Radiations

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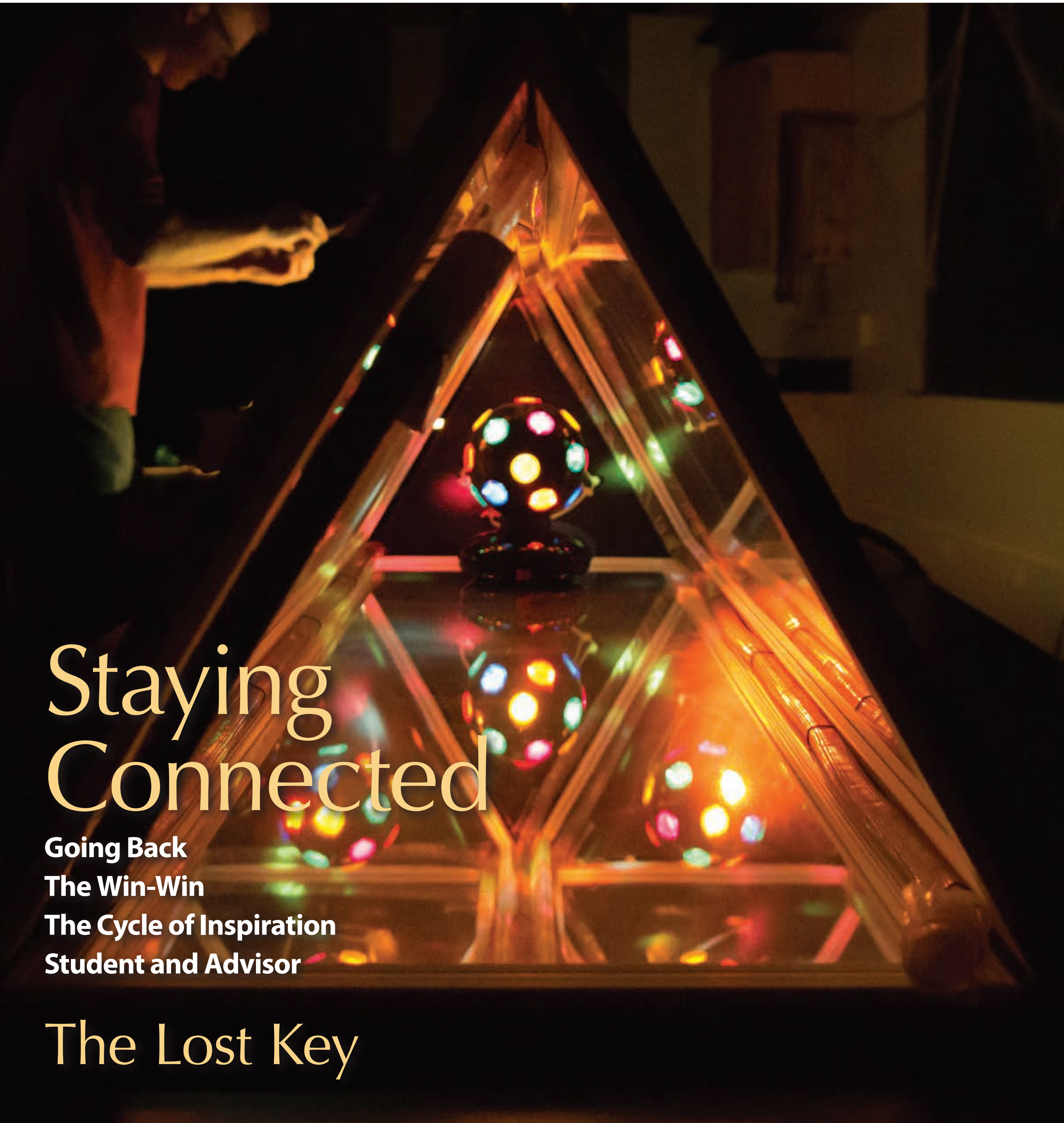

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Lights and mirrors set the eerie mood at a physics haunted house created by an SPS chapter at Luther College. See Erin Flater's story on p. 15 to learn more about the chapter. Photo courtesy of Luther Photo Bureau.

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Finding Historical Ties

by Toni Sauncy

I first heard the story of Sigma Pi Sigma's origins when I was inducted into the society as a student at Texas Tech University in Lubbock. I have retold the story countless times while presiding over induction ceremonies for my students and other students at campuses around the country. Telling the story puts the ceremony in context. It lets new inductees know that they are part of something bigger than their departments and campuses, something with strong historical ties.

The story starts with a handful of students who had a shared enthusiasm for physics. They founded the Sigma Pi Sigma fraternity in 1921 at Davidson College in North Carolina. Then, at a 1934 conference at Purdue University in Illinois, the founders realized that their fraternity should become a society. As a woman enthusiastic about physics, that part of the story holds personal significance for me.

Working in the Sigma Pi Sigma National Office has deepened my connection to that story. I have flipped through the national office's copies of the Sigma Pi Sigma "Red Books," the ledgers of member names. Every chapter has one Red Book. The habit of recording the name of every single inductee in those ledgers was started at the founding of the organization, and it continues today. But now the names are not penned as they once were but rather printed from a computer and affixed to the page. The full set of Red Books serves as a robust physics alumni list, a historical record of scholars who have excelled in physics and gone on to success in a wide variety of careers. The weighty volumes are shelved modestly—in numerical order by chapter—in a room full of outreach supplies where SPS summer interns turn innovative ideas into engaging activities for future physicists.

Visitors to the SPS National Office often ask if they can look for their names in the Red Books. The delight of locating a chapter record in the collection of over 550 books is superseded only by the joy that ensues when the seeking index finger of the curious visitor scrolls down the sometimes yellowed pages and successfully points to the name of its owner. The satisfaction felt at knowing that your name is counted within these volumes comes, I believe, from the verification that you are part of something bigger than yourself.

I have watched the historic films of Marsh White and seen the photos of the Davidson College inauguration of the society many times. I knew that the founders carefully designed the symbols associated with the honor society. But it

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The Director's Space

wasn't until the SPS National Office received a "lost" Sigma Pi Sigma key sent anonymously in the mail that I picked up the Davidson Red Book and let my own index finger do the perusing in the chapter record that started it all.[1] I was curious to know the names of the first few Sigma Pi Sigma members. I began with inductee number one, scrolled down, and slowly realized that all of the inductees were men. Of course. Davidson was originally an all-male school; the first class of women matriculated in 1973.[2]

Curious, I wondered, "Who was the first female inductee listed in the Davidson chapter record?" I let my finger continue to pass over the dusty pages until I found her. To my delight the name belonged to a woman I know: Beth Ann Thacker, a Texas physics colleague and professor at my alma mater, Texas Tech University. Wow! Those historical ties can surprise you.

In April it was my great pleasure to visit Davidson and meet the newest members of the oldest Sigma Pi Sigma chapter to return the "lost key." This ceremony at the original home of Sigma Pi Sigma provides a fitting centerpiece to this issue of *Radiations*, in which we look to the past with an eye on the future. I challenge our alumni to make new ties to nearby physics students. Provide those students with some context.

During a recent chapter visit, I spoke to a student about the importance of connecting with alums. The student said to me, "We need to see them and meet them and talk to them." Ties to physicists who have already walked the paths that students walk today cannot be replaced by videos or even written stories. Let students know in person that they are part of something bigger that extends beyond their classes. The value of forming relationships between alumni and students is immeasurable; such relationships can provide transformative experiences for both parties.

You, the alumni members of our society, can be the secure links between the new inductees joining today and the rich history of Sigma Pi Sigma. You can be the historical ties between the past and the future—or, for some of us, the historical bows.

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1 See p. 8 for the full story of the "lost key."
2 "Active and Benevolent Ladies: A Short History of Women at Davidson College," Davidson College Library, available online at http://library.davidson.edu/archives/women/.

Read more about Sigma Pi Sigma's history at www.sigmapisigma.org/history.htm.

Letters & Feedback

To: Dr. Toni Sauncy, Director, Sigma Pi Sigma

Just got my *Radiations* for Fall 2013, and was fascinated to read the abbreviated account of Worth Seagondollar's lecture to the Sigma Pi Sigma Congress in 2004. I had to read the whole transcript on your website, and was fascinated to learn things I had never heard before. Thank you for making the transcript available. (I look forward to reading each issue of *Radiations*, especially the "Elegant Connections in Physics" by Dr. Neuenschwander.)

I never met Dr. Seagondollar personally, but worked with colleagues at the Oak Ridge National Laboratory (ORNL) who knew him. I notice that at the end of the transcript, Chairman Jim Stith remarks, "And we hope that when we get this transcribed, you could take a look at it and tell us those things that you meant to say and those things that we still need to know." If you are interested, I offer some corrections and suggestions to the transcript for your consideration.

I am a long-time member of Sigma Pi Sigma, having joined at Emory University in 1961. My PhD in physics is from the University of Tennessee in Knoxville, and I worked at ORNL (in the Fusion Energy Division) for almost 30 years, retiring in 1994.

Richard Dyer

Editor's Note: *The corrections were made and a new version of the transcript is online at http://goo.gl/XNB0OY.*

Staying Connected

by William DeGraffenreid
Professor of Physics, California State University in Sacramento
President, Sigma Pi Sigma

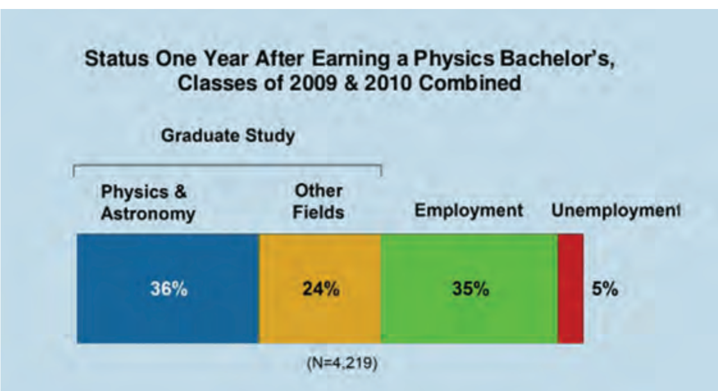
As I see it, members of Sigma Pi Sigma who share their own experiences with today's students provide outstanding opportunities both for their students, and for themselves.

As I approach the end of my 12th year as a faculty member at Sacramento State, I find myself with a relatively long mental list of students who have been through my classes, earned their degrees, and moved on to the next stages of their careers. It is always fun to get phone calls, e-mails, Facebook status updates, and even office visits from them. (While working on this letter, I was visited by a former student who now teaches at a local public high school.) One finds a remarkable diversity in what students do after graduating; some go to academia and to industry, while others take jobs in education or government or technical writing.

