Cornell Society of Physics Students
2015–2016 Annual Report

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1 Preamble

The Society of Physics Students at Cornell has experienced an incredible amount of change this year. Our executive board has expanded from just a handful of officers, to a dozen. Within the Cornell community, we have implemented measures to create a stronger physics community: not only for members of the Physics major, but for members of the Engineering Physics and Electrical and Computer Engineering majors as well. Outside the Cornell community, we have gone from simply participating in other organizations’ outreach events to creating our own from scratch. In the process, we have inspired the community learn more about science, technology, engineering, and mathematics. This year, we have created the strongest SPS in chapter history, and in the next year and beyond, we hope to expand our presence as a student organization at Cornell University.

2 Activities within the Cornell community

2.1 SPS Physics and Pizza Lecture Series

Description: Approximately once a month, we sponsor a physics talk aimed toward the undergraduate student body. The physics department and many others (Applied and Engineering Physics, Astronomy, Electrical and Computer Engineering, etc.) sponsor weekly colloquia that are open to the physics community, but unfortunately, most of these talks are aimed at the first–year graduate level. Therefore, our talks are designed to be accessible to our undergraduate population, giving them an opportunity to learn about cutting–edge physics research. This year, we have been focusing on inviting several graduate students as speakers, since graduate students are often more relatable in experience and interest to undergraduate students.

Attendance: Between ten and twenty students usually attend these talks. Most of them are Physics and Engineering Physics majors, but some engineering students also attend. We schedule the talks on different days of the week each time to accommodate as many schedules as possible. In previous semesters, we found out that students do not tend to populate the talks in the middle of the semester due to prelims (preliminary examinations), so in the Spring 2016 semester, we changed our scheduling method so that the talks are clustered at the beginning and end of the semester. The result has been a higher attendance in general.

The Activity: We use the time just before the talk to make announcements about upcoming events. The talk itself lasts for an hour, after which many students remain to ask questions and converse with the speaker while eating pizza.

Funding: The Physics department provides financial support for pizza and drinks. This year, we implemented a new system in which one of the SPS officers volunteers to host one of the speakers. Each volunteer is charged with contacting the speaker, advertising
via fliers and emails to the listserv, and coordinating the pizza and soda orders with the department’s undergraduate coordinator, Susan C. Sullivan.

**Advertising:** For the first talk of the year, the officers attempt to visit all of the introductory physics lectures to make an announcement about our activities for the semester, especially promoting the first talk. We have fliers for each talk, which we put up around the physics buildings about a week before the event. We then send reminders to the SPS listserv before each talk.

Below is a list of the talks that we had, with the title of the talk and a short abstract:

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**Figure 1: Cyclically:** Katja Nowack, Nandini Ananth, Michael Niemack, Ji-Woong Park, Csaba Csaki, John Stout, Ira Wasserman, Carl Franck, Yogesh Patil, and Ivan Bazarov.
September 8th, 2015: **Professor Katja Nowack** (Laboratory of Atomic and Solid State Physics)

**Title:** *Imaging current in a two-dimensional topological insulator*

Abstract: An ordinary insulator conducts electricity neither in its interior nor on its boundaries. Like an ordinary insulator, a topological insulator (TI) is insulating in its interior, but can carry current along its edges (in 2D) or on its surfaces (in 3D). The presence of conducting states on the boundaries of a TI is a direct consequence of a topological non-trivial texture of the wavefunctions in the interior of the TI. In this talk, I will first introduce topological insulators and then describe how we can use magnetic imaging to directly visualize the edge currents in a 2D topological insulator.

October 1st, 2015: **Professor Nandini Ananth** (Department of Chemistry and Chemical Biology)

**Title:** *Quantum dynamics from classical mechanics: with applications to complex chemical systems*

Abstract: Understanding the mechanisms of thermal and photochemical charge and energy transfer reactions is a key step towards the rational design of energy-efficient devices, including organic photovoltaics and molecular electronics. Addressing this challenge using theoretical simulations requires the development of methods that scale well with system dimensionality, that can accurately describe coupling between electronic state transitions and nuclear vibrational motion, and that can provide a consistent framework to characterize the competing thermal and photochemical processes which drive exciton transport and dissociation in organic photovoltaics. This talk will serve as an overview of the methods we develop to investigate quantum dynamics in complex systems using classical molecular dynamics simulations.

