



Physics and Astronomy

ANNUAL REPORT 2015/2016

Pomona College Department of Physics and Astronomy



Prepared by David M. Tanenbaum, Dept. Chair 2011 -2016

DEPARTMENT OF PHYSICS AND ASTRONOMY ANNUAL REPORT

This annual report of 2015/16, covers our first year in the new newly re-constructed Millikan and Andrew buildings that include state of the art facilities for teaching and research, as well as a fully digital planetarium, machine shops, an electronics shop, a microscopy center, extensive laboratories and student project space, and more. We also completed a new detailed (300 page) self study and external review of our department and its programs.

Graduating Seniors and Faculty in Spring 2016



Physics Graduates '16 and Faculty, from left: [back row] Scott Tan, Carson Witte, Prof. Moore, Prof. Tanenbaum, Prof. Zook, Prof. Kwok, Prof. Mazhborter, [middle row] Ferrel Atkins, Andy Biekert, Jerry Martinez, Chanud Yasanayake (Caltech 3-2) Vicente Robles, Prof. Whitaker, [front row] Prof. Krabn, Prof. Vetere, Melina Mastrodimos, Jonah Grubb, Madeleine McGaughey, Hannah Bishop, Prof. Hudgings, [seated] William Buchholtz, and Tatsu Monkman. Not pictured are David Sharfi and David Khatami, Prof. Choi, and visiting Prof. Quetin.

During the academic year of 2015/16, our department of Physics and Astronomy graduated 14 majors, one minor (CS major) and has two students completing years 4 and 5 of the Caltech 3-2 engineering program. Six members of the class participated in Engineering Clinic projects at Harvey Mudd College. There are three women in the class, and of the

eleven male students, two are hispanic and three identify as multi-racial. Students are headed into graduate programs at highly respected institutions: UC Berkeley (2 students), Georgetown University, UC Riverside, and MIT. One is pursuing a post-bac in health metrics at U Washington, another is working at the Army Research Lab, another is entering the Japan Exchange and Teaching (JET) program, while others enter the job market. Six of our majors have incorporated time abroad in their time as Pomona students (UK, Switzerland, France, Japan, and Germany). Beyond academics, our students were active in sports, music, outdoor programs, social justice movements, outreach and education programs during their time at Pomona. This was a large group of majors and probably the most diverse group we have ever had.

Summary profiles of each of these students and their plans are presented below.

Ferrel Atkins

Ferrel is a physics major in the astrophysics program. He will be working at the Army Research Lab on night vision sensor research this summer, followed by some time off traveling before looking for his next job. Ferrel did summer research with Prof. Vetere here at Pomona, as well as with the Army Research Lab. He also worked as a TA for both both majors and non majors.. He participated in the HMC Engineering Clinic program and was a member of the Pomona Swimming team. His thesis, "An Overview of Satellite Communications: Topics in Satellite Television", was primarily supervised by Prof. Hudgings.

Andreas Biekert

Andy is a physics major who will enter the physics PhD. program at UC Berkeley this fall with a prestigious NSF fellowship. Andy did summer research with Prof. Mawhorter, including trips to Germany to collect data. He also did summer research at Yale. He served as a department liaison, and worked as a TA, and mentor, for our department. His thesis, "Aiding the Search for New Physics Through the Spectroscopy of Diatomic Molecules", was supervised by Prof. Mawhorter. Andy shared the Edmunds Physics Prize from our department with Madeline McGaughey and Scott Tan.

Hannah Bishop

Hannah is a physics major who will be entering the workforce with an interest in medical physics, nursing, or possibly in a small start up company. Hannah did summer research with Prof. Tanenbaum and has also worked for the Information Technology Services at Pomona. She has been active in the Claremont Colleges Hackathon programming contests and made interesting projects for electronics and experimental physics courses, the latter a wave machine that hangs in our stairwell. Her thesis "Fabrication of Plasmonic Nanostructures using Electron Beam Lithography" was supervised by Prof. Tanenbaum.

Will Buchholtz

Will is a physics major who will enter the physics PhD. program at Georgetown this fall. He did two summer SURPs with Profs. Mawhorter and Moore. Will served as a department liaison and worked as a TA and a mentor in our department. Throughout his time at Pomona Will has been active in the orchestra. His thesis “Modeling the Evolution of Surface Charge on a Wire-Capacitor Circuit” was supervised by Profs. Moore and Zook.

Jonah Grubb

Jonah is a physics major who is will be returning to work in his family’s business in the adventure travel area, as well as continuing his popular freelance video production. Jonah has kept busy leading kayak outings, and making films throughout his time at Pomona, including a semester leave where he made a documentary as he paddled one of the most polluted rivers in Mexico.. His thesis connected with his long standing interest in fluid dynamics, “On the Design and Construction of a Tow Tank and Particle Image Velocimetry System for the Study of Exploding Plants” was supervised by Prof. Whitaker.

David Khatami

David is a physics major in the astrophysics program who will enter the astronomy and astrophysics PhD. program at UC Berkeley this fall. David spent three summers doing astrophysics research with scientists at Carnegie Observatories and Caltech. David worked as a grader for the department, but in a year when discussions of climate and diversity were a major focus, David played a key role in the organization of discussions both at the department and college level. His thesis, “A Meshes Approach to Radiation Hydrodynamics Simulations in Astrophysics”, was supervised by Prof. Philip Hopkins from Caltech, in collaboration with Prof. Choi. David shared the Brackett Prize in Astronomy from our department with Melina Mastrodimos and Tatsu Monkman.

Jerry Martinez

Jerry is a physics major with a strong interest in engineering. He is currently looking for an entry engineering position. Jerry did summer research with Prof. Tanenbaum here at Pomona, as well as in Louisiana. He also worked for our outreach program for high school teachers. Jerry participated in the HMC Engineering Clinic program and was a residence hall advisor for two years. His thesis, “Automotive Radar Systems: Status and Future Developments”, was supervised by Prof. Hudgings.