Given the diversity of careers that physics majors pursue, one could wonder what it is that they all have in common. What is it that leads them to these wide-flung places? Perhaps our physics students are remarkable because they have learned how to solve complex problems; I personally believe that this training is the most valuable service we provide in colleges and universities. Every profession values the ability to look at a complex issue, understand the interrelated factors that contribute to its knottiness, apply thoughtful approaches, and then explain possible solutions.

Most students entering physics programs do so thinking that they will become research scientists or professors. (Blame could be placed on the television show *The Big Bang Theory*, but this mindset existed well before the show.) Though many will enter such professions, many will not. The American Institute of Physics Statistical Research Center reported in 2012 that only about 60 percent of bachelor's degree recipients move into graduate school within a year of earning their degree, and many do so in fields other than physics. You can read the report, "Physics Bachelor's One Year Later," at http://goo.gl/2DZKt8.

As I see it, members of Sigma Pi Sigma who share their own experiences with today's students provide outstanding opportunities both for their students, and for themselves. In this issue of *Radiations*, we are showcasing alumni connections. If you are an alumnus, by taking a little time out of your day to visit a physics department or SPS / Sigma Pi Sigma chapter, give a talk, and share a meal with students, you can open doors to career possibilities they have never considered. And you might find students who can contribute to your laboratory, company, or organization—as interns, research assistants, or lab technicians, to list a few examples. And you will certainly find that you will feel good sharing your story with the next generation of physicists and physics-minded professionals, whatever career paths they ultimately choose. If you are a student, reach out to those who have gone before—they have much to share.



LEFT
Students with a bachelor's in physics contacted in the winters of 2009 and 2010, following the academic year in which they received their degree, shared their employment or graduate school experiences in the survey data shown here. Image courtesy of the AIP Statistical Research Center, www.aip.org/statistics.

The Milky Way galaxy over Mornington Peninsula, south of Melbourne, Australia. Photo by Alex Cherney.

The First Astronomers?

Cataloging Indigenous Australian stories of the night sky

by Cilla Norris and Ray Norris

In the remote community of Dhalinybuy (in Northeast Arnhem Land in the Northern Territory of Australia), we have been invited to meet some of the elders. As we approach, we see a group of men and children sitting on a mat surrounding an elderly man. His chest bears the proud scars of a fully initiated Yolngu man, and his bearing and charisma tell you that he is a leader of his people.

After we are invited to sit with them, the old man is introduced as "Mathulu." We are astonished. Mathulu Munyarryun? Famous ceremonial leader, custodian of ancient stories of the sky?

In our multiyear quest to understand the astronomy of the Yolngu people, we have often heard tales of Venus as the Morning Star. But when we ask people about the corresponding Evening Star, we are told to ask Mathulu, custodian of the "Evening Star story." At last, in this remote Yolngu community of Dhalinybuy, we meet him.

The First Astronomers?

There were once about 400 different aboriginal cultures in Australia. Each had its own language, stories, and beliefs, although most were centered on the idea that the world was created in "the Dreaming" of an ancestral spirit. The spirits left a user's guide to life in their songs and stories. Aboriginal people searching for meaning in the dark skies of ancient Australia noticed that particular stars were visible only at certain times of year, and so the night sky is naturally an important chapter of this guide.

The 50,000-year-old aboriginal cultures are believed to be the oldest continuous cultures in the world. Since the night sky seems to play such an important role for them, it is sometimes said that embedded in these these cultures are the earliest traces of astronomy. But astronomy is more than just stories—it also is a quest to understand the stars, as well as the motions and eclipses of the Sun, the Moon, and the planets. The goal of our research project is to understand the importance of astronomy in aboriginal cultures, and, ultimately, to answer the question, "Were the Australian aboriginal people the world's first astronomers?"

Tragically, many of the aboriginal cultures have been severely damaged, or even wiped out, since the arrival of Europeans. People like those in Arnhem Land have managed to keep their culture pretty well intact, and still conduct initiation ceremonies in which knowledge is passed on from one generation to the next. But in southeastern Australia, only the legacy of beautiful rock engravings and stone arrangements provide us with clues about cultures that do not exist anymore.

Much traditional aboriginal knowledge is sacred and can be given only to those who have been properly initiated. Naturally, we respect this and are careful not to intrude where we are not welcome. But aboriginal elders have encouraged us to learn a little of the knowledge and pass it on so that others may understand something of the richness and complexity of their culture.

Sun-Woman and Moon-Man

In almost all aboriginal cultures, the Moon is male and the Sun is female. The Yolngu people tell how Walu, the Sun-woman, lights a fire each morning, bringing us dawn. As she decorates herself with red ochre, some spills onto the clouds, creating a red sunrise.

The Yolngu people tell how Nglandi, the Moon-man, was originally a fat and lazy man (the full Moon), who demanded that his wives and sons feed him. When his sons refused to do so, he beat and killed them. When his wives found out, they attacked him with their axes, chopping bits out of him. As a result, he became thinner (the waning Moon) and tried to escape by following the Sun. But it was in vain, and he died of his injuries. After remaining dead for 3 days (the new Moon), he rose again, growing fat and round (the waxing Moon), until, after two weeks, his wives attacked him again. This cycle continues to this day.

Other Yolngu stories explain the association between the Moon and the tides. Sailors know that tides follow the Moon, and that the highest tides occur at full Moon and new Moon. Astronomers explain this in terms of the Moon's gravity. The traditional Yolngu explanation is that when the tides are high, water fills the Moon as it rises through the horizon, causing a full Moon. Later, when the Moon is only half full, the tides become lower. A week later, the water runs out of the Moon, raising the tides, leaving the Moon empty for three days. Although the explanations are a little different from our modern version, traditional aboriginal cultures contain a detailed account of the Moon's effects on the Earth.

Astronomers tell us that solar eclipses are caused when the Moon gets between the Sun and the Earth, blocking the Sun's light from reaching those of us on Earth. A lunar eclipse, on the other hand, happens when the Earth gets between the Sun and the Moon, casting the Earth's shadow on the Moon. Total lunar eclipses are quite common and come in clusters every few years. Solar eclipses, however, are rare. A total solar eclipse is visible in any one location only once every 370 years, on average, so most people living there will never see one. It is surprising, then, that aboriginal stories contain explanations of both solar and lunar eclipses. The people of Northwest Arnhem Land say a solar eclipse happens when the Sun-woman is hidden by the Moon-man as he makes love to her. On the other hand, a lunar eclipse occurs when the Moon-man is pursued and overtaken by the Sun-woman. The two stories demonstrate that traditional aboriginal people had already figured out that the Sun and Moon move on different paths across the sky, and that eclipses occur on those rare occasions when the two bodies meet at the intersection of their paths.

The stories of multiple observations of solar eclipses imply an amazing continuity of culture and learning over many generations, passed orally by individuals who probably would never see an actual eclipse in their lifetimes.

Morning Star and Evening Star

The silvery glow of Venus, the Morning Star, must be one of the most spectacular sights in the sky. It is extremely important to Yolngu people, who call her Banumbirr, and tell how in "the Dreaming" she came across the ocean from the east, from the Island of the Dead, Baralku. As she crossed the shoreline near Yirrkala, Banumbirr named and created the animals and places. The path that she followed is now traced by a "song line" which is still commemorated in Yolngu songs and ceremonies, and provides a navigational route across the Top End of Australia.

Unlike the planets Mars and Jupiter, which travel across the sky, the planet Venus is only seen close to the Sun, either as a Morning Star rising just before dawn, or as an Evening Star just after sunset. Modern

CONTINUED ON PAGE 27

The Lost Key

CONNECTING WORLDS, FROM 1923 TO 2014

by Elizabeth Hook, with contributions from Earl Blodgett, Daniel Golombek, and the Sigma Pi Sigma National Office

Figure 2

On Tuesday, April 2, 2012, the Sigma Pi Sigma National Office received a letter with no return address. Inside was a handwritten note (figure 1).

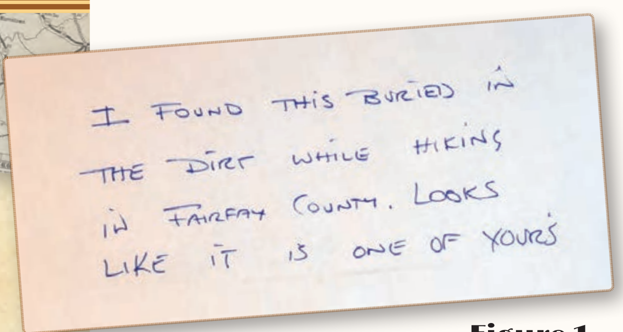
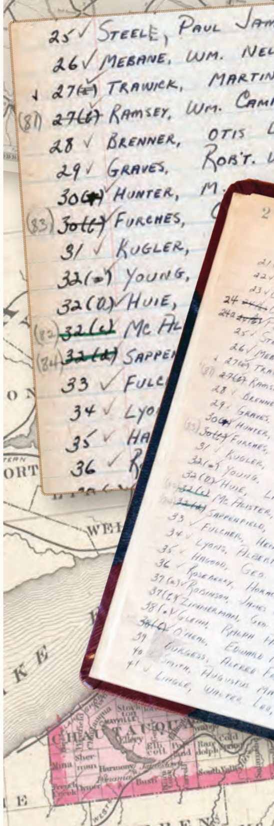


Figure 1

Taped to the piece of white paper was a Sigma Pi Sigma key (figure 2). But this important Sigma Pi Sigma insignia was clearly from the past. This key was old. It was not made from the same golden-colored alloy as the Sigma Pi Sigma insignia pins donned by new initiates. The metal was tarnished, and the sharp edges had been smoothed. The staff in the Sigma Pi Sigma National Office faced an interesting mystery. In an effort to discover the origin of the key and locate its owner, the text of the letter and a photo of the key were posted in the Sigma Pi Sigma and the Society of Physics Students social media channels.

Facebook and LinkedIn chatter prompted a search on eBay for Sigma Pi Sigma artifacts. The reports were that sometimes interesting historic Sigma Pi Sigma memorabilia could be found there, offered up for sale for interested collectors. We found this to be true. We found and purchased a photo showing attendees of the 1962 Sigma Pi Sigma Congress, an addition for our archive. Another key, similar to the one received, was also available for purchase. In the ad, the general description of the object included a note that the back of the key bore an engraved name and school. We purchased that key and hurried to remove the tape from our mystery key so that we could inspect its back.



Like the eBay key, our mystery key also had engraving (figure 3)! It read:

W M Mebane 26.

