Night
2012 October 10: Outreach Training: Air Pressure
2012 October 20: COSI Columbus + dinner + ice cream
2012 October 24: General Meeting
2012 November 8-10: PhysCon, Orlando
2013 March 27: General Meeting
2013 April 20: Community Science Day 5
2013 April 28: Taylor Bowl 24 (Math/CS 106.1 Physics 98.2)

## Officers:

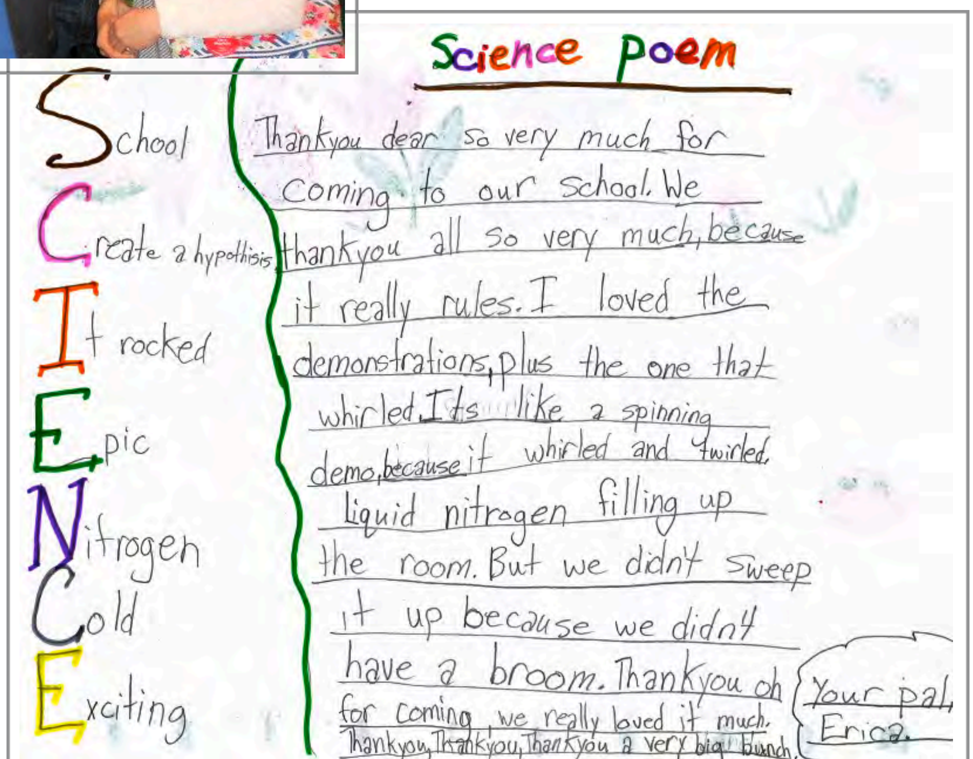
*President: Lily Christman*
*Vice President: Vanessa Logan*
*Secretary: Duncan Price*
*Treasurer: Matt Schmitthenner*

*Advisor: Professor Lindner*


*Our students attending PhysCon 2012 had the amazing experience of meeting Freeman Dyson.*

## Outreach

This past year, the Wooster Physics Outreach team did 17 school visits at 6 different schools. Schools participating were: Shreve Elementary, Parkview Elementary, Melrose Elementary, St. Mary's School, Cornerstone Elementary, and a special visit to Triway High School for a holography demonstration.


Science Poem
School
Create a hypothisis
It rocked
Epic
Nitrogen
Cold
Exciting

Thankyou dear so very much for coming to our school. We thankyou all so very much, because it really rules. I loved the demonstrations, plus the one that whirled. It's like a spinning demo, because it whirled and twirled. liquid nitrogen filling up the room. But we didn't sweep it up because we didn't have a broom. Thankyou oh for coming, we really loved it much. Thankyou, Thankyou, Thankyou a very big bunch.

Your pal, Erica.

