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# A Letter from the SPS President

by Alina Gearba-Sell, PhD, Professor of Physics, United States Air Force Academy

"The mere formulation of a problem is often far more essential than its solution, which may be merely a matter of mathematical or experimental skill. To raise new questions, new possibilities, to regard old problems from a new angle requires creative imagination and marks real advances in science."

—A. Einstein

**Stephen Hawking once said: "No one undertakes research in physics with the intention of winning a prize. It is the joy of discovering something no one knew before." Within the Society of Physics Students, we would also suggest that this joy extends to sharing the discovery with the community and learning from one another.**

The Society of Physics Students (SPS) is a professional organization designed to support students, faculty, and departments with a variety of programs, activities, and initiatives. These initiatives aim to enrich the undergraduate experience outside the classroom, along with building a strong community. SPS provides scholarships, research, and outreach awards, as well as career and professional development resources.

By providing financial aid through travel awards, SPS offers opportunities for undergraduates to present their research at professional conferences. During these conferences, students are able to enhance their understanding of the field, interact with their peers, and make valuable connections that will benefit them throughout their careers. With the relaunch of the *Journal of Undergraduate Reports in Physics* (JURP) in the summer of 2018, undergraduates now also have the opportunity to publish their research findings in a peer-reviewed and searchable journal dedicated to highlighting student contributions to any physics-related field.

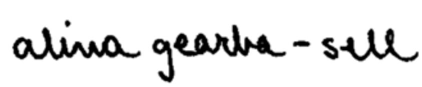
As an instructor, research mentor, and SPS faculty advisor, I truly believe that involvement in a research project enhances an undergraduate's experience in a way that no amount of coursework can. The hands-on problem solving and critical thinking skills that research develops are invaluable tools that will be useful in graduate school and in whatever profession you might find yourself. Written and oral communication skills are just as vital, which is why research projects usually incorporate at least one of these aspects. Further, writing a research article for a professional journal and experiencing the peer-review process cultivates a related, yet distinct, set of skills. Moreover, it instills in undergraduates a sense of belonging to a scholarly community while opening the door for future collaborations.

JURP is more than an avenue for disseminating results of undergraduate research. To showcase what our talented physics majors are capable of, JURP also includes a collection of student writings documenting their experiences at various professional meetings, award-winning chapter programs, the SPS summer internship program, and other special SPS programs.

The Society of Physics Students proudly invites you to read the second annual issue of *Journal of Undergraduate Reports in Physics*. In addition to student research, you will learn about the experiences of students attending national meetings, such as CUWiPs or the APS March Meeting. You will also read about chapters that have been awarded for their outreach and contributions they have made to their communities, and so much more.

It is our hope that you will keep JURP in mind when starting your research project or chapter programs in the fall and consider contributing to next summer's issue. It is also our hope that JURP will increase awareness of the diversity of the SPS programs and that you will take advantage of these opportunities as you engage with others in your chapter and zone. //

Alina Gearba-Sell



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# Research

# Effects of Electron-Beam Irradiation on Graphene Oxide

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**Abstract.** Graphene oxide (GO) is a nanofilm composed of graphene with various oxygen functional groups attached. GO is of interest due to its unique mechanical-enhancement properties, its tunable electronic properties, and its potential use in the wide-scale production of graphene. Scanning electron microscopes (SEMs) are frequently used to characterize and study GO films. The purpose of this project was to study the effects of SEM-imaging on GO films. Using an SEM, we irradiated GO samples at electron beam-energies of 10, 20, and 30 keV (at a constant emission current of ~40 ± 2 μA) for times ranging from 15 minutes to 1 hour. Raman D- and G-band intensities were used to examine structural modifications/damage to GO samples as a function of beam energy and exposure time. The results suggest that imaging with a 30 keV electron beam for 30 minutes may lead to the formation of amorphous carbon, while imaging with 10 keV or 20 keV beams for 30 minutes does not have a significant effect on GO samples.

## INTRODUCTION

Graphene is a single atomic layer of carbon atoms arranged in a hexagonal form. Graphene oxide (GO) is a sheet of graphene with various oxygen functional groups covalently attached. GO has attracted substantial interest due to its unique mechanical properties[1] (which include the ability to enhance the tensile strengths of materials[2, 3]), its tunable electronic properties[4], and its potential use in the wide-scale production of graphene[5]. Scanning electron microscopes (SEMs) are commonly used to analyze the surface morphology[1] of GO and graphene samples.

SEMs produce images by scanning samples' surfaces with electron beams with energies typically ranging from 500 eV to 50 keV. Exposure of GO and other nanomaterials to electron beams during SEM-characterization is known to introduce defects[6] that can significantly alter thermal and electrical conduction[7].

Raman spectroscopy is a vibration-based technique that is commonly used to characterize disorder in $sp^2$ carbon materials[8]. Raman spectroscopy involves shining monochromatic light (typically from a laser) on a sample and studying the light that is inelastically scattered from it in order to learn about the vibrational and rotational modes of the sample. The Raman D-band is commonly found in Raman spectra at a wavenumber of ~1350 $cm^{-1}$. The prominent D-band peak (which is not present in the Raman spectra of pristine graphene) is defect-dependent. In the case of GO, the D-band's existence in Raman spectra is primarily due to structural imperfections as the result of the presence of hydroxyl and epoxide groups. The first-order G-band is commonly found at a wavenumber of ~1580 $cm^{-1}$. It is related to the stretching of $sp^2$ pairs, and, unlike the D-band, is not defect-dependent. The Raman D- to G-band peak-intensity ratio ($I_D/I_G$) is, thus, proportional to the $sp^2$ defect-density of carbon-based samples[9]. In this study, we used Raman analysis to compare defect-densities in GO samples irradiated using an SEM and as-purchased GO samples.

## EXPERIMENTAL PROCEDURE

For this experiment we used GO samples (Graphenea Inc., Spain) prepared by the filtration of a monolayer GO dispersion. The circular GO samples had thicknesses of 12-15 μm and diameters of 4.5 ± 0.2 mm. The GO films were composed of 49-56 wt% carbon, 41-50 wt% oxygen, 0-2 wt% sulfur, 0-1 wt% nitrogen, and 0-1 wt% hydrogen.

Samples were irradiated using a Hitachi S-3000N SEM at emission currents of 40 ± 2 μA and accelerating voltages ranging from 10 kV to 30 kV. While irradiating the GO samples, every effort was made to stabilize the SEM's emission current at 40 μA by continuously monitoring the emission current and adjusting the filament voltage, when necessary. As the emission current was essentially held constant during all irradiations, and as the same aperture and magnification settings were used during each irradiation, irradiation dosages were approximately proportional to exposure times. An SEM image of a typical GO sample is shown in Fig. 1.

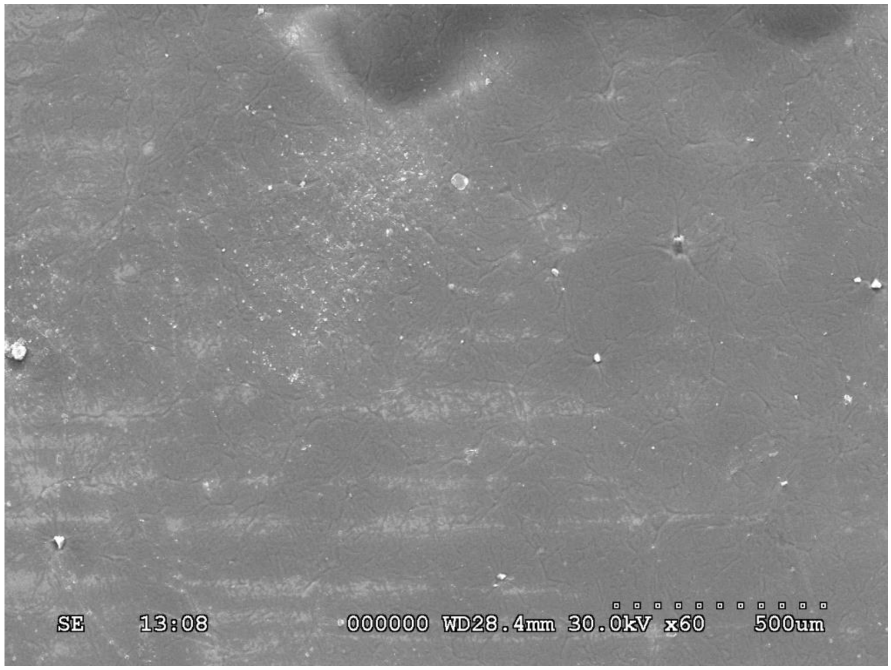


**FIGURE 1.** SEM image of typical GO sample.

Raman spectra were obtained using a Bruker Optics Senterra dispersive Raman microscope spectrometer, equipped with a 2 mW, 532 nm-wavelength laser. Background contributions were subtracted from the spectra using software developed by Candeloro *et al.*[10] A typical Raman spectrum from an irradiated GO sample (with background subtracted) is shown in Fig. 2.

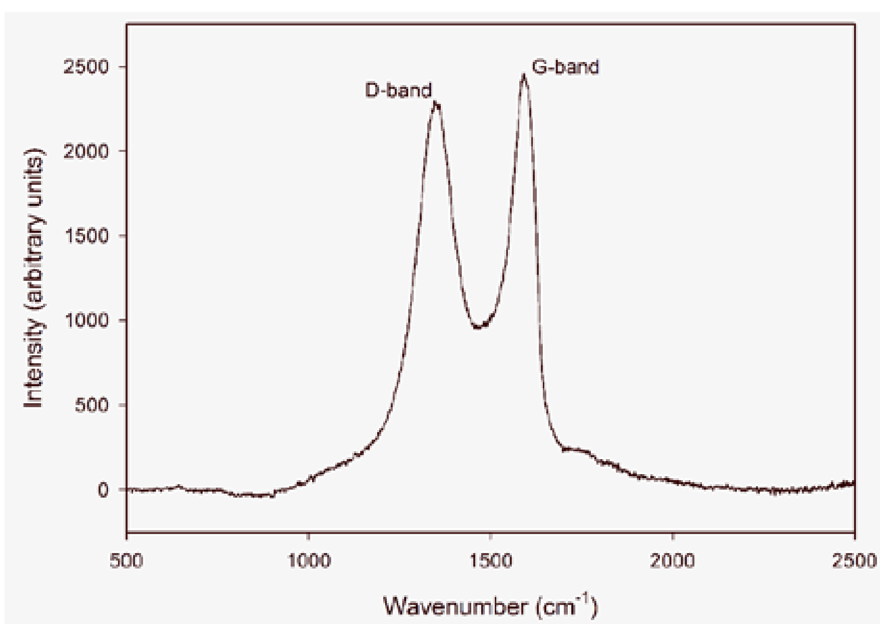


**FIGURE 2.** Typical Raman spectrum from an irradiated GO sample after background has been subtracted.

## RESULTS AND DISCUSSION

The $I_D/I_G$ values for GO films irradiated using 0 keV, 10 keV, 20 keV, and 30 keV electron beams for 30 minutes are shown in Fig. 3a. The sample "irradiated" using a 0 keV beam is simply an as-purchased sample. The uncertainties represented by the error bars in Fig. 3a were calculated by combining the uncertainties in background subtraction and statistical uncertainties in quadrature. The data shown in Fig. 3a suggests that $I_D/I_G$ decreases as the SEM's electron beam-energy increases. This is likely due to the introduction of defects leading to the formation of amorphous carbon. As the beam increases the number of defects in the GO and reduces the in-plane correlation length, the number of ordered rings in the GO decreases, which leads to a decrease in $I_D$[7]. As the G-band is only related to the stretching of $sp^2$ pairs, its intensity remains unchanged. However, the wavenumber at which the peak-intensity of the G-band ($I_G$) appears was observed to consistently shift to lower wavenumbers as the electron beam-energy was increased. The wavenumbers at which $I_G$ appears in the Raman spectra for GO samples irradiated with 0, 10, 20, and 30 keV electrons are shown in Table 1. This shift is also consistent with a partial change from a crystalline to amorphous structure[6]. The results shown in Fig. 3a are consistent with the results of similar experiments involving graphene performed by Teweldebrhan and Balandin[7].

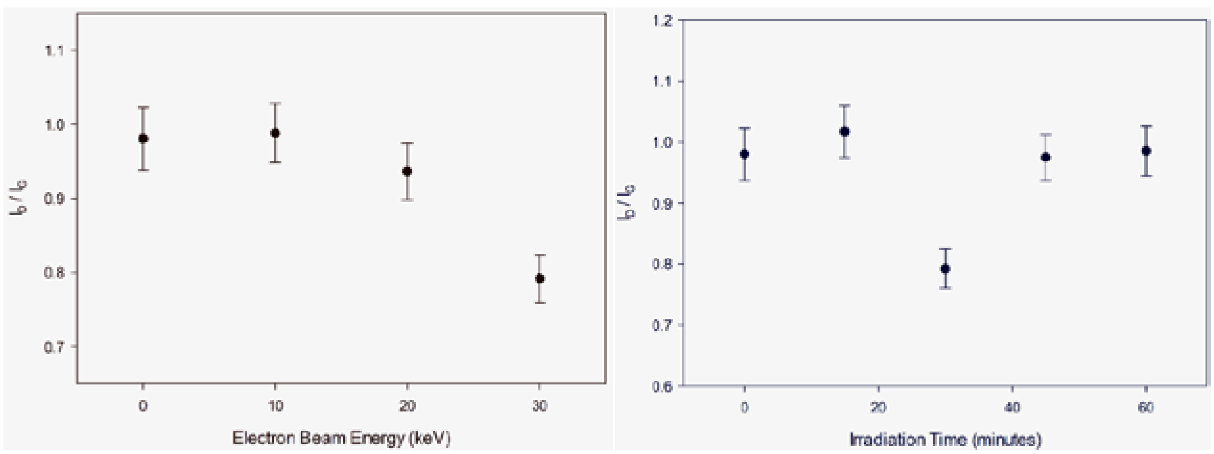


**FIGURE 3.** (a) Raman D- to G-band peak-intensity ratios ($I_D/I_G$) for GO samples irradiated for 30 minutes using 10 keV, 20 keV, and 30 keV electron beams. The data point at 0 keV corresponds to an as-purchased (unirradiated) GO sample. (b) Raman D- to G-band peak-intensity ratios ($I_D/I_G$) for GO samples irradiated using a 30 keV beam for 0, 15, 30, 45, and 60 minutes.

| Accelerating Voltage (kV) | $I_G$ Wavenumber ($cm^{-1}$) |
|---|---|
| 0 | 1594.5 |
| 10 | 1592.0 |
| 20 | 1591.5 |
| 30 | 1591.0 |

**TABLE 1.** Wavenumbers at which IG appears in the Raman spectra for GO irradiated with 0, 10, 20, and 30 keV electrons.