Figure 3

The "26" indicated one of two things: either W M Mebane was inducted in 1926, or his membership number was 26. In either case, the key certainly belonged to one of the first of the Sigma Pi Sigma members either at Davidson College (the first chapter) or Duke University (whose chapter was established in 1925). A quick look at the copy of the Davidson College Red Book[1] kept in the National Office revealed the following entry on its second page (see figure 4 for the full page):

26 MEBANE, WM. Nelson, Jr. ASST. PROF. MATH Dec. 17, 1923

Figure 5

The key anonymously mailed to us was most certainly the induction key given to the 26th member of Sigma Pi Sigma ever to be inducted. But who was William Nelson Mebane, Jr.?

Quips & Cranks

Davidson College's yearbook, entitled *Quips and Cranks*, is publicly available online, along with other institutional documentation. The 1924 issue of *Quips and Cranks* lists the appointment of Dr. Mebane as acting professor of physics the year before (figure 5). It is possible that this is an error in the publication, because the 1923 induction record lists him as an assistant professor of mathematics. (See the page from the "Red Book" record.) We discovered that Mebane's hometown was Dublin in Pulaski County, Virginia (some 265 miles southwest from where his Sigma Pi Sigma key was found). In 1918 he graduated from Davidson, where he played football and basketball. His entry as a member of the 1918 Senior Class (1918 *Quips and Cranks*, page 39) reflects on his love of physics: "If the celestial universe forgets to follow its orbit someday, just ask Mebane, and he'll find a law in physics for it."

Sigma Pi Sigma staff found contact information for a William Nelson Mebane IV and verified that he was likely a relative of Sigma Pi Sigma member number 26. An e-mail from him confirmed that he was the grandson of our key holder! The reply message provided a tantalizing clue about the career of William Mebane, Jr. His grandson wrote, "I knew him pretty well, but he died when I was young. I'm still using his tools and metal working equipment from the Manhattan Project!"

After sharing with Mr. Mebane that we had received his grandfather's Sigma Pi Sigma key in the mail and would love to return it, Mr. Mebane was kind enough to share more about his grandfather.

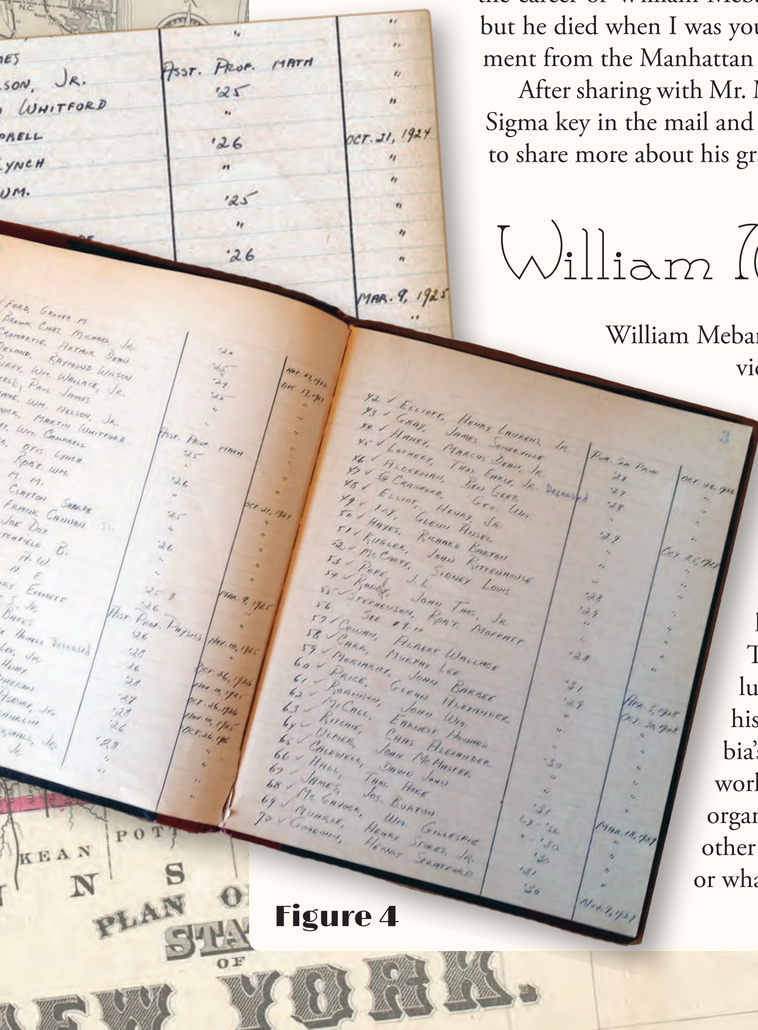


Figure 4

William Mebane, Jr.

William Mebane, Jr., was called into service from his position at Davidson College to work on a secret project in Manhattan. "During this time nobody really knew what he did, but, based on the mailing address of the lab in New York, we think he worked on part of the machinery for the detonating device on the atomic bomb—he probably didn't even know," his grandson commented. Davidson's 1945 *Quips and Cranks* lists him as associate professor of mathematics on leave. Could he have been at one of the labs as stated by his grandson? The archives of the Manhattan Project housed at Columbia University include a folder with documents with his name. Although the contents are restricted, Columbia's university archivist could confirm only that he did work for the National Defense Research Committee (the organization that managed the secret research that, among other projects, developed the atomic bomb), but not where or what he did. Mebane returned to Davidson after the war.

ABOVE
William Nelson Mebane, Jr., (left) is pictured with his father, son, and grandson. Photo courtesy of Bill Mebane.

Four Generations

It turns out that there are four generations of men named William Nelson Mebane, and all four attended Davidson College for various periods of time. William Nelson Mebane, Sr., returned to Davidson at the age of 98 to complete his degree. Science also seems to run in their blood. The afore-mentioned grandson, Bill Mebane, is a marine biologist who founded the Sustainable Aquaculture Initiative (SAI) at the Marine Biological Laboratory in Woods Hole, Massachusetts. The initiative promotes sustainable fish farming to feed families in Haiti.

Returning the Key

William Mebane's key returned to its alma mater when Sigma Pi Sigma Director Dr. Toni Sauncy presented it to the Davidson College chapter at its 2014 induction ceremony.

Both Mebane's key and the one purchased on eBay are fascinating pieces of Sigma Pi Sigma history and proof that history can emerge in the most unlikely places. Our past as an honor society is rich and full of stories and connections. Tied together by a common interest in physics, Sigma Pi Sigma's members are diverse and have contributed substantially to a wide variety of spheres. As we celebrate this induction season and welcome hundreds of new members into our society this spring, let us also remember and thank the many great individuals who have brought us to where we are today.

As the custodians of the society and its traditions, we at the Sigma Pi Sigma National Office are always eager to learn more about those individuals. We must express our gratitude to the anonymous sharp-eyed person who started this whodunit story by spotting the key and sending it to us! And to all our readers: if you happen to come across a piece of Sigma Pi Sigma's past, send us a note! You never know where it might lead . . .

BELOW
Dr. Sauncy (left) hands over the key to Grace Watt, the newest member of the Davidson College chapter. Photo courtesy of Mario Belloni.

Footnotes

[1]Each Sigma Pi Sigma chapter keeps a historic record of all its members in a book with red covers (the "Red Book"). Each new member signs the chapter book at the induction ceremony. The National Office keeps a copy of each Red Book in which staff members enter the information as submitted by the chapters.

CONTINUE THE INVESTIGATION!

See SAI's website.
http://www.mbl.edu/sai/

Peruse Davidson's Quips and Cranks.
http://goo.gl/qMxyjY

Going Back

Visit to alma mater strengthens ties

by Andrew Watson, Graduate Student, Temple University, Philadelphia, PA

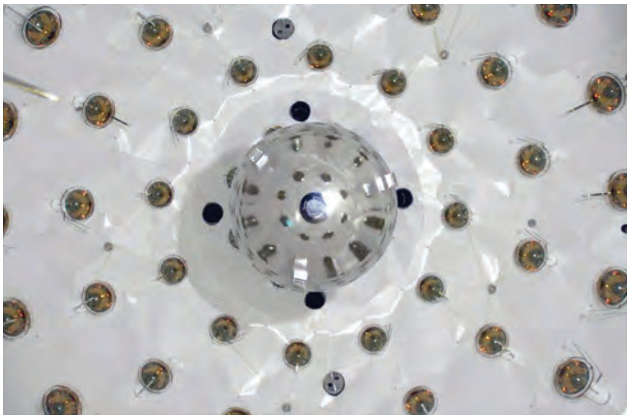
LEFT
Andrew Watson (right) is pictured with a student at Temple University. Photo courtesy of Andrew Watson.

If an event has free food, you should attend—this is something any student knows. So when my undergraduate alma mater invited me back to give a talk (and promised free food), I said yes.

During my time as an undergraduate student at Moravian College in Bethlehem, Pennsylvania, I was involved in the school's Society of Physics Students chapter. As a senior, I was elected president of SPS and Sigma Pi Sigma. The purpose of my recent return was to give a short, informal lecture on my experiences as a graduate student.

I am currently a graduate student at Temple University and a member of DarkSide (http://darkside.lngs.infn.it/), an international collaboration of universities and labs working together to detect hypothetical particles called weakly interacting massive particles, or WIMPs, that could solve the dark matter problem. When I gave the talk, I had not begun any intense research, so half of my presentation was about adjusting to grad school and half was about doing research and teaching in grad school. I also discussed the work that previous students in my lab accomplished on the WIMP problem.

Dark matter, as I told my undergraduate audience during my talk, is a form of matter that balances some equations of classical mechanics that describe how galaxies rotate.



ABOVE
The DarkSide experiment's spherical inner chamber, shown here, contains liquid argon, used to search for dark matter at the National Laboratory of Gran Sasso in Italy. Photo courtesy of LNGS.

To explain what is seen in the rotation curves and thus make the equations work out properly, most of the matter in the universe must be dark matter, i.e., stuff that does not emit light. This surprised some of the undergrads in the audience. They wanted clarification on why dark matter was necessary. They wanted to know what dark matter was made of. They wanted to know if there were any alternative theories that would make dark matter unnecessary.

I tried my best to answer their questions, impressed by their level of interest in the subject. The experience reminded me of lectures presented by SPS alumni while I was still in college—including the first time I learned about vortex lattices in superconductors—and bolstered my faith in the future of the physics department at Moravian, which is clearly still inhabited by inquisitive minds.

After I completed my bachelor's degree at Moravian, I was concerned about how my chapter would fare. Keeping a group of students interested in an academic organization such as SPS can be difficult. Moravian is a small liberal arts college; at times, some of the organizations I was involved in had so few members that you could count them on one hand. It was a fantastic feeling to return to my alma mater and find that things are going just as well—if not better—as when I left them.