*Our favorite Outreach thank-you from Erica at Shreve Elementary*

# PhysCon 2012

Connecting WORLDS 2012 through science & service

2012 Quadrennial Physics Congress

Hosted by Sigma Pi Sigma, the physics honor society

So how did members of The College of Wooster SPS chapter, hailing from a small liberal arts college in Ohio, end up at one of the largest conferences for undergraduate physics majors? Passion, hard work and organization! We gathered a group of seven diverse physics majors, four seniors, two juniors, and one sophomore, who were all interested in a variety of fields of physics and were extremely committed to attending the Congress. In May, planning began for various aspects of the trip including transportation, lodging, and funding. We were fortunate to receive the SPS Reporter's Award, along with a vocational grant from the College of Wooster. The Wednesday before the conference, we hit the road, driving 1009 miles from the small town of Wooster, Ohio to sunny Orlando, Florida.

As a whole, the Congress was compelling for one simple reason: it reminded and reinforced our drive to join a professional scientific community. While there, we were able to communicate with many influential people and have productive interactions with other students, scientists, and representatives. Individually, our visiting members may have found one speaker or event more compelling than the other, but the tours of the NASA research labs were one major event that stuck out in all of our minds, making the trip something truly special.

Through the SPS Reporter's Award, two of our group's individuals were able to take part in a unique behind the scenes tour of the research labs at Kennedy Space Center. This tour allowed them to relate to the scientists working there, as they were able to hear about current research and have meaningful conversations with them. In particular, they noted that inspiration was found in their discussion with Dr. Metzger, the lead research physicist and founder of the Granular Mechanics and Regolith Operations Lab. A simple conversation about a white board drawing made them both realize they could see themselves holding a position similar to this man in the future. Dr. Metzger explained that the solar system drawing on the white board, of planets and moons riddled with icons of outposts and colonies and mining facilities, was simply a doodle he and his colleagues had done during some break in their day of research, something they had done for fun, just a rough "plan" to colonize our solar system. It reminded our two members that even once you have a professional job, you don't have to lose your excitement about physics. This particular event is one of many that has motivated members of our group to continue pursuing their interest in physics and has reinvigorated their drive to join the physics and science community.

Our point-of-focus during this Quadrennial Physics Congress was the workshop entitled "Connecting Students with Career Paths." This workshop was led by Roman Czujko, representing the Statistical Research Center at the American Institute of Physics. Before even beginning the workshop, we were instructed to sit by individuals who did not come from our school. As a result, we found ourselves seated with a mixture of other undergraduate students, graduate students, professors, and other professionals.

Mr. Czujko began the workshop with an overview of the paths physics students take after graduation. For instance, he presented charts detailing the number of individuals who pursue the field of engineering versus those who actually enter into a field of physics. He then went on to discuss examples of particular jobs that exist in each of the areas previously shown. We were then given an overview on tailoring resumes, cover letters, and interview skills for a job in the field of science. Since we are all at a point in our lives where the prospect of beginning a career is a fast-approaching reality, this workshop proved to be both interesting and beneficial.

The interactive portion of the workshop followed the introduction. First, we were instructed to brainstorm skills and qualities of a student focusing on physics. These included aspects such as problem solving abilities, laboratory skills, ability to work as a team member, and modeling/simulation knowledge. We then discussed which of these skills were resume-worthy and how they should be presented in a resume or cover letter for a job in science. This information will be extremely useful for us as we leave the academic world and enter the working world. Each of us will, one day, need to apply the knowledge we gained from this workshop either in applying for internship positions, graduate school, or a position in the workforce.

Overall, we felt the Congress was a truly positive experience, knowing that we each made memories that will last a lifetime. Hearing the wonderful speakers and having personal conversations with individuals who have accomplished so much really helps us to stay motivated and continue pursuing physics, knowing one day we each may be standing where they are. Much of what we experienced will help us in the future whether we wish to enter directly into the workforce or pursue further learning in graduate school. Wherever our knowledge of physics takes us, it will always be an honor for each one of us to say we participated in the 2012 Quadrennial Physics Congress.