October 27th, 2015: **Professor Michael Niemack** (Department of Physics)

**Title:** *Cosmic Microwave Background polarization measurements*

Abstract: Measurements of the cosmic microwave background (CMB) have enabled powerful probes of the physics and cosmology of our universe. CMB observations are helping to address fundamental questions, such as the nature of dark energy, and are being used to probe the physics of inflation at energies a trillion times higher than the Large Hadron Collider. This is the 50 year anniversary of the first detection of the CMB, and I will discuss some of the things we have learned from CMB measurements. I will also describe the status of CMB polarization measurements and focus on our recent results from the Atacama Cosmology Telescope, one of the highest telescopes on earth.
November 24th, 2015: Professor Ji-Woong Park (Department of Chemistry and Chemical Biology)

Title: \textit{2D layered materials}

Abstract: 2D layered materials are like color papers: they can be glued, stacked, cut and folded to form integrated devices with atomic thickness. In this talk, I will discuss how different 2D materials can be grown with distinct electrical and optical properties (coloring), how they can be connected laterally to form patterned circuits (stitching) and how their interaction with light can be designed by controlling the interlayer rotation and the valley degree of freedom (twisting).

December 1st, 2015: Professor Csaba Csaki (Department of Chemistry and Chemical Biology)

Title: \textit{Particle physics after the discovery of the Higgs boson}

Abstract: The discovery of the Higgs boson at the LHC in 2012 is a major milestone for particle physics. I will explain the significance of this discovery for our understanding of particle physics, and discuss the implications of this discovery (together with the other LHC results) for what might lie beyond the standard model.

January 29th, 2016: John Stout (Graduate Student, Department of Physics)

Title: \textit{What is string theory good for?}

Abstract: Physicists have been excited about string theory for the past 30 years, and I would like to explain why. In particular, I am to explain what string theory is, what it tells us about the quantum world, and how physicists use it in their day-to-day.

February 4th, 2016: Professor Ira Wasserman (Departments of Physics and Astronomy)

Title: \textit{How Fast Can a Neutron Star Rotate?}

Abstract: Neutron stars are like giant atomic nuclei that are held together by gravity although they are even denser than atomic nuclei on Earth. Their masses are comparable to the mass of the Sun but their radii are only about 10 km. The result of exhaustive searches is that the fastest rotating neutron star observed so far has a spin period of just below 1.4 milliseconds. Theoretical models would allow faster spinning neutron stars, perhaps as fast as 0.5 milliseconds. Why don’t they exist?
February 10th, 2016 : **Professor Carl Franck** (Laboratory of Atomic and Solid State Physics)

**Title:** *Synchronized Cell Cycling: Unexpected Collective Behavior in Living Matter*

Abstract: I will report on surprising multicellular behavior: the spontaneous synchronization of cell division by amoebae in dilute groups. I’ll describe our accidental discovery of the phenomena and what we have found out about the necessary intracellular communication. We’ll see how the effect can be readily quantified through Kuramoto’s theory of synchronization among a collection of clocks. This will lead us to our current efforts to explore and appreciate this new form of dynamical order both biologically and physically. I’ll highlight the fun we have been having developing and exploiting the necessary experimental tools: protocols, instruments and algorithms.

April 12th, 2016 : **Yogesh Patil** (Graduate Student, Laboratory of Atomic and Solid State Physics)

**Title:** *Weeping Angels and Cold Atoms*

Abstract: The process of measurement can modify the state of a quantum system and its subsequent evolution. I will explain how quantum systems can ‘freeze’ when they are being observed (or measured), a bizarre quantum phenomenon known as the Quantum Zeno effect. This is much like the Weeping Angels of Dr. Who lore, beings which can move only when they are not being looked at. I will elaborate on how this effect can be used to create, control and manipulate exotic states of matter. And also how such techniques developed right in our basement can lead to the next generations of quantum technologies.

May 3rd, 2016 : **Professor Ivan Bazarov** (Department of Physics)

**Title:** *Bright Electron Beams - Beyond the 'Star Wars'*

Abstract: This talk will informally relate a fascinating story of bright electron beams: how they are made, physics challenges that face accelerator scientists who create them, and how such beams help us to better understand the nature.