Melina Mastrodimos

Melina is a physics major in the astronomy program. She will be entering the MD/PhD. program at UCLA this Fall. Melina switched to Physics from Neuroscience/Chem, and took an unconventional path through the major. Her research was primarily at UCSD prior to transferring to Pomona College. Her thesis, “Delineating the Evolution of Organic Molecular Synthesis”, was primarily supervised by Prof. Choi. Melina shared the Brackett Prize in Astronomy from our department with David Khatami and Tatsu Monkman.

Madeline McGaughey

Madeline is a physics major who is pursuing a post-bac fellowship for public health data analysis at Univ. of Washington. She spent one semester doing study abroad at CERN, and did summer research with Prof. Tanenbaum. She served as a department liaison, and worked as a TA, grader, and mentor, for our department. Madeline participated in the HMC Engineering Clinic program and has been an active member and leader of our group, Awesome Ladies in Physics and Astronomy (ALPhA). Her thesis, "A Review of the Development and Current Status of Quantum Key Distribution", was primarily supervised by Prof. Kwok. Madeline shared the Edmunds Physics Prize from our department with Andy Biekert and Scott Tan.

Tatsu Monkman

Tatsu is a physics major in the astrophysics program who will be going to Japan in the JET program to teach English for the coming year. Tatsu spent summers doing astrophysics research with Prof. Zook, and with scientists at Carnegie Observatories. Tatsu worked as a grader and as a TA for the department. His thesis, "Mapping the Galactic Orbit of an Extremely Low Metallicity Star", was supervised by Dr. Josh Simon from Carnegie Observatories, in collaboration with Prof. Choi. Tatsu shared the Brackett Prize in Astronomy from our department with Melina Mastrodimos and David Khatami.

Vicente Robles

Vicente is a physics major with a strong interest in engineering who will be entering the Master's Engineering program at UC Riverside this fall. Vicente did summer research with Prof. Zook here at Pomona, as well as at Univ. of Illinois and UC Riverside. He also worked for our department managing 3D printers and served as a department liaison, and worked as a TA and grader in the department. Vicente participated in the HMC Engineering Clinic program. His thesis, "Exploring the Dynamics of Optical Thermocavitation Bubbles Using Planar Laser-Induced Fluorescence", was primarily supervised by Prof. Whitaker.

David Sharfi

David is a physics major who is planning to work and take UCLA extension courses after some time off to consider his future. David came to physics after starting in the chemistry major and did summer research with Prof. Mawhorter, including trips to Germany and Arizona to work with collaborators. He worked as a TA, and mentor, for our department. His thesis, "Designing Implementing and Teststing a Lesson Plan for Static Equilibrium in Introductory Mechanics", was supervised by Prof. Tanenbaum and included teaching material in both the Physics 71 and 41 courses.

Scott Tan

Scott is a physics major who will enter the Mechanical Engineering graduate program at MIT this fall with a prestigious NSF fellowship. Scott did summer research at both Univ. of Arizona and MIT, working in materials science. He also spent his junior year at Oxford University where he also did research. Scott was a varsity football player, worked as a TA for our department, and participated in the HMC

Engineering Clinic program. His thesis, "Signatures of the Soft Phonon in Impedance Spectroscopy of Barium Titanate Nanoparticle Colloidal Solutions", was supervised by Profs. Hudgings and Krahn at Pomona and Prof. Haskell from HMC. Scott shared the Edmunds Physics Prize from our department with Madeline McGaughey and Andy Biekert. Scott received a national SACNAS award and an ARCS scholarship as well as the Stauffer Prize awarded to a student of exceptional academic achievement in the sciences at Pomona College.

Carson Witte

Carson is a physics major with a strong interest in engineering who will be moving to New York to work in the energy sector. He did summer research for with Prof. Mawhorter here at Pomona, as well as in Germany. He worked as a TA in the department, and was active on the soccer team at Pomona. Carson did a study abroad in Lyon, France and participated in the HMC Engineering Clinic program. His thesis, "Diatomic Molecular Spectroscopy of Potassium Iodide", was supervised by Prof. Mawhorter.

Our class of 2016 was diverse in both backgrounds and interests. In addition this class includes Chanud Yasanayake who has completed year 4 of the Caltech 3-2 engineering program and Reid Callen (computer science) who completed the minor in physics.

Physics and Astronomy Faculty and Staff

The Physics and Astronomy department has a wonderful team of talented hardworking personnel. Faculty routinely go above and beyond their job descriptions to support students and the college. Staff help turn a wide range of ideas into a smoothly operating reality. We were fortunate to be able to hire Loredana Vetere, Elijah Quetin, and Graham Krahn as full time visiting faculty, and Hillary Smith, Elias Penilla (Po '06), and John Koulakis (Po '06) as part time visiting faculty in the department this year. We are pleased to retain Profs. Vetere and Quetin for the coming year and were excited for Prof. Krahn to land a tenure track position even though we will miss his many contributions.

Glenn Flohr, Anthony Grigsby, David Haley, and Natalie Hughes all made numerous contributions this year, which was our first in the new Millikan and Andrew buildings. Our staff worked incredibly hard to move us into the new spaces and work out all the small details that needed to be adjusted. We had fantastic support from Brian Faber who was our project manager for the building.

Our regular faculty continue to be active well beyond their classroom teaching. Each submits a detailed professional activities report at the end of the calendar year. However, a few notable highlights are provided here as well.

While we will miss Prof. Penprase, we look forward to our search to bring a new tenure track faculty member into the department to support our Astronomy Program which is arguably one of the best in the country in terms of access to facilities and research opportunities for undergraduates. These facilities have grown substantially in their sophistication over the past decade and as an example the new Planetarium was used for over 1000 guests this year with more than thirty shows for various groups. However these new facilities require staff support for operating, maintaining, and training of new users. Most Planetariums have a full time director with staff. Our telescopes get mechanical and electronic support from our staff, but would benefit from a staff member with expertise in Astronomy as well. Once upon a time we had a postdoc who helped support the Astronomy program. Our regular staff are still fully occupied and cannot expand to cover all these things.