The $I_D/I_G$ values for GO films irradiated using a 30 keV electron beam for 0, 15, 30, 45, and 60 minutes are shown in Fig. 3b. Just as in Fig. 3a, the uncertainties represented in Fig. 3b were calculated by combining uncertainties in background subtraction and statistical uncertainties in quadrature. The decrease in $I_D/I_G$ values between 0 and 30 minutes of irradiation-time may be due to the aforementioned change from a crystalline to amorphous structure. However, the increase in $I_D/I_G$ values after 30 minutes of irradiation-time is not completely understood. The results shown in Fig. 3b are not consistent with those of Teweldebrhan and Balandin[7]. However, the experiments performed by Teweldebrhan and Balandin involved graphene, rather than GO, and it is possible that discrepancies in the results are due to the presence of oxygen groups. It is also possible that the uncertainty in some factor, such as background subtraction, was underestimated, and that the low $I_D/I_G$ value for 30 minutes of irradiation-time is simply the result of experimental error.

## CONCLUSIONS

There is still a need for measurements of $I_D/I_G$ values at more frequent intervals to better understand the effects of irradiation-time on GO samples. Presently, we do not have enough information to completely understand the effects of long-term electron irradiation-times on GO films.

The data presented here suggests that 30 minutes of irradiation-time has little effect on GO for electron beam-energies of 10 keV and 20 keV. However, exposure to a 30 keV electron beam for a duration of 30 minutes led to a partial change from a crystalline to amorphous structure. This change is evident through a decrease in $I_D/I_G$ values, as well as through a consistent shift in the peak-intensity of the G-band to lower wavenumbers, as the electron beam-energy was increased. In the future, additional experiments should be performed in order to more accurately determine the accelerating voltage at which amorphous carbon begins to form as the result of electron-beam irradiation. For the time being, the results presented here should be taken into consideration by researchers when performing analysis of GO samples subsequent to SEM imaging.

## ACKNOWLEDGMENTS

The authors wish to thank Juliusz Warzywoda at Texas Tech University for his assistance with obtaining the Raman spectra.

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# Generalized Non-Standard Lagrangians

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**Abstract.** A generalized Lagrange formalism is developed for Ordinary Differential Equations (ODE) with the special function solutions [1]. The formalism is based on non-standard Lagrangians, which represent a novel family of Lagrangians. It is shown that the Euler-Lagrange equation needs to be supplemented with an auxiliary condition to retrieve the original equation - this is a new phenomenon in the calculus of variations.

## INTRODUCTION

Consider differential equations of the form $y''(x) + B(x)y'(x) + C(x)y(x) = 0$, where B(x) and C(x) are ordinary smooth functions of x. Note that many important equations of mathematical physics, such as Bessel, modified Bessel, spherical Bessel, Legendre, associated Legendre, Laguerre, associated Laguerre, Hermit, Chebyshev, Jacobi, etc. [2], can be derived from the above ODE by proper choices of B(x) and C(x). In general, there are at least three different methods to obtain the ODE, namely, by the method of separation of variables in the wave, Helmholtz, Laplace and other Partial Differential Equations (PDEs), by using the Lagrangian formalism, and by the so-called Lie group method. The separation of variables method is the most commonly used in mathematical physics and applied mathematics. The Lagrange formalism is already well-established for the so-called standard Lagrangians [3]. Finally, the Lie group approach uses irreducible representations of Lie groups that correspond to any special function ODE [4]. The main disadvantage of the last two methods is the requirement of knowledge of the Lagrangian for each ODE or Lie group associated with such ODE. Neither is easy to be determined. In this paper, we concentrate on the Lagrange formalism and present a general method of deriving the required non-standard Lagrangians.

The Lagrangian formalism is commonly used in modern classical and quantum physics, and the principle that underlies this formalism is the principle of least action, or Hamilton's Principle. The main aim of this paper is to extend the formalism to ODEs whose solutions are the special functions of mathematical physics by using the so-called non-standard Lagrangians. The obtained results are important, as they show that the calculus of variations must be modified by setting a new condition called the auxiliary condition, and that without this condition the formalism does not allow deriving the original ODE. We apply our formalism to the Bessel equation and present its new non-standard Lagrangian. Our choice of the equation is justified by the fact that the Bessel equation is used in some physical applications, for example, describing different wave motions, and therefore the result of such application should be of interest to undergraduate and graduate science students, as well as to physicists, applied mathematicians, and engineers who use this equation in their work.

### Calculus of Variations, Euler-Lagrange Equation, and Lagrangians

In order to find maxima and minima of functionals that are given as integrals, the calculus of variations uses small changes to these functionals known as variations. Functions that maximize or minimize these functionals can be found by solving the Euler-Lagrange equation. Fermat's theorem in calculus, which states that when a local extremum is achieved by a function its derivative is zero at that point, is analogous to the Euler-Lagrange equation in the calculus of variations.

The dynamics of a system is determined by a functional called the Lagrangian of the system. Lagrangians are one of the most sophisticated ways of formulating theoretical physics. Lagrangians are advantageous when including additional forces, studying the stability of solutions, applying perturbation theory, establishing the existence of resonances, and calculating Lyapunov exponents. Historically, Lagrangians do satisfy the Euler-Lagrange equation; however, our results show that for our new class of non-standard Lagrangians, Euler-Lagrange needs to be supplemented with an auxiliary condition.

For a Lagrangian to be called standard, it is required that the terms of the Lagrangian are identified as the kinetic and the potential energy terms. However, if there is a Lagrangian whose terms cannot be related to the well-known kinetic and potential energy terms, then the Lagrangian is called non-standard (NSL) and it still has the same mathematical properties as its standard counterpart. Among various applications, Alekseev and Arbuzov (1984) used the NSLs to formulate the Yang-Mills field theory [5], which is responsible for our basic understanding of the Standard Model of particle physics [6] and hence demonstrates the usefulness of NSLs for fundamental theories of modern physics and theoretical physics.

Standard and non-standard Lagrangians form two distinct families of Lagrangians, and possible mathematical and physical relationships between them will be explored and discussed in another paper. The non-standard Lagrangians should be treated as new generating functionals for ODEs for which standard Lagrangians are already known [7]. A method to derive such non-standard Lagrangians for the ODEs of mathematical physics is developed in this paper.

## Non-Standard Lagrangians

### Proposition 1

Functions f(x), g(x), h(x) described below exist for the following NSL such that this new NSL gives us the general ODE of $y''(x) + B(x)y'(x) + C(x)y(x) = 0$ [8]. Our new general $L_{NSL}$ is the following:

$$L_{NSL} = \frac{1}{f(x)y'(x)+g(x)y(x)+h(x)} \tag{1}$$

where

$$f(x) = v(x)^3\, e^{\int^x 2B(t)dt} \tag{2}$$

$$g(x) = -v'(x)v(x)\, e^{\int^x 2B(t)dt} \tag{3}$$

$$h(x) = v^2(x)\, e^{\int^x B(t)dt} \tag{4}$$

such that v(x) is a solution to the original equation.

### Proof

Substituting $L_{NSL}$ into the Euler-Lagrange (E-L) equation

$$\frac{d}{dx}\left(\frac{dL_{NSL}}{dy'}\right) - \frac{dL_{NSL}}{dy} = 0 \tag{5}$$

we obtain the following set of three ODEs for the functions f(x), g(x), and h(x). Solutions to the following three differential equations yield f(x), g(x), and h(x), and the generalized $L_{NSL}$ is obtained as desired:

$$\frac{3}{2}\frac{g(x)}{f(x)} + \frac{1}{2}\frac{f'(x)}{f(x)} = B(x) \tag{6}$$

$$\frac{\frac{1}{2}g^2(x)}{f^2(x)} + \frac{g'(x)}{f\ \ (x)} - \frac{\left(\frac{1}{2}f'(x)g(x)\right)}{f^2(x)} = C(x) \tag{7}$$

$$\frac{\frac{1}{2}g(x)h(x)}{f^2(x)} + \frac{h'(x)}{f(x)} - \frac{\frac{1}{2}f'(x)h(x)}{f^2(x)} = 0\,. \tag{8}$$

In order so solve this set of equations, we define $u(x) = \frac{f'(x)}{f(x)}$ which yields the following Riccati equation:

$$u'(x) + \frac{1}{3}\, u^2\,(x) - \frac{1}{3}\, B(x)u(x) - [\frac{2}{3}\, B^2\,(x) + 2B'\,(x) - 3C(x)] = 0\,. \tag{9}$$

To solve this Riccati equation, we use the $u(x) = 3\frac{w'(x)}{w(x)}$ transformation to obtain the following second order differential equation:

$$w''\,(x) - \frac{1}{3}\, B(x)w'\,(x) - \frac{1}{3}\,[\frac{2}{3}\, B^2\,(x) + 2B'\,(x) - 3C(x)]w(x) = 0\,. \tag{10}$$

By solving Eq. (10), we find f(x), g(x), and h(x) to construct our generalized $L_{NSL}$ **,** which is obtained when these functions are substituted into Eq. (1). This concludes the proof.

## Proposition 2

The following auxiliary condition to the E-L equation is needed in order to retrieve the original equation back:

$$v''\,(x) + B(x)v'\,(x) = -C(x)v(x)\,. \tag{11}$$

## Proof

We substitute the obtained $L_{NSL}$ into the E-L equation (Eq. (5)) to get our original ODE back but instead we obtain the following equation:

$$-v(x)y''(x) - B(x)v(x)y'\,(x) + [B(x)v(x) + V''\,(x)]y(x) = 0 \tag{12}$$

and this equation does not allow for the reproduction of the original equation on its own. However, **s**upplementing this equation by Eq. (11), we obtain the original ODE as desired:

$$y''(x) + B(x)y'(x) + C(x)y(x) = 0\,. \tag{13}$$

This concludes the proof.

## Non-Standard Lagrangians for the Bessel Equation

For the Bessel equation, we have $B(x) = \frac{1}{x}$ and $C(x) = 1 - \frac{\mu^2}{x^2}$ where μ is either real or integer constant. The above procedure allows finding the functions f(x), g(x), and h(x). Therefore, the non-standard Lagrangian for the Bessel is

$$L_{NSL}^{B} = \frac{1}{v^3 y' e^{2ln|x|} - vv' y e^{2ln|x|} + v^2 e^{2ln|x|}} \tag{14}$$

where v(x) is given by one of the solutions of Bessel Equation. These solutions are power series expansions and they are Bessel functions; the solutions are typically denoted as $J_\mu(x)$ and $J_{-\mu}(x)$ for μ being real and as $J_\mu(x)$ and $Y_\mu(x)$ for μ being an integer. This dependence of non-standard Lagrangians directly on one of the Bessel solutions is a new phenomenon in the calculus of variations.

## CONCLUSION

We considered second order linear ordinary differential equations with non-constant coefficients. We developed a new class of non-standard Lagrangians for these equations. We also showed that an auxiliary condition to the calculus of variations is required to obtain the original equation; this is a new phenomenon in the calculus of variations.

In our application, we presented the first non-standard Lagrangian for the Bessel equation. Since the standard Lagrangian for the equation is already known [7], the obtained non-standard Lagrangian can be of interest to physicists, applied mathematicians, and engineers who use the Bessel equation.

# SIMULATIONS AND ANALYSIS OF GRAVITATIONALLY REDSHIFTED KERR BLACK HOLE ACCRETION DISCS

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**Abstract.** The Kerr black hole rotates with two parameters, mass *M* and angular momentum *a*, and is characterized by the Kerr metric (Taylor and Wheeler 2000). Hence, a binary pair of a black hole and a star can create an accretion disc. A Kerr ray tracer algorithm was used to simulate accretion discs in the Seyfert-1 galaxy. The power law observed flux of relativistic emission lines and Kerr Fourier image analysis methods were applied to the simulated discs. Simulated image characteristics were analyzed. Power laws were fitted to the simulated data of the Mrk110 accretion disc. Lastly, the simulated images were transformed into Fourier space and characteristics are discussed.

## INTRODUCTION

Accreting black holes are of particular interest in modern cosmology. An accreting black hole has a disc of matter pseudo-orbiting the black hole. Systems such as active galactic nucelli (AGN) and supermassive black holes are accreting systems that yield characteristic information about the black holes. The AGN considered in this paper are Seyfert-1 galaxies that emit luminosity characterized spectral lines (Carroll and Ostlie 1996).

Emissivity theory is a method of finding the emission lines of an accreting black hole. By theoretically simulating accreting black holes, a best fit power law can be produced that describes the relationship between the redshift as a function of radius along the accretion disc. Hence, the effects of gravitational redshift in the neighbourhood of a Kerr black hole can be examined. Furthermore, inclinations, mass, and best fit slopes can be extrapolated and interpolated from these best-fit power laws.

From Fourier theory, images in the spatial domain can be transformed into the Fourier domain. Thus, frequency intensities in the transformed images can be seen more distinctly and discs with higher inclinations should show a greater degree of structure.

### Kerr Ray Tracer

Light rays emitted from the accretion disc near the black hole travel on a null geodesic. The Kerr ray tracer maps the emitted points of light rays in the equatorial plane of a Kerr black hole to points on the observer's plane.

