WOOSTER

PHYSICS

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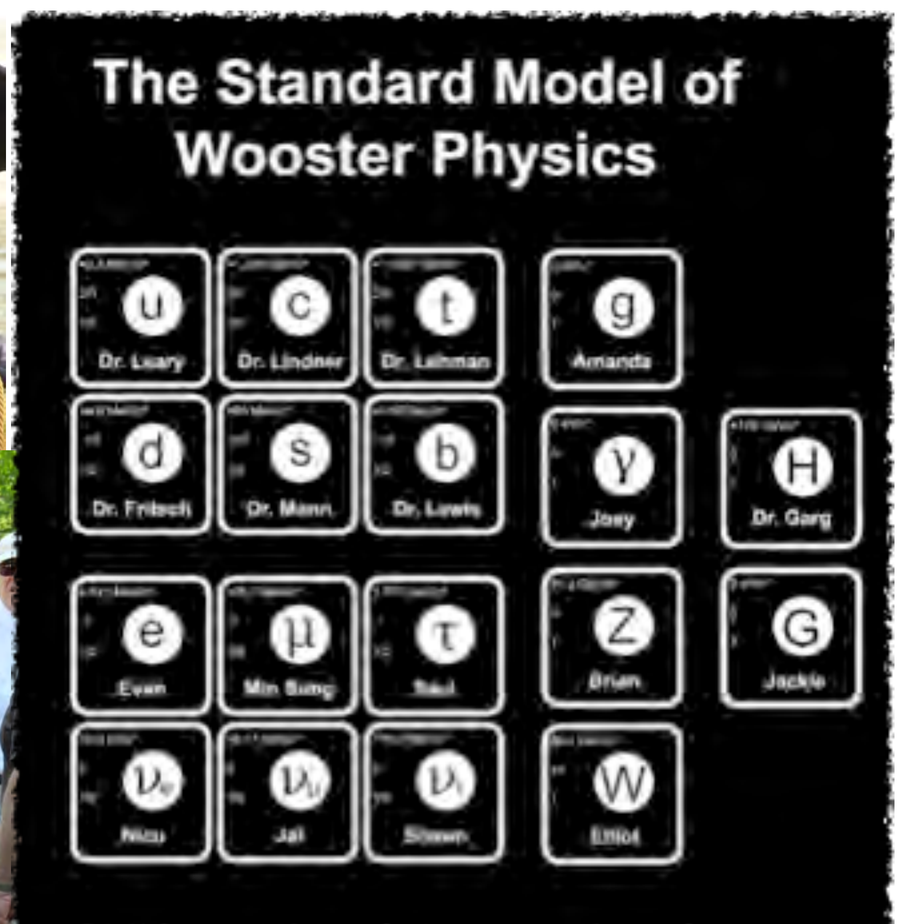


Wooster Physics Majors I.S. Monday T-shirt

CLASS OF 2015

Shawn Bowman
Physics major
Mineral City OH

Evan Hagedorn
Physics & Chemistry double major
Mineral City OH
Grad School: Northwestern University (chemical engineering)

Nicolae (Nicu) Istrate
Physics Major
Chisinaou, Republic of Moldova
Grad School: Washington University St. Louis

Min Sung Kim
Physics & Studio Art double major
Anyang, Republic of Korea
Plans: Korean military, then a career in architecture

Brian Maddock
Physics & Math double major
Elyria OH
Grad School: University of Cincinnati

Saul Propp
Physics & Philosophy double major
La Jolla CA
Grad School: University of Oregon

Jairaj Ranchod
Physics major
Shaker Heights OH
Plans: employment

Shawn, Saul, Jairaj, Brian, Joey, Evan, Min, Elliot, Nicu, Amanda

Joseph Smith
Physics and Math double major
Clinton OH
Grad School: The Ohio State University

Amanda Steinhebel
Physics & Math double major
North Canton OH
Grad School: University of Oregon

Elliot Wainwright
Physics & Math double major
Elyria OH
Grad School: Johns Hopkins University (materials science)

PHYSICS FACULTY

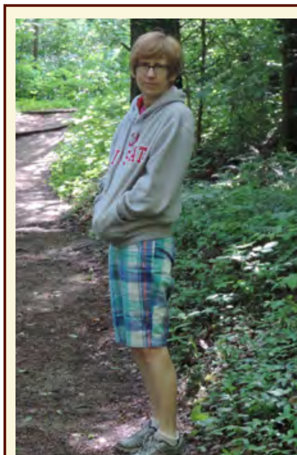
Dr. Lehman, Dr. Fritsch, Dr. Mann, Dr. Lewis, Dr. Leary

PHYSICS STAFF

Manon Grugel-Watson

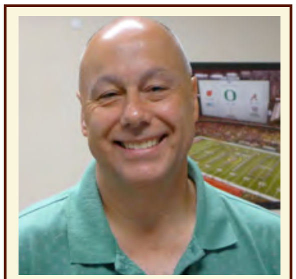
Laboratory Coordinator & Adjunct Instructor

Courses taught: Algebra Physics labs, Calculus Physics labs



Jackie Middleton

Administrative Coordinator



Tim Siegenthaler

Instrument Technician/Machinist

Tim began last fall after spending 28 years with the Hoover Company as a tool & die maker and then a developmental engineering technician. We are fortunate to have someone with his skill set to provide support for our students' and faculty's laboratory needs.

PHYSICS FACULTY

Dr. Fritsch (right) and his I.S. advisee/twin Nicu Istrate

Adam Fritsch

Visiting Assistant Professor of Physics

Courses taught: Modern Physics, Electronics for Scientists, Electronics lab, Algebra Physics II and lab, Nuclear Physics, advisor for 2 Senior Independent Study projects

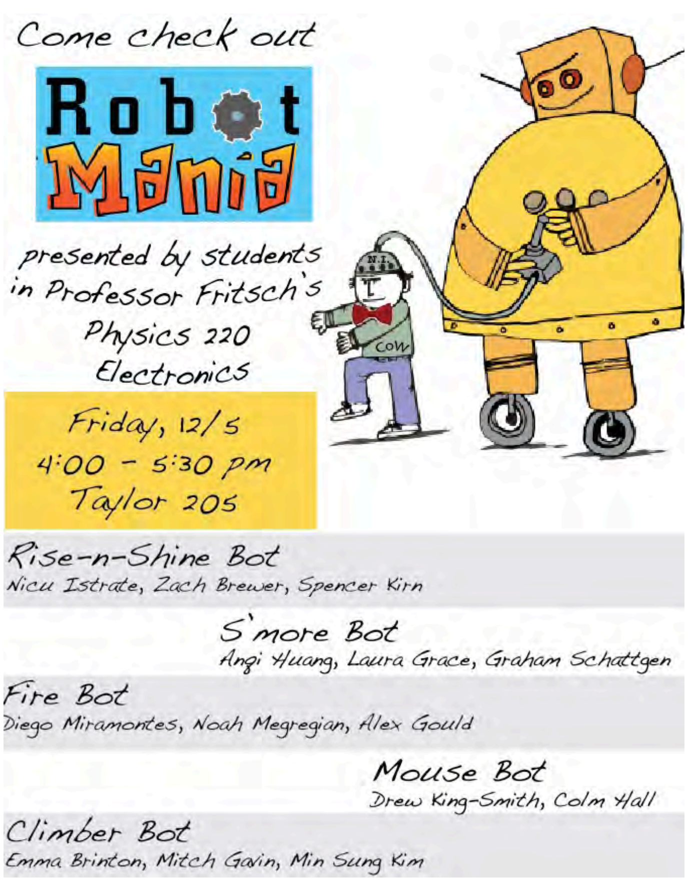
In October, Dr. Fritsch traveled to Waikoloa, Hawaii, and gave a talk at the Fourth Joint Meeting of the Nuclear Physics Divisions of the American Physical Society and the Physical Society of Japan entitled "Search for Cluster Structure in ^{14}C by Investigation of $^{10}Be+^{4}He$ Resonant Scattering with the Prototype AT-TPC".

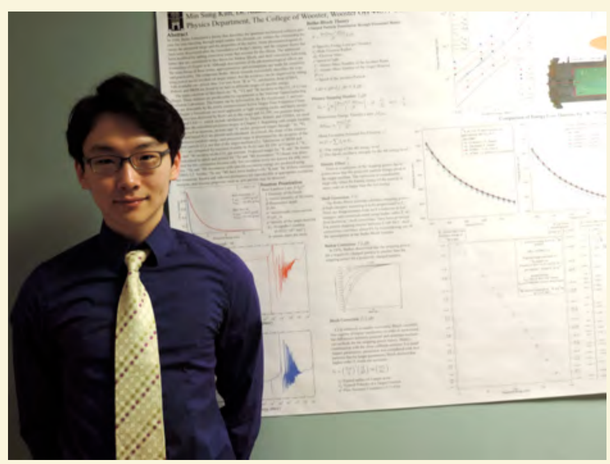
Dr. Fritsch took students in his nuclear physics course on an overnight field trip to the National Superconducting Cyclotron Laboratory at Michigan State University. This trip was partially funded by a College of Wooster APEX mini-grant.

Students in Dr. Fritsch's electronics course presented their Lego MindStorms robot projects to the campus community.

This past summer, Dr. Fritsch worked at the National Superconducting Cyclotron Lab with Wooster student Michael Wolff '17.

In the fall, Dr. Fritsch will begin a tenure track position at Gonzaga University.