### 2.2 Colloquium Advertising

While the physics department’s weekly colloquia are geared towards first-year graduate students, we have found that many advanced undergraduates choose to attend. As a result, we have begun advertising the talks each week to our list-serve. In the Spring 2016 semester, we realized that a significant portion of the undergraduate student body was interested in astrophysics and cosmology, so we began to advertise the astronomy department colloquia jointly with physics.
2.3 Special Luncheons

Figure 2: From left to right: Hans Bethe, Hitoshi Murayama, Francis Halzen, and Nima Arkani–Hamed.

2.3.1 Bethe Lectures

Hans Bethe was a Nobel Prize–winning physicist at Cornell. From the Physics Department website, the Bethe “lectureship will bring to Cornell distinguished persons working in physics to enrich and stimulate the intellectual atmosphere of the University in the manner that Hans Bethe did throughout his career.”

In the fall, we were lucky to have Professor Hitoshi Murayama from UC Berkeley as our Bethe lecturer. From his faculty page, he “is a well-known theoretical particle physicist who works broadly, even on astrophysics, cosmology, and condensed matter physics.” We were delighted to engage in conversation about the world of theoretical particle physics. About 25 undergraduates attended this lunch, which was on October 21st, 2015.

This spring, we were delighted to have Professor Francis Halzen from the University of Wisconsin–Madison. We spoke at length about the IceCube experiment—which he heads—and its search for neutrinos. About 25 undergraduates attended this lunch, which was on March 23rd, 2016.

2.3.2 A.D. White Professorship

From Cornell’s website, “At any one time, twenty outstanding intellectuals from across the globe hold the title of Andrew Dickson White Professor-at-Large and are considered full members of the Cornell faculty. During the six-year term appointment, each Professor—at–Large visits the campus for about a week in each three-year period while Cornell classes are in session during the academic year under a single mandate — to enliven the intellectual and cultural life of the university.”
Nima Arkani-Hamed from the Institute for Advanced Study is one of these twenty A.D. White Professors–at–Large. On Tuesday, April 19th, 2016, we hosted a “Pizza with Nima” luncheon that was well-attended (10-15 students). We had a great time conversing with Nima about theoretical physics, and look forward to his next visit!

2.4 LN2 Ice Cream Social
At this year’s first SPS meeting, we made ice cream by freezing the ingredients with liquid nitrogen. This event provided a chance for the freshmen physics students to socialize outside of the classroom. It also provided an opportunity for them to ask the upperclassmen about living and studying physics at Cornell. About 30 incoming physics majors attended. Funding for the ice cream ingredients and the liquid nitrogen was provided by the Physics Department. The liquid nitrogen ice cream has been so popular that we started to make it a recurring part of nearly every social event that we hold. We also perfected our ice cream recipe, so that it tastes like true soft serve instead of like Dipping Dots.

2.5 \LaTeX{} Tutorials
SPS members Omar B. Alam and Jonathan Karsch created a new \LaTeX{} tutorial from scratch. We had great attendance for our two sessions in the fall semester, and our one session in the spring semester. In all, we taught about 40 students how to use \LaTeX{}! The public link to our PDF is available here.

2.6 Mathematica Tutorials
SPS members Chad Burton and Michael Lee taught about 20 students how to use Mathematica in the fall. In the spring, we had an advanced Mathematica tutorial headed by graduate student John Stout, geared towards teaching undergrad the tools they’d use if pursuing a graduate degree in theoretical physics.

2.7 Physics GRE Preparation Sessions
Graduate student Daniel Citron held his annual PGRE crash course in the spring. 10–20 SPS members attended, and later took the PGRE on April 16th, 2016.

2.8 Peer Advising Program
SPS Officers Omar Alam and Jessi Hersh helped pioneer an SPS peer advising program geared towards bringing together freshmen with upperclassmen. We encouraged the advisors to set up a meeting with the advisees to answer any questions and offer advice about life at Cornell as a physics major. Twelve advisor–advisee pairs were made, with a detailed matching process, and the feedback indicated that people enjoyed the program. In the fall, we plan to integrate the peer advisor program with the freshman orientation.
2.9 Cornell Days

We held two separate events this spring for admitted high school seniors. Members from the peer advising program were invited to form a student panel. The panel talked about their experiences as physics majors at Cornell: classes, social life, research, etc. The panel also answered student and parent questions. Following the discussion was a liquid nitrogen ice cream social. Both events were well–received, and the parents and students stopped us afterward to comment that they were swayed towards considering Cornell as a result of these panels. There was liquid nitrogen ice cream at both events. An alumnus, Troy Hoffa ’14, joined us for the panel.