The redshift factor *g* is a factor that measures the distribution over the accretion disk and is defined as

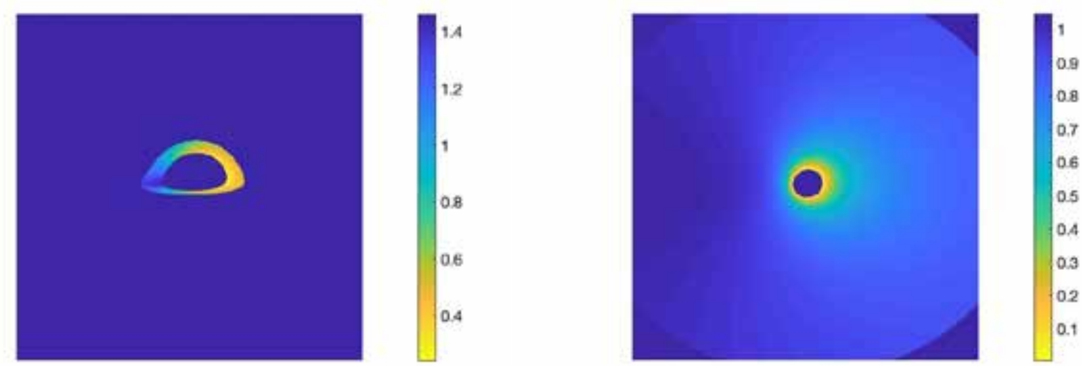
$$g \equiv \frac{v_{obs}}{v_{em}} = \frac{1}{1+z} \tag{1}$$

where $c = 1$, $v_{obs}$ is the observed photon momentum, $v_{em}$ is the emitted photon momenta, and $z$ is the redshift.

The MATLAB computational program based on Chen et al.'s KERTAP was used. The KERTAP uses a GUI and then prompts the user for parameters of an accretion disc around a typical black hole, the image resolution, and the number of parallel works used in the program's computation. At termination, the GUI produces a redshifted image of the accretion disc (i.e., Figs. 1 and 2). Due to the emission region's close proximity to the black hole, the standard linearized gravitational lens theory cannot be applied. Thus, a backward ray-trace is required. This is done by dividing the solid angle of the beam into a uniform grid of pixels (Chen et al., 2015). Therefore, in the computation of the observed flux, the pixels are numerically computed as

$$F_{\nu_0} = \int g^3(\hat{n}) I_{\nu_e}^{source}\left(x^a(\hat{n}), p_a(\hat{n})\right) d\Omega_0 \tag{2}$$

where $\nu_e$ is the source frequency, $I_\nu$ is the radiated energy field that is a conserved quantity along the light path, $\hat{n}$ is the three-dimensional photon direction at the observer, and $\left(x^a(\hat{n}), p_a(\hat{n})\right)$ is the photon's position and momentum at the emitter.




(a) (b)

**FIGURE 1.** (a) Simulated Kerr accretion disk of radius $6.2r_g$ around a black hole of mass 6.2 M, angular momentum a=0.8, inclined at $i = 80°$, and an observational radius of $1x10^6 r_g$. The scale indicates redshift factor, g. (b) Simulated extreme Kerr accretion disk of $31.015r_g$ around a black hole of mass 31.995 M with angular momentum of a=0.999999, inclined at $i = 30°$, and an observational radius of $1x10^6 r_g$. The scale indicates redshift factor, g.

Figure 1a is a simulated highly inclined, fast rotating accretion disc. The accretion disc is beamed, (i.e., *g>1*), on the lower left side (indicated by the dark blue). On the right side of the accretion disc, the region close to and around the horizon, that is, the yellow part of the right side, is strongly redshifted, i.e., (*g<1*). Hence, for highly inclined rotating discs the blue beaming part (i.e., the dark blue in Fig. 1a) approaching the observer is significantly strong and can be seen intensely. Therefore, if an observer were to look at a highly inclined standard accretion disc of a cosmic black hole, a sudden step in gravitational redshift is a distinct and real observable feature. The anti-symmetry of the figure is due to the *g*-factor changing from high values in the beaming feature to smaller values. It should be noted that the colours in Figs. 1a and 1b do not have any relation to the continuum spectra of AGNs nor Doppler effects, but rather are a product of simulation scaling.

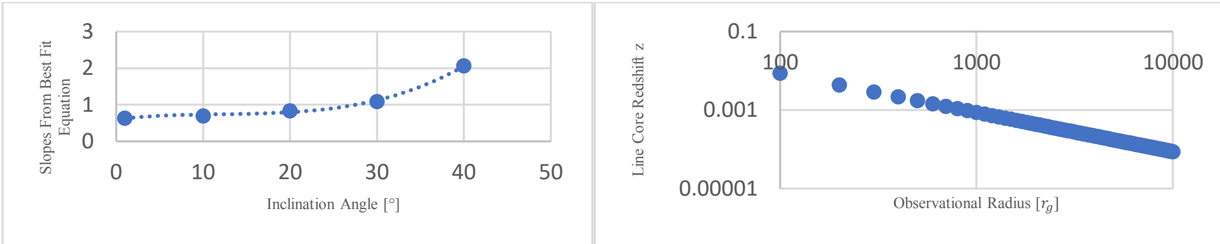
Figure 1b is an extreme Kerr black hole in a typical Seyfert-1 galaxy. The accretion disc has a blue beam wing approaching the left side, which is the triangular-shaped blue region seen on the left side of Fig. 1b. This wing represents a region where the redshift factor is greater than 1; though, the gravitational redshift becomes sufficiently greater as the event horizon is approached, since the redshift factor approaches 0 until *g* vanishes at the event horizon.

## Power Laws

A simple power law can be used to find core redshift values for accretion discs, as simulated in the Seyfert-1 galaxy. A power law equation (Müller et al., 2006) describing the core redshift values is

$$z = pr^s \tag{3}$$

where $r$ is the radial range of the accretion disc, $p$ is the projection parameter, and $s$ is the slope at an inclination $i$.




(a) (b)

**FIGURE 2.** (a) Best fit slopes versus inclination angle. (b) Linearized line core redshift for the p=0.88 Mrk110 accretion disc.

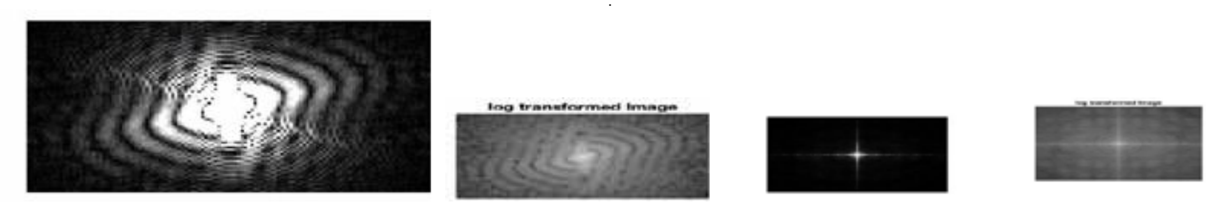
The Mrk 110 accretion disc from the Seyfert-1 galaxy was simulated for a radial accretion disc at an inclination of $i = 30°$ in the Thorne limit of a = 0.998, that is, a theoretical limit found by Thorne (1974) to be the maximum angular momentum of a Kerr black hole, $a = J/m^*$, and $m^*$ is the mass of a black hole such that $m^* = Gm/c^2$. The line core redshifts were computed using equation 3 for different inclinations of the Mrk110 accretion disc from $I$ = 1, 10, 20, 30, and 40, a theoretical Kerr power law slope $s$ = -1.

When plotting the slopes of the best fit equations from the line core redshift plots of Mrk110 accretion discs against inclination angle, a third-order polynomial provided the best fit (Fig. 2a).

Figure 2b shows the reciprocal line core redshifts for the inclinations aforesaid plotted against observational distance (1 to 10000). The reciprocal was taken to linearize the line core redshifts such that a linear best fit trendline can be created. It was found that points were spread within $5 \times 10^{-3}$ to $10^{-5}$ range. The best fit slope for p = 0.88 was found to be -1.1364, which is lower than Muller et al.'s (2006) slope of $-1.002 \pm 0.005$.

## Kerr Fourier Image Analysis

Simulation images produced for the Mrk110 accretion disc from the Seyfert-1 galaxy (such as Fig. 1) were Fourier transformed using the Fourier image transform and log-Fourier image transform.




(a) (b) (c) (d)

**FIGURE 3.** (a) Normalized Fourier transformation accretion disc of radius 6.2 $r_g$ around a black hole of mass 6.2 M, with angular momentum a=0.8, inclined at $i = 80$ °, and an observational radius of $1 \times 10^6$ $r_g$. (b) Log Fourier transformation of the same disc. (c) Normalized Fourier transformation of an accretion disc of radius 31.015 $r_g$ around a 31.995 M black hole with an angular momentum of a = 0.999999, $i = 30$ °, and observational radius of $1 \times 10^6$ $r_g$. (d) The log-transform of (c).

It was found that higher inclination angles (such as in Fig. 3a) were highly structured in Fourier space while in lower inclination angles (such as Fig. 3c) the images were less structured in Fourier space. However, in all cases, the images in Fourier space show the sites of the gravitational redshifts more distinctly. The circular rings in Fig. 3d are an indication of a source of discontinuity on the images in Fourier space.

## CONCLUSIONS

The highly inclined rotating disc was found to have a blue beaming part approaching the observer far away from the event horizon. Extreme Kerr black holes were found to have a blue beaming wing in the shape of a triangular-like pie that represents a region where *g>1*. For the Mrk110 accretion disc in the Seyfert-1 galaxy, a best fit slope for p =

0.88 was found to be -1.1364, which is lower than the well-established slope of $-1.002 \pm 0.005$. This is due to the data points being mainly on the right side of the linearized figures ,which effects the slope in the least-squares fit.

When the least-squares fits were plotted against inclination angle, the data conformed to a pseudo-polynomial that best fits to a cubic polynomial. The plot is an empirical model that is useful for interpolation and extrapolation. It was found that for accretion discs with higher inclinations, there was a higher concentration of structure in Fourier space; while for lower inclinations there was a lower concentration of structure in Fourier space.

In conclusion, we confirmed the Muller et al. analysis on Mrk110 and other accretion discs (2004, 2006) and expanded on them. Moreover, further experimental analysis can be done to interpolate and extrapolate gravitational redshift values from the pseudo-polynomial plot. Also, further Fourier analysis on the transformed images could show more physical characteristic information about the accretion disc.

## ACKNOWLEDGMENTS

I would like to thank Dr. Steven J. Desjardins for all of his inspiring discussions and support. I would also like to thank Dr. Christian Gigault for all of his help. I have personally and professionally benefited from all of their support. Special thanks to the anonymous reviewer for their feedback.

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# Using HECTOR for Cross Section Measurements of $^{102}Pd(p,\gamma)^{103}Ag$

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**Abstract.** The High EffiCiency TOtal absorption spectrometeR (HECTOR) consists of 16 scintillating crystals that are made of thallium-doped sodium iodide (NaI(Tl)). Each of the crystals is coupled to two photomultiplier tubes (PMT) and the detector is oriented to create a cubic array surrounding a target. This cubic array orientation allows for simultaneous measurements of the individual gamma (γ) rays produced during the de-excitation of the reaction products, creating a coverage of nearly 4π steradian. HECTOR was constructed to measure capture reactions relevant for the nucleosynthesis process at low energies. The work presented here focuses on a (p,γ) reaction on $^{102}Pd$, one of the p-nuclei produced during the p-process. The experiment was conducted at the University of Notre Dame using the FN tandem accelerator at the Nuclear Science Lab. A highly enriched $^{102}Pd$ target was bombarded with a proton (p) beam at energies between 3.5 and 8.0 MeV in 200 keV steps. The measured cross section is compared with experimental data found in literature and theoretical models.

## INTRODUCTION

Nucleosynthesis of elements heavier than iron (Fe) in stars occurs via three different processes: the s-, r-, and p-process. The s- and r-processes are responsible for the production of a majority of nuclei past Fe by means of "slow" or "rapid" neutron capture, respectively, followed by $\beta^-$ decay.[1] The p-process occurs less often on the proton-rich side of the line of stability and is responsible for the production of only 35 proton-rich nuclei such as $^{102}Pd$ and $^{108}Cd$, which are known as p-nuclei.[1] This process occurs in specific stellar environments – burning phases of stellar interiors and supernova explosions – and uses cascades of gamma (γ) rays to initiate reactions.[2] During the explosion, γ-rays then penetrate the supernova and destroy s-nuclei, shifting the overall abundance towards p-nuclei by means of photodisintegration reactions, (γ,p), (γ,n), and (γ,α), that produce unstable nuclei that $\beta^+$ decay back towards the line of stability.[3] Although the reactions taking place in the stellar environments are (γ,p), (γ,n), and (γ,α), their cross sections can be determined from the capture reactions (p,γ), (n,γ), and (α,γ), which can be studied in the lab.

Measuring the cross sections, or probability, or p-process reactions can shed light on different p-process scenarios that occur during the supernova explosions. The experiment, conducted at the University of Notre Dame in June 2018, focused on measuring the cross sections for p-nuclei that could prove important to the p-process itself. These cross sections continue to be constrained in hopes of improving theoretical models of the p-process scenarios with different outcomes during a supernova explosion to improve the accuracy of the model network.

## EXPERIMENT

The detector used for this experiment was the High EffiCiency TOtal absorption spectrometeR (HECTOR). This detector consists of 16 $4 \times 4 \times 8$ inch thallium-doped sodium iodide (NaI(Tl)) scintillating crystals.[4] Each of these crystals is coupled to two photomultiplier tubes (PMT), utilizing a total of 32 PMTs, partially shown in Figure 1 (a). The detector is then oriented to create a cubic array surrounding an inserted target, as shown in Figure 1 (b), creating a 4π steradian coverage. This orientation allows for the individual γ-rays produced during the de-excitation of the reaction products from the target to be measured simultaneously.