Dr. Fritsch's I.S. student Min Sung Kim at the Senior I.S. Symposium

PHYSICS FACULTY

Cody Leary

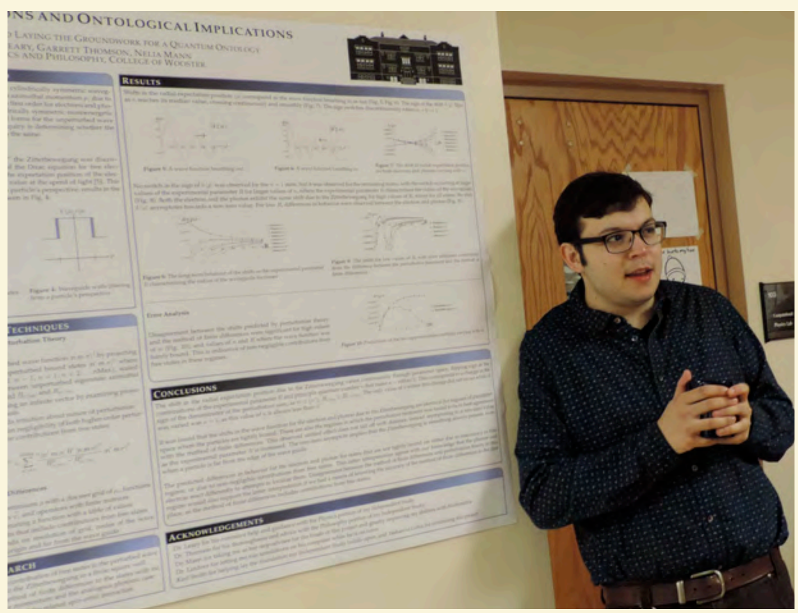
Assistant Professor of Physics

Courses taught: Calculus Physics I, Modern Physics lab, Electricity & Magnetism, advisor for 1 Senior Independent Study project

Dr. Leary had a productive pre-tenure research leave working with collaborators at the Universities of Oxford and Glasgow in the United Kingdom during the spring semester of 2015. He attended the 2015 Conference on Optics and Optoelectronics in Prague, Czech Republic, where he authored a conference paper along with two student coauthors, which was presented there by Wooster student Maggie Lankford '16, supported by Clare Boothe Luce funds. The conference presentation was based on research performed during summer 2014, where Dr. Leary worked together with two Wooster students on projects connected with his 2014-2016 Cottrell College Science Award from the Research Corporation for Scientific Advancement. He also gave an invited talk at Denison University entitled "*Measurement and control of the spin and orbital degrees of freedom of photons undergoing two-photon quantum interference,*" based on work performed in collaboration with a 2013-2014 senior independent study student.

Congratulations are in order to Dr. Leary and his wife Melissa who welcomed their second son, Weston, last fall.

Dr. Leary and physics major Popi Palchoudhuri '16



Dr. Leary's I.S. student Saul Propp at the Senior I.S. Symposium

PHYSICS FACULTY

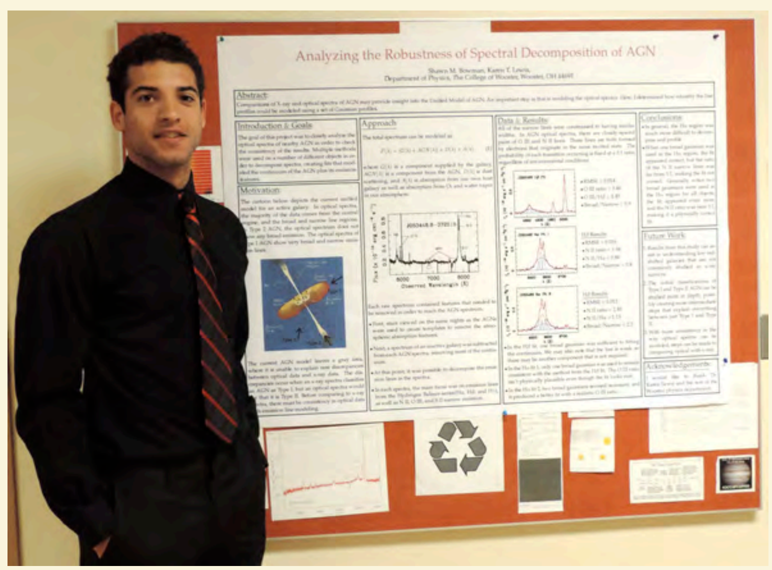
Dr. Lewis and two young protégés at Community Science Day

Karen Lewis

Assistant Professor of Physics

Courses taught: Algebra Physics I and labs, Physics of Sustainable Energy, Math Methods for Physical Sciences, Astronomy of the Solar System, advisor for 1 Senior Independent Study project

Dr. Lewis is leaving the College at the end of 2014-15 academic year. We wish her the best in all of her future endeavors.



Dr. Lewis's I.S. student Shawn Bowman at the Senior I.S. Symposium

Dr. Lewis celebrated the 25th birthday of the Hubble Space Telescope by making a "Hubble Deep Field" cake for students and faculty attenidng Astronomy Table.

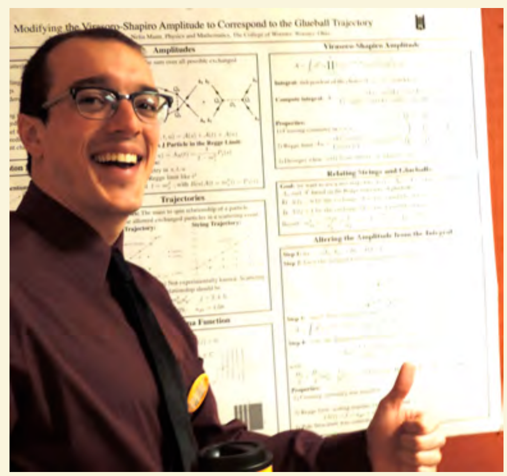
PHYSICS FACULTY

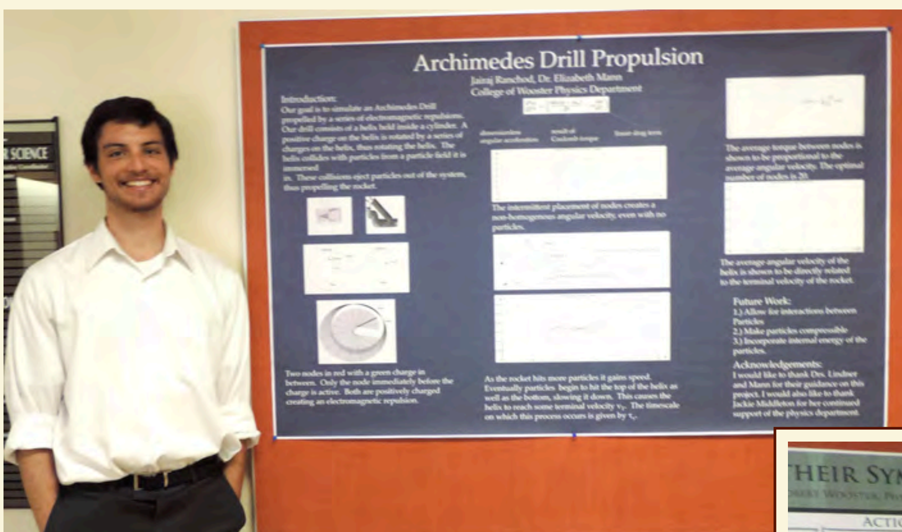
Nelia Mann

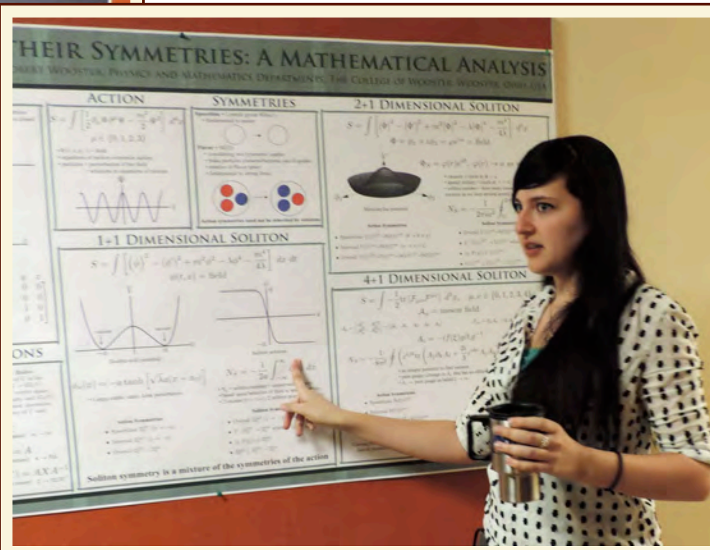
Visiting Assistant Professor of Physics

Courses taught: Calculus Physics I and labs, Mechanics, Computational Physics, Thermal Physics, advisor for 3 Independent Study projects

Dr. Mann will leave the College at the end of 2014-15 academic year to begin a tenure track position at Union College in Schenectady NY. We wish her well!







Dr. Mann's I.S. students at the Senior I.S. Symposium: Brian Maddock, Jairaj Ranchod, Amanda Steinhebel

PHYSICS FACULTY

John Lindner

Professor of Physics

Moore Professor of Astronomy

Dr. Lindner was on sabbatical in 2014-2015 at the University of Hawai'i at Manoa.

Publications:

Nonlinear Dynamics Based Digital Logic and Circuits, B. Kia, J. F. Lindner, W. L. Ditto, *Frontiers in Computational Neuroscience*, volume 9, pages 00049 (2015)

Coupling reduces noise: applying dynamical coupling to reduce local white additive noise, B. Kia, S. Kia, J. F. Lindner, S. Sinha, W. L. Ditto, *Chaos: An Interdisciplinary Journal of Nonlinear Science*, volume 25, pages 1550040(1-12) (2015)

Strange nonchaotic stars, J. F. Lindner, V. Kohar, B. Kia, M. Hippke, J. G. Learned, W. L. Ditto, *Physical Review Letters*, volume 114, pages 054101(1-5) (2015)

The strange stars research has been reported extensively in the press, including Scientific American, New Scientist, Physics.org, TechTimes, Smithsonian, Serious Science, Science-News, PhysicsWorld, Space.com, Nature Physics, Quanta Magazine, and The Huffington Post and has spawned an international conference that Dr. Lindner helped organize.