Philip Choi is grateful for the collaboration and support of two visiting Professors Loredana Vetere and Elijah Quetin this year that has led to an astronomy program that has never been healthier or more robust. We have seen record enrollments up and down the curriculum; we have an unprecedented number of students actively engaging in both summer and academic year research; and we have expanded our outreach efforts by an order of magnitude, primarily due to the planetarium leadership of Professor Vetere and strong student participants.

Since the integration of the Pomona Adaptive Optics instrument (KAPAO) at JPL Table Mountain Observatory (TMO), Professor Choi has continued working with students (Allison Ho '18 & Sarah Hale '18) on the development of multiple on-sky AO observing programs. Beyond KAPAO, Professor Choi, along with a large team of student researchers has fully ramped up the observational program at TMO to search for ultra-faint near-earth asteroids. That project, which began last year as an exploratory project with JPL has fully flourished with a dozen undergraduate majors serving as the lead observers on the project.

This summer alone we have obtained over 250 hours of on-sky observation and should hit the 400 hour mark by the end of the summer. Based on the success of our TMO observing program, we are planning a major JPL-funded instrument upgrade for September 2016 that should improve our instrument efficiency by a factor of four.

Janice Hudgings continues to be an enthusiastic and committed teacher. She enjoyed teaching Modern Physics and the Senior Seminar in the fall, and Electronics with lab in the spring. Notably, she partnered with the Draper Center to develop a community partnership between her electronics course and the Femineers at the Fremont Academy for Engineering and Design, an underserved public school in Pomona. Janice continues to engage actively with the scholarship of teaching as well, attending the winter meeting of the American

Association of Physics Teachers and a weeklong workshop on Scientific Teaching, sponsored by the National Academy and HHMI, in the spring.

In addition, Janice is deeply committed to broadening participation in STEM fields, to which end she attended talks and workshops on diversity and inclusion throughout the semester and experimented with a number of interventions in her classes, one of which is the subject of a forthcoming essay. Janice also partnered with Dean Lozano and two of our mathematics colleagues to submit an NSF S-STEM grant aimed at expanding our Pomona Scholars in Math cohort program across the physical sciences.

On the research front, Janice successfully restarted her research program, after a multi-year hiatus in administration. She is enjoying the opportunity both to build on prior work and also to explore new directions, including most notably a neuroscience collaboration with Professors Parfitt and Stranford. Janice worked with eight undergraduate research students in her lab during the course of the academic year and summer, including specifically reaching out to women and members of underrepresented groups. Three of her students will be presenting their work at the Frontiers in Optics / Laser Science conference in Rochester, NY this fall.

Alfred Kwok has mainly been responsible for teaching Physics 42 (the second semester of the introductory course for chemistry and biological sciences students) since its inception in Fall 2009. He used to cover Brownian motion and its applications in Molecular and Organismal Biology only in Physics 150, the upper level Biological Physics course. However, when he attended an AAPT (American Association for Physics Teachers) meeting in March 2014, Alfred learned that a new the IPLS (Introductory Physics for Life Science) community has been incorporating Brownian motion into IPLS courses in the past few years. Therefore, when he returned from sabbatical in Fall 2015, Alfred spent the first week of Physics 42 on Brownian motion. In addition, Alfred worked with the visiting instructor in charge of Physics 42 lab to introduce a laboratory related to Brownian motion (that was only done in Physics 101 previously) to Physics 42 lab. Alfred used to teach all the sixty to seventy-five Physics 42 students in one large lecture section. When he taught the course in two smaller sections in Fall 2015 in the new Millikan classroom that is designed for group activities, he found that the students were more eager to engage with one another in the in-class exercises.

In Spring 2016, Alfred taught Physics 174 (Contemporary Experimental Physics) and Physics 175 (Statistical Mechanics). We had been teaching Physics 174 in a "distributed model" where each faculty member in the department runs an experiment or two for the course that is related to her/his expertise. Since three members of the department will be on sabbatical in Spring 2017, Alfred used the Spring 2016 Physics 174 course as a platform to

start developing three experiments that are not as tied to a particular faculty member's experimental expertise. This will enable a larger number of faculty members to be able to use these experiments when they teach the course.

Richard Mawhorter best sums up 2015-16 as having a wide spectrum of active student engagement. In Physics 170 *Quantum Mechanics*, the success of the tutorial method showed in outstanding student final presentations on a wide variety of topics. Physics 101 *Atomic & Nuclear Physics* was the largest this class has been in my 27 years at Pomona, and while Prof. Hudgings deserves the lion's share of the credit for one of the best subsequent retention ratios in recent memory, my laboratory sections aided this with a multiple-week study of cosmic ray muons up at Mount Baldy and on campus as well as a San Diego field trip to a fusion energy research facility. And although I was on sabbatical this spring, I continued weekly meetings with a total of 6 Pomona students, in the process supervising 2 completed senior theses and contributing to a successful NSF Graduate Fellowship proposal.

My research concerns the detailed study of exotic diatomic molecules used to investigate the fundamental phenomenon of handedness in nature, i.e. parity violation. In this pursuit I am proud to have facilitated significant student interaction with 7 outside senior scientists from Caltech, JPL, Arizona State (ASU), Stony Brook, Yale, University of New Brunswick, and Leibniz Universität in Hannover, Germany, including trips with students to Caltech, JPL (twice), ASU (thrice), and Stony Brook. Last summer I took 3 students to Hannover and another 2 this summer. These 5 join 8 previous Pomona students who have taken publishable data with me there. Indeed, three undergraduates are co-authors on my three 2015-16 publications (in *Physical Review A* on lead fluoride PbF, in *Molecular Physics* on ytterbium fluoride YbF, and in *Journal of Molecular Spectroscopy* on tantalum nitride TaN), and two Pomona students presented our work at an international conference last summer. Other sabbatical activities included hosting as well as a second visit to my Stony Brook colleague, giving research talks at ASU and UCLA and a poster presentation at a national APS meeting, as well as forging some new connections with physicists at UCSB.