Vanessa Logan '14 and Elliot Wainwright '14, Roving Reporters

# Astronomy Club

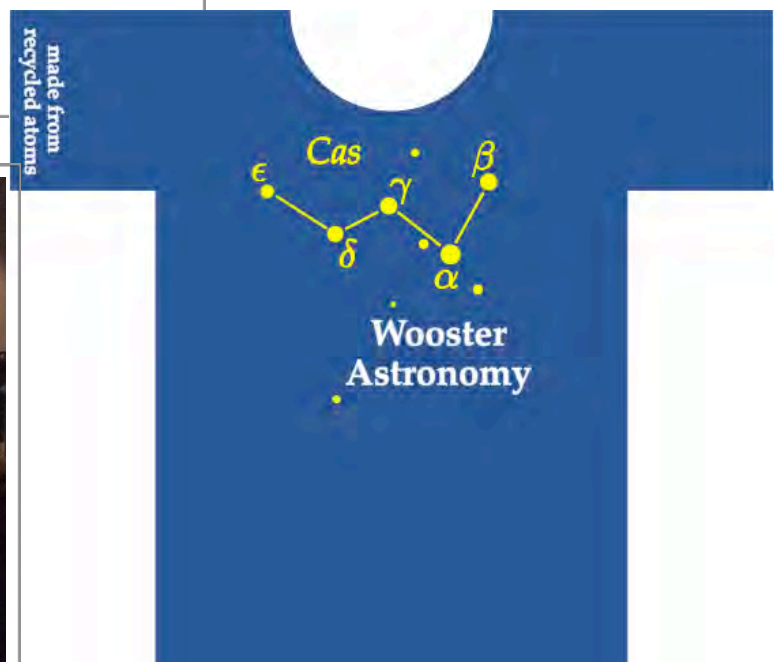
## Officers:

*President: Andrew Blaikie*
*Treasurer: Lorenzo Dumancas*

*Advisor: Professor Lewis*

## Events

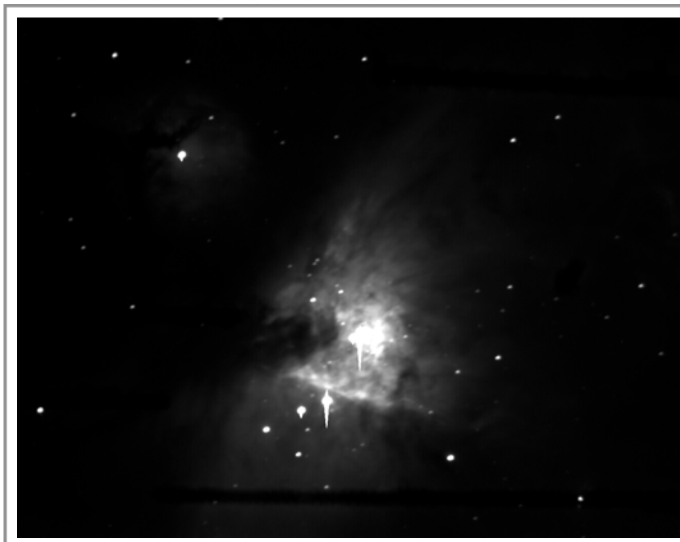
2012 September 15: Observing on the golf course
2012 November 16: Observing on the quad
2013 January 18: Observing at the observatory (Jupiter, Orion Nebula, and quarter moon)
2013 March 30: Cleveland Natural History Museum Trip
2013 April 26: Campus community viewing of Saturn





*Viewing Apollo 12 Moon rock at Museum of Natural History*

*The Wooster contingent at PhysCon had the opportunity to meet Jocelyn Bell Burnell, the discoverer of pulsars.*



*Orion Nebula, first photo from our new observatory, taken by Tyler Rhoades '13*

# Observatory

For much of the 20th century, the College had an astronomical observatory on the site of the Andrews Library. When the library was built circa 1960, the observatory building was moved a half block east and has been known recently as the Rubbermaid Building, while the refracting telescope was moved to the observatory in Freedlander Park.