Pulsation period variations in the RRc Lyrae star KIC 5520878, M. Hippke, J. G. Learned, A. Zee, W. H. Edmondson, J. F. Lindner, B. Kia, W. L. Ditto, I. R. Stevens, *Astrophysical Journal*, volume 798, article 42, 16 pages (2015)

Watch your step: Integrating nonlinear dynamical flows by stepping through space and time, B. Kia, J. F. Lindner, W. L. Ditto, *International Journal of Bifurcation and Chaos*, volume 24, pages 1450145(1-6) (2014)

Noise Tolerant Spatiotemporal Chaos Computing, B. Kia, S. Kia, J. F.Lindner, S. Sinha, W. L. Ditto, *Chaos: An Interdisciplinary Journal of Nonlinear Science*, volume 24, pages 043110(1-7) (2014)

Simple and inexpensive stereo vision system for 3D data acquisition, S. E. Mermall*, J. F. Lindner, *American Journal of Physics*, volume 82, pages 1005-1007 (2014)
*undergraduate co-author '13, based on Senior I.S. project

PHYSICS FACULTY

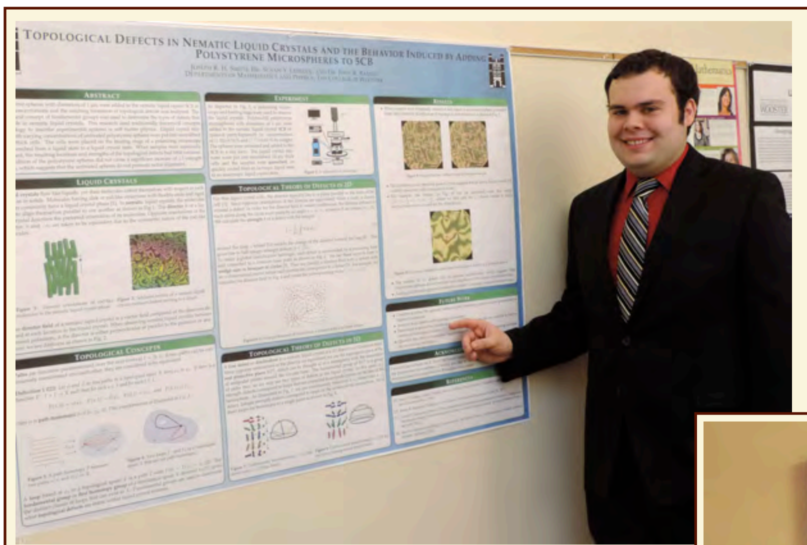
Susan Lehman

Clare Boothe Luce Associate Professor & Chair

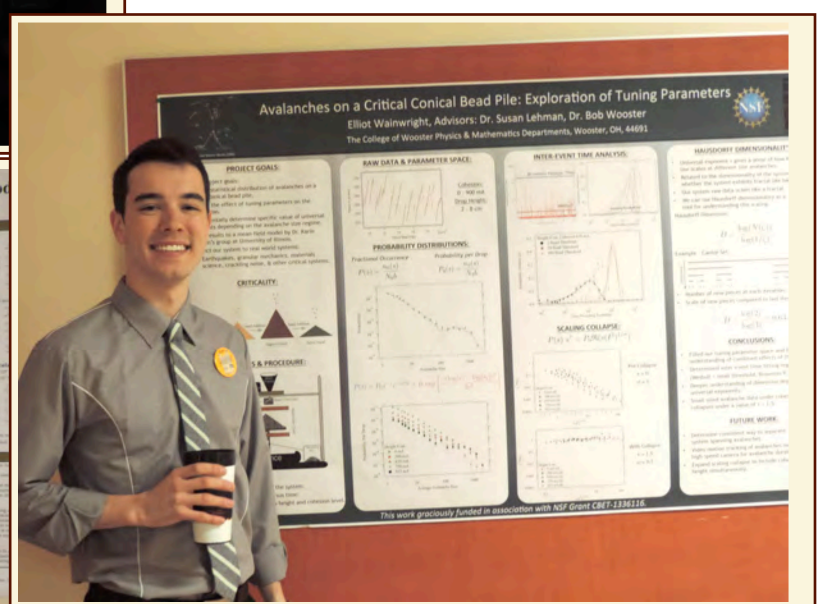
Courses taught: Calculus Physics II, Junior Independent Study (fall & spring) advisor for 3 Senior Independent Study projects

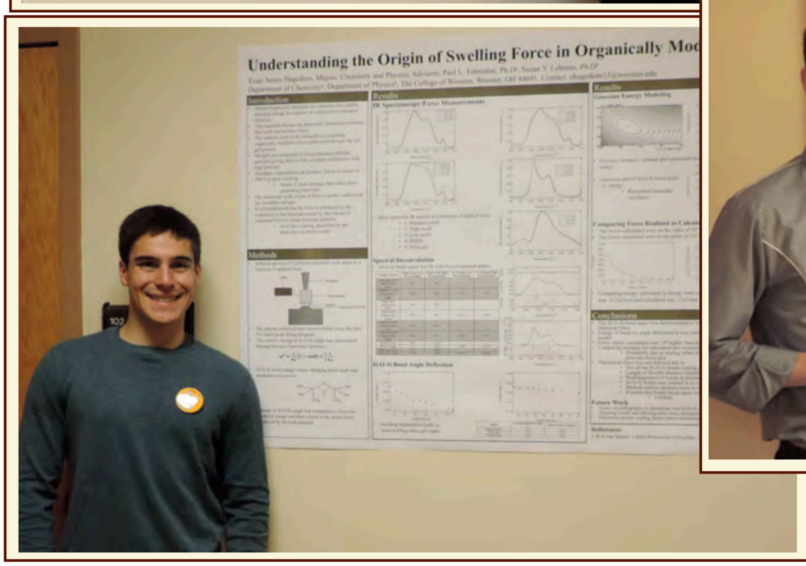
In March, Dr. Lehman accompanied the Wooster contingent to San Antonio for the National Meeting of the American Physical Society where she presented "Analysis of of inter-event times for avalanches on a conical bead pile with cohesion". She also attended the Complexity in Mechanics: Intermittency and Collective Phenomena in Disordered Solids conference at the Kavli Institute for Theoretical Physics in Santa Barba, CA in October and presented "Effects of Cohesion on the Dynamic Response of a Slowly-Driven Conical Bead Pile" with Donald T. Jacobs, Emeritus. This research is supported by a 4-year grant from the National Science Foundation awarded in 2013.

Dr. Lehman served on the Financial Advisory Committee, was a reviewer of the Physics Department at Stetson University, and led the physics portion of the Buckeye Women in Science & Engineering summer camp for middle school girls. She also undertook the launch of the Wooster Physicists blog: *woosterphysicists.scotblogs.wooster.edu.*



Dr. Lehman's I.S. students at the Senior I.S. Symposium: Joey Smith, Elliot Wainwright, Evan Hagedorn

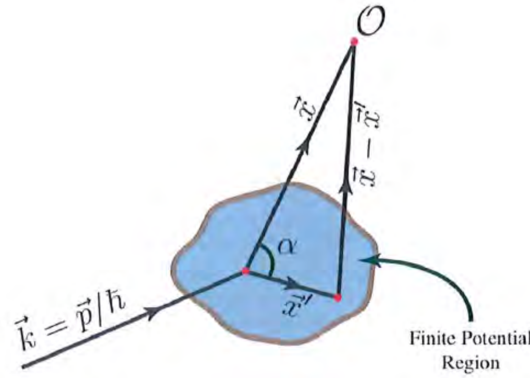




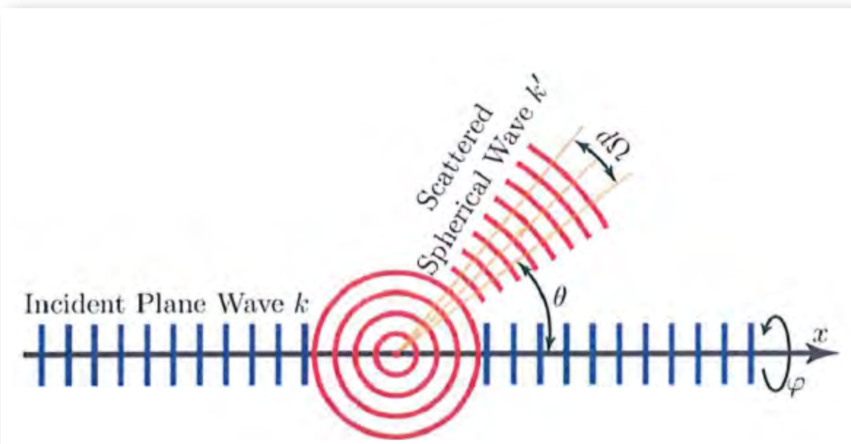
SENIOR INDEPENDENT STUDY

Theoretical Resonance Calculations for the Isobaric Analogs ^{133}Sn and ^{133}Sb

Nicolae Istrate (advised by Adam Fritsch, Physics)



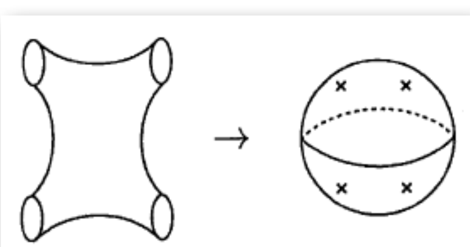
The formation of a compound nucleus during a nuclear reaction is identified by resonances in the excitation function. Isobaric analog resonances are a special type of resonance that have a narrow width and denote a pair of isobars. Isobaric analog resonances are caused by the isospin correlation between isobaric analog states. The isospin correlation is a direct result of the mechanism of (*p*, *n*) nuclear reactions. By analyzing isobaric analog resonances, valuable information about unstable exotic nuclei can be determined. This technique has become a standard in the repertoire of the experimental nuclear physicist. A theoretical calculation of isobaric analog resonances corresponding to elastic proton scattering off ^{132}Sn is performed in the energy range 5.0 to 15.0 MeV. By analyzing the excited states of the compound nucleus ^{133}Sb, the single particle states of its isobar ^{133}Sn are predicted. A total of five energy levels of ^{133}Sn are identified for the 7.5 to 9.5 MeV center of mass energy range. An additional resonance with spin-parity $J^{\pi} = 5/2^{+}$ is identified in the energy range 12.0 to 13.5 MeV and corresponds to an unusual phase shift. The exact characteristics of this resonance could not be determined, although the shape of the excitation function suggests an isobaric analog resonance which would correspond to an unidentified energy level of ^{133}Sn.

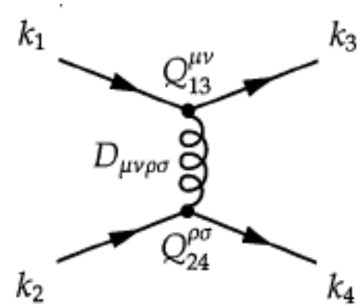


Modifying the Virasoro-Shapiro Amplitude to Correspond to the Glueball Trajectory

Brian Maddock (advised by Nelia Mann, Physics, and Jim Hartman, Math)

High energy proton-proton scattering is dominated by the exchange of glueballs along a leading Regge trajectory. This contribution can be calculated using the particle scattering amplitude. In 26 dimensional bosonic string theory, the corresponding closed string amplitude has similar structural features to the particle amplitude, but corresponds to a non-physical trajectory. In this project we take the closed string amplitude and modify its trajectory to correspond to the glueball trajectory, while maintaining the other important features that it contains. We find a family of closed string amplitudes related by a scaling factor which meets our requirements.