Thomas Moore has been very busy continuing his work on research pedagogy and its applications to both the *Six Ideas that Shaped Physics* textbook series and his *General Relativity Workbook*. New editions came out this year and were implemented in courses both at Pomona and many other institutions. He has been developing the new websites and ancillary materials including solution guides, self-study guides, software programs, etc. that support the books. He is working on a new computer program that is designed to teach students expert-like problem solving styles by guiding them through a series of processes and recording their progress as they go. He submitted a grant proposal to enhance this program to the Spencer Foundation this year. In a similar vein he designed a new software package to help solve the Einstein equation of general relativity and published that package

on his website as well as a paper "Using Worksheets to Solve the Einstein Equation" in the *American Journal of Physics*, (84, 360) published in May 2016. On June 6, 2016, he gave an invited presentation at the Gordon Research Conference entitled "Making Einstein personal: How to help undergraduates "own" general relativity."

In the Fall Tom taught a successful new IDI course and the popular upper division General Relativity elective course. He has been on sabbatical in Spring 16. Tom gave a presentation at the national AAPT winter meeting "Climate Change in the Introductory Course" on January 11, 2016. As a local expert on gravity wave detection, he gave talks at both Pomona College and Cal State San Marcos on "Hearing the Universe: What's Exciting About the Detection of Gravitational Waves." Tom was formally appointed to the AJP Editorial Advisory Board on January 1, 2016, and has actually informally served in that capacity since last August. In the process, he has given editorial advice and formally reviewed multiple papers for this premiere journal in Physics education.

Bryan Penprase has resigned from his full time position at Pomona College to become a permanent member of the new Yale NUS program which he has been developing for the past five years. Bryan is maintaining a connection with Pomona as a summer visitor working on collaborative grants with Caltech.

David Tanenbaum completed his 5th year as department chair with the completion of Andrew and Millikan buildings, including both the new microscopy center and the outdoor physics laboratory which have been used extensively both for our students, but also for large numbers of outreach programs and events. David took a hands on role in establishing procedures and training for our new facilities. He also led the department through its self study and external review process covering the last 12 years, and along with Philip Choi worked to prepare an FPC petition for the replacement of Bryan Penprase following his resignation in December of 2015. David taught Physics 70 labs in the fall and Physics 71/72 courses in the spring. He also supervised 3 senior theses including one Scripps student.

David continues to have active research in organic photovoltaics (plastic solar cells), graphene, and electron beam lithographic processing. He gave an oral presentation at the IEEE 42nd Photovoltaics Specialists Conference in New Orleans in June 2015 and has one new paper published this year, "Comparative Indoor and Outdoor Degradation of Organic Photovoltaic Cells via Inter-laboratory Collaboration" in *Polymers Special Issue on Organic Photovoltaics*, December 2015. The paper is based on the theses of Charles Owens (Po '14) and Gretta Mae Ferguson (Po '13) and the work of several international collaborators but performed here at Pomona College largely on the rooftop solar laboratory at Pomona Hall. There were three students working with David in the lab in summers 15 and 16, and a few more during the academic year.

David submitted a Fulbright Proposal to Spain where he will be visiting Institut Català de la Nanociència i la Nanotecnologia (ICN²) on the campus of the Universitat Autònoma Barcelona in AY 2016-17.

Dwight Whitaker spent the past year as the interim co-director of the Sontag Center for Collaborative Creativity (aka the Hive), in addition to his usual role in our department. Dwight was part of the initial steering committees that helped create the Hive in 2014-2015 and with co-director Pat Little helped launch the center this past academic year. With the arrival of the \$25 gift from the Sontag family last fall the center is now expanding its space in Seeley G. Mudd library and welcoming a full time staff. For his biophysics research Dwight presented his work on *Ruellia ciliatiflora* seeds with Sophie Zagerman '18 at the annual conference for the Society of Integrative and Organismal Biology in Portland, OR. Dwight also published a paper with Jonathan Wright (Pomona Biology), Anna Ahn (HMC biology), Maria Young (PO '16) and Yonni Rubin (PZ '15) on the dynamics of a running mite. ["Exceptional running and turning performance in a mite." *Journal of Experimental Biology* 219: 676-685]. This year Dwight will be spending his sabbatical in his lab in Millikan building out his new tow tank for studying the aerodynamics of seed and spore dispersal.

Alma Zook spent fall 2015 on sabbatical working with the Table Mountain Observatory and doing preparation for Physics 142, and practicing music and playing in recitals and orchestra concerts.

In the spring she taught Physics 125 and Physics 142. Physics 125 in a mostly-lecture format, but replacing some lectures with in-class problems and activities. At the beginning of the semester, not quite every other week, the students were given three or four problems from the textbook and worked the problems in small groups with guidance. About a month into the semester, worksheets were added students were assigned a single problem for everyone and given more guidance on the route to the solution as the course material became more difficult. At the end of the semester, students reported that they found the worksheets the most helpful. Physics 142 had eight students this year, pushing the limit for giving it in tutorial format. This course was very successful in its third iteration.

This summer, Prof. Zook is working with a SURP student, Angela Twum '18, who worked with her last summer as well. The new polarimeter is installed on the telescope at TMO and they are currently observing several standard stars (with known polarizations) to test the instrument before going back to monitoring blazars. In addition to the polarimetry project, Angela has been observing with the JPL near-earth asteroid monitoring project to give her experience with a different type of astronomical observations. Angela has just submitted an application to present her work this summer at the annual SACNAS conference which will be held in Long Beach in October 2016.

Physics and Astronomy Facilities

The newly re-constructed Millikan and Andrew buildings include state of the art facilities for teaching and research, as well as a fully digital planetarium, machine shops, an electronics shop, a microscopy center, extensive laboratories and student project space, physics outdoor laboratory courtyard and more. In addition, the department maintains two astronomical observatories, one on-campus and one at the JPL Table Mountain Facility about 45 minutes from campus. Facilities are used not only by members of the department, but also available to others within the both Pomona College and the Claremont College Consortium. The Pomona College Physics and Astronomy Department features some of the most advanced research-grade equipment in physics and astronomy for any undergraduate college.