2.10 Senior Send-Off

SPS officer Roman Marcarelli organized an event to honor the graduating seniors. This was a casual social event with pizza and liquid nitrogen ice cream. All in all, everybody had a blast!

2.11 Poster Session

Figure 3: Clockwise, from top left: Zach Porter presents his research from Stanford, Christian Zollner presents his research from CNF, conference organizers Omar Alam and Mallika Bariya, and the overhead view of the poster session.

SPS officer Omar Alam helped pioneer an undergraduate research showcase for the Physics and AEP majors. About 10 people presented their posters, which helped them with the graduate school applications.
2.12 Career Day

SPS officer Omar Alam worked with the Department of Physics and the School of Applied and Engineering Physics to set up the university’s first annual Career Day for physics majors. This had a detailed process, including: (1) obtaining recommendations for Career Day speakers from the undergraduate student body; (2) relaying these changes to the physics department; and (3) planning the day-of agenda after determining who the speakers would be.

3 Activities outside of the Cornell Community

3.1 Bristol Hills Summer Camp

Figure 4: Clockwise, from top left: crystal radio, Ariel Donlin teaching a student, Ethan Arnault demoing a makeshift radar gun, and the outreach workspace.

SPS members Alison Rugar, Ariel Donlin, Ethan Arnault, and Tabatha Felter participated in Professor Carl Franck’s outreach program at the Canandaigua Bristol Hills 4–H camp. Activities included building a crystal radio, and various smaller demos such as demoing gravity, playing with a radar gun, and listening to amateur ham radio operators.
3.2 Expanding Your Horizons

The SPS continued their involvement in the Expanding Your Horizons conference at Cornell University. The purpose of this conference is to inspire 500+ middle school girls to pursue STEM careers. For the second year in a row, SPS officer Omar Alam led a workshop entitled “Make your own Radio!” in which 45 girls got to build and keep their own miniature crystal radios. Everyone had a blast at the workshop! We also continued our science demos, including the curvature of spacetime, slinky drop, polarization of light, and gyroscopic motion.

3.3 Weather Balloon Outreach Project

Figure 5: Top: Logos created for the SPS After School Program ”Journey to the Edge of Space.” Bottom: Program Mentor Joseph Parisi helps students fill weather balloon.

Former Outreach Chair Joseph Parisi led an initiative to create the first SPS after–school activity for local Middle Schools. “Journey to the Edge of Space” was the first original program in this series. The team of directors consisted of three program mentors: Joseph Parisi, Roman Marcarelli, and Peter Chen. The program was advertised as a
stratospheric exploration program to the DeWitt Middle School. Students would be able to engineer an experiment that launched to the stratosphere. This would test their knowledge of the course material and allow them to conduct scientific analysis of the collected data. Topics consisted mostly of thermodynamics, atmospheric science, and their applications.

The program consisted of three class periods: Edge of Space Science, Experiment Design, and Launch Day and Data Analysis. For the first class, we discussed the Ideal Gas Law and demonstrated to students the interdependent relationship between volume, pressure, and temperature. We then characterized the climate of the stratosphere and discussed U.S. Standard Atmosphere, explaining how density, temperature, and pressure change with increasing altitude. On the second day, we explained some of the mechanisms of balloon physics. For instance, we described how in the stratosphere, the exponential decrease in pressure and subtle increase in temperature force the balloon to expand dramatically. The balloon expands and expands until the internal pressure exceeds the strength of the balloon material and it pops. We then reviewed the Stratocraft Apparatus and then encouraged students to brainstorm designs for the payload. For the remainder of the class, students outfitted the avionics layout in a Styrofoam container that we provided. On Launch Day, students helped unravel and fill a weather balloon. Program mentors supervised the dispensing of helium into an eight foot diameter balloon. We had to coordinate our launch with the local airport and students recorded observations.

The students decided on an experiment to test whether popcorn would pop under low pressure. A future class session on Data Analysis was scheduled for students to learn from the results of their experiment. The program was a huge success and the DeWitt Middle School is eager for us to return next year.