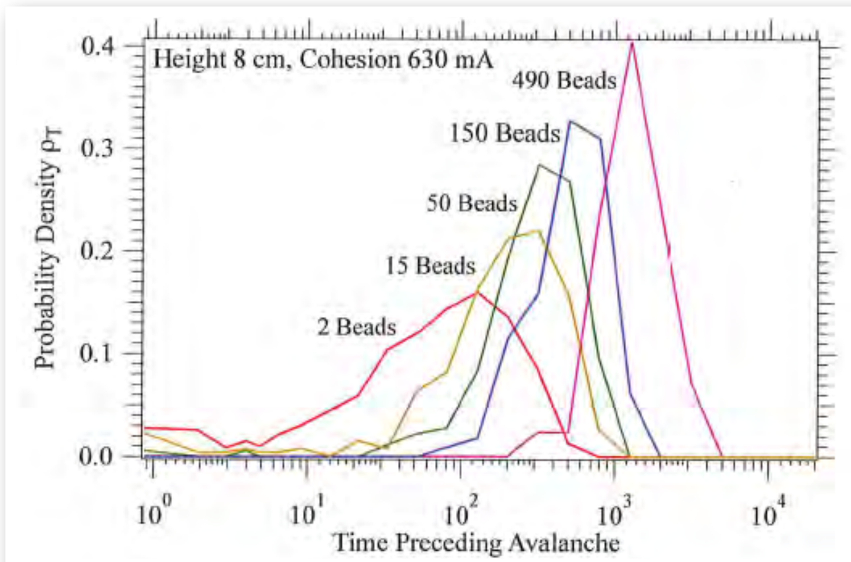
SENIOR INDEPENDENT STUDY

Avalanches on a Critical Conical Bead Pile: Exploration of Tuning Parameter Space and Mathematical Foundations

Elliot Wainwright (advised by Susan Lehman, Physics, and Robert Wooster, Math)

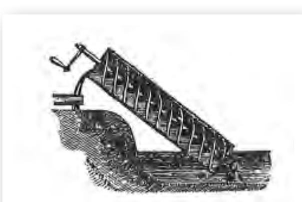
The effect of tuning parameters on a critical conical bead pile, specifically the effect of drop height and inter-particle cohesion on the avalanche size distribution, has been explored. The pile is slow driven by dropping one steel bead on the apex of the pile at a time. The cohesion of the pile is generated using variable current through Helmholtz coils surrounding the pile. We have compiled data at drop heights between 2 cm and 8 cm at 2 cm intervals, and current values of 0, 500, 630, 750, 835, and 900 mA. We observe the interplay of these two tuning parameters across our entire parameter space, with areas of particular interest at the maximum and minimum drop heights of 2 cm and 8 cm respectively.

The avalanche distributions observed are consistent with previous research, and the analysis has been expanded to calculations of fractional occurrence, probability per drop, complimentary cumulative distribution functions, ratio of total number of avalanches to total bead drops, inter-event time, and angle of repose. When using scaling functions to collapse multiple fractional occurrence runs under cohesion variation, we find that a universal tau exponent value of 1.5 successfully eliminates small avalanche regime power law behavior. For inter-event time avalanche probability densities, the system-spanning avalanche regime is well fit to a Brownian passage-time distribution, while the mixed avalanche regime is well fit to a Weibull distribution.

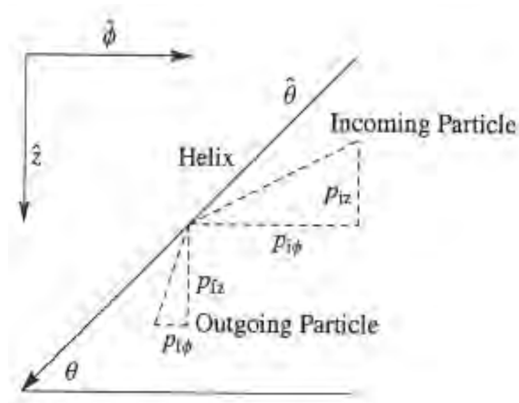


Archimedes Drill Propulsion

Jairaj Ranchod (advised by Nelia Mann, Physics)



In this project, we simulate the rotation of a helix set inside a cylinder, akin to an Archimedes drill. There is one positive charge on the edge of the helix and charges that can be turned on and off placed periodically around the cylinder. These charges work to rotate the helix with respect to the cylinder. This system interacts with a three-dimensional field of particles. The helix hits the particles backwards, thus propelling the system forwards. We find the moment of inertia of our helix and characterize its angular motion. We find that due to particles colliding with the top of the helix as well as the bottom, the system reaches some terminal velocity. We also find the number of nodes to be placed around the cylinder to optimize the average angular velocity of the helix. Finally, we characterize the effects of changing the concentration of the particle field and the mass of the individual particles in the field.

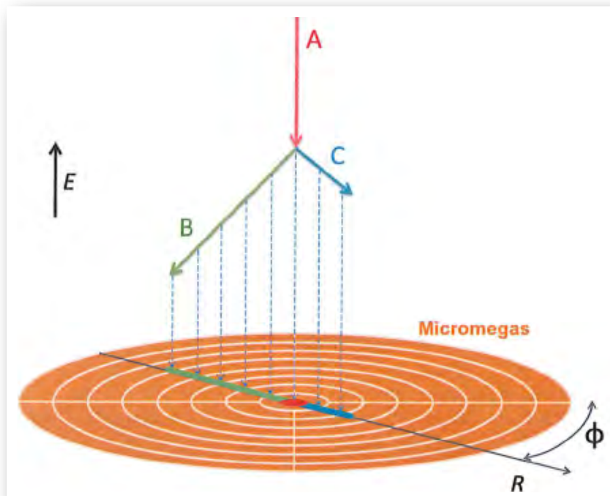


SENIOR INDEPENDENT STUDY

Stopping Power Analysis of ^{37}K, ^{44}Cl, and ^{71}Br Incident on a He: CO_2 (9:1) Gas Target

Min Sung Kim (advised by Adam Fritsch, Physics)

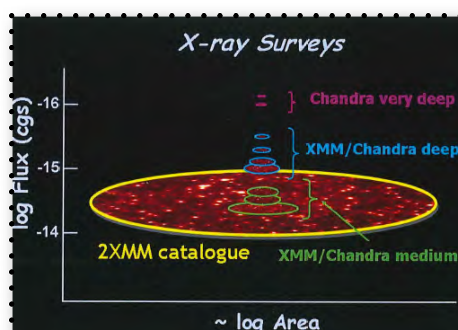
In 1930, Bethe formulated a theory that describes the quantum mechanical collision process for ions traveling through target matter. His formula calculates the relationship between the projected range and the properties of the nuclei. Some phenomenological effects were discovered after the formation of Bethe's theory, and the original theory has been modified by adding correction terms that account for the effects. The additional terms that are considered in this thesis are Barkas, Bloch, and shell corrections, following formalisms of Ziegler et al. Although descriptions of the phenomenological effects are the main focus of these terms, approximations and assumptions are made for simplicity and practicality. The composite Bethe-Bloch formula successfully describes the stopping power nuclei incident on target matter, but the accuracy can be improved by fitting with available empirical data. For ions from $_{19}K$ to $_{92}U$, tabulations from ATIMA, Hubert, and SRIM are found to be best in different ranges of specific energy. The main reactions of this thesis are ^{37}K, ^{44}Cl, and ^{71}Br incident on He:CO_2 (9:1) Gas Target. These reactions are produceable by equipment in the National Superconducting Cyclotron Laboratory. The beams can be delivered by the Re-Accelerator 3, and reactions are detectable by they newly commissioned Active Target-Time Projection Chamber. Ziegler's formalisms are most applicable to light stopping media and heavy projectiles. Since ions delivered by ReA3 are in this range and the AT-TPC uses gaseous targets, SRIM and LISE++, which include tabulations by Ziegler, Humbert, and ATIMA, are used to compare the calculated projected ranges. Beginning with simple incident particles such as neutrons, protons, and ^{12}C nuclei, projected ranges through ^{27}Al, ^{56}Fe solids, and liquid H_2O are plotted and calculated. As a result, the slope of the relationship between incident energy and projected range is determined by the property of the incident particle, not that of the target medium. Tabulations in SRIM and LISE++ are compared for reactions feasible by ReA3 and the AT-TPC: ^{37}K, ^{44}Cl, and ^{71}Br incident on He:CO_2 gas mixture. Projected ranges for ^{37}K and ^{71}Br beams are calculated in detail and plotted for ^{41}Sc and ^{75}Rb resonances. ^{41}Sc and ^{75}Rb resonances with specific excitation energy are predicted using ATIMA 1.2 Neither ^{41}Sc nor ^{75}Rb have been studied with ^{37}K and ^{71}Br. If these reactions are measured, missing properties such as spin parities may be detected.



Modeling the Optical Emission Line Profiles of Active Galactic Nuclei: Working Towards a Continuous Optical Classification Scheme Beyond Type1/Type2

Shawn Bowman (advised by Karen Lewis, Physics)

The most robust method to model the optical spectrum for active galaxies has been explored. An effort has been made to find if there is a consistent way to model the visible spectrum for AGN. Spectra of eight objects have been refined and decomposed into their individual components and re-plotted. This has been done in order to explore if there is any consistency in the ability to model these spectra by comparing the methods used for each decomposition. There were only a small number of methods that actually yielded valid results for each object. Thus, there was some consistency in how each spectrum was modeled in that the regions showed similarities when finding line fits.

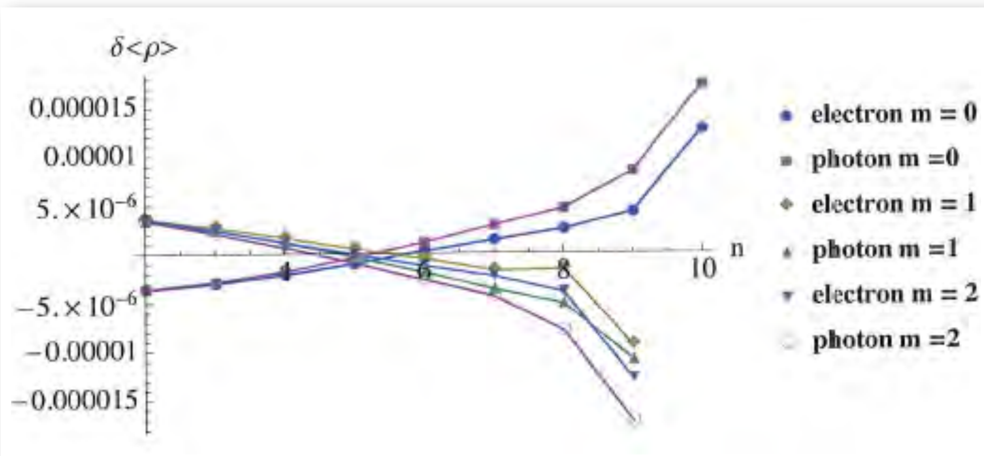


SENIOR INDEPENDENT STUDY

Relativistic Perturbations and Ontological Implications: Exploring the Zitterbewegung and Laying the Groundwork for a Quantum Ontology

Saul Propp (advised by Cody Leary, Physics, and Garrett Thomson, Philosophy)

The effects of the Zitterbewegung on the wave functions of low-energy electrons and photons in cylindrically symmetric waveguides were compared, and the philosophical implications for existence of considering quantum entities like photons and electrons to be fundamental were explored. Using degenerate perturbation theory, the changes in the radial wave function $\psi(\rho)$ due to the Zitterbewegung were approximated to first order for electrons and photons. These perturbed wave functions were used to calculate the perturbed expectation values and standard deviations of the radial coordinate ρ, which was compared to the unperturbed values. The validity of this perturbative approach was checked by comparing it to the results found via the method of



finite differences, and perturbation theory found to be accurate for the low Δ, low *n*, high *R* regime. It was also found that the effect of the Zitterbewegung varies drastically between states with $m = 0$ and $m \neq 0$, as well as varying gradually with subsequent nonzero values of *m* and subsequent values of *n*. It was found that despite the analytic forms of the first order corrections to the radial wave functions being different for the photon and electron, there exists a unified behavior in the high *R* limit, with the unification being stronger for low values of *n*. Violations of this unified behavior were tentatively observed in the low *R* regime, but it was impossible to be certain without better error estimates. If real, these violations were explained by the differences in how electrons and photons react to localization, and a physical analogy to the Zitterbewegung for $m \neq 0$ states was developed that connects intuition and data. Through this, a groundwork for a heuristic understanding of the Zitterbewegung was established.