In the late 1990s, the Physics Department began seriously thinking about a replacement observatory. Shila Garg and John Lindner even climbed to the top of Kauke fortress looking for a suitable flat spot but discovered an A-framed roof. When we first saw an architectural rendering of Morgan Hall, we asked the president if we could incorporate a roll-off roof observatory into its roof, but we were too late in the planning sequence. In 2001 Jenn Goetz and John Lindner obtained a small College grant to purchase a 12-inch Mead Schmidt-Cassegrain telescope and hired summer student Dave Merriman '04 to design a 12-telescope teaching observatory for the golf course. The president was enthusiastic about our proposal, but decided that the observatory would not be part of the financial campaign for that decade, and he asked us to try again next decade. Last year, Karen Lewis and John Lindner tried again with a more modest proposal, which was enthusiastically received. After our first and second site choices were denied, our third golf-course site choice was approved.

The observatory was constructed largely by Backyard Observatories (www.backyardobservatories.com) between November 2012 and January 2013. Our 12-inch 2001 telescope was installed by Karen Lewis, Ron Tebbe, and John Lindner on 2013 January 11. Tyler Rhoades '13 achieved "first light" by photographing the Orion Nebula. The roll-off roof observatory has a warm room from which the telescope and a CCD array can be controlled. Astronomy Club members can check out a key to the observatory once they have been trained. Our first training session was in early April. First club viewing was in January and first campus community viewing was in late April. Learn more about this new facility at our observatory web site: physics.wooster.edu/observatory

# Nat'l Meeting of the American Physical Society

## Baltimore MD, March 2013

### Presentations by Wooster Physics Majors*

*Bimodal Hong-Ou-Mandel Interferometry*, Deepika Sundarraman*, Thomas Gilliss*, and Cody Leary

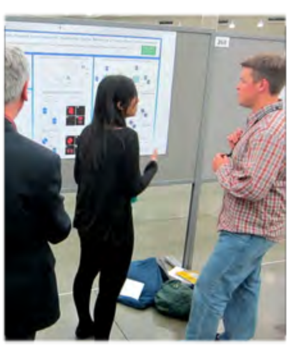
*Elastic constants and material properties of novel shaped liquid crystals*, Matt Schmitthenner*, P.K. Challa, J.T. Gleeson, Shila Garg

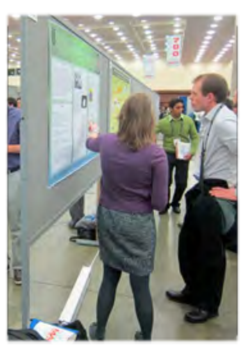
*Entanglement and Relaxation of Liquid Crystal Shaped Granular Media*, Theresa Albon*, Wilder Iglesias, Antal Jakli, and Shila Garg

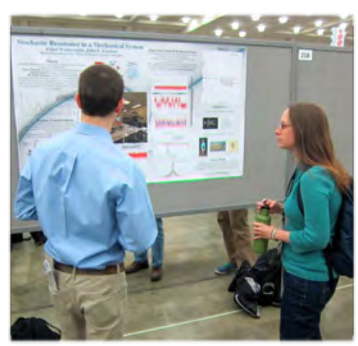
*Mechanical Stochastic Resonance*, Elliot Wainwright* and John Lindner

MARCH MEETING 2013

*Front: Theresa Albon, Deepika Sundarraman, Elliot Wainwright*
*Rear: Shila Garg, Tom Gilliss, John Lindner, Matt Schmitthenner*







*Several Wooster Physics alumni stopped by at the APS poster session to catch up on the Department, including Nick Harmon '04 (left), Danny Shai '07 (center), and Kathy McCreary "06 (right).*

# Summer Research
## in the Department

*Pattern Formation in Liquid Crystals: Experiment and Simulation*, Carlos Gonzales-Mendoza ’16, advised by Shila Garg