Keeping in touch once you've graduated can be difficult, as you focus on new responsibilities and relationships. But it's worth it! It takes minimal effort to send an e-mail to your old SPS advisor asking how things are going. Professors like to know that their students are doing well postgraduation; after publishing a paper in *Physical Review D*, I made contact with a few of my former professors. It was nice to find out about the current construction going on to improve the natural sciences building at Moravian, to learn about how a recently retired professor was faring, and to keep in touch with the people who had nurtured and strengthened my interest in physics. I'll be sure to e-mail them again sometime soon, or maybe stop in for a visit when I'm in the area.

Of course, giving colloquia at your alma mater is also a fantastic way to see how the department is doing, catch up with your old professors, and check in on the students. In my experience, most universities welcome alumni speakers, but you just might have to take the first step. Who knows, you may even get some free pizza out of the deal!

The Win-Win

Connecting undergrads to research in your laboratory

by Jim Gaier, Research Physicist, NASA Glenn Research Center, Cleveland, OH

I came to the Society of Physics Students and Sigma Pi Sigma late in life. I was, after all, a chemistry major in college. But I also took lots of physics courses as an undergraduate (just one short of a major, really), and my work as a chemist has refused to stay neatly within traditional disciplines. My graduate studies in x-ray crystallography solidly straddled the line between chemistry and physics. To make matters worse, my research focused on determining the structures of biological molecules. After graduate school, NASA hired me as a research physicist to do chemical synthesis and characterization of intercalated graphite fibers. I then joined the chemistry faculty of Manchester College (now Manchester University) in North Manchester, Indiana. One spring soon after, I was invited to join Sigma Pi Sigma. This is when I started my relationship with SPS—late in life, as I mentioned earlier.

After accepting the position at Manchester, I continued to straddle lines by recruiting students from both the chemistry and physics departments to work with me on my research. One of the disadvantages of being a student at a small school such as Manchester is that opportunities and resources to try out research, particularly with expensive, state-of-the-art equipment, are often limited. One of the disadvantages of being a professional scientist at NASA is that we are often constrained by the availability of personnel, so utilizing students to help with NASA research seemed to be the perfect win-win. Indeed, it has been.

Nearly 10 years ago, when I left the faculty at Manchester and returned full time to NASA, I saw no reason why my relationships with students and faculty members at Manchester, the best part of my experiences at the university, should have to end. So I and Greg Clark, the Manchester physics department chair, remain in weekly contact, keeping each other appraised of opportunities at both institutions to collaborate. There have been many.

RIGHT Jim Gaier, research physicist at NASA Glenn Research Center, Cleveland, OH. Photo courtesy of NASA.

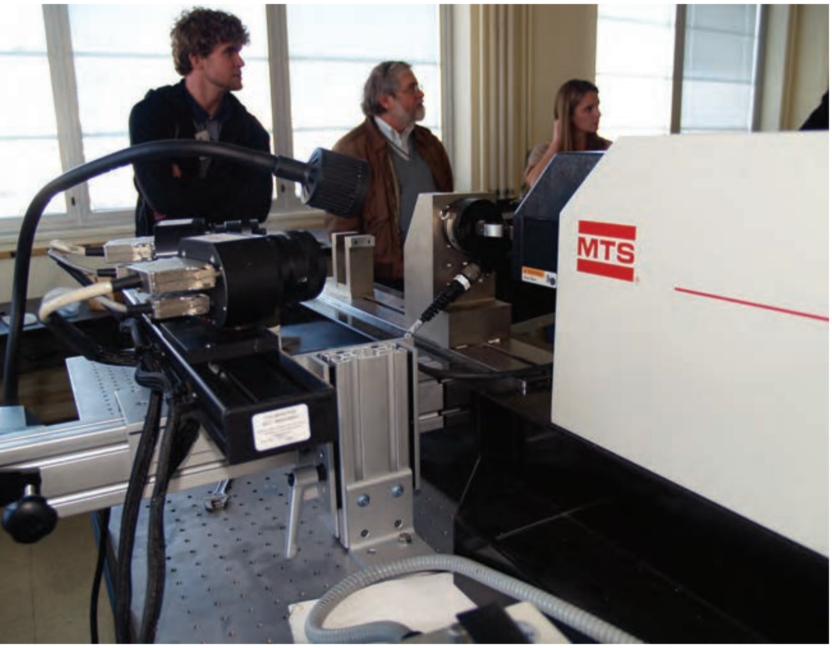
"Many of the ideas students bring are obviously crazy and may even violate physical laws, but they also may spark a new insight, or even an innovation."

For example, last year students and SPS members Alyssa Loos and Dylan Ford took advantage of Manchester University's January term, a month-long break from students' usual coursework, to do research in my lab for course credit. Alyssa set up a new Fourier transform infrared spectrophotometer (FT-IR), and then studied the degradation of white ortho-fabric samples that had covered large battery packs mounted on the International Space Station for nine years. She used not only the new FT-IR, but also a field emission scanning electron microscope (FESEM) equipped with an energy-dispersive x-ray spectrometer (EDS). This work paved the way for NASA and industry partner ILC Dover, based in Frederick, Maryland, to understand the space environment degradation mechanisms for spacesuit fabrics, which will inform the design of the next generation of spacesuits.

Dylan put together an apparatus to measure the diameter of tiny carbon nanotube yarns *in situ* while they were being tensile tested using a single-slit-like diffraction technique. This was required because, like any yarn, the material weave tightens up as it is pulled, so to determine the intrinsic ultimate tensile strength, the cross-sectional area must be well determined.

Other students, such as Kerry Rogers and Greg Robison, applied to and were accepted into NASA summer internship programs. Paid for their efforts, they leveraged their NASA work by using equipment at both NASA and Manchester. Kerry wrote a software algorithm to statistically sample microscopic locations on spacesuit fabrics in order to determine the amount of simulated lunar dust left on them after exposure and cleaning. He then looked for damage on other scales using not only NASA's FESEM/EDS, but also Manchester's atomic force microscope. Greg designed and built an apparatus to measure the electrical and thermal conductivity of carbon fiber epoxy composites *in vacuo* at NASA, and then characterized their gamma ray shielding ability at Manchester.

Stephen Berkebile worked both at NASA and Manchester, where he designed and built an instrument to map the two-dimensional electrical



LEFT
Gaier (middle) and intern Dylan Ford (left) set up their measurement apparatus on a tensile tester. Photo courtesy of Jim Gaier.

conductivity of symmetric and asymmetric woven carbon fiber composites. After graduate school, Stephen returned to NASA as a postdoctoral fellow. He measured the tendency of a synthetic volcanic glass that mimics the major component of lunar dust to adhere to metals and plastics found on spacecraft. He also completed a detailed design of a cosmic ray telescope to be used to characterize the effectiveness of new cosmic ray shielding materials for spacecraft. Whether effective cosmic ray shielding materials can be developed may ultimately determine whether human journeys to Mars and the outer planets are feasible.

I believe that research internships, preferably outside of an academic setting, are critical to the development of young scientists. I recall one of my first Manchester interns, after one of those intensely frustrating days that are so common in research, looking up at me and saying, "You really don't know the answer, do you?" She had been so accustomed in school to wrestling for an answer that the instructor already knew that she had missed the point of science—to develop new knowledge. This was a revelation that completely changed her view of science, and her role in it.

Students also revitalize a workplace's vitality, which can wane when the same team works on the same projects or slowly evolving projects. Our group at NASA brings in many interns during the summer; some years they nearly double our size. As they arrive you can feel the enthusiasm level rise. This is our most productive time of the year, not only because we have extra hands, but because we have extra minds with new ideas. Many of the ideas students bring are obviously crazy and may even violate physical laws, but they also may spark a new insight, or even an innovation.

In addition to hosting these and many other Manchester students over the past 20 years, I have also been invited back to Manchester to give several seminars to the science students, to deliver a convocation to the entire student body, and, twice, to be the keynote speaker at the year-end SPS banquet. Many of us in our work seldom get out and talk to nonspecialists about what exactly we do and why we do it. Framing our work such that its value can be glimpsed by college freshmen adds perspective, and getting an enthusiastic response affirms that our work is important. I believe that my ongoing involvement with the students and faculty of Manchester University has deepened and enriched their connections to the world of science. I know that our work together has deepened and enriched my life.

ABOVE
Lunar dust, the object of study for many of Gaier's interns, is notoriously sticky stuff; it turned astronaut Harrison Schmitt's space suit gray during the Apollo 17 mission (top) and penetrated the weave of Apollo 12 astronaut Alan Bean's suit (bottom). Photos courtesy of NASA.

The Cycle of Inspiration

Alum donor pays it forward

by Candice Fazar, Associate Professor of Physics, Roberts Wesleyan College, Rochester, NY

In the spring of 2012, a student in our Society of Physics Students chapter learned about the upcoming Quadrennial Physics Conference in Orlando, Florida, and during one of my lectures, proposed that the chapter attend the meeting. The majority of the students in the chapter had strong interest in going, even if they had to pay some of the costs themselves.

A simple calculation indicated that if everybody attended we were going to need more than $8,000 to cover all the costs. Fortunately, Roberts Wesleyan College (RWC) has a strong alumni network that supports the school and its students. As I considered how to raise the money, I thought of one particularly special alum: Neal Redmond, who graduated from RWC in 1978 and was inducted into the physics honor society the next year as a graduate student at Adelphi University in Garden City, New York. While working first for Lockheed Martin and subsequently for Science Applications International Corporation, Neal remained involved at RWC as a trustee and donor.

ABOVE
The RWC chapter at the 2012 PhysCon.
Photo courtesy of Candice Fazar.

When I first met him in 2006, Neal made it a point to let me know that physics at RWC is in his heart. I remember telling him that I would love to be able someday to give back to my alma mater in honor of my professors there, because I was so thankful for what they had given me. He told me that was the very reason he chose to give to RWC. Proud of the legacy left by his physics and engineering professors, Philip M. Ogden and Donald D. Kerlee, Neal created and endowed the Ogden and Kerlee Scholarships for physics and engineering students at RWC. He asked me to contact him if we needed any additional support.

When our SPS chapter started in 2009, we had an enthusiastic group of students and very little money. I funded a few initial get-togethers out of my own pocket so that the students could have pizza to go with their movie nights or Nerf gun wars. We also managed to attend an American Association of Physics Teachers conference in nearby Syracuse that year. Although we did not need much additional funding, Neal generously donated funds to cover lodging.