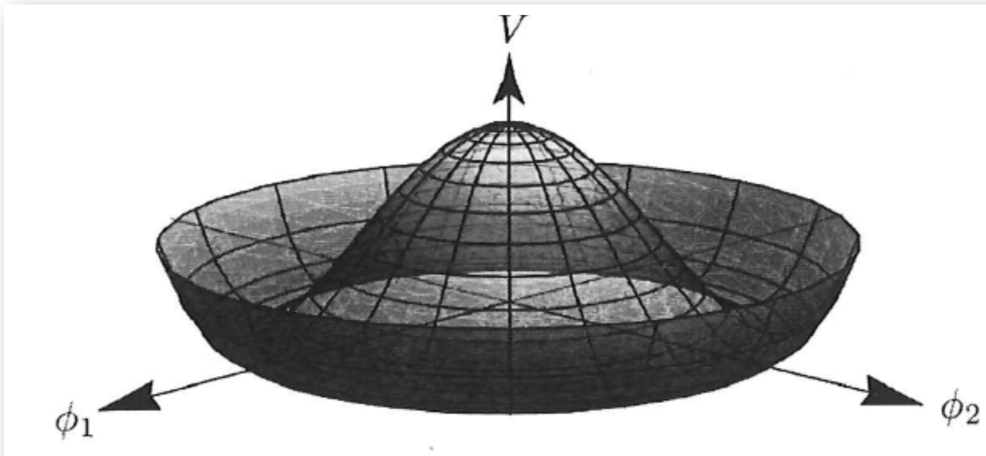
The implication for the notion of "existence" due to the empirical fact that quantum mechanical entities like electrons and photons exist were explored conceptually by unpacking the notions of "entity" and "this universe". In the case of the former, a classical understanding of what it means to be a fundamental entity was contrasted with multiple quantum understandings and analyzed through the lenses of three interpretations of quantum mechanics: the Copenhagen interpretation, the Many Worlds interpretations, and the Bohemian interpretation. For each interpretation of quantum mechanics, a precise summary of what must be given up in the classical account was presented. Unpacking "this universe" required understanding the problems of observer and measurement in quantum theory, and understanding the division between undivided wholeness and perspective as embodied by differing interpretations of quantum mechanics. By analyzing the implications of various interpretations of quantum mechanics for these problems and focusing on the issues posed for a classical ontology by the quantum reality, the groundwork for a quantum ontology was established.

SENIOR INDEPENDENT STUDY

Solitons and Their Symmetries: A Mathematical Analysis

Amanda Steinhebel (advised by Nelia Mann, Physics, and Robert Wooster, Math)

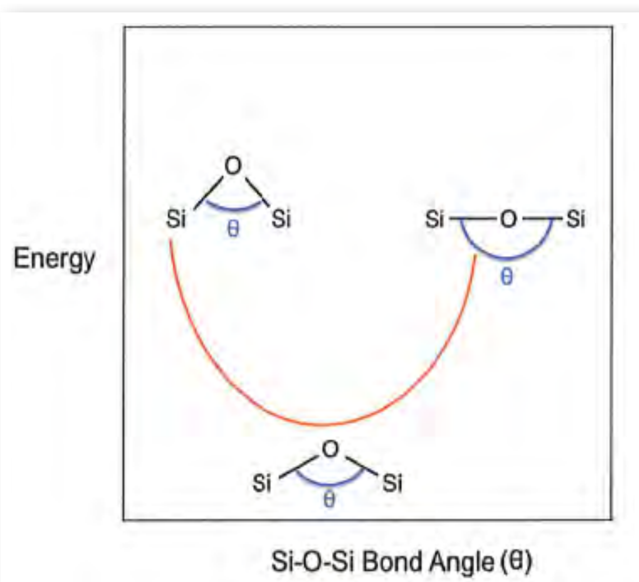
This work represents a rigorous investigation of the symmetries of soliton creation. Natural symmetries are expressed mathematically as matrix Lie groups. From a pure math perspective, we present characteristics of Lie groups and their algebras. With these, we develop functions of groups and algebras that we use to define matrix Lie representations, or actions of the groups. In particular, we are interested in the spacetime symmetry of the Lorentz group SO(3,1) and the flavor symmetry SU(2).



We introduce classical field theory as a framework for the creation of particles as perturbations of a field. Of particular interest are large, stable perturbations called solitons. We find through the use of toy models of fields in 1+1 and 2+1 dimensions that solitons break the spacetime and flavor symmetries of the original action of the field, but gain their own symmetry group in the process. This new symmetry involves a mixing of the original symmetries and leads to the presence of a conserved soliton number. It is this conserved quantity that indicates that the soliton created is a stable particle. We graduate to the creation of a Yang-Mills soliton in 4+1 dimensions which lays the groundwork for the creation of a string theory soliton.

Understanding the Origin of Swelling Force in Organically Modified Silica

Evan Hagedorn (advised by Susan Lehman, Physics, and Paul Edmiston, Chemistry)



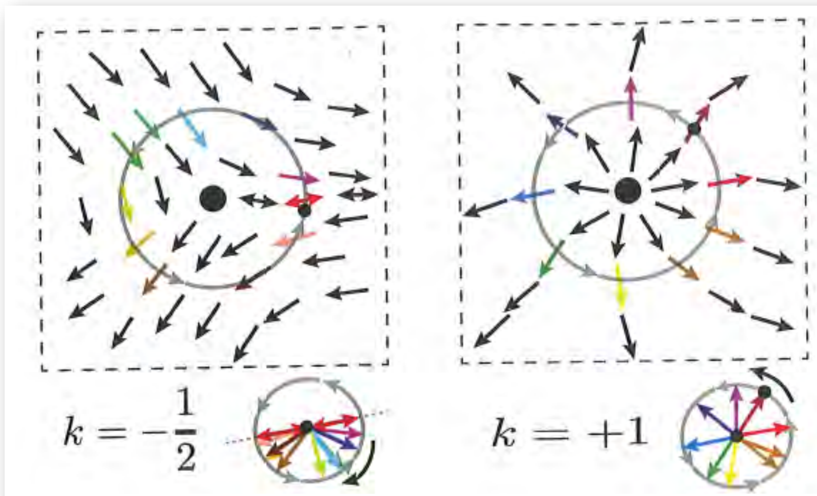
Swellable organically modified silica swells in the presence of organic liquids, producing forces in excess of 500 N/g. The mechanism of force generation is hypothesized to be due to the spring-like behavior of the change in the interparticle Si-O-Si bond angle. IR spectra of swellable organosilica were collected as a function of applied force. The Si-O-Si vibrational band was analyzed and found to decrease with applied force. Spectra deconvolution was used to determine the peak position and the area of the Si-O-Si vibrational band so that the average Si-O-Si angle could be calculated. Forces of around 10^9 N/g were calculated for swellable organosilica by *Gaussian* modeling. If true, the measured force is around 10^6 N/g less than the maximum potential force that could be generated. The research provides a novel interdisciplinary analysis of how force can be generated from bond deflection.

SENIOR INDEPENDENT STUDY

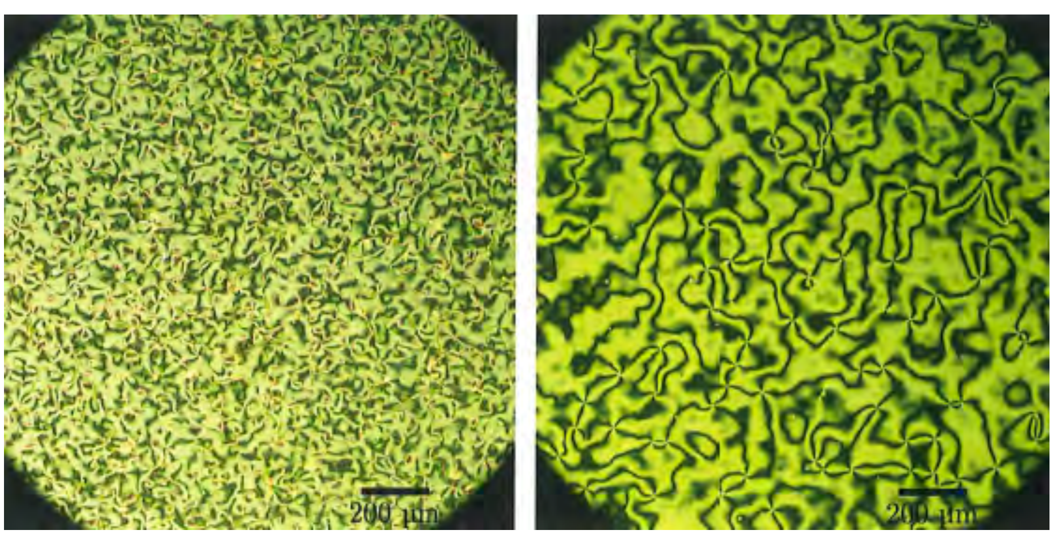
Topological Defects in Nematic Liquid Crystals and the Behavior Induced by Adding Polystyrene Microspheres to 5CB

Joseph Smith (advised by Susan Lehman, Physics, and John Ramsay, Math)

Polystyrene spheres with diameters of 1 µm were added to the nematic liquid crystal 5CB (4-cyano-4´-pentylbiphenyl) in varied concentrations and the resulting formation of topological defects was analyzed. The topological concept of fundamental groups was used to determine the types of defects that are stable in nematic liquid crystals. This research used traditionally theoretical concepts in topology to describe experimental systems in soft matter physics. Liquid crystal mixtures with varying concentrations of untreated polystyrene spheres were put into nonrubbed 10 µm thick cells. The cells were placed on the heating stage of a polarizing microscope and quenched from a liquid state to a liquid crystal state.