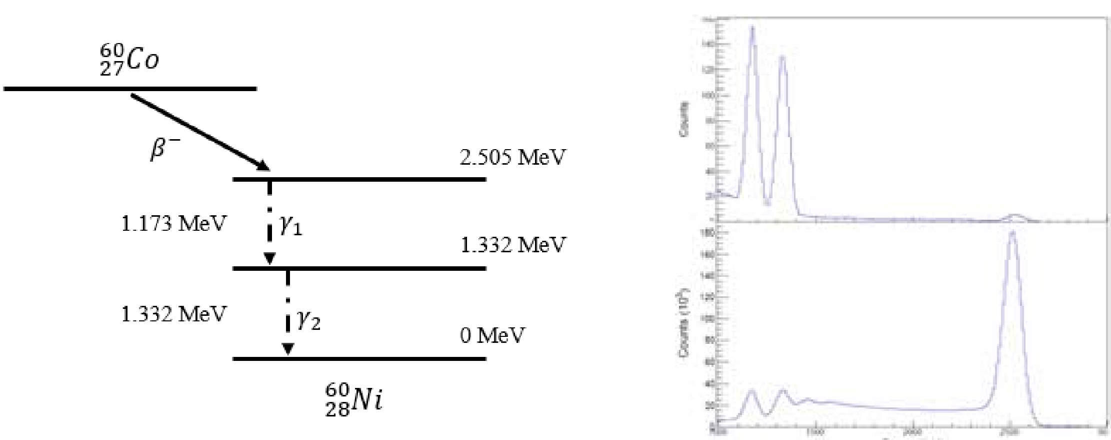
(a) (b)

**FIGURE 1.** (a) 16 PMTs on the top of HECTOR coupled to the top 8 scintillators. (b) HECTOR in a cubic array.

Using the FN tandem accelerator at the University of Notre Dame, a beam of protons was accelerated towards HECTOR and the targets of interest. The experiment took measurements for $^{90}$Zr, $^{102}$Pd, $^{108}$Cd, and $^{110}$Cd. However, the data inspected in this analysis focuses specifically on the p-nucleus, $^{102}$Pd.

## GAMMA-SUMMATION

A single decaying nucleus emits a cascade of photons that can be detected as single photons in individual peaks on a spectrum, which is typically produced by conventional detectors.[5] However, in gamma-summing detectors such as HECTOR, each individual γ-ray cascade is recorded as one single energy peak. To demonstrate this technique, the simple decay scheme of $^{60}$Co is examined (Figure 2a).




**(a)** **(b)**

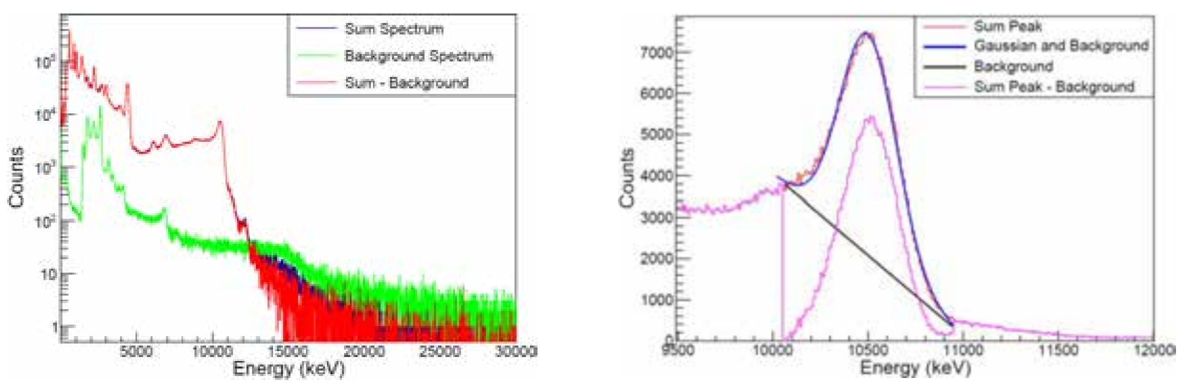
**FIGURE 2.** (a) Decay scheme for $^{60}$Co. (b) TOP – single γ-ray spectrum. BOTTOM – γ-ray summation peak.

After $^{60}Co$ has $\beta^-$ decayed to $^{60}Ni$, the new $^{60}Ni$ nucleus is excited to an energy of 2.504 MeV and two γ-rays are emitted to return $^{60}Ni$ to its ground state. The gamma rays have energies of 1.173 MeV (1173 keV) and 1.332 MeV (1332 keV), respectively. In Figure 2b (top), a traditional γ-ray spectrum displays the two individual γ-rays and their energies, with a very small peak at the sum energy of the rays. In Figure 2b (bottom), the sum spectrum shows one large peak at the total excess energy the nucleus must release when it de-excites.

In the case of beam induced reactions, the energy of the sum peak, which is the excitation energy of the reaction product, is equal to the sum of the proton beam energy in the center-of-mass system and the Q-value of the reaction, where Q = 4.1885 MeV for $^{102}Pd(p,\gamma)$. For example, if the beam energy is 8 MeV, a γ-ray sum peak would be expected at approximately 12.2 MeV. By taking the integral of this peak, the number of total counts recorded by the detector can be found and used for further cross section calculations.

## BACKGROUND SUBTRACTION AND INTEGRATION

Tto get the correct γ-ray spectrum, a spectrum from the recorded data and a background run, where there is no target or beam in HECTOR, needed to be plotted. The background runs taken for the experiment were at least 4 times longer than most of the data collection runs and therefore needed to be scaled by calculating a time ratio between the data and background runs. The now-scaled background spectrum was subtracted from a recorded data spectrum, shown in Figure 3 (a). This subtraction removes excess γ-rays produced from cosmic rays around the detector that could affect the number of counts recorded by HECTOR during the runs where reactions are taking place.




(a) (b)

**FIGURE 3.** (a) Full γ-ray sum spectrum for a 6352.2 keV beam energy. Each colored line represents the following: original sum spectrum (blue), background spectrum (green), and sum spectrum after background subtraction (red). (b) Sum peak of the spectrum. Each colored line represents the following: original sum peak (red), Gaussian and first-order polynomial background fit (blue), background fit (black), and sum peak with background subtracted (purple).

To get the integral of the sum peak from the data spectrum, the peak needed to be fit with a Gaussian and a first-order polynomial function (to account for the background fit). The parameters of this fit varied between energies in order to get the best possible shape of the curve so that it closely matched that of the sum peak. Because it is known that the peak should appear at approximately the sum energy, the Gaussian and polynomial were fit over a range around that energy (Figure 3 (b)). After the fitted background was subtracted, the plot was integrated underneath the sum peak to obtain the number of counts collected by the detector.

## MULTIPLICITY AND EFFICIENCY

One of the values recorded during the experiment keeps track of the multiplicity of an event. The multiplicity is the number of detectors that fired for one specific γ-ray cascade. The number of γ-rays in the cascade is correlated to the number of segments that fired.

The multiplicity then affects the efficiency of HECTOR. The efficiency (ε) gives the percentage of decays that can actually be detected by HECTOR. The values needed for the efficiency curves cannot be found experimentally but instead are found through simulations that provide efficiency as a function of multiplicity and sum peak energy. Details of the procedure are described in Ref. 4. This procedure generates constants ($p_0$, $p_1$, and $p_2$) that, when multiplied with the multiplicity using a second-order polynomial function, produce the efficiency of each reaction, shown in Equation (1):

$$\varepsilon(m) = p_0 + p_1 + p_2 m^2 \tag{1}$$

## CROSS SECTION CALCULATIONS

The cross sections (σ) of $^{102}$Pd(p, γ) reactions at given energies are calculated using the following formula:

$$\sigma = \frac{N_{det}}{N_{beam} * d * \varepsilon} \tag{2}$$

where $N_{det}$ is the number of counts from the detector found by the integral of the sum peak, $N_{beam}$ is the total number of particles from the beam that were found using an analog scaler throughout the experiment, $d$ is the thickness of the target in atoms/cm$^2$, and $\varepsilon$ is the efficiency of the detector at a given beam energy. The uncertainty in the $N_{beam}$, target thickness ($d$), and efficiency was taken at 5%. The center-of-mass energy ($E_{CM}$) was found by averaging the energy before the beam hits the target and the energy after. The uncertainty in the $E_{CM}$ was found by subtracting either the initial or final energy value from the average beam energy. Finally, the uncertainty in $N_{det}$ was found by taking the square root of $N_{det}$ and the integral of the first-order polynomial fit to the background. Error propagation was then used to calculate the uncertainty of σ.

## RESULTS

Cross section measurements were taken at 15 different beam energies. The calculated values of the cross section, labeled as HECTOR in Figure 5, were then plotted with theoretical values and measured values from Dillmann et al. and Ozkan et al.[6,7,8] The predictions are taken from published results obtained with the NON-SMOKER code, which is a standard model for cross section calculations in nuclear astrophysics.[6] Only 14 energies are shown in Figure 4 because the lowest energy resulted in γ-ray measurements that coincided with a background emission line.

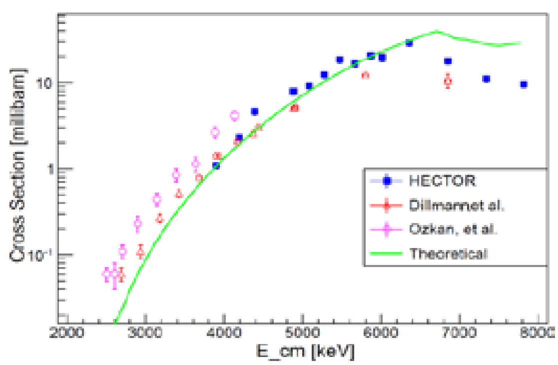



**FIGURE** 4: Measured cross section values from this work and other literature compared to theoretical values.

## CONCLUSIONS

By using γ-summing techniques, cross sections can be easily obtained and more information regarding the production of p-nuclei in exploding supernova can be found. Using HECTOR and its sum-peak spectroscopy properties, γ-summation was completed in an experiment at the University of Notre Dame in attempts to simulate (γ,p) reactions in the supernova explosion by measuring the cross section of (p,γ) in the lab. The $^{102}$Pd(p,γ) reaction was further analyzed and cross section measurements were obtained.

The cross-section measurements that were acquired from the HECTOR experiment were then compared to other measurements by Dillmann et al., and Ozkan et al., as well as theoretical values from NON-SMOKER models. The data collected kept the same overall trend as the other experimental values but more closely matched the theoretical values from 3.5-6.5 MeV and lay between the theoretical and Dillmann et al. values at energies between 6.5 and 8.0 MeV. It is important to point out that this deviation lies above the neutron emission threshold. This threshold is the point in which (p,n) reactions can occur instead of the (p,γ) reactions that produce the cross section measurements. Therefore, the results are the new cross section measurements from this (p,γ) reaction.

These new cross section measurements are to be used in network calculations that take the measurements as parameters to simulate potential p-process scenarios and produce possible outcomes. By changing the cross sections, supernova explosions can be simulated, and the p-process scenario can be compared to the observed amounts of p-process nuclei.

## ACKNOWLEDGEMENTS

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# JURP ACCEPTED MANSCRIPTS AVAILABLE ONLINE

## Noether's Theorem Applied to the Classical and Schrödinger Wave Equations

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**Abstract.** Noether's Theorem, which relates continuous transformations to conservation laws, is applied to the classical wave equation and the Schrödinger equation. Transformations are derived that lead to invariances and conservation laws.

## An Even Simpler "Truly Elementary" Proof of Bertrand's Theorem

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**Abstract.** We present a further simplified derivation of a "truly elementary" proof of Bertrand's theorem, which predicts the exponents in a central power-law potential that produce closed orbits.

## Quasinormal Modes of Static Moded Gravity (MOG) Black Holes

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**Abstract.** Using an asymptotic iteration method, we calculate the gravitational and electromagnetic quasinormal mode (QNM) perturbations for a static neutral black hole described by a Scalar-Tensor-Vector Modified Gravity framework (STVG-MOG). We show that the first few harmonic modes differ from their general relativistic (GR) equivalent for a Schwarzschild black hole. Specifically, the real and imaginary components of the QNM frequencies are smaller for STVG-MOG than for GR. We posit that the differences are sufficiently large to potentially be observed in present and future black hole binary merger gravitational waveforms.

# Programs

# 2018–19 SPS and Sigma Pi Sigma Year in Review

by Kayla Stephens, SPS Programs Manager

"If I have seen further it is by standing on the shoulders of Giants." –Isaac Newton

**The Society of Physics Students (SPS) and Sigma Pi Sigma (ΣΠΣ) have had another productive, impactful year ensuring that opportunities for undergraduates interested in physics and astronomy are plentiful and accessible. With research, scholarship, outreach, leadership, and advocacy at the forefront, there has not been a dull moment in 2018–19.**

The year started off by welcoming a new National Council eager to serve all 18 zones by supporting chapter growth, providing access to resources, and promoting local and national initiatives, as well as seeking to improve inclusiveness and diversity within the physics and astronomy community. To this end, the following committees were formed within the National Council: Centennial Recognition, Strategic Communications, Sigma Pi Sigma Engagement, Governance, PhysCon, and Outreach.

The committee work resulted in many notable items. The Governance Committee wrote two SPS statements that were approved for general dissemination by the National Council. These statements support diversity and inclusivity as well as undergraduate spaces that encourage a student-led sense of community. *The SPS Statement on Diversity, Inclusion, Ethics, and Responsibility* and *The SPS Statement on Common Rooms, Department Health, and Identity* are now available to view on the SPS National website (www.spsnational.org/about/governance/statements). Later this fall, departments will receive a printed copy of the diversity statement to display in their lounge or student space.

Effective communication among the National Office, National Council, and chapters is fundamental to our success but challenging to achieve; therefore, the Strategic Communications Committee developed a communications survey that will be sent out to members later this year. This will help us assess the best ways to communicate resources and ensure we have the most updated contact information for all chapters.

With PhysCon 2019 coming this November, the largest gathering of undergraduate physics students in the United States, the National Council's PhysCon Committee had much work to do! The committee developed campaigns to encourage chapters to fundraise so that every student has the opportunity to attend this year's congress, which will be held November 14–16 in Providence, Rhode Island.

The National Council also had the pleasure of welcoming new SPS and ΣΠΣ chapters in the 2018–19 year.