After that exciting start, though, the group became rather small and relatively inactive for a few years. Despite my repeated prompts, new members were not as interested in doing things as the inaugural group.

But our classroom discussion about the 2012 PhysCon excited them again. I reached out to Neal, and he donated more than $3,000 to cover my travel costs and the conference registration fees for each student. With this overly generous springboard, we were able to fundraise enough money for six students to attend with minimal out-of-pocket expense.

Attending PhysCon was an absolutely amazing experience, as any one of the students would tell you. Two students toured labs at NASA's Kennedy Space Center. Two other students presented their research. All enjoyed the talks and group events, which gave them a view of the greater community of physics students and a deeper appreciation for how to fit in. The trip breathed new life into the group and birthed within the students a sense of connection to the greater physics community. Last spring we started a Sigma Pi Sigma chapter to celebrate academic excellence and service, two values of our physics department. We decided that our Sigma Pi Sigma chapter was going to help our city school students in math and physics.

None of this would have happened without Neal's incredible support. We invited him to our inaugural Sigma Pi Sigma ceremony as an honored guest, along with professor Ogden, now retired. The ceremony brought together RWC students and alumni for the first time, and we inducted several alumni who had graduated before our Sigma Pi Sigma chapter was established.

We hope to continue the tradition of holding an induction ceremony and inviting Sigma Pi Sigma alumni to a catered dinner. Maintaining a connection between students and alumni is important, not just to encourage donations. Our students will someday become alumni themselves, and we want them to invest in a cycle of inspiration and encouragement that will continue from generation to generation at RWC.

Student and Advisor

Seeing Sigma Pi Sigma from both sides

by Erin E. Flater, Associate Professor of Physics, Luther College, Decorah, IA

I was inducted into Luther College's Sigma Pi Sigma chapter as a sophomore in April 1999. At the time I knew very little about the organization, but I knew it was an honor to be inducted. The ceremony was a joint awards ceremony for the physics, math, and computer science departments, and I clearly remember my professors and fellow students dressed up in suits-and-ties, which was very different from their normal attire.

Little did I know that a decade later I would be Luther College's advisor to Sigma Pi Sigma and SPS, working to promote community among the physics students, encourage SPS chapter members to delve into physics a bit more deeply outside of their classes, and mentor SPS chapter officers. Nowadays, we are much less formal about our Sigma Pi Sigma inductions, and the ceremony is no longer held jointly with other departments. Instead, we often hold our induction ceremonies at an SPS picnic, so the atmosphere is much more lighthearted than at the suit-and-tie ceremony in which I was inducted.

Our SPS has gone on road trips to local universities and to Fermi National Accelerator Laboratory. We watch episodes of *The Big Bang Theory* together and answer student-posed questions submitted to our "Ask a Physics Major" box. We design yearly physics-themed t-shirts and put on the annual "Haunted Physics Lab" for community members and their kids.

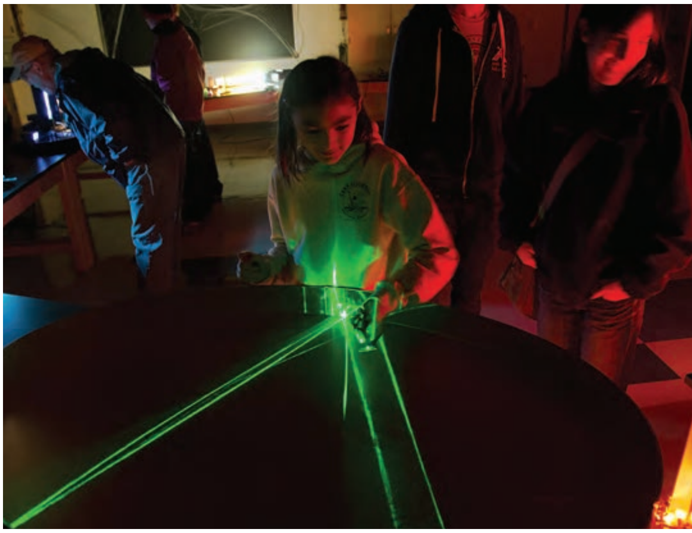
Our longest-running event has been our semiannual SPS Picnic, where physics faculty, staff, and students gather at a local park to grill and play games. It's a fun event for students to geek out and spend time together.

Community building is my favorite aspect of SPS and the Luther College Physics Department as a whole, a small department currently with five faculty members and 3–12 majors graduating each year. The department and SPS sponsor a number of events, including the semiannual SPS Picnic and the weekly Physics Tea. I love that these times allow students and faculty to just hang out together, eat donuts, drink coffee, and talk about anything from recent physics news to the latest viral video.

In our department the physics faculty members take turns as SPS and Sigma Pi Sigma advisor, and I've been happy to serve for the past 5 years. I am very proud of my students, and I hope that they feel it is a privilege to be a part of SPS and Sigma Pi Sigma, just like I did when I was a student.

ABOVE
Erin E. Flater. Photo courtesy of Luther College.

BELOW
The Luther College SPS chapter's annual "Haunted Physics Lab" thrills community members and their kids. Photo courtesy of Luther College Photo Bureau.



Spotlight on Hidden Physicists

Share your story at www.sigmapisigma.org

The Communicator

Ben Stein
Director, Inside Science,
American Institute of Physics, College Park, MD

Twenty-five years ago, I was, like you may have been once, a physics major and Society of Physics Students member. One of my favorite ways of taking a break during a study session at the science library was to go to the newspaper stacks, get the Tuesday *New York Times*, and read the latest science news. I know what you are thinking—what are newspaper stacks? There's no hiding the fact that news dissemination has changed dramatically since I was an undergraduate. Technology pushed the stacks aside, and, as a result, it's now easier than ever to keep up with the latest research advances.

I have been fortunate to be a part of this news evolution, ever since I traded in my college lab notebook for a reporter's notebook in grad school. Equipped with a bachelor's in physics and master's in science journalism, I began my career in science communication. Within a year I was working in the American Physical Society's newsroom at a major national physics meeting, helping to inform famous science correspondents about a new discovery concerning the afterglow of the big bang that would win the 2006 Nobel Prize in Physics. Between 2007 and 2011, I was the director of media relations at the National Institute of Standards and Technology in Gaithersburg, Maryland, where I got an inside look at physicists developing the latest quantum-computing technology and studying the behavior of ultracold gases unbelievably close to absolute zero. My physics background gave me the ability to understand and communicate these amazing scientific accomplishments to a wide audience, including my nonscientist family members.

To this day, my most treasured experience has been helping to create Inside Science, a nonprofit news service for the general public that covers research developments in all fields of science, technology, engineering, and mathematics. Produced at the American Institute of Physics in College Park, Maryland, Inside Science publishes news articles, videos, guest columns, and blog entries prepared in an accurate, engaging way and picked up by other news outlets. Visit Inside Science's website (www.insidescience.org) to watch students fire ping-pong balls faster than the speed of sound through solid aluminum, find out how the fascinating D-Wave quantum computer is raising new questions, learn how only eight percent of Usain Bolt's energy usage contributed to his world-record-setting performance, and read about one physicist's theory that our universe may be inside a black hole. I never knew a newspaper stack that could deliver all of that in one fell swoop, and it brings me enormous satisfaction to help spread the word about science.

Photo courtesy of AIP.

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The Origin of the Term "Hidden Physicist"

Everyone who earns a bachelor's degree in physics undergoes similar training, but only about one-third will ultimately have a job title that explicitly includes the term "physicist."

During the 1996 Sigma Pi Sigma Diamond Jubilee Congress, a title was created to identify this group within the physicist population: "explicit physicists."

The other two-thirds were dubbed the "hidden physicists," a term inspired by the hidden symmetries central to the physics of elementary particles and condensed matter systems.

"Hidden" behind other job titles and roles, these individuals nonetheless bring to the diverse professions they chose the skills and perspectives of the physicist. These persons may have overlain their physics backgrounds with new identities, but there is still a physicist inside of each of them, and their chosen professions are all the richer for it.

For more information about the genesis of this term, see* Radiations*, Spring 1996 and Spring 1997 issues.

The Filmmaker

Ian Harnarine
Adjunct Faculty, New York University

When I was an undergraduate at York University in Toronto, I did a lot of work with the high energy physics group. We were part of the international ZEUS Collaboration, which ran a large particle detector at the photon-proton collider at the Deutsches Elektronen-Synchrotron (DESY) in Hamburg, Germany. I helped to construct particle detectors and spent a summer at DESY. That experience changed my life. It was my first time "on my own," completely immersed in a foreign culture with a foreign language. It was also when I realized that I wanted to pursue graduate studies in physics, because the work I was doing was so awe inspiring. In addition to the experiments at DESY, I also did a research project analyzing images from the Hubble Space Telescope and the extrasolar planet hunter Kepler (then in its development phase).

ABOVE
Harnarine receives a Genie, Canada's Oscar. Photo by Elizabeth Harnarine.

In grad school at the University of Illinois at Chicago, I was part of the Phobos Collaboration, working on a high energy experiment based at the Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratory in Upton, New York. I worked in the tunnel and did data analysis that resulted in my thesis, "A Study of Pile-up in 200 GeV Au+Au Collisions at RHIC."

Ultimately, though, I lost my passion for doing research. Don't get me wrong. I still love physics and the pursuit of knowledge. But when I looked at my grad school friends and professors, I saw that they were really immersed; they could feel fulfilled by hours of solving equations and coding. I just didn't get as much satisfaction from that kind of work. What I did find fascinating and fulfilling was learning about the people I was working with. I loved hearing their stories and discovering what motivated them to do what they do. That's when it hit me. I was far more interested in the story of science and scientists than in the actual day-to-day work of being a scientist. I decided to become a filmmaker.

There is no doubt that my training in physics has a profound impact on me as a filmmaker. It taught me how to think in a disciplined, critical, and unbiased way. It also taught me how to look at a problem from different angles and try different approaches to solving it. When I find myself analyzing films and scripts, there are patterns that appear in every story. I've learned how to identify them, use them, and, ultimately, subvert them in my own work.

Like research, filmmaking is an incredibly collaborative effort involving many people. Knowing how to work with others to achieve a single goal is something I learned while being a part of physics collaborations. The ultimate goal is different, but the ins and outs of managing and connecting with people are very much the same.

I'm currently working on the movie *Time Traveler* with Spike Lee. It's the true story of Ronald Mallett, who teaches at the University of Connecticut and is trying to build the world's first time machine. The story is incredible and involves a lot of theoretical physics, but mostly it's a father-son story. To me, it's the perfect blend of science and heart.

ABOVE
Harnarine and actor Errol Sitahal discuss a scene in *Doubles with Slight Pepper*.