Our faculty and staff were busy this year installing new systems in our buildings, particularly for the new shops, the new planetarium, and laboratories. Each new system requires accessories, training, and complex installation. Many require learning new software packages as well. This year we greatly expanded our 3D printing facilities and now regularly print parts not only for physics research, but for outreach, and as a service to other departments. Our staff have been phenomenal working with facilities, and the contractors. The outdoor physics laboratory features a series of interactive experiences where a student becomes an integral piece of the experiment, not simply an observer of the experiment. These whole body experiences internalize fundamental physics concepts without abstraction, build physical intuition, and emphasize the reality of forces, reference frames, torque, balance, and other key concepts. We have been making major upgrades on the 1 meter telescope facility at Table Mountain Observatory. We have made upgrades to the Microscopy Facilities as well, now having Scanning Electron Microscopy, Optical Microscopy, Raman Microscopy, and Atomic Force Microscopy all housed together in a centralized facility. The new Planetarium has been running shows for events and employed in Astronomy classes. It continues to be upgraded with our guidance by the manufacturer. Our facilities have been used by well over a thousand people this year, and have become popular for a wide range of events that are not specifically associated with Physics, Astronomy, or Mathematics.

Grants and Fundraising Efforts

Our department has continued working with the Advancement Office in efforts to help raise support for the new Millikan Laboratory. We provide tours, suggestions of foundations and donors, data and concepts to highlight why this is a compelling project. We were thrilled this year to support our second group of Sontag Physics SURP students using endowment funds from a major grant from the Sontag Family to the Department of Physics and

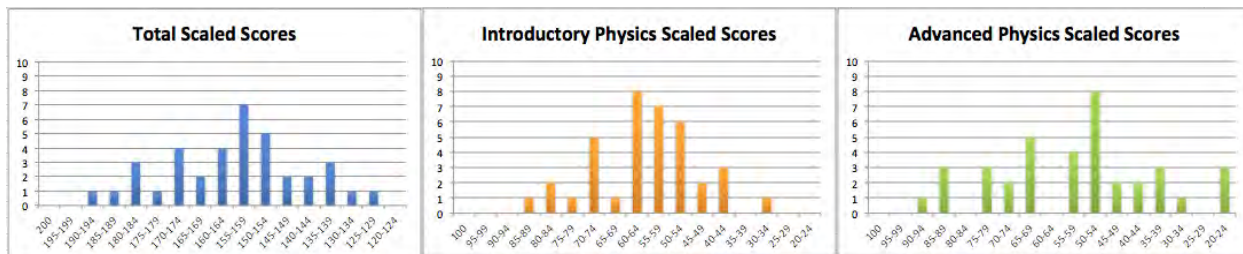
Astronomy. Income from this endowment grant supported 9 students working on research in the department starting in the summer of 2016.

Student Learning Objectives and Curriculum Assessment

Our department continues to discuss our curriculum in light of our learning objectives, which include the following key elements:

- *Students will understand the important conceptual models used in the core subject areas of physics and demonstrate their ability to correctly draw logical conclusions from these models and use them to make accurate quantitative predictions in realistic situations.*
- *Students will understand a broad range of experimental and data-analysis techniques and demonstrate their ability to use these techniques in both designing and conducting scientific experiments and observations.*
- *Students will develop certain fabrication skills useful in the field, such as the ability to design and construct electronic circuits and other experimental devices.*
- *Students will demonstrate their ability to read, understand, and critically analyze the physical ideas presented in published textbooks and journal articles.*
- *Students will demonstrate their ability to present information clearly, logically, and critically, both orally and in writing.*
- *Students will demonstrate both understanding and the practical application of the ethical standards implicit in science, such as appropriate attribution of ideas, good record-keeping, and truthful presentation of data and conclusions.*
- *Students will be fully prepared for graduate study in physics or astronomy and/or careers in scientifically oriented jobs in the public or private sector.*

As part of the senior capstone exercise, all our seniors take a comprehensive exam. Originally this was an exam written by our faculty, but preparation for the exam seemed to interfere with students preparation for the GRE, and for many years the GRE was used in place of the locally generated exam. There were several reasons that this was not satisfactory, and now our department uses the Physics Mean Field Test for this purpose. The MFT has many advantages and we have participated for 3 years. We administer the exam, and get national normative data for evaluation of both individual students and our program. We have had 37 students take the exam over the past 3 years. The exam reports scaled total scores, introductory physics scores, and advanced physics scores. Histograms of our 37 seniors are shown below:



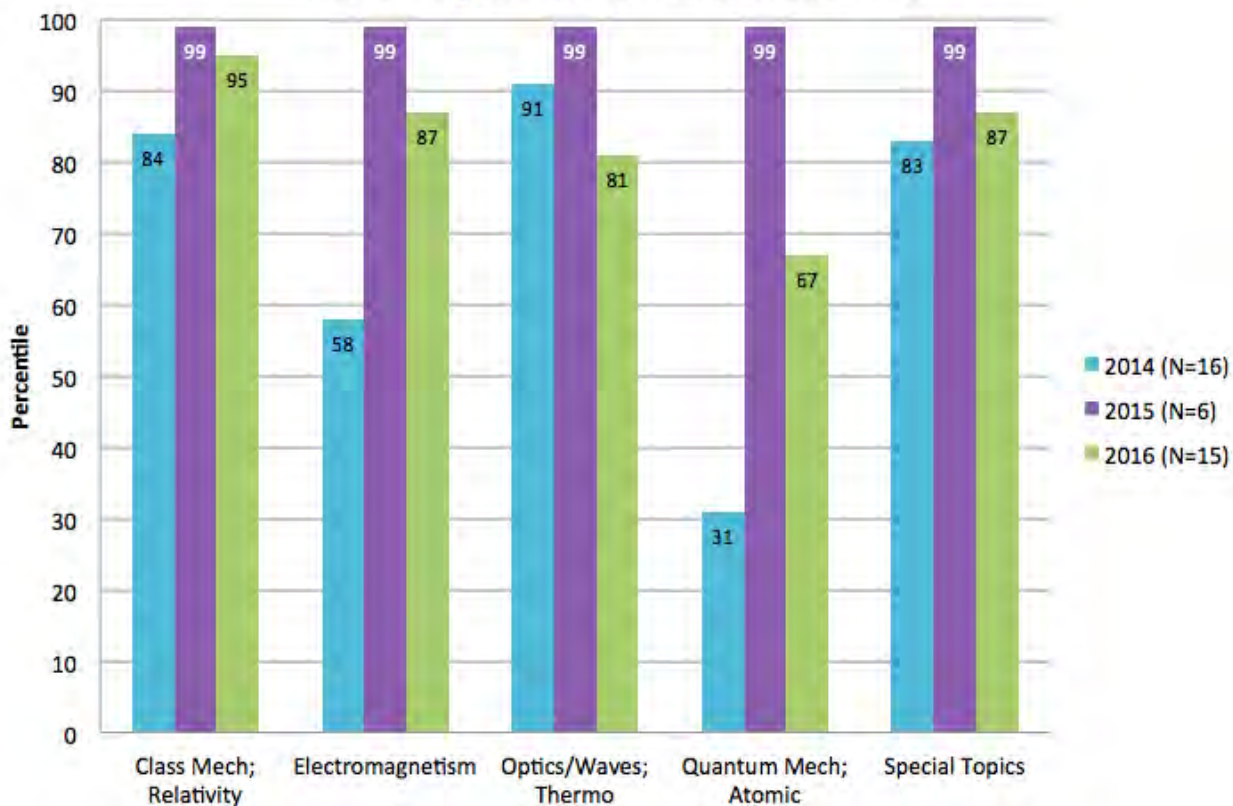
Using the 2015 MFT Comparative Data Guide for the MFT Physics, we can compare our programs average scores against the ~125 other institutions that are issuing the MFT to their seniors.