**New SPS Chapters**

#2929 Howard Community College (Zone 4)
#6388 Santa Rosa Junior College (Zone 18)
#3616 LaGuardia Community College/CUNY (Zone 2)
#3291 Universidad Autonoma de Ciudad Juarez (Zone 6)
#3667 University of La Verne (Zone 18)
#3140 Institute of Engineering & Management (Zone 18)
#6757 CUNY of Staten Island (Zone 2)

**New Sigma Pi Sigma Chapters**

#581 University of Wisconsin-Parkside (Zone 9)
#582 New College of Florida (Zone 6)

As of May 15, 2019, we have 5,935 national members in over 548 chapters or in at-large status. This is a significant increase from last year, largely due to our new chapter membership program that allows an unlimited number of members from a chapter to join at one flat rate. We also are proud to report that a zone meeting was successfully held in all 18 zones this year. Zone meetings are crucial to the life of SPS and healthy chapters. This success would not have been possible without the 18 volunteer host institutions!

Of the 50 applications submitted by chapters for fall awards, including the Marsh White, Future Faces of Physics, Chapter Research, and Sigma Pi Sigma Awards, 36 chapters received support. A total of $24,935.91 was granted to the fall awardees.

The SPS internship program continues to be a touchstone for our society. This year we had 76 applications and placed 16 interns with the American Institute of Physics (AIP), NASA, NIST, Capitol Hill, and various AIP Member Societies in the Washington, DC, area.

Spring brought another opportunity for awards and recognition with SPS scholarships, Outstanding Undergraduate Research Awards, and the Outstanding Chapter Advisor Award. We granted $37,000 in total for our spring awards.

Throughout the year, chapters are able to request Science Outreach Catalyst Kits (SOCKs), at no cost, which they can use during outreach events for local K–12 students. The 2018–19 SOCKs explored the physics of sound through a Chladni plate—a metal plate vibrating on a speaker. There were 78 kits distributed across the nation this year!

ΣΠΣ continues to honor outstanding scholarship in physics and service, cutting across generational and professional lines and encouraging connection and excellence in the physics community. This year, hardly a week passed without an induction ceremony occurring somewhere in our network of chapters. A total of 1,669 new members were inducted into the lifelong membership of ΣΠΣ across 285 chapters.

SPS and ΣΠΣ continue to value the professional development of their members and help students effectively navigate their career options. We have a suite of career resources online as well as the Careers Toolbox, which serves students who are entering the workforce following a bachelor's degree. Chapters also have taken advantage of our newly launched Alumni Engagement Program to connect with SPS alumni and ΣΠΣ members and learn about their careers.

For our students pursuing graduate school, we provide not only advice but also the most comprehensive directory of graduate programs in the physical sciences through GradSchoolShopper (GSS). This year, staff enhanced the SPS National website and GradSchoolShopper.com to provide students with even more resources to help bring the future into focus.

Members of the SPS team were engaged in many national meetings this year, including meetings of the AMS, AAS, AAPT, and APS, as well as CUWiPs, PhysTEC, and the Emerging Researchers National Conference. Summer meetings include ACA, AAPM, AAPT, and OSA/FIO. Through financial aid, SPS provided students with opportunities to travel to these meetings and present their research or write about their experiences. Thanks to the contributions of ΣΠΣ alumni and other SPS supporters, a total of $13,800 in financial aid was awarded this year.

This also has been a great year of disseminating the research and programmatic activities of our members, enabling them to share their voice within the physics community through our publications. We published four issues of the *SPS Observer* (including JURP) and two issues of *Radiations*.

***SPS Observer***

Fall 2018: "Finding Equilibrium"
Winter 2019: "Get Ready to Make Waves at PhysCon"
Spring 2019: "Big Labs: Impacting the World in Big Ways"
Summer 2019: "Journal of Undergraduate Reports in Physics (JURP)"

***Radiations***

Fall 2018: "Nobel Prizes in Physics"
Spring 2019: "PhysCon Preview"

The 2018–19 year of SPS and ΣΠΣ embodied the mission of enriching the lives of students locally, regionally, nationally, and internationally. Through providing tools to allow members to flourish professionally, fostering connections through a diverse network of physicists, and impacting lives through outreach services, SPS and ΣΠΣ have worked to transform the future of physics and astronomy. We are looking forward to what 2019–20 brings! If you are interested in continuing this legacy of opportunity and would like to donate, please visit **donate.aip.org**. And, of course, we hope to see you in Providence in November for PhysCon 2019! **//**

ABOVE: The 2018-19 National Council. This elected board comes from all across the US Photo Courtesy of SPS National Office.

*Meeting Notes* are SPS member reflections on their experiences while attending professional scientific meetings. Professional meetings offer undergraduate students a unique opportunity to network amongst their peers, develop valuable skills and connections, present their research, and gain invaluable knowledge within the field. The following articles are select student reporter reflections from meetings that occurred within the last year.

You can find out how to apply for a reporter award here: spsnational.org/awards/reporter.

## A "WICKED SMAHT" REVIEW

*The American Physical Society March Meeting*

by Alyssa Alvarez, Thao Nguyen, and Eddy Velazquez, SPS Members, St. Mary's University–San Antonio

**"You're a physics major? Well then you must be wicked smaht. Welcome to Boston." That memorable line was directed to Eddy Velazquez, one of the six undergraduates from St. Mary's University traveling from San Antonio to Boston for the APS March Meeting. They were definitely encouraging words that got our APS March Meeting experience off to a good start. The week that followed was full of many highlights.**

***Highlight: Enjoying the Diversity in Weather and Research Areas,*** *by Thao Nguyen*

Arriving in Boston for this year's APS March Meeting from the blazing heat of San Antonio, Texas, the first difference we noticed was, inevitably, the weather. We are accustomed to San Antonio, where the temperature can go up to more than 100 degrees in the summer, so experiencing Boston in March (when the temperature was in the 20s) was definitely something we had to acclimate to. Despite our initial reluctance, however, Boston turned out to be quite pleasant, as did the conference.

Like the weather, the APS meeting turned out to be different than what we were used to but enjoyable. Even though we are interested in completely different fields in physics, all of us were able to attend talks that pertained to our preferences because of how well organized and diverse the March Meeting was. Overall, attending different sessions throughout the week on research in fields within our interests, and even fields we had never heard about, was an intellectually stimulating experience.

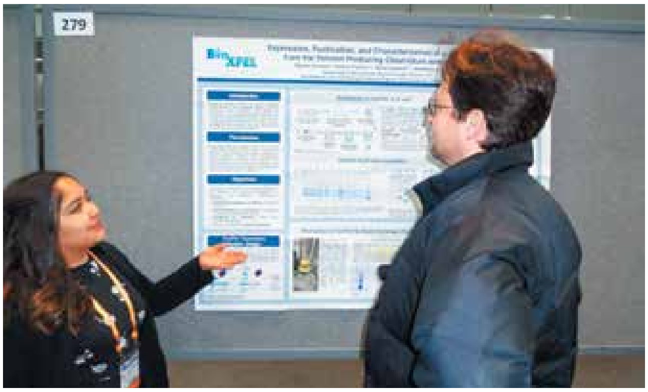
***Highlight: Participating in the Undergraduate Poster Session,*** *by Alyssa Alvarez*

I've always found presenting to be nerve wracking, but I recognize the importance of practicing this skill. The APS March Meeting provided me with an excellent opportunity to do so during the undergraduate poster session.

In the summer of 2018, I did research at Rice University on proteins called flavodoxins that are found in the bacteria *Clostridium acetobutylicum*. At the end of my 10-week research experience, I created a scientific poster. Even though my research was biology focused, I decided to submit an abstract for this poster to the APS March Meeting. APS has a lot of diversity when it comes to the subfields of research that are included in the meeting. This diversity

TOP: St. Mary's University APS meeting attendees, Boston, Massachusetts, 2019. Photo courtesy of Alyssa Alvarez, Thao Nguyen, and Eddy Velazquez.

ABOVE: St. Mary's students meet with Dr. Giovanni Fazio, Harvard University. Photo courtesy of Alyssa Alvarez, Thao Nguyen, and Eddy Velazquez.




is definitely a positive attribute—not only did I get to present my own research, but I was able to find other presentations within my interest areas.

It was also very interesting to hear from students about their research, learn what schools they were attending, hear about their goals and interests, and even exchange advice on how to improve our presentation abilities. The undergraduate poster session allowed me to develop my poster presentation skills and gain feedback, and connect with other people who are doing research in similar fields.

***Highlight: Meeting an Alum,*** *by Eddy Velazquez*

Dr. Giovanni Fazio is a senior physicist at one of the most prestigious universities in the country, Harvard University, and an alum of St. Mary's. The six of us from St. Mary's who attended the APS meeting were able to talk with Dr. Fazio there. We heard about his experiences at our university when he attended in the 1950s, as well as the challenges he faced on his journey to earning a PhD and becoming an award-winning physicist. He offered us some good advice about graduate school and not giving up, even in the face of adversity.

I think it's safe to say that every one of us enjoyed our time in Boston. We were able to learn more about fields within our interests, connect with other undergraduates who share similar goals, meet an alum from our university, and practice our presentation skills during the poster session. We are grateful for everyone that supported us and helped us to attend the conference. If you have an opportunity to attend an APS meeting as an undergrad, you should definitely take it—you will have the time of your life. //

## WHERE DISTINCT PHYSICAL SCALES AND GEOGRAPHY MEET: QUARKS TO COSMOS 2019

*The American Physical Society April Meeting*

by Emma Clarke, SPS Member, University of New Hampshire

**After packing up my things and getting ready for yet another flight during my senior year as a physics major at the University of New Hampshire, I made my way to the APS April Meeting 2019 in Denver, Colorado. I arrived at the "Mile High City" (Denver is 5,280 feet above sea level) the evening before the meeting commenced. Travelling by taxi from the enormous Denver airport to my hotel, I looked out the window and carefully observed my surroundings. The sides of the roads were lined with snow fences that had collected tumbleweeds. The landscape appeared flat for many miles; however, looking out toward the horizon I could see the outlines of mountains. Located at the boundary between the Great Plains to the east and the Rocky Mountains to the west, the capital of Colorado is a populous modern city situated between two distinct geographic features. I couldn't help but think that the variety in the landscape reflected the range of physical scales explored at the "Quarks to Cosmos" meeting.**

The first day of the April Meeting began with a session titled "Physics and Society." The talks in the session reviewed disruptive energy futures (Amory Bloch Lovins, the Rocky Mountain Institute), the role of science and science advisors in American politics and the White House (Kirstin Matthews, Rice University), and the role of physics and physicists in social media (Katie Mack, North Carolina State University). All of these topics are highly relevant to modern physicists, as well as the public, and provided the audience with perspectives on our work within the larger context of society.

There were several other sessions throughout the week that focused on intersections of physics and society. One such session I learned from was "Stereotype Threat: What is it, and what to do about it?," which discussed gendered performance in introductory STEM courses. Timothy McKay, a physics professor at the University of Michigan, presented an analysis on how courses are taught and how this affects student performance. Beyond these

TOP LEFT: Alyssa Alvarez presenting her poster at the APS March Meeting undergraduate poster session. Photo courtesy of Alyssa Alvarez.

ABOVE: Katherine Freese (left) and Emma Clarke. Photo courtesy of Emma Clarke.

sessions, there was an abundance of sessions dedicated to the latest scientific research in physics fields falling under the blanket of quarks to cosmos.

Not all of the sessions at the April Meeting were about research. For example, at "Lunch With the Grads," a Future of Physics Days event, undergrads chatted over lunch with a panel of graduate students. Lunch breaks were also a great opportunity to explore the exhibits and vendors. The exhibit table that was arguably the most popular among undergraduates was that of the Chandra X-Ray Observatory. With provided virtual reality goggles, viewers were able to look out from the center of our galaxy and observe the effects of massive stellar giants and their winds.

A personal highlight for me was Katherine Freese's public lecture on dark matter in the universe. Based on a rough estimate using a show of hands, about half of the audience members at the lecture were from the general public. This was an impressive turnout showcasing public interest in science. After the lecture, I was excited to have the opportunity to meet Dr. Freese. I read her book, *Cosmic Cocktail*, when it came out on shelves several years ago.

After a solid few days packed with interesting physics, presentations, and social events, the April Meeting 2019 came to a close. I am thankful that I was able to experience this conference. I returned to my university with more knowledge and insight on physics and the physics community, as well as some handouts and swag to share with my SPS chapter. My experience at this meeting was invaluable, and I hope to attend again and encourage other students to attend meetings as well. //

## VISITING THE SOUTHEAST AND DISCUSSION ON A DIVERSITY PANEL

*The 85th Annual Meeting of the APS Southeastern Section*

by Justin Craig, SPS Member, Millikin University

**It might be strange for someone from Illinois to head to a conference catered to colleges and professionals in the southeastern states. However, all physics conferences have proved to be opportunities to network, learn about ongoing research, and provide information on different areas of physics.**

ABOVE: View of conference hotel in Knoxville, Tennessee, where the 85th Annual Meeting of the APS Southeastern Section was held. Photo courtesy of visitknoxville.com.

**Overall, physics conferences are learning opportunities for everyone, so I was determined to get out of my comfort zone and attend one of these conferences. But before I tell about my conference experience, let me tell you a little bit about myself and my SPS chapter. I just finished my second year as a double physics and mathematics major at Millikin University in Decatur, Illinois. Furthermore, I am the president of Millikin University's SPS chapter, and I am currently serving as the associate zone councilor of Zone 8 in the SPS National Council.**

While the Southeastern Section of the American Physical Society (SESAPS) conference hosted many excellent research presentations, there is one noteworthy event that I would like to highlight. During the Friday of SESAPS, the conference hosted a paneled discussion on the "Diversity of Physics: How to Be an Ally." The panel discussed that although, generally, awareness of the experiences of underrepresented groups has increased and that increased awareness has promoted a better environment in the physics field, there still exists a substantial amount of discrimination in the scientific community that is both obvious and subtle. They emphasized that as a community, there must still be a continued heightening of awareness of discrimination, including the awareness of microaggressions, which are small statements that cause a person harm even if the harm is not intentional. The discussion also led to the recommendation of having preferred pronouns in signatures of emails in order to be more inclusive to the LGTBQIA+ community. Furthermore, the panel encouraged people to go to human rights events and interact with human rights groups both on and off college campuses. Participants also discussed the idea of SPS chapters drafting statements of inclusion. While it may seem redundant for some chapters, a written statement can make persons of underrepresented groups feel more included. In essence, this panel, for me, was both instructional and informative, and I believe that APS and SPS should continue these events for all regional and national meetings.