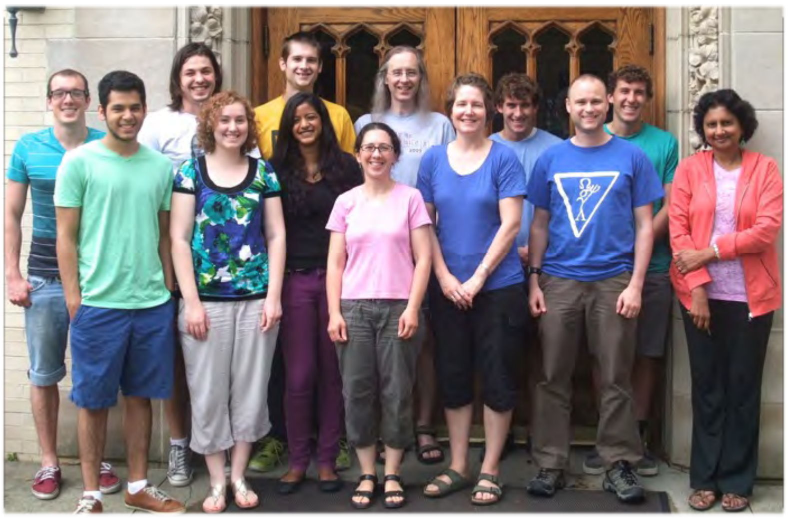
*Creating an artificial gravity field using U-I junction conditions*, Nicolae Istrate ’15, advised by John Lindner

*// The Gravitational Interaction of Two Line Segments*, Maggie Lankford ’16, advised by John Lindner

*Classical Entanglement: From Spheres to Rods to Staples*, Brian Maddock ’15, advised by John Lindner

*Stochastic Resonance in a Mechanical Bi-stable System*, Nate Mathewson ’16, advised by John Lindner

*Effect of Drop Height and Cohesion on Avalanches in a Conical Bead Pile*, Paroma Palchoudhuri ’16, advised by Susan Lehman

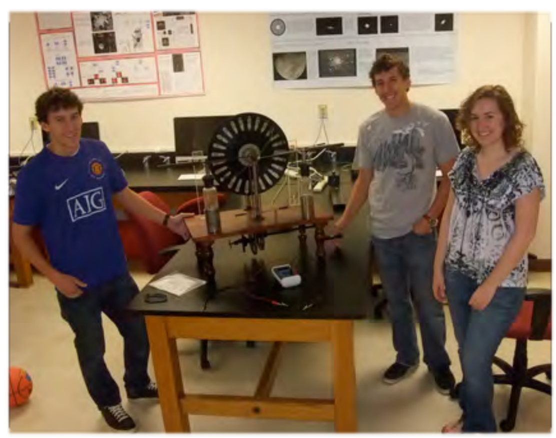



*Brian Maddock, Carlos Gonzalez-Mendoza, Nicu Istrate, Maggie Lankford, Nate Mathewson, Popi Palchoudhuri, Manon Grugel-Watson, John Lindner, Susan Lehman, Matt King-Smith, Cody Leary, Drew King-Smith, Shila Garg*

Matt King-Smith and Drew King-Smith worked on several projects in the Physics Department this past summer. They vastly improved the lecture demos inventory and added many demos with photos to our web page: physics.wooster.edu/Demonstrations.

Matt also worked on building an array of one-way coupled oscillators. Drew worked on enhancing the optical tweezers experiment in preparation for the addition of an optical “spanner” (Brit. *wrench).*

In the photo at right, Matt, Drew and Maggie test out the department’s Wimshurst machine, an electrostatic generator. Spinning the handle crank will result in two disks rotating in opposite directions. Next to the surfaces of the disks are metallic brushes and needle heads to absorb the charge. Since the wheels are moving in opposite directions, the charges build up in the Leyden jars, which allows a greater charge to build. A spark gap is created with two metallic balls attached to the Leyden jars. Eventually the charge jumps the gap.