When samples were repeatedly quenched from 40°C to 30°C, we found that the resulting locations and strengths of the topological defects had little variance. This suggests that the inner surfaces of the cells treated with indium tin oxide and polyimide PI 2555 play a major role in the alignment of the molecules. The novel technique of using bouquets of circles to describe the topological defects in a Schlieren texture was applied to regions of our samples. The consistency over repeated quench cycles suggests that using bouquets of circles is a promising method for describing these textures. The addition of the polystyrene spheres did not cause a significant increase of ±1 strength defects, which suggests that the untreated spheres do not promote radial alignment. We also observed that the addition of the spheres lowered the transition temperature between the nematic liquid crystal phase and the isotropic liquid phase, although additional work is needed to isolate the cause and quantify this effect. This thesis served as a new exploration into the area of topological defects both experimentally and theoretically and it has provided multiple directions for future study.



JUNIOR INDEPENDENT STUDY

A Sampling of Junior I.S. Projects

Fall Semester 2014

Michael Bush, *Impact of the Gravitational Force on Star Formation*

Nathan Johnson, *Novel Methods of Avalanche Duration Measurement*

Andrew King-Smith, *Creating Laguerre-Gaussian Modes Using a Spatial Light Modulator*

Matthew King-Smith, *A Nonlinear Electrical Circuit Exhibiting Period Doubling Bifurcation and Chaotic Behavior*

Maggie Lankford, *Using Double-exposure Holographic Techniques to Evaluate the Deformation of an Aluminum Can Under Stress*

Yash Lohia, *The Spin-orbit Interaction of an Electron in a Cylindrical Potential*

Paroma Palchoudhuri, *A Study of the Phenomenon of Spontaneous Parametric Down-Conversion*

Catherine Tieman, *A Simulation of Social Forces and Collective Motion*

Trent Ziemer, *The Development and Numerical Modeling of a Chua Circuit as a Pedagogical Tool*

Attractor produced by Chua circuit

Spring Semester 2015

Noah Megregian, *Measuring Particle Concentration Through Turbid Suspension*

Colm Hall, *Determining Sphere Size Through the Observation of Brownian Motion*

Graham Schattgen, *How Center of Mass Affects the Acceleration and Final Velocity of a Pinewood Derby Car*

Nate Stone, *Examining the Effect of Additional Driving Forces on a Mechanical Oscillator*

Carlos Gonzalez, *Using Holographic Techniques to Evaluate Deformations of a Stressed Alumnimum Can*

Johanna Malaer, *Determining the Relation Between the Power Radiated by a Black Body and its Absolute Temperature*

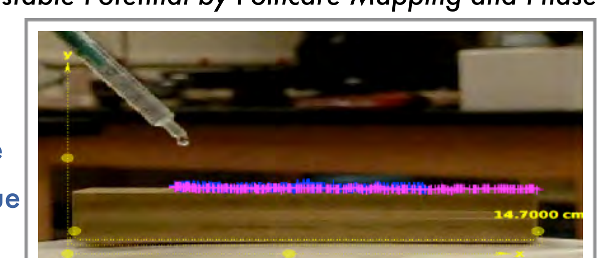
Spencer Kirn, *Separation of Seyferts and LINER Galaxies Using Eddington Ratio Derived from the Spectral Energy Distribution*

Laura Grace, *An Investigation into the Impact of Particle Mass and Liquid Surface Tension on the Capillary Force Between a Floating Particle and a Nearby Massive Wall*

Diego Miramontes Delgado, *Measuring the Magnetic Permeability Constant μ_0 Using a Current Balance*

Calvin Milligan, *Chaotic Analysis of a Mechanical Oscillator with Bistable Potential by Poincare Mapping and Phase Space Analysis*

Mitch Gavin, *Investigating the Dynamics of Leidenfrost Droplets*



Mitch's frame by frame video analysis technique

HONORS AND AWARDS TO PHYSICS MAJORS

Latin Honors

Summa cum laude

Joseph Richard Harrison Smith
Amanda Lynn Steinhebel

Magna cum laude

Saul Benjamin Propp
Elliot Richard Wainwright

Cum laude

Evan James Hagedorn
Nicolae Istrate
Brian Forrest Maddock
Jairaj Ranchod

Phi Beta Kappa

Saul Propp
Joseph Smith
Amanda Steinhebel

Arthur H. Compton Prize in Physics

Joseph Smith
Amanda Steinhebel

Mahesh K. Garg Prize in Physics

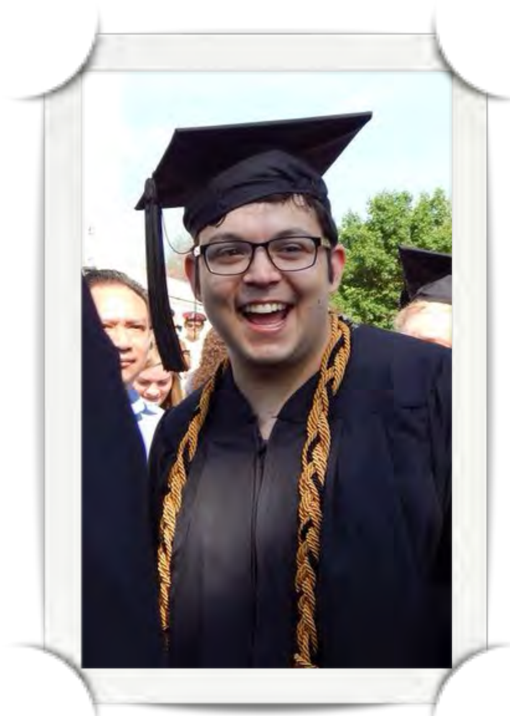
Nicolae Istrate

Joseph A. Culler Prize in Physics

Robin Morillo '17
Preston Pozderac '17

Departmental Honors in Physics

Nicolae Istrate
Saul Propp
Joseph Smith
Amanda Steinhebel
Elliot Wainwright



Wm A. Galpin Award for General Excellence in College Work

Elliot Wainwright (2nd)

Campus Council Leadership Award

Elliot Wainwright

Wm H. Wilson Prize in Mathematics

Joseph Smith

Theron and Dorothy Peterson Award for Outstanding Academic Achievement

Elliot Wainwright

American Chemical Society Senior Award

Evan Hagedorn

University Physics Competition

The team of Michael Bush '16, Zane Thornburg '18 and Nathaniel Moore '18 earned the rank of Accomplished Competitor in the 2014 University Physics Competition.

COLLOQUIUM SERIES 2014-2015

Junior I.S. self-designed presentations, 28 April

Mellita Caragiu, Professor of Physics, Ohio Northern University, Low-energy electron diffraction (LEED) as a tool in the study of surfaces, 16 April

C. Wesley Walter, Denison University, Atomic Negative Ions: Correlation and Dynamics Probed with Lasers, 7 April

APS Conference for Undergraduate Women in Physics Roundtable Discussion, 5 February

Robot Mania, 5 December

Junior I.S. self-designed presentations, 2 December

Nicholas Mauro, Lawrence University, Racing against the (thermodynamic) clock: How thermodynamics is always against (us and why we like it that way), 24 November

Senior Progress Reports 2, 20 November

Laurel Winter, Nat'l High Magnetic Field Laboratory, Characterizing Materials at Low Temperatures and High Magnetic Fields, 19 November

Senior Progress Reports 1, 18 November

Niklas Manz, Henri Begleiter Neurodynamics Laboratory, SUNY Medical Center, Excitation Waves in Heterogeneous Systems, 14 November

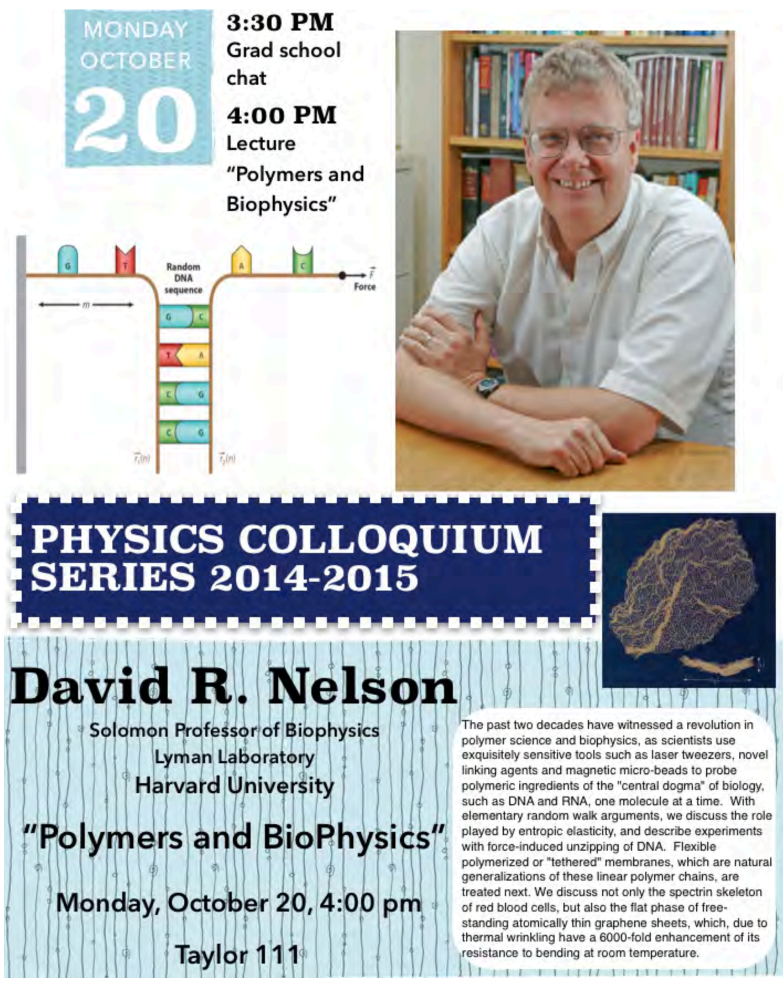
David R. Nelson, Solomon Professor of Biophysics at Harvard University, Polymers and Biophysics, 20 October

Adam Fritsch, The College of Wooster, Nuclear Alpha Clustering and Statistics on Students in Physics, 16 October

Nelia Mann, The College of Wooster, Strings and the Strong Force: Another Look at Particles and Interactions, 2 October