Pomona'14-'16/ National '15 MFT	Mean	Std. Dev.		Instit. Mean	Instit. Std. Dev.	Pomona's Percentile
Total Test Scaled Score	159/151	15/15		149	8	89
Intro. Physics	60/50	12/15		49	8	93
Advanced Physics	57/51	19/16		50	8	79

The percentile scores suggest that we are doing well, especially with the introductory physics material.

The MFT also provides feedback based on specific subject areas for institutions. This data for the three classes is shown in the chart below. It is clear that while the class of 2015 was very small, it was also very strong, scoring 99th percentile (the top institution) in each subject category. Including the larger classes, '14 and '16 we still perform quite well with 12/15 subject area rankings above 80th percentile compared to the other institutions that administered the tests.

Summary of Assessment Indicators



Other aspects of the senior exercise also received significant attention in the department. The senior seminar class was taught by Janice Hudgings and continued to provide an excellent entry to senior theses including literature reviews, timed oral presentations which are recorded and self-critiqued by the presenters, and drafting of introductory and background materials. The seminar helps students be successful beyond Pomona. A series of Alumni Panels and high profile guest speakers using Skype were combined with assignments where students research and speak with alumni continue to be very effective not only for our students, but also for our alumni relations. Discussions in senior seminar helped form conversations with the entire department about issues of inclusiveness, diversity, and pedagogical styles.

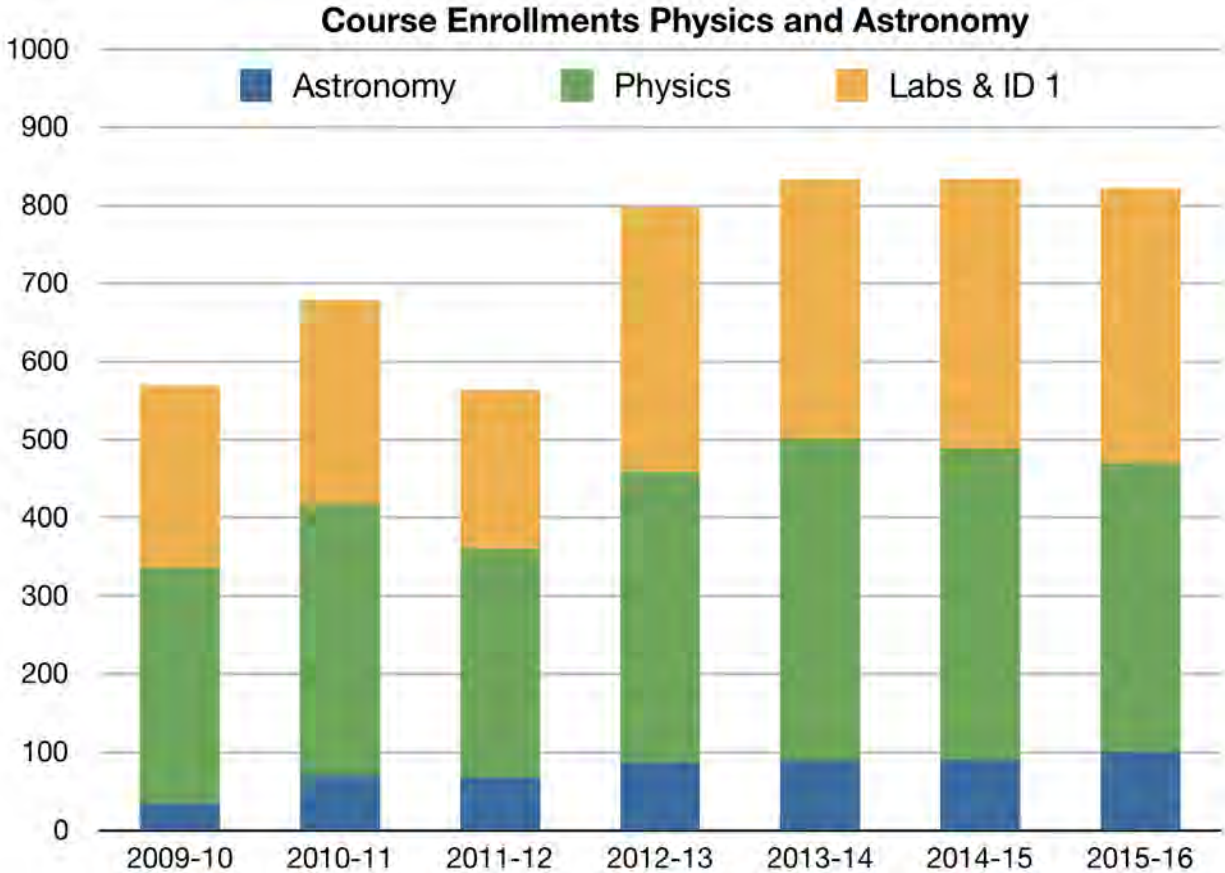
With a larger group of majors the Senior Theses processes was a challenge. We moved the engineering clinic students' theses into the Fall term, which generally was a success, but is still a topic we are exploring with our colleagues at HMC as well. Grant Yasanayake (father of our student Chanud) graciously offered our students a chance to take a course he offers in preparation for the *Fundamentals of Engineering* (FE) Exam which is part of the licensing of professional engineers.