ABOVE: CUWiP participants greet each other during a video conference call with keynote speaker Dr. Fabiola Gianotti at the Mayo Concert Hall at The College of New Jersey. Photo courtesy of Andrew Cislak.

Despite the energy from the diversity panel, and due to an eight-hour drive ahead of me, I decided to leave Knoxville on Saturday morning, unfortunately missing the last day of presentations. Overall, the conference was an enlightening experience, and as I left Knoxville, there was much to reflect upon. As a scientific community of students, professors, and independent researchers, we need to be leaders not only in research but also in inclusion. There must be a continued drive and support for the inclusion of all races, ethnicities, genders, sexualities, and faiths. With a drive for more diversity and inclusion, we allow the scientific community to accept more gifted and brilliant minds who can push the boundaries of physics. As a national society, SPS aims to include all types of people, and it committed itself to this goal with the adoption of a new Statement on Diversity, Inclusion, Ethics, and Responsibility this last March. So as I move on from this conference, there was much I learned, and I would encourage others to go to conferences to learn about the scientific community. //

## A WEEKEND OF INSPIRATION AND LEARNING

*Conference for Undergraduate Women in Physics at The College of New Jersey*

by Camila López Pérez and Shanjida Khan, SPS Members, Drew University

**"I feel like within the department it's often a competition—who's got the best lab group, highest GPA, the most awards, etc. This is especially true between women in our program, because there's almost a vibe of 'only one of us can make it.' I really liked that CUWiP was pretty much only about the love of physics and supporting other women," shared Morgan Caswell, a physics major from Temple University.**

Although it was Morgan's second time attending one of the Conferences for Undergraduate Women in Physics (CUWiP), her reaction still captured how we (and most likely, many other students) felt our first time attending the conference. CUWiPs are three-day conferences held annually by the American Physical Society (APS) at various universities across the United States and Canada.

The College of New Jersey's CUWiP had an exciting schedule, full of workshops, panel sessions, and networking events relevant to empowering women in physics and providing us with tools and advice relevant to physics careers. We started the first day with immense energy! About 30 of us were taken to the Princeton Plasma Physics Laboratory (PPPL) for a tour before the opening remarks from the representatives from TCNJ and APS. Shortly after, the first plenary speaker—Dr. Jami Valentine Miller, the first African American woman to earn a PhD in physics from Johns Hopkins University—unfolded for us how she decided to work for the US Patent Office. Her animated demeanor really captivated the students.

The next morning, we split up and attended a total of three workshops: Setting Yourself Up for Success: A Journey from College to Industry, Mental Health and Awareness, and Optical Engineering. Soon after, we reunited to attend a networking fair

ABOVE: Camila López Pérez (center) and Shanjida Khan (foreground) observe Galinstan, a compound made of gallium, indium, and tin, during the Princeton Plasma Physics Laboratory tour. Photo courtesy of Elle Starkman.

where we met with representatives from graduate schools such as Johns Hopkins and Carnegie Mellon and companies such as Edmund Optics and ExxonMobil.

That afternoon was the keynote address, given by Dr. Fabiola Gianotti, the director general at CERN, the European Organization for Nuclear Research. She presented to all of the CUWiP sites through a video call. It was wonderful to hear her explain how she became interested in physics after studying the humanities throughout high school.

The final program of the day was a panel discussion led by the senior program associate of the PPPL, Shannon Greco, with three women in diverse careers: Dr. Emily Conover, a physics reporter from *ScienceNews*, Nicole Callen, a research technician from ExxonMobil, and Dr. Katey Shirey, program officer at the Knowles Academy. One of the messages, given by Dr. Shirey, that really stuck with us was, "Apply to everything you find . . . and then show up and try!" Listening to the stories of physics career trajectories was very motivating and worthwhile!

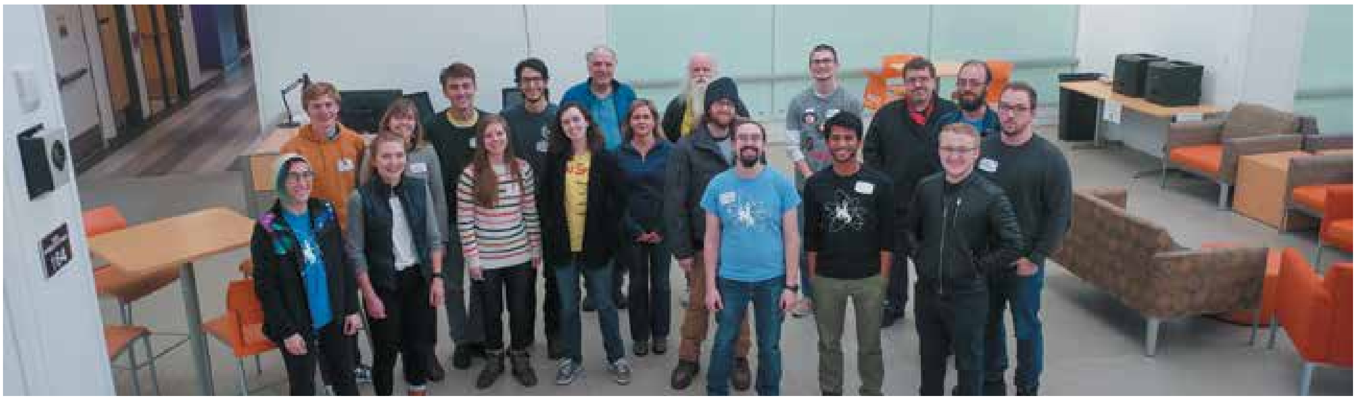
The final day of CUWiP started off early with a relaxed and quiet atmosphere. We weren't sure if students were tired from the two previous long days or if we were sad because it was the last day of the eventful conference. Perhaps it was both. However, we knew we would miss seeing all the amazing women from different universities.

There were many great takeaways from the conference that resonated with both of us. One is how every panelist at the conference mentioned how they were (and still are) affected by the imposter syndrome—feeling like a fraud or like everyone else is just as good or better than you. It was shocking but also really interesting for us to see so many successful women in physics feeling out of place or not competent enough.

All in all, CUWiP was an amazing opportunity to grow as a student and a scientist. It gave us tools to prepare for and plan our careers through informative workshops, networking, and talks by women scientists who shared their experiences and advice with us. After meeting so many women with similar aspirations, we hope to attend CUWiP again next year and recommend that everyone, especially women, attend at least once during their time in college! //

**Zone meetings are an opportunity for SPS members and chapters to engage with other undergraduate students and advisors within their geographical region. These meetings often combine a fun and informal platform for students to network while also enabling students to present their research, interact with relevant speakers, visit local labs, and participate in other engaging activities. Each SPS zone meeting takes on a unique style and culture, shaped largely by the traditions of the schools in that region. The following article highlights one such meeting.**

**To learn more about SPS zone meetings, visit spsnational.org/meetings/zone-meetings.**



ABOVE: Attendees at the 2019 Zone 14 Meeting hosted by the University of Wyoming. Photo courtesy of Aman Kar.

# Welcome to Wyoming

by Ryan Parziale, SPS Chapter Secretary, University of Wyoming

**It has been over four years since the Zone 14 meeting has been held in Wyoming, so with the regional student and faculty representative to the SPS National Council both from the University of Wyoming (UWYO) in 2018–19, we thought it was time to bring it back. Our physics department is small, but along with our SPS chapter, it has been growing and doing more events. Hosting the zone meeting seemed to be a good way to get our chapter to be even more active.**

Speakers were the highlight of the meeting, providing insights into research, outreach, and careers. Will Chick, a current UWYO graduate student in astronomy, opened the talks by sharing the features of UWYO's 2.3-meter observatory, WIRO. Since the university owns the telescope, all of the observing time is devoted to students, giving undergraduates time to observe. It is one of my favorite aspects of UWYO, and it was exciting to share that with the visiting students.

Next, Dr. Randall Tagg of University of Colorado Denver presented his talk, "Physics, Innovation, and Entrepreneurship". This engaging and interactive presentation provided a "toolbox" of different skills used in physics and explored how those skills apply to different areas of study. We were encouraged to think creatively and practically to solve a problem or meet a need. My favorite idea was to break down rocks and minerals on other planets into oxygen to use for the future of space exploration. This presentation was a sneak peek of the full presentation that Tagg will give at PhysCon 2019!

The last speaker was Kerry Kidwell-Slak from the SPS National Office. She walked us through the Careers Toolbox to illustrate the different career paths a student with a bachelor's in physics could take. As a senior, this presentation was especially relevant to me. It may seem that career options are narrow and limited to only physics or astronomy, but there is a world of options available to a student with a physics degree.

To make the weekend truly unique, attendees were also able to tour our labs, the 3D cave, the science kitchen, and the geology museum. The science kitchen was a great way to show the type of outreach done in our department. This is where K-12 students and teachers get to investigate scientific ideas through experiments and hands-on exploration. The 3D cave is one of the lesser known attractions on the campus but also one of the more interesting ones. In the 3D cave, researchers use virtual environments to analyze spatially related data, providing invaluable insights into complex problems.

Overall, the Zone 14 Chapter Meeting was a success. While we were expecting a larger turnout, the weather prevented many students from being able to attend. However, we were able to learn valuable lessons about streaming presentations and fostering connections, and we brainstormed ways to make the next zone meeting even better. This was a great opportunity for UWYO, and we look forward to continuing to contribute to the zone and the national organization in the future. //

SPS awards are generously funded by donations from SPS alumni, Sigma Pi Sigma members, and friends of SPS. All awardees submit a final report highlighting how they carried out their proposed project. The following articles are abbreviated reports from recent Future Faces of Physics, Marsh W. White, Sigma Pi Sigma, and Chapter Research awardees.

To learn more about the SPS Chapter Awards, visit spsnational.org/awards/chapter-awards.

## A PHYSICS-FILLED FIELD TRIP

*2017–18 SPS Future Faces of Physics Award*

California State University San Marcos (CSUSM)

**Project Lead:** Jesus Perez

**Chapter Advisor:** Justin Perron

**Project Summary:** Studies have shown that an educational field trip can pique students' interests and encourage them to learn more about a subject. To spark interest in physics, we brought more than 250 eighth-grade students to the local planetarium for a day filled with physics fun. The students came from nearby middle schools that serve socioeconomically disadvantaged communities with high percentages of underrepresented minority groups.

**In San Marcos, students learn about the solar system and are introduced to the basic concepts of physics in 8th grade. In 2017, our SPS chapter brought 120 eighth-grade students from one local middle school to the planetarium at Palomar College, our local community college. Everyone loved the event, and survey results indicated that the field trip may have influenced how students thought about college majors and careers. We used this Future Faces of Physics Award to open our second annual event to even more students by adding another school.**

Our SPS chapter is two-thirds female, and we come from many different cultures. We saw this project as a chance to mentor students from similar backgrounds who most likely don't have college graduates in their homes. We chose these particular schools because they don't have the resources to conduct immersive STEM field trips like this, which can expose students to the real-world applications of physics and motivate them to keep studying. Our goal with this project was to show students that people with similar backgrounds are successfully pursuing science, with the hope that this will inspire them to consider pursuing physics or other STEM fields.

This year, we were able to bring 256 students to the planetarium for a full day of physics-themed activities, including a movie on the cosmos inside the planetarium, an interactive plasma demonstration by representatives from General Atomics, liquid nitrogen–themed demos by two chemistry professors, an undergraduate student panel, and a physics and chemistry show to finish off the day. Since the planetarium can hold only 180 people at a time, we hosted the middle schools on two different days.

Everyone involved in the project—the teachers, speakers, volunteers, and especially the students—loved the event. The students really enjoyed the physics demonstrations we performed at the end of the day. The teachers appreciated the student panel the most, as it included middle school alumni who are now STEM

TOP: Volunteer Joe Ayalla leading a group of middle school students to the planetarium. Photo courtesy of Felix Flores.

college graduates. We hope to repeat the program next year and incorporate more hands-on activities and interactive presentations. Our SPS chapter strengthened relationships among its members as well as between CSUSM, our local middle schools, and our local community college.

This project was a community effort that brought together people from our SPS chapter, both middle schools, the school district, the planetarium, the STEM center at Palomar College, and multiple departments on our campus. Looking forward, we are focused on building up the next cohort of SPS officers. Many of the current officers are graduating, and we want to make sure that the next set of officers values outreach and has the tools and information they need to make this field trip a recurring event. //

**For more details on this project, visit our award page at spsnational.org/awards/future-faces-physics-award/2018/california-state-university-san-marcos.**

## G5: GIRLS ARE THE 5TH FUNDAMENTAL FORCE

*2017–18 SPS Future Faces of Physics Award*

Coe College

**Project Lead:** Anne Ruckman

**Chapter Advisor:** Firdevs Duru

**Project Summary:** The underrepresentation of women in physics has motivated our SPS chapter to proactively engage the next generation of scientists. Our chapter used a Future Faces of Physics Award to implement a mentorship program for girls at Franklin Middle School and Harding Middle School in Cedar Rapids, Iowa. We visited the schools for five mentoring sessions and then invited the girls to campus for interactive demonstrations, research laboratory tours, and hands-on experiments.

**For this project, we recruited undergraduates from Coe College's SPS chapter, Physics Club, Women in STEM organization, Chemistry Club, Biology Club, Mathematics Club, and Computer Science Club to mentor local middle school girls. By bringing together mentors with diverse passions, we were able to offer the girls a greater range of engaging opportunities and expose them to more possibilities for their future. Each volunteer mentor was matched with one of two schools.**

TOP LEFT: Everyone wants in on science during the field trip. Photo courtesy of Felix Flores.

ABOVE: Mentors Sam Collins, Amy Houle, and Megan Houle take a break from talking about careers in STEM to pose for a picture with middle school participants. Photo courtesy of the Coe College SPS chapter.