RIGHT
Harnarine and his film crew shoot near a market in Trinidad. Photos by Elizabeth Harnarine.

MORE INFORMATION

Harnarine's short film, *Doubles with Slight Pepper,* won the Telefilm Canada Pitch This! contest at the Toronto International Film Festival. Watch it at https://vimeo.com/41997098.

The Software Developer

Michael McNeary
Scientific Software Consultant, McNeary & Associates

ABOVE
McNeary poses with one of his favorite puzzles. Photo courtesy of Michael McNeary.

Born in the early 1950s in Southern California, I was a surfer in high school and worked as a draftsman in the evenings and on weekends. After graduating from Los Angeles High School, I enrolled in the engineering program at Wayne State University in Detroit, Michigan, but quickly found out how ill prepared I was for even the most basic math courses. I left college.

Two years after returning to my home state, I completed an associate degree at El Camino College Compton Center, where I passed all of the math and physics courses the school offered. This gave me the opportunity to participate in a pre-engineering program run by the Lockheed Corporation in Burbank, California, in which I reviewed specifications for microelectronic devices. I then enlisted in the US Air Force (USAF), becoming a mechanic and serving one tour of duty.

Working at the aircraft company McDonnell Douglas after my time in the USAF, I prepared electrical wire harness assemblies. It was there that I remembered how much I had enjoyed physics. So I applied and was accepted to California State University, Dominguez Hills, where I earned a bachelor's degree in physics. After graduating I worked for a number of years in the fields of acoustics and vibration before being accepted to the physics masters program at California State University, Long Beach.

As I worked toward that degree, the hands-on nature of experimental physics was very appealing and led me to computer programming. I've since written hundreds of scientific software applications. In the field of acoustics, I designed a digital filter for sound attenuation and absorption measurements that processes one-third octave band sound data generated in an anechoic chamber (which completely absorbs sounds) or a reverberation chamber (which creates a diffuse sound field).

I went on to explore several other disciplines. Working in semiconductors, I designed software that used pattern-recognition algorithms to ensure quality control in microelectrical mechanical systems (MEMs) electroplating operations. I then wrote several automatic test equipment applications that programmed the field-programmable gate arrays of advanced avionic flight equipment and performed component and system compliance and reliability tests. I now work in geophysics and petrophysics, writing software that controls experiments in special core analysis and analyzes the properties of rocks.

Almost all of the software applications I've written over the years, regardless of the field or the application, contain components of fundamental physics principles hidden inside.

Taking the "Hidden" *out of* "Hidden Physicists"

Connecting physics students to careers with the Career Pathways Project

by Kendra Redmond, Toni Sauncy, and Roman Czujko,
Career Pathways Project Investigators,
American Institute of Physics

One of the biggest challenges facing undergraduate physics programs when it comes to recruitment and retention can be summed up in one word: JOBS. Although most departments focus primarily (and sometimes exclusively) on preparing students for physics graduate school, in reality only about one in six physics bachelor's degree recipients eventually earns a PhD in physics, and 40 percent of the physics graduates in the United States enter the workforce within one year of receiving their bachelor's degree. These graduates commonly pursue engineering and information technology careers, but many go on to become teachers, medical doctors, lawyers, science writers, analysts, and other types of professionals.

Although people who enter the workforce after earning their physics bachelor's degree have successful, fulfilling, and lucrative careers, physics students often do not know about these opportunities. This is because, in general, faculty members have not worked outside academia and have few professional connections outside of academic circles. Thus students who are deemed by the faculty as "not physics graduate school material" or who are not interested in attending physics graduate school are often left to explore their career options on their own.

Anecdotal evidence suggests that this lack of knowledge about career opportunities and nearly exclusive focus on getting students ready to enter graduate school can have a significant negative impact on students, as well as on recruitment and retention within the physics major. Students who need or want to go to work after earning a bachelor's degree may become dissuaded from studying physics and drawn in by other fields with well-known career paths (e.g., engineering), even if their true interests are more aligned with the study of physics. The fact is that a physics degree is excellent preparation for a wide variety of fields, as exemplified by the "hidden physicists" stories featured in each issue of *Radiations* (see page 16). Increasing the number of physics bachelor's degree recipients could add significantly to the "STEM workforce" of people highly trained in problem solving, critical thinking, and valuable technical skills.

In light of these circumstances and with support from the National Science Foundation, the American Institute of Physics—home to Sigma Pi Sigma and the Society of Physics Students—began in 2010 a multiyear Career Pathways Project (CPP). The goals include exploring how physics departments can better prepare students to enter the STEM workforce and how physics students can better prepare themselves to enter the workforce. Sigma Pi Sigma has a history of celebrating physics graduates who use their physics training in unique and interesting ways. This project is a kind of next step in the process of taking the "hidden" out of "hidden physicists" and exposing the many options that are commonly available to physics graduates.

The project began with exploratory site visits to a set of diverse physics departments that graduate high numbers of physics students who enter the STEM workforce upon graduation. The visits did not produce a universal recipe for success, but a number of common features emerged that seem to influence a department's success in preparing students for the STEM workforce:

Curricular

» Varied and high-quality lab courses
» Research opportunities for undergraduates
» Curricular flexibility
» Communication skills as part of the undergraduate physics experience

Extracurricular

» Faculty and staff commitment to the success of all students
» Strong community of students
» Connections with alumni
» Relationship with the career services office
» Mentoring and advising physics majors in accordance with their interests and goals
» Opportunities for physics majors to be involved in outreach activities

These results, bolstered by many stories shared during site visits, indicate that alumni connections can play a significant role in educating physics students and departments about career opportunities for physics students and in helping students connect with such opportunities. For example:

- Department seminars that feature alumni speakers are well received and offer students unique insight into career paths that physics faculty members are often not familiar with themselves.

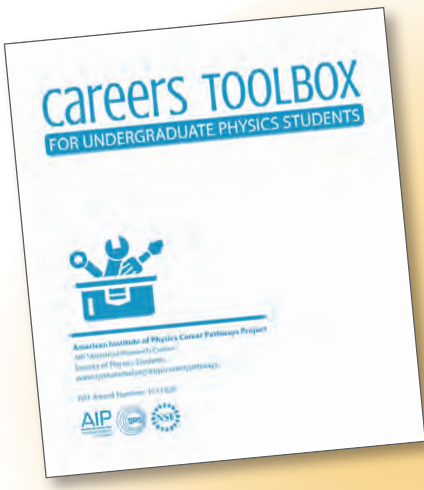
- Alumni who serve on advisory boards or work with students and faculty in other capacities can be excellent resources for networking and identifying research and internship experiences. This is especially true when the alumni are local. (See Jim Gaier's story on p. 12.)

- Physics students often hear about research, internships, and job opportunities from recent graduates with whom they are still friends. (See Andrew Watson's story on p. 11.)

- A simple list of physics department graduates and their current employers alongside general physics career information can be a great recruiting tool for potential majors and their parents.

- Some career services offices (or their equivalent) effectively engage alumni in interviewing students during mock interview sessions. Although the site visit teams did not see physics alumni being engaged in this way, doing so may be especially useful for helping physics students learn to communicate their skills in a way that is meaningful to potential employers.

The CPP findings are being disseminated through reports, resources, and workshops aimed at faculty and students. There is also a great opportunity for alumni to step forward and help create a physics community that embraces all students interested in physics, regardless of physics graduate school ambition. So, Sigma Pi Sigma alumni, we encourage you to take a short break from this issue of *Radiations* and send a brief note to the physics department at your alma mater (or a department near where you live) detailing where you are now, what you are doing, and any ways that you are open to engaging with students. Let's see where this goes.



CAREERS TOOLBOX

The interactive resources presented in the *AIP Career Pathways Workshops* are relevant to all physics students. Even those who go to graduate school will need to get a job someday! Materials center on helping students identify and clearly articulate the knowledge and skills that stem from their physics background, with resources for building an effective resume, interviewing, networking, and other aspects of the job search. Image courtesy of the American Institute of Physics.

Freeman Dyson

ON LIVING THROUGH FOUR REVOLUTIONS

by Kendra Redmond, Simga Pi Sigma Programs Manager

Freeman Dyson at PhysCon. Photo by Ken Cole.

At its core, the Sigma Pi Sigma Quadrennial Physics Congress (PhysCon) is about building community and looking forward. Early congresses brought together students from the first chapters of Sigma Pi Sigma to talk about the future of the society and how to transform the fraternity into a widely recognized honor society. As the society has grown, its congresses have engaged an increasing number of students and alumni, who come to set priorities for the organization and to explore the future of physics more broadly.

But looking forward can best be done in the context of looking backward; previous generations can provide the newest generation with advice and a foundation on which to stand. At the 2012 PhysCon, this spirit was perhaps best exemplified by Freeman Dyson's talk, "Living Through Four Revolutions." Society of Physics Students (SPS) student reporters from the University of Louisville (UofL) who attended the talk describe it here in their own words:

"Pacing gently on stage and speaking candidly, Dyson guided 800 people through the knowledge revolutions that made history and brought humanity to where it is today. Beginning with the atomic revolution, Dyson touched on both the excitement of successfully splitting the atom and the devastation caused by the first nuclear bombs. Looking to get a start in physics, a young Dyson [to take the reader back in time] sought out the scientific minds who first worked on the bombs at Los Alamos National Laboratory in New Mexico. He eventually became a graduate student at Cornell University in Ithaca, New York, where many had gone after the war. 'Within one week, I hit the jackpot,' Dyson recounted. 'I got to know Dick Feynman, and it was obvious this guy was a genius. He was a marvelous guy, a clown, a buffoon, a great teacher.' Dyson then told stories of how Feynman once learned never to care for another person's boa constrictor and refused to sleep in a tennis-themed hotel.

The second revolution also began with the Second World War, but involved developments in the field of rocketry that would eventually lead humanity into space. Dyson worked on Project Orion, a mission to use nuclear bombs as the launching mechanism for a spacecraft, a program that never quite took off. The bomb, developed as a means of destruction, would have been used for purposes of exploration and scientific advancement.

Next came the biological revolution, which started with the model of DNA established by Rosalind Franklin, James Watson, and Francis Crick; the last two earned a Nobel Prize for their work. Dyson warned the audience never to take his advice, as he had tried to convince Crick to stay in physics rather than go into biology.

The most contemporary revolution described by Dyson was the computing revolution. Dyson's colleague John von Neumann advised the US government that the country would never need more than 18 computers, an unfathomably low number from today's perspective, considering the smartphones, graphing calculators, televisions, cars, and other modern conveniences that now run on computers. The proliferation of computation has left humanity, in Dyson's words, 'living on little islands of understanding in a sea of information,' which is 'cheaper to collect . . . than to understand.'