We continue to use field trips and guest lecturers in many of our courses both for majors and non majors. Getting out of the routine classroom sessions can really stimulate students and make them appreciate what they have learned when hearing from someone who is not their regular professor. Getting beyond the classroom also works when students become the experts either in outreach programs or even in the online community. Prof. Hudgings turned electronics into a community partnership course, and Prof. Tanenbaum incorporated NanoDays directly into the course structure of Physics 72 this spring. Many of our students helped host our giant Grand Opening and Founder's Day party in October which included students, staff, alumni, and the local community. Students report great satisfaction teaching at a variety of off campus science outreach events, planetarium shows, and open houses.

Working with large numbers of visitors, we covered all our course needs in 2015-16, but did not introduce new courses. Beyond our department we continue to work with IDI, EA, STS, PPA, and colleagues in the natural sciences both at Pomona and at the other schools in the Claremont consortium. We enjoyed having colleagues join us in the new building and using our new facilities.

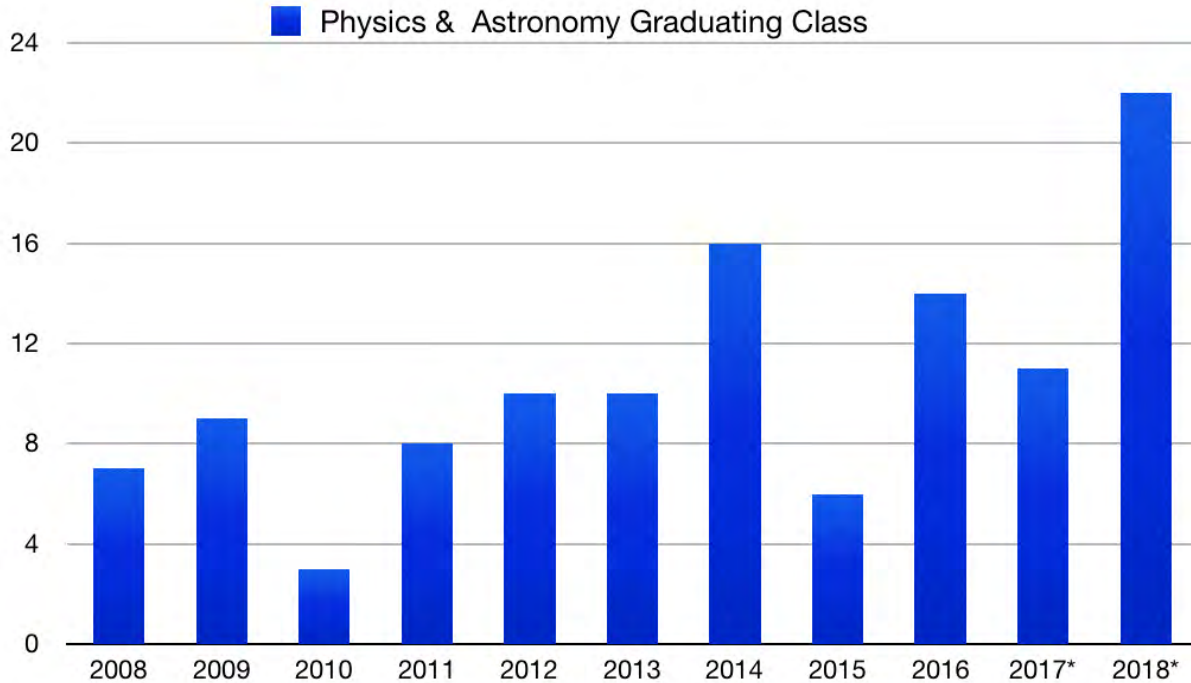
Trends in Enrollment and Majors

Enrollment trends in our department are presented below with total enrollments in Physics and Astronomy versus time. Physics enrollments (green) and Astronomy enrollments (blue) are both shown. The enrollments for lab sections and IDI sections (orange) which are substantial are shown as well. We see very high numbers continuing in 2015-16, almost exactly matching the data from previous three years. We see this is driven by enrollments in the General Physics courses, 41/42 and 70/71/72, an overall increase in Introductory Astronomy enrollments, and a huge sophomore class of majors. We greatly appreciate the support from the Dean's office and the Registrar staff based on pre-registration data and opening of hidden lab sections. We continue to split the students in Physics 40 and 70 courses into two sections rather than a single giant lecture. The enrollments in Astronomy show the value of keeping Visiting Prof. Vetere and Prof. Quetin as visitors as Prof. Penprase decided to take a permanent position at Yale-NUS.



Enrollment trends for each academic year from 2009-2016, including total physics and astronomy enrollments, showing total physics enrollments (green), astronomy enrollments (blue), and lab and ID 1 enrollments (orange). Data taken from the Registrar's spreadsheet (by multiplying course credit by course enrollment for each course, except for laboratories.)