Wooster Physics Majors, I don't know what you did last summer, 18 September

Oleg Lavrentovich, Kent State University, Statics and Dynamics of Colloidal Particles in Liquids, 14 September



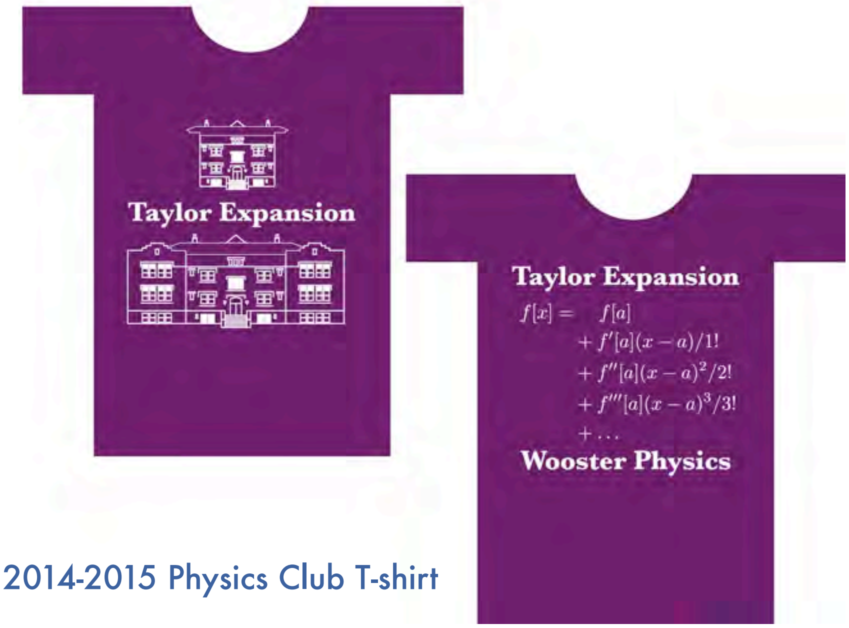
PHYSICS CLUB/ASTRONOMY CLUB

Physics Club Officers

President: Elliot Wainwright
Vice President: Amanda Steinhebel
Treasurer: Joey Smith
Secretary: Brian Maddock

Astronomy Club Officers

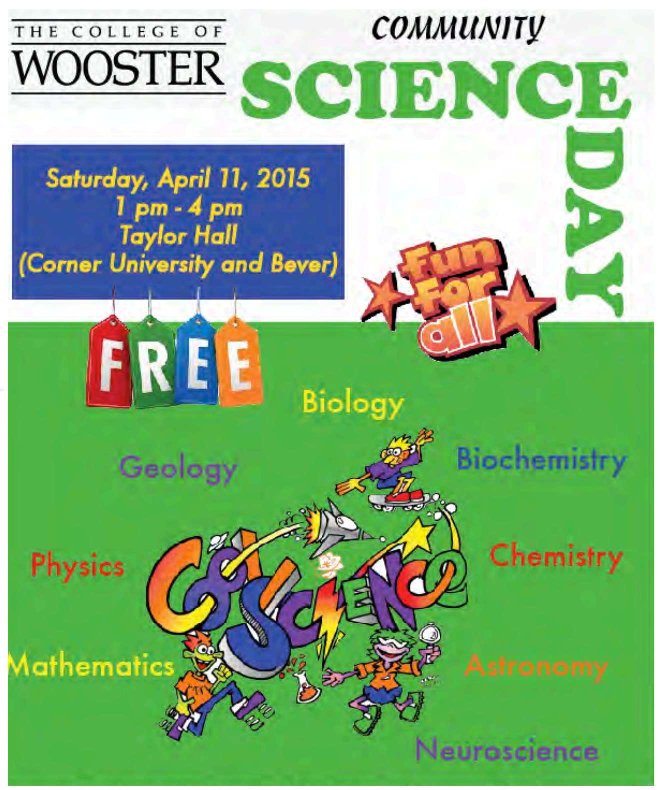
President: Amanda Steinhebel
Vice President: Yash Lohia
Treasurer: Michael Bush



2014-2015 Physics Club T-shirt

Events

Physics Table weekly at noon
Astronomy Table weekly at noon
2014 August 29: Scot Spirit Day
2014 September 3 : Pizza and Liquid Nitrogen Ice Cream
2014 September 10: General Meeting
2014 November 22: COSI field trip
2015 April 11 : Community Science Day 7
2015 April 18: Taylor Bowl 26 (Math/CS 104.7, Physics 93)
2015 April 19: Astronomy Club Cleveland Natural History Museum



Outreach

In addition to Community Science Day when several hundred guests visited Taylor Hall for demos by all the CoW science clubs, the Physics Club made seven trips to local elementary schools for demos in forces & motion,air pressure, electricity & magnetism, and light & sound.


Physics majors Dylan Hamilton and Colm Hall prepare the E&M demo for Community Science Day.

CONFERENCES

Maggie Lankford, Laura Grace, Justine Walker, Popi Palchoudhuri, Catherine Tieman, Amanda Steinhebel, Ziyi Sang

CUWiP

Seven Wooster physics majors attended the 2015 APS Conference for Undergraduate Women in Physics (CUWiP) at the University of Michigan. The conference explored and showcased career opportunities for physicists through activities such as tours of national labs, research presentations, discussion panels, and opportunities for networking. Discussion panels included topics such as applying for and succeeding in graduate school, how to get involved in undergraduate research or summer programs, and the multitude of careers available to physicists. The aim of CUWiP is to allow undergraduate women physicists to meet, network with, and be inspired by both peers and established women scientists.

National Meeting of the American Physical Society, San Antonio Texas, March 2015

Student presentations:

Ziyi Sang, John Lindner, "Nonlinear dynamics of three gravitating rods”

Catherine Tieman, Susan Lehman, “New Analysis Techniques for Avalanches in a Conical Bead Pile with Cohesion”

Nathan Johnson, Susan Lehman, “Use of a magnetic field to modify and detect avalanche behavior on a conical bead pile”

Michael Bush, John Lindner, "Balancing Newtonian gravity and spin to create localized structures"

SOLAR SYSTEM MODEL

Brass plates like this one have been installed along Beall Avenue to represent the size and scope of our solar system.

Installation Enables Residents and Guests to "Stroll" through the Solar System

Our solar system is so large that even light takes hours to cross it, but thanks to a new installation at The College of Wooster walkers can traverse it in a matter of minutes.

The scale of the solar system model is approximately five billion to one (1:5 000,000,000) according to John Lindner, professor of physics at Wooster who conceived the idea along with Amanda Steinhebel, a senior physics and mathematics double major from North Canton, Ohio, during her Sophomore Research Experience several years ago. "Both the planets and the distances between them are to scale," said Lindner. "Pictures engraved on 3.5-inch brass markers embedded along the west sidewalk of Beall Avenue through campus represent the planets."

The four terrestrial planets (Mercury, Venus, Earth, Mars) can be found near the sun between Pearl and Stibbs Streets, according to Lindner. The planet Jupiter is alone on the block between Pine and University Streets opposite the Gault Alumni Center, while Saturn is across from Andrews Library. The modern planets Uranus (discovered in the 1700s) and Neptune (discovered in the 1800s) are opposite the tennis courts and just before Bloomington Avenue, respectively. (Dwarf planets like Pluto, Ceres, and Eris were too small to be included in the model.) "The Beall Avenue model dramatically demonstrates that the solar system is mainly empty space," said Lindner. "It provides an educational opportunity that can be enjoyed by anyone walking or jogging through campus,"

The project took just under three years to complete and cost just $3,500. Steinhebel, who is president of the Astronomy Club and vice-president of the Physics Club, marked the locations of the planets and sun based on her design. Beau Mastrine, director of grounds, and his staff, installed the markers, and Manon Grugel-Watson, physics laboratory coordinator and adjunct Instructor, handled the complicated process of ordering the markers and accessories.

"We hope that the presence of the model on campus helps to make science more assessable to the masses, and sparks curiosity among students and community members," said Steinhebel. "It also complements the existing tree walk, and invites community members and guests to explore the campus.

"I value the opportunity to leave a lasting monument of science on campus," added Steinhebel, "and I hope that the model inspires passers-bye to take a moment to consider the wonder of our solar system." *—John Finn, CoW Public Information*

SUMMER RESEARCH

Summer research @Wooster

Avi Vajpeyi '18 and **Justine Walker '18** worked with Dr. Susan Lehman and Dr. Donald Jacobs (Emeritus) on Dr. Lehman's NSF-funded criticality and avalanche experiment, also known as the bead pile experiment. The essence of the project is the creation of a pile, using small metal beads. As additional beads are added, the pile topples. The avalanche characteristics are demonstrated when a critical point is reached or surpassed, changing in order to return to a stable point. The bead pile models critical systems – a few examples are avalanches, forest fires, stock markets (to a certain extent), and even dynamical synapses in neural networks! By studying the pile, the conclusions will be used to better understand complex critical systems in the real world.

Several of our double majors participated in Wooster's Applied Mathematics & Research Experience (AMRE) in summer 2015:

Robin Morillo '17, completed a revenue forecasting project with Artiflex Manufacturing.

Joey Smith '14 and **Carlos Gonzalez '16** worked with Goodyear Tire and Rubber Company on a project to provide both tools and analysis in regards to optimal aviation tire wrapping.

Michael Bush '16, along with Wooster math major Brian Foley, continued an ongoing knot theory research project involving the "unknotting problem".

SUMMER RESEARCH

Summer Research @Elsewhere

Popi Palchoudhuri '16 worked at CERN, the European Organization for Nuclear Research, that sits astride the Franco-Swiss border near Geneva. She worked under the supervision of Dr. Michael Doser on the AEGIS experiment. The primary scientific goal of the Antihydrogen Experiment: Gravity, Interferometry, Spectroscopy (AEGIS) is the direct measurement of the Earth's gravitational acceleration, g, on antihydrogen. AEGIS is a collaboration of physicists from all over Europe.The AEGIS experiment will represent the first direct measurement of a gravitational effect on an antimatter system. More specifically, Popi worked on designing an optical cavity that will be used to cool the antiprotons that are to be used to produce and trap anti-hydrogen in a penning trap.

Nathan Johnson '16 worked at NASA's Glenn Research Center investigating the high-temperature interaction of CMAS (Calcium-Magnesium-Alumino-Silicate) glass (it's essentially lab-engineered sand) with rare-earth materials. The materials are going to be used as coatings for the inside of large aircraft engines and will help increase efficiency for those engines.