The mentors traveled to their respective middle schools for five one-hour after-school sessions. During the sessions, a program leader taught the girls to program robots through MakerBot, helped them analyze the effectiveness of various sunscreen brands with UV beads, and explained light diffraction with balloons and lasers. SPS members assisted small groups and encouraged participants to discuss their goals and interests. Additionally, SPS members led sessions on the forces that cause soil erosion, animal cells, denatured proteins, and the effects of electric charge on the human heart.

This program gave SPS members the opportunity to not only interact with future female physicists, but also develop personal relationships with the 46 middle school participants. Fourteen SPS members served as mentors, and eight more SPS members led sessions when the participants visited campus for our first Women in STEM @ Coe Day. It was wonderful to witness mentors and mentees gain more confidence in themselves as they conversed about their scientific journeys, academic plans, and personal struggles. Additionally, the male SPS members acquired a greater understanding of the challenges faced by women in physics, discussed how to better support minorities, and served as examples of supportive peers for the young women.

Our SPS chapter hosts annual community events and frequently visits middle and high schools; however, this was the first program we offered with sessions that were completely student developed and executed. Through this experience, our SPS chapter grew closer to other campus organizations, learned to work with the local middle school administration, and truly developed relationships with local youth. We hope to repeat this program each spring. //

For more details on this project, visit our SPS award page at spsnational.org/awards/future-faces-physics-award/2018/coe-college.

## SOLARPALOOZA: A SOLAR VIEWING EXPERIENCE

*2017–18 Marsh White Award*

University of Alaska Fairbanks

**Project Lead:** Riley Troyer

**Project Advisor:** David Newman

**Project Summary:** One of the main foci of the University of Alaska Fairbanks (UAF) physics department is space physics. While this subject is a fascinating and important one, getting the general public interested in it can be challenging. To help engage the public with the research being conducted at UAF and space physics in general, the UAF Society of Physics Students held a public solar viewing event.

**We decided to include our event in the College of Natural Science and Mathematics' (CNSM's) annual Science Potpourri. This is a college-wide event that highlights the diversity of science at the university. Physics always has several stations, but they have been the same demos for several years. This year we changed things up and set up several solar telescopes that we purchased with award funds, a larger Schmidt-Cassegrain telescope, and the "Fabric of the Universe" gravity well demonstration provided in the 2017 SPS SOCK kit.[1] The demonstrations combined teaching from physics students and participant interaction with the telescopes and SOCK gravity well.**

Because the Science Potpourri has a 20-year history, we had a good idea of the audience to expect. The audience was primarily families with kids between the ages of 3 and 13 but also included community members of all ages. We found that the telescopes were best suited to kids above the age of 8, although many younger kids also enjoyed the demonstrations.

Our first goal with this project was to teach the Fairbanks community about the sun and physics involved with it. More than 100 people stopped by our telescope station and safely viewed the sun, learning a little about sunspots, the aurora, and telescopes.

TOP: Two event participants listen intently as UAF physics student Jason Beedle explains solar physics.

ABOVE: Picture of Solar Observations. Photos courtesy of University of Alaska Fairbanks SPS chapter.

Through our gravitational well demonstration, they learned why the planets orbit the sun. Another goal was to show the community how UAF is involved with solar physics. We don't feel that this goal was achieved as strongly as it could have been. For future events, we recommend inviting a physics professor to explain their research and make the connection between the sun and UAF research. A final goal was to add some new physics demos to the UAF CNSM Science Potpourri. We were definitely able to achieve this. Our two biggest demos—the solar telescopes and the gravitational well—were brand new this year. They were very well received, and we plan to set them up again next year.

We estimate that 150–200 people used the solar telescopes over the course of the day. For the overall event, the college estimated that around 1,200 people attended. This let us know that while we reached many people, with a more visible location and more signs we probably could have reached a lot more. In addition, we learned a lot through face-to-face interactions with participants. For instance, we got some complaints and noticed people having trouble with the tripods on the solar telescopes, so we purchased nicer tripods when the event was finished. However, we also learned that a large majority of the people who attended had never seen the sun through a telescope before and that they were excited to experience it. To build on this enthusiasm, we are planning to lead these activities again next year and supplement our equipment with a hydrogen-alpha solar telescope for even better views of the sun. //

For more information on this project, visit spsnational.org/awards/marsh-w-white-outreach-award/2018/university-alaska-fairbanks.

1. SOCKS, or Science Outreach Catalyst Kits, are provided free to SPS chapters each year. Check out 2017's version at https://www.spsnational.org/programs/outreach/science-outreach-catalyst-kits/2017/fabric-universe.

## LUNCHTIME PHYSICS CLUB FOR TRUE INQUIRERS

*2017–18 Marsh White Award*

Cleveland State University

**Project Leads:** Samantha Tietjen & Jim Pitchford

**Project Advisor:** Kiril A. Streletzky

**Project Summary:** The 2017 school year saw the opening of Campus International School's (CIS) brand-new building, and with it several new student programs. Cleveland State University's (CSU) SPS was asked to help with the Programme of Inquiry, a K-5 grade educational structure focusing on globally minded, investigation-based lessons and learning with a specific focus on "How the World Works."

**Our chapter delivered outreach lessons during three after-school visits referred to as Physics Fridays and one school-day visit. In order to follow the progression of the Programme of Inquiry as closely as possible, we designed and delivered lessons in the following order: Center of Mass/Intro to Simple Machines, Density/Phase Changes, and Light/Optics. Each station engaged students with a basic demo followed by hands-on activities of increasing complexity through the lesson.**

The first visit featured lessons on density and Newtonian forces as demonstrated by simple machines. In the density station, students were presented with objects of varying densities and encouraged to investigate how the objects behaved in water. Two separate stations focused on simple machines: one on the small scale, where students were given parts and allowed to construct their own machines to test, and another with large simple machines, including pulley and lever systems. Our second visit focused on different states of matter and started with basic experiments of freezing and melting of water. We then ventured beyond standard phase changes by inflating a balloon through dry ice sublimation and studying the mystery of an "instant freezing water bottle."[1] The true highlight of the lesson was introducing items like "boiling" soda, marshmallows, balloons, and dry ice into a vacuum and asking students to decide which were and weren't examples of phase change and why. The last after-school visit was all about optics and light. We asked students to recall what they know about waves and if they knew how this related to light. The demos for this visit included stations such as dispersion of light, geometrical optics, light and energy, and reflection/refraction. The students raved about this lesson, particularly because they were able to use lasers.

One Programme of Inquiry topic that we weren't initially sure how to incorporate into our lessons was environmental science and biological processes. The answer came to us in the form

TOP: Group photo of the SPS students who participated in the after-school visits to CIS for the Programme of Inquiry outreach sessions.

ABOVE: Students during the in-school visit learn about reflection and refraction with a laser box kit. Photos courtesy of CSU SPS chapter.

of a Foldscope[2]—a high-powered paper microscope that is assembled origami style and able to view things very clearly with a magnification of up to 140X and 2 μm resolution. During the lesson, students once again got to play with the laser box and lenses, compare a Foldscope to a standard microscope, and build one of the Foldscopes. Students were also shown some of the attachments that can go with the scopes, including a projector and a camera mount for a phone or tablet.

Over the course of the project, we reached 15–35 students in grades K-5 per event through each of the after-school Physics Friday program visits and 24 fourth-grade students through the school-day visit. Now that the first year has been completed, several other teachers in the school have already asked us to plan a similar sort of program for their classrooms. The goal for this project was to expand our audience from just the after-school Physics Friday program by starting an in-school science club for students. While we had hoped to get to more in-school visits, there were several issues with scheduling that kept us from going as often as we planned. Regardless, the students' enthusiasm made it clear that our in-school visit impacted students who are not as regularly exposed to hands-on learning. This bodes well for the program, and, hopefully, after several more classroom visits we will be able to transfer it to a full-on science club as originally intended! //

**To learn more about this project, visit spsnational.org/awards/marsh-w-white-outreach-award/2018/cleveland-state-university.**

1. Check out the instant freezing water bottle at https://www.stevespanglerscience.com/lab/experiments/instant-freeze-soda-ice/.
2. To learn more about Foldscopes, visit https://www.foldscope.com/.

## PHYSICS FOR THE PEOPLE: COMMUNITY LECTURE SERIES

*2017–18 Sigma Pi Sigma Chapter Project Award*

Colorado School of Mines

**Project Lead:** Emily Atkinson

**Project Advisor:** Timothy Ohno

**Project Summary:** The Colorado School of Mines Sigma Pi Sigma chapter hosted a lecture series on advanced physics topics aimed at nonacademics. Most university lectures are given at a very advanced level, so the goal of these lectures was to get high schoolers and community members more excited about physics. Through the efforts of this chapter, two community lectures were held, reaching over 80 people in the community.

**To encourage science literacy and increase awareness of our physics department, the Mines Sigma Pi Sigma chapter organized two lectures at the local high school auditorium: "Is Quantum Mechanics Hard, Or Is It Just Me?" and "The Dawn of Multi-Messenger Astronomy: New Ways to Observe the Universe." With a diverse group of attendees, including high school students, Mines students, and community members, and vibrant Q&A sessions, we achieved our goals in engaging the audience and making these complex topics approachable. Dr. Mark Lusk, the presenter for the quantum mechanics lecture and a physics professor at Mines, even received emails after the event from current high schoolers showing interest in the topic and the Mines physics department.**

ABOVE: The Colorado School of Mines Sigma Pi Sigma chapter officers. Photo courtesy of Colorado School of Mines.

This event also served as an opportunity to reinvigorate the Sigma Pi Sigma chapter on campus. As is the case at many schools, very few students or faculty, even in the physics department, knew that Sigma Pi Sigma was different from the Society of Physics Students. This lecture series established Sigma Pi Sigma's presence in the physics department and raised its profile throughout the university. Posters advertising the lectures and highlighting Sigma Pi Sigma as the host were placed in the physics building and throughout campus. There were also electronic advertisements sent to the entire student body, all highlighting Sigma Pi Sigma's involvement in the event. These efforts have caused a noticeable increase in Mines students' recognition of the organization. More people are aware of what Sigma Pi Sigma is, and we have even had some students ask how they can join Sigma Pi Sigma.

Beyond Mines, the lecture series has also caused an increase in the general public's awareness of physics at Mines and of Sigma Pi Sigma. Advertisements were placed in local restaurants and shops around the city of Golden, again with the Sigma Pi Sigma name. We also sent advertisements to over 90 high school science teachers in the Jefferson County school district. This led to a large presence of high school students at the lecture series, exposing them to physics and Sigma Pi Sigma. There was even one teacher that requested to bring her class to tour Mines and talk with the Sigma Pi Sigma officers about their time at Mines. We met with the students and thus further increased recognition of physics, Mines, and Sigma Pi Sigma.

In addition to increasing awareness of the organization, the lecture series also helped strengthen the community of new, current, and alumni members of Sigma Pi Sigma. New members were encouraged to and gladly helped with the advertising and setup of the lectures. Current members were active in the planning of the event, and nearly all attended the lectures. We even had several alumni members attend the lectures and talk with current members afterward. This increased the sense of community within the organization and will allow for continued success as the organization progresses. //

To learn more about this project, visit sigmapisigma.org/sigmapisigma/awards/chapter-project-award/colorado-school-mines.

## CONSTRUCTION OF A KIBBLE BALANCE—THE DEVICE THAT REDEFINED THE KILOGRAM

*2018 SPS Chapter Research Award*

University of Maryland, College Park

**Project Lead:** John Evans

**SPS Advisor:** Donna Hammer

**Project Summary:** Physicists have redefined the kilogram in terms of a natural physical constant using a Kibble balance (previously known as a “watt” balance), which measures mass by balancing opposing gravitational and electromagnetic forces. Here, we undertake the construction of a high-precision Kibble balance using low-cost and open-source hardware, in collaboration with UMD Physics Makers. We are implementing an asymmetric balance-wheel design modeled after the NIST-4 Kibble balance. Our Kibble balance is designed to be constructed by undergraduate students and give them opportunities to acquire skills in computer-aided design (CAD), electronics, 3D printing, machining, programming, data analysis, and optics.

**Imagine the chaos that would ensue if the definition of a meter or a second varied from place to place. Standardizing our base units—the second, ampere, meter, kilogram, kelvin, mole, and candela—is essential for modern industry and research.**

The kilogram, the base unit of mass, was first defined in 1795 as the mass of one liter of water at 4°C. In 1889, the kilogram was redefined as the mass of a specific cylinder made from a platinum-iridium alloy. That cylinder, called the international prototype kilogram (IPK), is stored just outside of Paris, France, and remained the mass standard until this spring. On May 20, 2019, the kilogram

ABOVE: The prototype components: wood frame, pivot mount (gray), coil housing (black), support piece for the nylon guides (yellow), balance wheel and razor-blade pivot (resting upside down on the right side of the wooden frame), webcam (far left), and data acquisition device (far right). Photo courtesy of John Evans.

became the last of the base units to be redefined in terms of the fundamental constants of nature. The definition of the kilogram is now tied to Planck’s constant, a value measured precisely with the state-of-the-art NIST-4 Kibble balance at the National Institute of Standards and Technology (NIST).

Inspired by a do-it-yourself LEGO watt balance designed by NIST researchers for education and outreach, physics students at the University of Maryland decided to create an inexpensive, high-precision Kibble balance that can be constructed by undergraduate students with access to a workshop. After building our own Kibble balance, we plan to release instructions that can be used by other SPS chapters.

A Kibble balance determines an object’s mass from the force required to offset its weight. The Kibble balance has two measuring modes that work together: the force mode and the velocity mode. In the force mode, a test object is placed above a wire coil. The object exerts a downward force equal to its weight. A current is applied through the coil and adjusted until the upward force of the induced magnetic field counterbalances the downward force of the object, and then that current is measured. In the velocity mode, the object is removed and the current is turned off. A voltage is induced by moving the coil through the magnetic field at a constant velocity. The velocity of the coil and the induced voltage are precisely measured. Since the coil and magnets are the same in both operations, the mass of the object can be calculated from the measurements of current, voltage, and velocity.