Our total number of Physics majors as a function of their graduation year, based on completed majors (Spring 2008-2017) is shown in the blue bar graph below along with an expectations for 2017 and 2018 based on declared majors. This data shows fluctuations. It is hard to know what causes any given year to have a large or small group. Certainly many of our seniors were able to do research both here and with collaborators. We have systematically been enhancing the engineering options for our students as well. This class of 14 majors had three women and eleven men. Four pursued the Astrophysicists/Astronomy track. Our programs with the Carnegie Observatories have a major positive impact upon students with an interest in Astrophysics. Six of the members of the class enrolled in the Engineering Clinic program at Harvey Mudd College. The class was racially diverse with two hispanic students and three multi-racial students. We continue to work on diversity in the major not only in terms of racial and gender issues.



Number of Physics and Astronomy graduates since 2008, as a function of graduation year. This year's class was large, and we have a record, 22, declared majors scheduled to graduate in 2018.

Statistically our running 3 year average of 12 majors per year would be in the top 11% of Bachelor's-Only Physics departments in terms of production of Physics Bachelor's, independent of our total student body or FTEs according to the American Institute of Physics Nov. 2015 report, *Focus on Physics Bachelor's Degrees*.

Diversity in Physics and Astronomy

Our department continues to discuss both the diversity and overall enrollments extensively. We had a series of discussions inspired by students and alumni about enhancing the climate for under-represented groups in our department. We strive to make our department welcoming to students of all backgrounds. This year Loredana Vetere and Janice Hudgings made a proposal to host the regional conference on undergraduate women in physics at Pomona, and while not selected, we had very positive responses. Our students and our faculty were very active in the discussions of how our department, Pomona College, and the Claremont Colleges Consortium work with underrepresented students, both positively and negatively.

We encouraged all our female majors to attend the Western Regional Conference for Undergraduate Women in Physics held at UC San Diego, Jan 15-17, 2016 and four women students from our department attended that event with support from the college. Our home grown ALPhA organization (Awesome Ladies in Physics and Astronomy) has continued to host regular dinners and special events this year as well. We also have been encouraging our students participation in the local SACNAS chapter, and some of our students are taking leadership roles in that organization for the coming year. We sent three students to the National SACNAS conference in Washington DC, and Scott Tan ('16) won an award for best student research poster at the national conference. While we do our best to help all our students find interesting summer opportunities for research in physics, we are very pleased that many of our underrepresented students have had research opportunities both within our department and at R1 research universities across the globe. These summer research positions have a significant impact on students perceptions of their future in science. In addition, we have participated in the PAYS program, the HAP program, Posse programs, and other events hosted by Pomona College to support diversity in STEM education.

As a department, we are keenly aware of the imperative that we continue to improve in terms of diversifying both our faculty and the student population in our classrooms, and, more importantly, provide an assertively inclusive and welcoming environment in which all of our students can thrive. In particular, we recognize that in spite of our efforts to date, the percentages of women and of students of color in our department are no better than the national average in physics.

Physics and Astronomy Events

The Physics and Astronomy department has worked hard to create strong bonds between students, faculty, and staff. Weekly events include Physics and Astronomy Lunches, a Friday afternoon happy hour, and a joint Tuesday afternoon colloquium series with the Harvey Mudd Physics department. ALPhA dinners were bimonthly. Special events included:

- a Welcome back reception
- Physics Outdoor Laboratory development socials
- a Physics and Astronomy Awards Banquet
- Open Houses at Brackett Observatory
- a Physics and Astronomy Halona Retreat
- a *The Martian* Movie Night (in Theater)
- a *Star Wars* movie series in our auditorium
- a Physics Video Analysis Awards Luncheon
- trips to special Caltech and UCLA Colloquia

- a trip to Caltech to see *Boldly Go!* a *Star Trek* musical starring Erika Carlson (Po '15)
- a Physics and Astronomy Bowling Night
- a Spring Physics and Astronomy Department BBQ luncheon
- a Physics hike
- an Astronomy Mojave Trip
- the Annual Physics Festival
- a Physics and Astronomy Alumni Reception
- a Physics and Astronomy Senior Dinner
- a Physics and Astronomy Luncheon for families of graduates at the Tanenbaum home

In addition to these events for our students, our students, faculty, and staff hosted a wide range of outreach programs and events as service and engagement with our local community. We strongly believe in the mission of educational outreach and have a rich and long history of a wide variety of programs. Outreach not only serves the communities, but also serves our mission to cultivate in our own students a vision of how they can "... bear their added riches in trust for mankind." Students who collaborate with faculty and staff on outreach report extremely high satisfaction working together as educators. Faculty have been recognizing the value of outreach by building outreach components into alternative assignments in courses rather than purely an extra curricular opportunity. Typically such efforts are guided by faculty and staff but conducted with participation of our students. A brief list of several of this year's outreach programs follows:

- Pomona College CIPT Lab Lending Outreach Program (hundreds of high school students)
- NanoDays Outreach Series (hundreds of participants at 3 events, grades 4-12 ++)
- Brackett Observatory Open Houses (hundreds of participants of all ages at four events)
- New Digital Planetarium Shows (over a thousand visitors in groups of ~30 each time)
- Stork Elementary Science Night
- Claremont After School Program (CLASP) summer event
- Sycamore Elementary Science Fair and Outreach event (over a hundred K-6 students)
- PAYS program events with the Draper Center (high school students)

Future of the Department

Having completed our self study and external review, we have been thinking hard about what we do well, where we can improve, and how we can best serve our institution, its students, the local community, and the physics and astronomy community. We have an annual department retreat to help us focus on specific issues.

We are still working toward several future goals that we believe will enhance our programs and the college:

- *Bring outreach programs into the physics curriculum rather than outside it*
- *Create new interdisciplinary courses and curricula across departments including HMC engineering while balancing our limited teaching resources to offer our existing interdisciplinary offerings.*
- *Developing better support mechanisms for our students in academic issues*
- *Develop more regional ties to other scientific institutions*
- *Bring in new federal and private grants for both research programs and revision of courses*
- *Enhance staff support: - Longer term visitors, Outreach coordination, Astronomy facilities support*
- *Develop support for nationally recognized speakers similar to the Robbins Lectures in chemistry*
- *Continue to improve retention rates for under-represented students*
- *Continually strive for our physics curriculum to prepare students for top ranked graduate programs.*
- *Continue to enhance research opportunities for our students on and off campus though out the year.*