More than just a history lesson, Dyson's talk was the personal story of a career physicist making his way to the top. When asked for advice on juggling career and family, he jokingly told everyone that he had lots of advice, 'but you don't have to take it.' Then he spoke briefly on the detrimental impact that going through a PhD program can have on one's personal life. 'If you don't need to get a PhD,' said Dyson, 'don't.' Flexibility and good fortune, according to the accomplished physicist, go a long way: 'The important thing in life is to be lucky.' Remaining on a single path limits options, claimed Dyson, citing software as an example of flexibility. The programming skills a student learns on one research project can be applied to future projects, allowing for respecialization down the line.

Dyson clearly struck a chord with the crowd. Hordes of students mobbed him between sessions. Seeking photos, advice, opinions, and stories from one of science's most esteemed figures, they lined the stage, pre-

"When [Dyson] signed a PhysCon t-shirt for us, I felt like I was in the presence of a rock star."
~ Student attendee from the Richard Stockton College of New Jersey in Galloway

paring their questions. One student hoped to hear more about Dyson's views on the modern educational path for doctoral students. Another asked about the safety and practicality of using atomic bombs as fuel for rockets, given the environmental impact. Whatever their reasons, students flocked to meet the living legend.

Discussions inspired by Dyson's talk continued throughout the meeting, during the car/van/bus/train/plane rides back to campuses around the country, and into SPS chapter meetings, blog posts, and social media pages in the following days and weeks. As this newest generation of physicists completes degrees and prepares to meet whatever revolutions are on the horizon, Sigma Pi Sigma and its congresses are a strand that will continue to connect the past, present, and future of physics. Dyson, says UofL student David Warder, 'taught us that we as physicists have our own revolutions to look forward to, to live through, and to learn from.' ”

WATCH A VIDEO OF
"Living Through Four Revolutions" on the 2012 PhysCon website:

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The Other-Worldly Career of Freeman Dyson

by Phillip F. Schewe
Director of Communication at the Joint Quantum Institute, a partnership between the National Institute of Standards and Technology and the University of Maryland in College Park

A portrait of Freeman Dyson in 1963. Photograph by Heka Davis, courtesy AIP Emilio Segre Visual Archives, Physics Today Collection.

Freeman Dyson is not one man but 10. His most famous scientific achievement, as a physicist, was his contribution to establishing quantum electrodynamics. But Dyson has also performed notable engineering feats, such as designing nuclear reactors and rocket ships. He has served in a crucial governmental advisory capacity, helping to secure a limited test ban treaty (whose 50th anniversary just occurred) and keeping tactical nuclear weapons out of Vietnam. While doing research in biology, he proposed a novel theory for the origin of life and wrote a book about it. As an astrophysicist, he helped launch in 1960 the search for extraterrestrial intelligence with his speculations about large-scale orbiting habitat platforms powered by stars, now better known as Dyson Spheres. He also helped create adaptive optics, a corrective system now used on most of the world's large ground-based optical telescopes, and he ushered in the formal study of the cosmos at very distant times.

Dyson admits to having a short attention span and believes that the current PhD system, which commits students pretty much to a fixed course of research on a single topic for five years or more, is too restrictive. Consequently, with the exception of two years at Cornell University in the 1950s, he has never taught at a university or supervised students. Nevertheless, he is committed to teaching in the larger sense, through his essays and his frequent appearances before student audiences. Dyson has been given two dozen honorary doctorates and has won many of the major physics prizes. But in his home, on the wall near the staircase, he displays a single framed award: the Oersted Medal, the highest award bestowed by the American Association of Physics Teachers, given to individuals who have had an outstanding, widespread, and lasting impact on the teaching of physics.

Dyson is better known now, at least among the general public, for his essays both in books and in *The New York Review of Books*. At the age of 90 he is still writing actively, and still proving controversial. His favorite topics: how the Internet and solar energy will eventually bring prosperity to poorer nations, without the need for expensive resources, as those countries become integrated into the world economy; the need for scientists to recognize the importance of religion and the arts in understanding the world; his argument that the current climate change debate is overheated, and that the good consequences of the changes will probably outweigh the bad; and the idea that biotechnology innovations should be carefully policed but promoted to raise standards of living.

Most daring of all are his long-term predictions—as a sort of cheerleader—concerning the eventual human migration into space. He is critical of the current human presence in space (the International Space Station) and believes that a grander human exploration of the solar system will begin only when the costs come down a lot. He figures that human habitation of space (probably on moons and comets in the Oort cloud but not planets) will be both liberating and scary, like the early voyages of Polynesians across the Pacific and Europeans across the Atlantic. Even if, through the use of genetic engineering for adapting to space conditions, the human race splinters into several rival species, Dyson believes such a gigantic upper migration is our ultimate destiny.

Putting these ideas into cogent essays as a way of getting society to ponder its far future will, I believe, prove to be Dyson's most important legacy.

CONTINUE READING

Schewe is Dyson's first and only biographer, the author of *Maverick Genius: The Pioneering Odyssey of Freeman Dyson*, published in 2013 by St. Martin's Press: www.phillipfschewe.org.

LETTER TO A LOGICIAN

by Dwight E. Neuenschwander
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This article is adapted from a 10-page letter written to one of my students about a year ago. He was a senior highly accomplished in formal logic who was taking my Science, Technology, and Society (STS) course, an overview of the relationships between ourselves and nature, our machines, and other lives as these are affected by science and technology.

The previous semester he took our Philosophy of Science course, team-taught with a philosophy professor. This student's weekly STS essays continued class discussion themes from the Philosophy of Science course. The student's privacy has been respected; Diodorus Cronus, to whom my letter is here addressed, was a Greek philosopher distinguished for logical innovations. The story goes that, while at dinner with the king and another philosopher, he was given a logical puzzle which he could not solve. He returned home, wrote a treatise on the problem, and died from despair (c. 284 BCE).

Dear Diodorus,

You are well on your way to being a superb master of logic. When I see you and your philosophy professor walking together across campus, I am reminded of *The School of Athens,* a fresco by Raphael that shows Plato and Aristotle, teacher and pupil, discoursing as equals.

I appreciate your genuine engagement with our readings and class discussions. Philosophy students have earned my respect. You care about your discipline and are serious about critical thinking. Your insights have helped me think more deeply about what my colleagues and I are doing in physics. Like you, we care about our discipline.

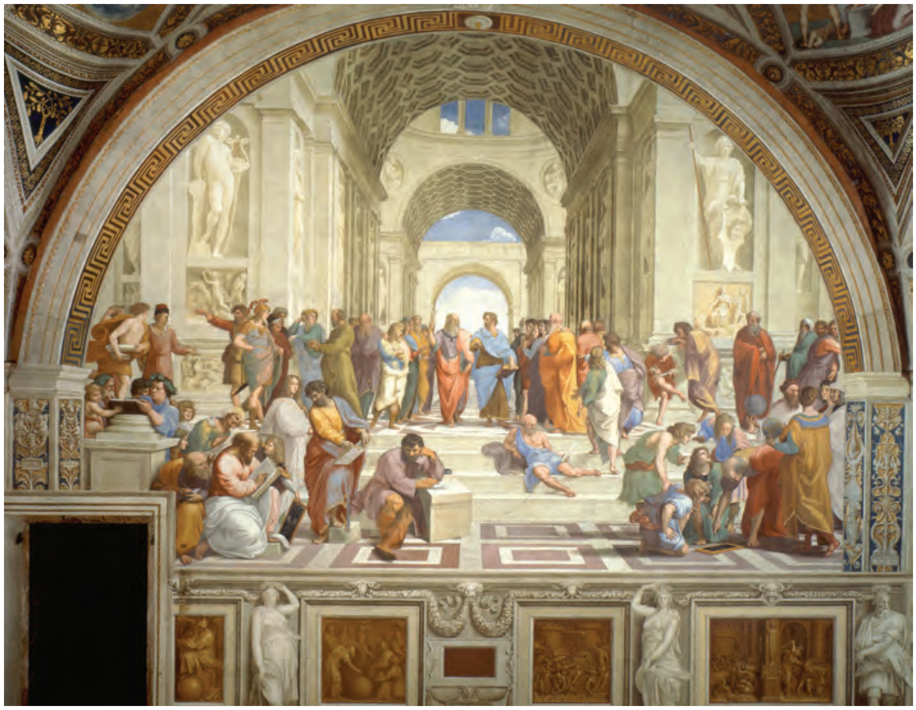
You have developed considerable skill in formal logic, which I admire. Examples of careful logical thinking in physics are abundant. Here is one that uses logical principles you will find familiar.

In the nineteenth century two statements of what we now call the second law of thermodynamics were articulated. Both statements were inductive generalizations from empirical observations. One maintained that no engine converts 100 percent of its heat input per cycle into work output. The other postulated that heat never flows spontaneously from a cold body to a hot one. These statements elevated to the status of axioms the notion that these unobserved processes do not occur because they *cannot* occur. To see if these postulates offer insight into reality, we work out their inferences and see to what extent they correlate to the real world.

The two statements are readily demonstrated to be logically equivalent by showing that if either one is false, then so is the other. Then another question arises: If no engine can achieve 100 percent efficiency, how efficient *can* an engine be, limited only by the matters of principle articulated in the second law? In 1824 Sadi Carnot offered a path to an answer by inventing a conceptual engine that operates between two temperatures while maintaining thermal equilibrium with its surroundings. Carnot's idealized engine led to a result, now called Carnot's theorem, which shows that the efficiency of any engine operating between a "cold" absolute temperature T_C and a "hot" temperature T_H cannot exceed $1—T_C/T_H$. Engines operating between more than two temperatures can be conceptualized as a sequence of Carnot engines. By such reasoning one deductively climbs to the summit of this subject, the Clausius inequality. In its simplest version for the two-temperature engine, it says that if the engine has efficiency e less than the Carnot efficiency e_o, so that $e = e_o - \delta$ where $\delta > 0$, then in each cycle during which the engine accepts heat Q_H from the hot side, performs work, and dumps the remaining energy as heat on the cold side, the sum of all the heat exchanged per temperature equals $-\delta Q_H/T_C$. In other words, more heat per temperature is dumped into the environment than is required by the second law if the efficiency is less than ideal. This result readily generalizes to arbitrary cycles, for which the Clausius inequality says $\oint \frac{dQ}{T} \leq 0$.