3.4 Carl Sagan Planet Walk

The Cornell University Society of Physics Students hosted a Guided Tour of the Ithaca Sagan Walk on April 16th. The Guided Tour started in the Ithaca Commons and followed a 1,200 meter long scale model of our solar system. This model solar system was built in 1997 and was made in order to serve as a memorial to Carl Sagan, the famous astronomer, Cornell professor, and Ithaca resident. A number of academic organizations on campus took part in the event including the Cornell Herpetology Society and the Cornell Astronomical Society.

It has been the longstanding goal of Cornell SPS to spearhead an event that would resonate with both the Ithaca community and the Cornell academic spirit. The guided tour of the Sagan Walk involved homage to Carl Sagan, interactive demos, and more.
Figure 6: Top: All the members of the Sagan Walk team pose for a picture in the Ithaca Commons after a long day of work. Tour Guide Omar Alam explains the Solar System to Ithaca Residents. Middle: Ithaca Community member does solar observing for the first time at the Sun station. The Cornell Herpetology Society explains biodiversity to interested voyagers. Bottom: Venus demo creator Roman Marcarelli explains how we can create sky-colonies in Venus’s Atmosphere.

Families received a solar system tour guide that led groups to each planetary station. The tour guides would talk about the approaching planet and interactively demonstrate how it relates to those around it. At the stations for the inner planets, voyagers would
be greeted by a large-scale physics demo or science activity. These demos served to teach families about the unique aspects of each of the planets in the solar system. Kids could carry “passports” to be stamped at each of the stations.

Interactive Demos included a demo on impact craters. Thomas Galvin, program demo participant, dropped balls into a bin of flour. He showed how size of asteroid and speed of impact change the formation of impact craters and the ejection of dust. He described how Mercury is pocket-marked with impact craters from meteors that were corralled into its gravitational field. Mercury has a very thin atmosphere, so many of these space rocks do not burn up when entering the atmosphere. When these rocks impact the surface, they eject dust into the air and form craters with elevated ridges.

Other Demos included a demo on the colonization of Venus, Orbit Patterns, and an opportunity to handle snakes and lizards with an accompanied discussion of biodiversity for the Earth Station. At the sun, Ithaca Community members could partake in solar observing and witness a large sun spot.

Physics majors, club officers, and volunteer teams alike worked hard with former Outreach Chair Joseph Parisi to coordinate the event. In preparation, they completed a twenty page document as a script for tour guides and instructions for completing our authentic demos. We were honored to have our local museum, the Sciencenter, sponsor the event as well. Almost two hundred people showed interest in the event on Facebook alone.

3.5 Comet Cones

Former Outreach Chair Joseph Parisi created a for profit Liquid Nitrogen Ice cream company called Comet Cones. The company has a socially responsible mission to increase science literacy in the local community.

3.6 Splash! at Cornell

SPS officer Omar Alam became the Co-Director of Splash! at Cornell for their Spring 2016 outreach event. Splash! is a one–day opportunity for 7th–12th graders to come to Cornell campus and learn any subject taught by any Cornell undergraduate. Many teachers in Splash! came from the Cornell SPS, and this made for a plethora of physics and physics–based classes that caught the attention of up to 200 middle and high school students.

3.7 CCMR Events

Our SPS members continued to participate in outreach events hosted by the Cornell Center for Materials Research (CCMR).
4 Acknowledgments

• **Professor Yuval Grossman** for his continued support and enthusiasm for making SPS the best it can be.

• **Professor Carl Franck** for his continued support as faculty advisor for Expanding Your Horizons, and helping to inspire 45+ middle school girls to build careers in STEM.

• The entire SPS Executive Board for their hard work: **Omar B. Alam, Joe Parisi, Cher Wang, Saaj Chattopadhyay, Roman Marcarelli, Cecilia Chen, Alex Wang, Kaiwen Zheng, Alexander Molina Schlotterback, Vivek Pisharody, and Jessica Hersh.**

• Our graduating seniors on the executive board for their commitment to SPS: **Sarah Marie Bruno, Prabudhya Bhattacharyya, and Brenna Mockler.**

• Physics department building managers **Mark Lory–Moran, Jenny Wurster, and Vince Kotmel** for their help in providing parts for our many outreach events.

• **Professor Jim Alexander** (Director of Undergraduate Studies), **Professor Jeevak Parpia** (Director), **John Miner** (Director of Administration), **Sue Sullivan** (Undergraduate Coordinator), and the rest of the Physics department for their continued support – we wouldn’t run without you!