After meeting with scientists and engineers working on NIST-4, we settled on a design. The next step was to select magnets for running current in the wire coil. We determined that two ring magnets would be ideal and chose neodymium magnets with an inner hole diameter of 0.25 inches and outer diameter of 2 inches. We then 3D-printed a structure to house the coil and magnets. Informed by simulations and calculations, we made a 3,000-turn coil of 36-gauge magnet wire. Given the coil and our other equipment, we expected to be able to handle a mass of 30 g.

Our main goal in designing the balancing mechanism was to create a low-friction contact between the mechanism and a supporting wood frame. We made a balancing wheel out of wood that balances on top of a tungsten carbide pivot mount via a razor blade. Grooves on the outer circumference of the balance wheel guide a titanium wire that connects it to a stepper motor, the mass pan (which holds the test mass), and wire coil. A counterbalance keeps the entire apparatus balanced during operation.

In velocity mode, we drive the coil through the magnetic field with a motor. Our original intention was to build an interferometer to measure the velocity of the coil housing, but we could not complete our interferometer in the time given. We ended up using a webcam to measure the position of a brightness contrast on the mass pan and were able to achieve positional precision of +/- 0.2 mm over 50 mm of travel.

We have yet to get to the point where we can press a button and measure a mass, but we are close. We have a design that works well and software that completes every aspect of calibration automatically. Our data acquisition device has been difficult to interface with, but we expect to have this figured out soon. We look forward to using this device at outreach events and conferences.

This was an amazing opportunity to develop and manage a research project. Ten SPS members were actively engaged, honing their skills in design software, woodworking, programming, and data analysis. The biggest lessons that we have learned are the importance of dedicated, committed group members and securing necessary resources (like a suitable workspace) early on. If you are considering applying for a chapter research award, we recommend a strong emphasis on recruiting interested and committed individuals and securing proper guidance. Also, make sure that your project is manageable in conjunction with a heavy academic workload.

Team members: John Evans, Brady Easterday, Paul Neves, Brandon Grinkemeyer, Matt Marks, Matthew Spooner, Stephanie Williams, Peter Zhou, Brendan Van Hook, and David Long. //

**For more details on this project, visit our SPS award page at spsnational.org/awards/sps-chapter-research-award/2018/university-maryland-college-park.**

## QUANTITATIVE EVALUATION OF PEDESTRIAN MOVEMENT MODELS: A REAL MANY-BODY PROBLEM

*2018 SPS Chapter Research Award*

Purdue University

**Project Lead:** Adam Kline

**Chapter Advisor:** Rafael Lang

**Project Abstract:** A number of papers have been published since 2000 that attempt to model pedestrian crowd flow dynamics using basic equations of motion. Here we undertake a study to collect research-grade pedestrian data on campus using an off-the-shelf aerial drone and then test pedestrian dynamics models with those data.

**Many researchers have attempted to model pedestrian crowd flow dynamics using basic equations of motion. Our chapter wanted to know whether a visible-range camera mounted to an unmodified quadcopter drone could be used to effectively collect quantitative crowd flow data, and, if so, which theoretical models do a good job of modeling reality.**

Prior to the year 2000, there were two foundational works in this area. In 1974, Leroy Henderson modeled a crowd as a sort of gas whose dynamics are determined by the Boltzmann transport equation.[1] In 1995, Dirk Helbing and Peter Molnar modeled humans as psychologically driven automata subject to reasonably defined social forces.[2] These forces, which include a motivational force, a general attractive force, and an interpersonal repulsive force, act on the agent as though it were a particle obeying Newtonian mechanics.

A number of predictive models were published in the 2000s that expand upon these works. A few focused on panicked crowd dynamics and flow through pinch points, while others attempted to advance the social force model. We aimed to provide a critical, quantitative evaluation of these theories based on data as well as an example of how to collect such data.

Our data consisted of aerial footage of pedestrian movement collected with a DJI Mavic Pro quadcopter drone. Initially, we took data at heights ranging from 25 to 75 m above ground level. To avoid alerting people to the drone's presence (and thereby affecting behavior) and to have a good balance between adequate number of features for detection and scope of detection, we eventually fixed the recording height to 35 m.

The primary technical challenge was translating the raw footage into identified trajectories. This was broken down into two problems: detecting humans from the birds-eye view and then running single-particle tracking. Birds-eye human detection was done via machine learning; however, we had to overcome two complicating factors—the large 4 K resolution of the drone and the fact that the angle of the camera view (directly above) was sufficiently unique that we could not find an adequate existing dataset for training.

To resolve the first issue, the field of view was split into sections, and then the outputs for all of the sections were stitched together after processing. The absence of an available training dataset was solved through the manual tagging of collected data. Footage of students walking between passing periods was collected and used as raw data that SPS chapter members manually tagged. In this way, a dataset of people viewed from above was created and used to help train the model.

Once human detections were made, we ran single-particle tracking to look at the underlying dynamics of the situation. Single-particle tracking has heavy applications in protein tracking in biophysics, so many libraries exist to generate trajectories, agnostic as to how the detections themselves were created. We used trackpy, an open-source and easy-to-use tracking toolkit.

After processing the data, we began to compare it to the aforementioned models. However, we quickly found that most of the papers offered very little description of how their models were implemented computationally. All the papers presented the basic equations, but the algorithms offered only a very general outline. The details of many aspects of the models were simply omitted—for example, how the models set the pedestrians' directional inclination (e.g., destination) and how the models defined obstacles. Due to the difficulty in reproducing accurate models, ambiguities and missing information, and time constraints, we were unable to conduct a satisfactorily thorough and conclusive evaluation of the models we studied.

Although we did not achieve all of our goals, we successfully demonstrated that research-grade empirical pedestrian data can be collected by a combination of an off-the-shelf commercial drone with no additional modification and modern computational tools enabled by the recent development of machine learning. Although there are several legal restrictions that apply to drones (e.g., requirement of permission when flying in crowded cities), we believe that the data collection method we have developed is nonetheless viable for many purposes. //

**For more details on this project, visit our SPS award page at spsnational.org/awards/sps-chapter-research-award/2018/purdue-university.**

1. Leroy F Henderson. On the fluid mechanics of human crowd motion. Transp. Res., 8(6):509–515, 1974.

2. Dirk Helbing and Peter Molnar. Social force model for pedestrian dynamics. Phys. Rev. E, 51(5):4282, 1995.

ABOVE: A sample frame taken on the Purdue campus with the drone. Image courtesy of the Purdue University SPS chapter.

The SPS Summer Internship Program offers SPS members 10-week positions in the Washington, DC, area. Interns participate in research, education, policy, and outreach and are placed in organizations such as the American Physical Society, American Association of Physics Teachers, Society of Physics Students, The Optical Society, Capitol Hill, NASA, and the National Institute for Standards and Technology, among others. Over the course of the summer, students engage in a diverse set of activities and projects that collectively provide the interns with a unique learning and professional development opportunity.

The interns maintain weekly blogs highlighting their work and significant experiences. The following articles are excerpts from the journals of a few SPS interns from last summer.

You can find out more about the SPS Internship Program here: spsnational.org/programs/internships.

## THE HILLS WE CLIMB TO SEE THE WORLD: MY SPS INTERNSHIP

by Samuel Borer, 2018 Mather Intern, SPS Member at University of Maine

*Disclaimer: All thoughts are my own.*

**Flying away from Washington, DC, my mind turned to a quote from one of my favorite short poems, "A Dream Within a Dream," in which Edgar Allen Poe said, "It is by no means an irrational fancy that, in a future existence, we shall look upon what we think our present existence, as a dream." It is so striking to me; there is so much truth in such few words. This past summer was a dream. While I wasn't able to write blog posts during the midst of the summer activities due to my work placement, I hope to now share some thoughts and observations on my experience.**

I was able to spend my summer as a legislative intern for Senator Tammy Duckworth, specializing in science and environmental policy. It was an eye-opening experience, and I was able to gain so much perspective on the legislative process in general.

As an intern in a member's office, you do very different tasks from what you would do if you were in a committee office (like the one my comrade Sarah Monk was in). Personal offices deal with the constituents of that congressional member, while committee offices deal with the agenda of that specific committee. Working with constituents is one of the toughest, but most rewarding, experiences you can get from working for Congress. Seldom will you be closer to the literal process of democracy. Senator Duckworth was elected by the great citizens of Illinois, so we had a responsibility to hear from those same citizens. When they call, write a letter, or send an email, they are engaging in the political process, and our office took that very seriously. As interns, you are "on the front lines," answering phone calls, listening and logging the opinions of the voters, sorting mail, and categorizing everything. From a science standpoint, I was amazed at how efficiently the office took in massive amounts of data and sorted everything appropriately so that it could be handled by the small team of staffers. Like a sequence of data filters, every bit of information always found where it was supposed to go.

ABOVE: Caption: 2018 Interns touring Capitol Hill. Photo courtesy of Samuel Borer.

Some of my most meaningful experiences happened when I was able to work on legislative tasks. I worked with two amazing staffers who were serving as legislative assistants (LA), managing Senator Duckworth's science, energy, and environment portfolio. Senator

Duckworth serves on several committees and subcommittees related to these areas, so the workload was always high.

I performed deep dives, researching specific topics we needed for various legislative reasons. One quickly becomes a master of internet resources, able to do things like find “that one quote” in a 350-page government report from eight years ago. It was not uncommon for an LA to come by and say something like, “I need to know more about how Brazilian biofuel exports could affect Illinois farmers,” and then I would be off to the races. I analyzed legislation that was in our committee and helped draft bill recommendations, which provided crucial information and context to the senator, helping her make informed decisions on legislation. I attended hearings and briefings, and wrote memorandums for staffers. I also wrote form letters that would eventually be sent as responses to constituent communication.

However, the most impactful aspect of working for Congress was simply being in that atmosphere. It is not something I find easy to put into words. There is a sense that you are in the middle of all these happenings, surrounded by giants. You pass senators in the hallway, you can go and sit in the Senate gallery and watch floor debates, you can attend hearings and witness our government work in front of your very eyes. Every day I walked from the metro station across the back porch of the US Capitol. I stood on the stairs that President Obama used when he left his life as a private citizen and walked out of the Capitol building for his presidential inauguration. I got the chance to attend a lecture by Justice Ruth Bader Ginsberg in the very courtroom that legalized same-sex marriage. Those are the experiences that made my summer more meaningful than any that came before it. //

ABOVE: The 2018 SPS Summer Interns. Photo Courtesy of the SPS National Office.

## AFTERTHOUGHTS AND ACKNOWLEDGMENTS

by Michael Welter, 2018 SPS Communications Intern, SPS Member at High Point University

**It's been about five months since the 2018 SPS interns packed up our stuff, said our goodbyes (for some of us through tears), and headed back to our corners of the country. When I returned to North Carolina, I felt . . . different. Initially, I attributed the feeling to making the transition back home, back to the same old places and routines after spending 10 adventurous weeks in Washington, DC. However, I realize now that the "difference" I was feeling was a change in perspective.**

The first thing I noticed, which became obvious after reading over my previous blog posts, was that I actually had an idea of what career I wanted to pursue—no simple feat as an undergraduate physics student! Being the communications intern opened my eyes to the beautiful yet practical applications of mixing science and art. From illustration to marketing to architecture to product design, I could now see the various doors that are open for an individual pursuing a jointly technical and creative career. But this internship also helped narrow my career focus in another way: by spending time with the other interns, I got a window into what it would be like to perform research in the labs of NASA or NIST, or work on Capitol Hill, or write for a science-fueled news publication, or work for any of the other 10+ organizations that SPS has a relationship with, and I found that the industry/position I had been placed in was exactly the one for me. I don't know how they do it, but the SPS team has an incredible talent for predicting which setting would best suit each intern.

Having become so close to the rest of the interns, the next thing I realized when returning to my university was how essential a sense of *community* is to a growing SPS chapter. Although our advisor and physics faculty have done an undeniably good job of fostering a healthy sense of community, I noticed that there weren't many procedures in place to ensure that our community maintained its inclusive and organized nature. By taking advantage of the tools provided by SPS National and pulling from what I had learned about other interns' chapters, I was able to set some mechanisms in place so that all of our current and future physics majors can feel safe and supported in our program. For example, our chapter voted on and posted a set of community guidelines for our shared research space, created a system to hold members accountable for their actions, and now we take time at each meeting to celebrate member accomplishments. Thanks to this internship, I was able to use my newfound knowledge and experience to strengthen my chapter at home.

Most notably, though, this internship changed my perspective on *life*. I had the opportunity to live and work with individuals that are doing—and undoubtedly will continue to do—amazing things, people that I will forever admire for their passion and respect for their drive. Thanks to their influence, I now have the confidence to set goals and the support I need to achieve them. //

## THANK YOU, SPS

by Amanda Williams, 2018 SPS SOCK Intern, SPS Member at Weber State University

**On our final day of the SPS internship, I was caught in a surreal trance. I realized this summer was special not just because of the location, or the people, but because of the notion that even when I come back to DC and meet up with members of this new family I have made, I will never be in the exact same spot or have this exact experience again in my life. There is something powerful and moving about this. After vicariously experiencing 14 different intern placements and meeting fellow physicists from all walks of life, I will carry this summer as a reminder—A reminder to put myself out there and be in the moment. A reminder to be open to sporadic opportunities. A reminder to continue with my passion for sharing things I love, like physics, because life is too short for anything else. I will use this summer as a reminder that, as Smash Mouth puts it, "Only shooting stars break the mold."**

*To sign it off,*
*The greatest gift SPS gave me*
*was putting me in the nation's capital*
*with other budding physicists,*
*and presenting me the opportunity*
*to connect with them*
*and grow alongside them.* //

**Apply to be a 2020 SPS intern by January 15 at spsnational.org/programs/internships. Applications open November 1.**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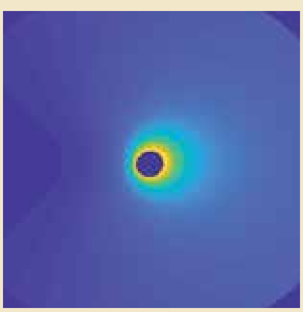

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