## Physics majors in AMRE

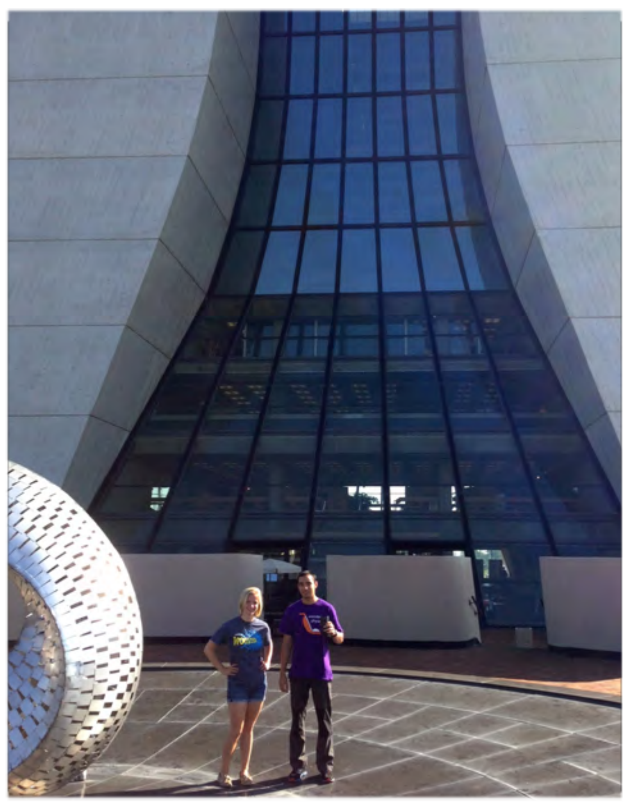
Joseph Smith ’15 and Michael Bush ’16 worked on undergraduate research in Knot Theory. Elliot Wainwright ’15 and Deepika Sundarraman ’14 studied the use of lasers to cut plastic film for AMRE client Kent Displays, Inc.

# Summer Research
## Off-Campus

**Vanessa Logan '14** participated in the Physics REU at the University of Michigan at Ann Arbor under Tim McKay. Her research was on the network theory of galaxy clusters. Network theory describes the connections and connection value between different points, such as a social network. This same concept is applied to galaxy clusters in large scale simulations that mock wide area image surveys. Using data from a photometric redshift algorithm developed at Michigan, Vanessa explored the properties of the weights (connection values) between galaxies for improvements to the algorithm, before it is applied to actual data from long term projects such as the Dark Energy Survey (DES).

**Prakrit Shrestha '14** worked in the Accelerator Division division at Fermilab. His project dealt with monitoring the beam loss in the Booster ring (previously used in the Tevatron as well, but now only in the Main Injector and the Booster rings). There are 24 Beam Loss Monitors (BLM) around the booster. When a beam deviates from its normal path and interacts with the surrounding magnet/metal, it sprays charged particles which are picked up by the BLM. The BLM then measures the charge accumulated per second (current) and then sends it

to an Integrator/Digitizer board. This card then integrates the current to measure the charge which is then digitized for processing. In Prakrit's project, he tested this Integrator/Digitizer board. Such a board with numerous chips with different functions has to be tested to make sure the data produced is correct and precise. There are two Field Programmable Gate Arrays (FPGAs) that control the logic of the integrators and interface with the signal digitizers (ADC) and the digital to analog converters (DAC). Firstly, he wrote a program in C that will program these FPGAs via the ROM with a certain file. Next, he wrote a program to read digitized test data from a file and convert it into an analog signal for integration and processing. By performing certain tests, Prakrit was able to test the memory, integrators, and ADC individually. This program will help future operators to take a faulty BLM board from the field and run tests to pin point where the problem is and repair the board more efficiently without having to replace the entire board.



*Vanessa took time out from her summer program at the University of Michigan to visit Prakrit at Fermilab.*

# Summer Research
## Off-Campus

**Amanda Steinhebel '15** did research in high-energy physics at the University of Colorado Boulder. There is a proposed neutrino oscillation experiment currently going through the Department of Energy grant process that will be built on American soil. Amanda used a simulation of this neutrino beam with dimensions specific to this proposal to track the total neutrino flux at a far detector as elements of the beam are misaligned. These results will then be used to find tolerances for all these separate elements, which will be helpful during construction. Since the proposal lacks a near detector, her research group is instead trying to analyze the muon flux at the start of the beam and the neutrino flux at a far distance. She also tracked this muon flux through a hadron absorber to find a way to relate the muon flux to the neutrino flux before the beam leaves Fermilab, the production facility.