Dylan Hamilton '17 Thin film photovoltaics, in contrast to traditional silicon, are of interest to the energy industry because of their use of less raw material and the lower energy needed for the manufacturing process. These advantages make thin film solar cells both viable as a large-scale energy source and lower the energy return on investment. The anatomy of a thin film solar cell consists in a transparent conducting top layer to serve as a front contact, a transparent buffer layer, a p-n junction created by two doped semiconductors, and a back contact. Dylan's research at University of Toledo concerned the transparent buffer layer which serves to hinder molecules from the back contact migrating up through the cell to the front contact, creating a short and thus decreasing efficiency. By blocking these molecules with the buffer layer, we are also able to decrease the thickness of the window layer (the top semiconductor) thereby allowing more light to pass through to be absorbed by the absorber (the bottom semiconductor), increasing efficiency. To maximize the performance of this buffer layer, the electrical and optical properties must be optimized. Dylan's work involved trying to produce a buffer layer with certain specifications by varying the deposition parameters of the film.

Diego Miramontes Delgado '16 spent the summer at Rutgers University.

Matt King-Smith '16 did research at Georgia Tech on the control of a robotic blimp. This research included using a localization lab to determine the x,y,z coordinates of a blimp as well as the roll, pitch and yaw of the blimp in a localized frame. From this information, algorithms are being developed to control the blimp real-time and make the blimp automatous. Matt specifically worked on modeling the state dynamics of the blimp, or how forces influence how the blimp moves throughout space. Since the blimp is analogous to underwater robotics, which is primarily the focus of this particular graduate lab, the researchers are hoping that algorithms developed can be implemented on under water vehicles. Aside from that goal, the blimp will be used to map light fields of the room, which will be done by using the light sensor attached to the blimp. Due to the blimp's light weight and small motors, the hope is that blimps may be a viable alternative to quad-copters to outdoor mapping since blimps can run off of small batteries for long periods of time, roughly 2 to 3 hours.

Spencer Kirn '16 spent his summer at the University of Kentucky helping Dr. Christopher Crawford create a coil that has a uniform magnetic field inside the coil. Dr. Crawford plans on using this coil in his experiments with neutrons. Spencer worked on calibrations for the robot that will be used to drill the magnet.

Maggie Lankford '16 worked at Fermilab this past summer building both a physical and computational model of a second harmonic radio frequency cavity that will go into their Booster accelerator. The radio frequency cavities are the workhorses of the accelerator. They show the protons an accelerating voltage, increasing their energy. This specific cavity is being designed to increase the luminosity of the particle beam in addition to accelerating.

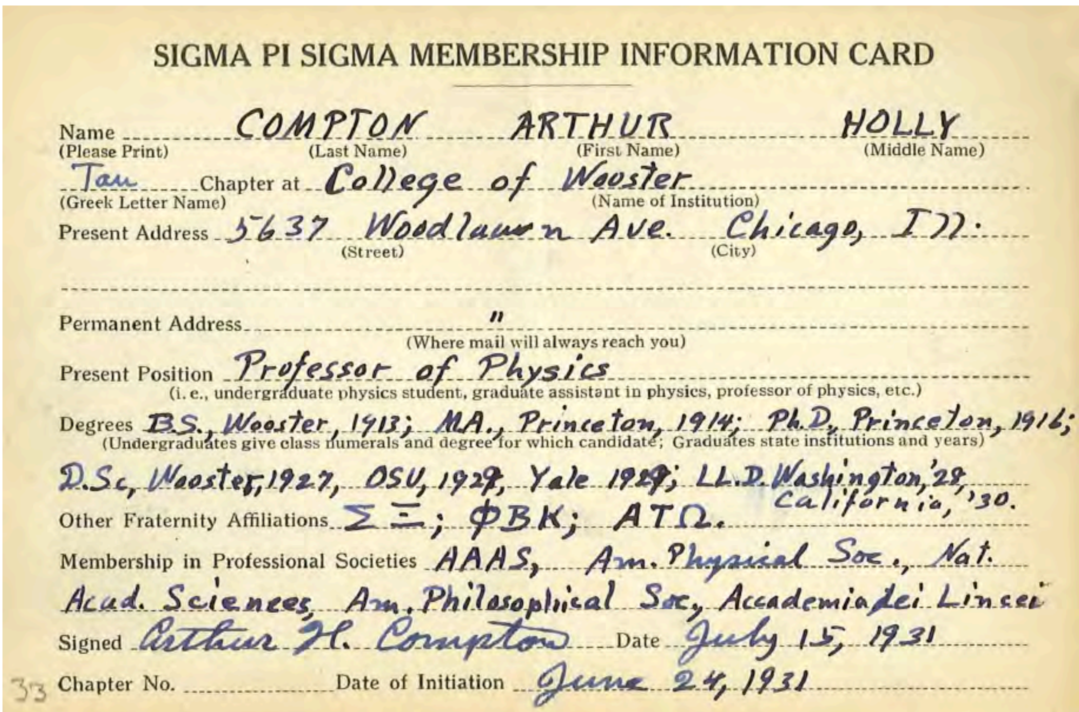
Michael Wolff '17 worked at Michigan State's National Superconducting Cyclotron Laboratory with Wooster visiting professor Adam Fritsch. Michael tested various active target gas configurations to see which provide the best gain and energy resolution for measuring nuclei that traverse the gas. The results of these tests directly determine how nuclear physics experiments to be run later this year at NSCL and the University of Notre Dame are designed and executed.

HISTORICAL FIND

Sigma Pi Sigma Membership Cards

Wooster physics alum Dr. Thomas Kirkman '74 was recently doing some cleaning of his office at College of St. Benedict/Saint John's University when he came across a stack of old Sigma Pi Sigma membership cards that he probably obtained during his time as the "nominal head" of Wooster's Physics Club. (There were three physics majors in his class in 1974.)

We were delighted to find some very notable names among the cards, including Arthur Holly Compton '13 and Karl Taylor Compton '08, as well as several other recognizable names such as Mateer, Kittredge, Andrew, and Longbrake.



SIGMA PI SIGMA MEMBERSHIP INFORMATION CARD

Name (Please Print): COMPTON (Last Name) ARTHUR (First Name) HOLLY (Middle Name)

Tau (Greek Letter Name) Chapter at College of Wooster (Name of Institution)

Present Address 5637 Woodlawn Ave. (Street) Chicago, Ill. (City)

Permanent Address " (Where mail will always reach you)

Present Position Professor of Physics (i. e., undergraduate physics student, graduate assistant in physics, professor of physics, etc.)

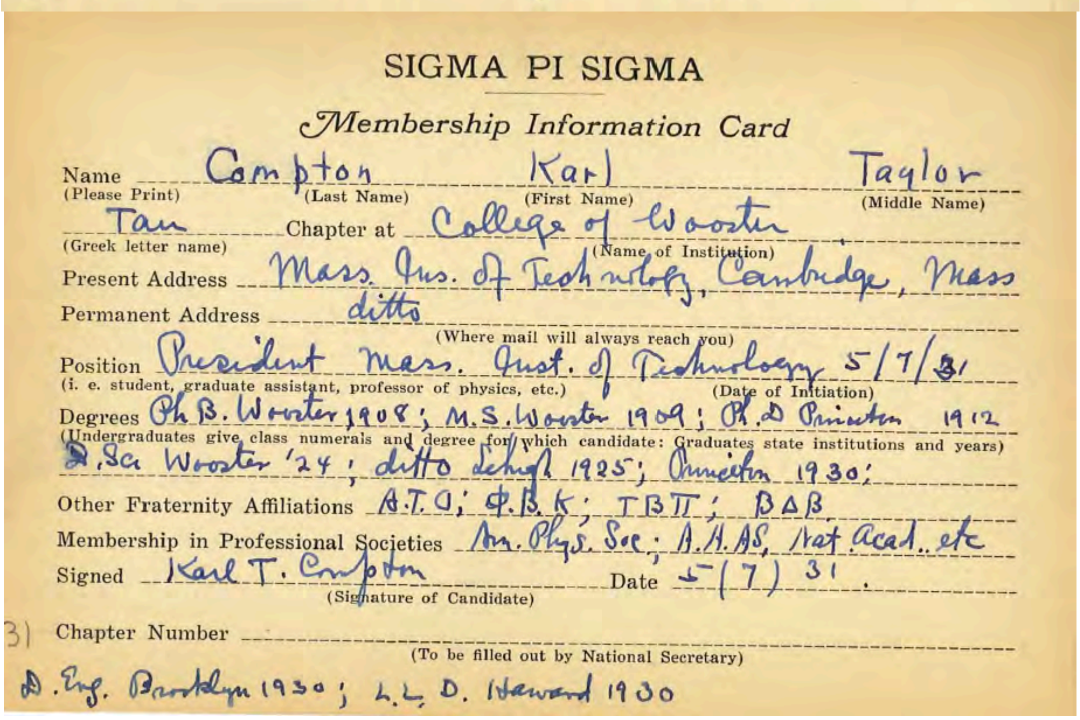
Degrees B.S., Wooster, 1913; MA., Princeton, 1914; Ph.D., Princeton, 1916; D.Sc, Wooster, 1927, OSU, 1929, Yale 1929; LL.D. Washington, '28, California, '30. (Undergraduates give class numerals and degree for which candidate; Graduates state institutions and years)

Other Fraternity Affiliations ΣΞ; ΦBK; ATΩ.

Membership in Professional Societies AAAS, Am. Physical Soc., Nat. Acad. Sciences, Am. Philosophical Soc., Accademia dei Lincei

Signed Arthur H. Compton Date July 15, 1931

33 Chapter No. Date of Initiation June 24, 1931



SIGMA PI SIGMA

Membership Information Card

Name (Please Print): Compton (Last Name) Karl (First Name) Taylor (Middle Name)

Tau (Greek letter name) Chapter at College of Wooster (Name of Institution)

Present Address Mass. Ins. of Technology, Cambridge, Mass

Permanent Address ditto (Where mail will always reach you)

Position President Mass. Inst. of Technology (i. e. student, graduate assistant, professor of physics, etc.) 5/7/31 (Date of Initiation)

Degrees Ph.B. Wooster 1908; M.S. Wooster 1909; Ph.D Princeton 1912 (Undergraduates give class numerals and degree for which candidate: Graduates state institutions and years) D.Sc Wooster '24; ditto Lehigh 1925; Princeton 1930;

Other Fraternity Affiliations A.T.Ω; Φ.B.K; TBΠ; BΔB

Membership in Professional Societies Am. Phys. Soc.; A.A.A.S, Nat. Acad., etc

Signed Karl T. Compton (Signature of Candidate) Date 5/7/31.

31 Chapter Number (To be filled out by National Secretary)

D. Eng. Brooklyn 1930; L.L.D. Harvard 1930