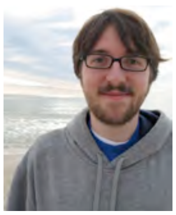
**Danielle Shepherd '14** worked at Davidson College in a collaboration with the Trackside Systems Director at Michael Waltrip Racing. The main project was in the field of computer vision. Given a set of images, the goal is to know whether one of the Michael Waltrip Racing cars is located in the photo. This information will be useful for the team as they analyze the photos after a practice session or a qualifying session to make necessary changes to their car. In addition to computer vision program, Danielle also did work regarding ranking of NASCAR drivers as well as authored a blog post for Davidson's racing blog "The Envelope". The post is titled "What Can We Learn In Six Years" and can be found at http://sites.davidson.edu/envelope/.

After completing an 8-week AMRE project here at Wooster, **Deepika Sundarraman '14** traveled to Germany for a research program at the University of Heidelberg. She worked for a biophysics research group advised by Dr. Dieter Heermann. This group is studying polymer models that explain the folding of DNA at different stages within the nucleus. Deepika's project was to use computational tools to analyze simulations of the nucleus for structural correlation with previously obtained experimental data. This method is popularly known as virtual microscopy. The project pools in knowledge from computational physics, statistical mechanics and polymer physics. While at the University of Heidelberg, Deepika topped off the summer by taking classes in German language and literature, expanding on her coursework from fall semester 2012, which she also spent in Germany.

# Alumni News

*Martha Roseberry '09* is a research librarian for the Sciences and Engineering at Virginia Commonwealth University.

*Chris Doherty '04* is a NASCAR race engineer for Dale Earnhardt Jr.'s No. 88 AMP Energy / National Guard Chevrolet.



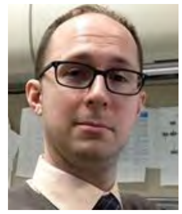
*John Gamble '08* recently earned his Ph.D. in physics from the University of Wisconsin and has been awarded the Harry S. Truman fellowship at Sandia National Laboratories.

*Katie Frato '04* earned her Ph.D. in biophysics and biophysical chemistry from Johns Hopkins University. She is now an assistant professor in the Chemistry Department at Seattle University.

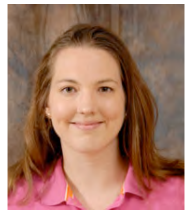
*Austin Carter '05* is a scientist at Wright Patterson Air Force Base in Dayton OH within the National Air and Space Technologies Division, disruptive technologies.

*Mike Davis '07* has completed his Doctor of Pharmacy degree at Northeastern Ohio Universities College of Medicine.

*Corey Atwood-Stone '10*, a graduate student in planetary science at University of Arizona, co-authored a paper in *The Astrophysical Journal* ("Modeling the Accretion Structure of AU Mon" based on his senior IS project at Wooster.

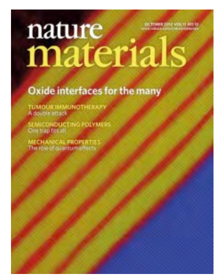


*David Miller '02* is an AAAS Science & Technology Policy Fellow at the National Institutes of Health.



*Christine Egnatuk '03* is a postdoctoral researcher at Lawrence Livermore National Laboratory, Chemical Sciences Division, Safeguards, Nonproliferation and Response Group. She earned her Ph.D. in nuclear and radiation engineering from the University of Texas in 2012.

*Danny Shai '07* is a Ph.D. candidate at Cornell, and his research group's work recently appeared on the cover of the October 12 2012 issue of *Nature Materials*. The team of Cornell researchers has shown how many-body interactions can be engineered at correlated oxide interfaces, an important prerequisite to exploiting such effects in novel electronics.




*Kathy McCreary '06* recently completed her Ph.D. in condensed matter physics at UC Riverside. She is now a postdoctoral researcher at Naval Research Laboratory, Washington DC.

*Henry Timmers '09*, a graduate student at University of Arizona, is the lead author on a publication in *Physical Review Letters* (**109**, 2012) reporting his research group's work with fast laser pulses catching the action of molecules and electrons getting knocked out of atoms.