From this follows the slide down to deductive consequences, including the existence of a new state variable called "entropy," a corollary that the entropy of an isolated system never decreases, and thermodynamic criteria for the occurrence of spontaneous processes. To make this logical exercise into a science, one tests, with measurements, these inferences against real systems. The second 1aw of thermodynamics echoes the real world so well that its inferences revealed some important limitations of classical mechanics and led to the development of quantum mechanics.[1]

As you appreciate, both logical rigor and empirical observations are essential in science. As we discussed in the Philosophy of Science class, the logical positivists tried to describe all of science in terms of classifying the logic of statements. A scientific assertion would have meaning only insofar as it could be correlated, with the precision of formal logical statements, to our sensory experiences.[2] But they quickly learned what scientists have found: that science sometimes has to color outside of logic's rigid lines. This predicament is not from lack of respect for logic. The devotion of physics to logic is illustrated by the persistence shown in reconciling quantum mechanics with electrodynamics—which took from 1900 to 1948.[3] It took that long for a community of exceptionally bright, hard-working people to work through the difficulties of showing how quantum mechanics and electrodynamics could be made mutually consistent.



ABOVE
"The School of Athens," by Raphel. Public domain image, courtesy of wikipaintings.org.

Formal logic offers a powerful lens for scrutinizing science. However, like all lenses, it may contain aberrations. Over the years I have observed curious patterns of behavior among students who see rigorous logic as trumping all else. These include a tendency toward literalism in analyzing sentences while ignoring the larger perspective, and an irresistible urge to classify everything into taxonomic categories with maximal worry about the ambiguity of language. I am not writing to argue but to relate empirical observations I have seen over the years. I speak only for myself.

Literalism and Perspective

Once a sentence is written or uttered it becomes a potential object of logical scrutiny. A literal reading is certainly essential for analyzing the legal possibilities open to a defendant's lawyer, for instance. But we must remember that context is crucial for most statements. Where is the other person coming from? What does he or she care about? What motivates him or her? What competing values is one trying to reconcile?

For example, during our discussion of environmental sustainability in the Science, Technology, and Society course, someone asked the follow-up discussion question, "Why should we care?" We suggested several reasons, such as our dependence on healthy ecosystems, our concern about our own quality of life and that of our descendants, and so on. One reason was recast as the following question about ethics: "What gives us the right to wantonly destroy the lives of other creatures who value their own lives?" To focus what we were trying to say, we turned to Albert Schweitzer's "Reverence for Life" writings. Starting from his observation, "I am life which wills to live in the midst of life which wills to live," he taught that all life, not only human life, should be treated with reverence.[4] He advocated an ethic based on the foundational principle that we kill no living thing unless doing so is unavoidably necessary. One illustration of "necessity" that arose in class discussion came from the prereservation Lakota, who depended on the buffalo for their survival. As part of the buffalo hunt, they held ceremonies to thank the slain buffalo and apologize to them.[5] Another illustration came from Schweitzer's own experience, when a pelican took up residence at his clinic in Lambaréné.[6] Pelicans survive on fish, so Schweitzer regretfully fed fish to the pelican.

Your response to Schweitzer's ethics was a virtuoso performance on the meanings of "necessity." You reminded us that every dictator or general who orders a genocide rationalizes such colossal crime as "necessary." While your demonstration scored a point for logic by exploiting the unavoidable ambiguity of the word, it left me concerned that your focus on a pedantic analysis of Schweitzer's words led you to overlook his message. Any "ethnic cleansing" or genocide is a machine for destroying lives on a large scale. By comparison and contrast, the meat-packing industry also ends lives on an industrial scale. Leaving aside the question of whether we should eat other sentient creatures at all, we can still notice one important distinction between scenarios: One treats its victims with deliberate cruelty and contempt, but the other can be done in a way that shows respect to the creatures raised for slaughter, doing everything possible to eliminate their terror and suffering.[7] Do we need to have "necessity" spelled out in single-valued rigor for us to recognize the difference? If so, then perhaps we need wider perspective more than we need narrower precision. Schweitzer's point was to urge a robust principle for ethics: If I treat all life with reverence (to the point of carrying a beetle outside instead of squashing it),[8] then I will not be susceptible to the propaganda of those who would have me buy into the "necessity" of genocide or any other expression of contempt for any life.

When Schweitzer turned 30, he kept a promise he had made to himself to spend the rest of his career in service to others. Even though he already had a PhD with a dissertation on Kant and was a Bach organist of international reputation, he returned to university to earn a medical degree. Preparing to spend the next several decades as a jungle doctor in equatorial Africa, Schweitzer had a powerful reaction to the science he learned, as he recalls in his autobiography:

> *But the study of the natural sciences brought me even more than the increase of knowledge I had longed for. It was to me a spiritual experience. I had all along felt it to be psychically a danger that in the so-called humanities with which I had been concerned hitherto . . . a mere opinion can, by the way in which it deals with the subject matter, obtain recognition as true. . . . The argument from facts is never able to obtain a definite victory over the skillfully produced opinion. How often does what is reckoned as progress consist in a skillfully argued opinion putting real insight out of action for a long time!*
>
> *. . . Now I was suddenly in another country. I was concerned with truths which embodied realities, and found myself among men who took it as a matter of course that they had to justify with facts every statement they made. It was an experience which I felt to be needed for my own intellectual development.*[9]

Classification and Ambiguity

Philosophers have brought attention to the problem of classification, and have long pointed out that something can be categorized more than one way, depending on the experiences of the person doing the classifying. Thus I have found puzzling the rigidity that so many students, highly trained as logicians, bring to the task of classifying things and concepts and people.

A revealing incident occurred one day in our first Philosophy of Science section. We were discussing whether the quantum-mechanical wave function ψ is part of the real world. Physicists do not observe it *directly*; we observe its *consequences*. The wave function (times its complex conjugate ψ^*) is interpreted as a probability density for locating a particle. I told the class that the Schrödinger equation that one solves for the wave function ψ, can, if one wishes, be seen as a "black box" into which one inputs the particle's mass and potential energy. The black box produces as output the distribution function $\psi^*\psi$. At this point a senior student declared to me, "Oh, you are an instrumentalist." Had this student said, "Your scenario represents an instance of instrumentalist thinking," he would have been correct. Although I may use instrumentalist reasoning on today's problem, on some other topic I might apply, say, utilitarian thinking. There is a profound distinction between pronouncing *what I am* rather than noting a *tool* I use to address a specific problem.

Classification schemes are useful boxes that help us get organized. Thus I was fascinated by your letter that defined three categories and insisted that numbers must fit exclusively into one and only one of them:

> *Numbers can be one of three things. (1) Numbers can be ontologically existing entities. (2) Numbers can be mental conceptions. (3) Numbers can be symbols that are shifted around in a type of game. However, if option 2 is true, then numbers should not be able to predict the exterior world. Hence, if numbers can predict the exterior world, then there is evidence that options 2 and 3 are false. . . . If numbers are ontologically real, then objects exist without mass and without energy.*[10]

Very tidy categories—but why should numbers fit in only one of these three? Why can't numbers be all of these entities? Whatever a proton may be, each atomic nucleus contains an integer number of them; a pair of human hands contains ten digits. These are about as close to ontologically existing entities as nature will offer. The notion that *nothing* can be represented as a *number* is rather astonishing; "zero" as a number was invented twice in human history. That numbers are symbols which can be shifted around in a "type of game" is evident to anyone who has ever done a physics problem, worked out an amortization schedule, or estimated the cost of a construction project. Sometimes the games seem to be only for intellectual play, as non-Euclidean geometries and hypercomplex numbers initially were. Then they were found to fall readily to hand respectively in general relativity and in the Dirac equation that describes the quantum state of a relativistic electron. We use such mental conceptions as symbols to manipulate our thoughts and conclude something about nature that can be tested against the real world. One could imagine other categories too: shall we say that numbers either *mean* things, or that they *do* things? In digital computers numbers have *both* roles. [11] Granted that the philosophical status of numbers is a difficult and controversial problem, nevertheless the versatility of their uses and interpretations would, it seems to me, caution against demanding that they fit into only one category.

Whatever numbers *are*, perhaps the more interesting puzzle is why numbers—and other mathematical concepts that spring to mind, such as derivatives and Lie algebras and Legendre polynomials—correlate so well with nature. In a 1960 paper, Eugene Wigner, whose work in using symmetry groups to classify nuclei and elementary particles was recognized with the 1963 Nobel Prize in Physics, discussed the "unusual effectiveness of mathematics in the physical sciences." He wrote,

> *[I]t is important to point out that the mathematical formulation of the physicist's often crude experience leads in an uncanny number of cases to an amazingly accurate description of a large class of phenomena. This shows that the mathematical language has more to commend it than being the only language which we can speak; it shows that it is, in a very real sense, the correct language.[12]*

One might think that at least the term "science" would be unambiguously classified or defined. Another revealing incident occurred in the Philosophy of Science course when we read one of Jacob Bronowski's books. As a mathematician, biologist, historian, and poet, he was well acquainted with the flexibility of language in both science and the humanities. Here is a partial list of Bronowski's descriptions of science, from *Science and Human Values*:[13]

> *"I define science as the organization of our knowledge in such a way that it commands more of the hidden potential in nature." (p. 7)*

> *"Science is nothing else than the search to discover unity in the wild variety of nature—or more exactly, in the variety of our experience. Poetry, painting, and the arts are the same search." (p. 16)*

> *" . . . All this is plain once it is seen that science also is a system of concepts . . ." (p. 41)*

> *"Science is the creation of concepts and their exploration in the facts." (p. 60)*

The logic specialists in the class took these statements as a set of axioms and gleefully proceeded to show how dreadfully inconsistent they appear to be: "Science" is a noun ("a system") in some places and a verb ("the search") elsewhere; it is sometimes the organization of what we know and sometimes the discovery of what we don't know. By viewing him through the soda straw of sentence deconstruction and picking his sentences apart as if each one was meant to stand alone, these students, it appeared to me, were oblivious to Bronowski's message. The statements in question are not axioms or definitions intended to be unique. They are photographs taken from different angles; they are explorations of the many facets of science offered by one who has lived it.

What, then, are numbers? What are "laws of nature?" What is "science?" These questions are easy to ask and hard to answer. Here is one description of the latter. Science is a conversation we carry on between two worlds: the *conceptual* world, and the *real* world.[13,14] The real world contains rocks, trees, stars, sunlight, magnets, water, horses, engines, bugs, and brains. The conceptual world contains geometries, coordinate systems, entropy, atomic orbitals, angular momentum, electric charge, Lagrangians, isospin, mass, and evolution. Concepts are symbols we manipulate in the imagination, working out the consequences they imply in various situations.

For example, gravity—whatever it is—has held the Earth together throughout its history. I can assert, empirically, that gravity is real. I know from experience that when you fall off a roof there's only one way to go—down—and that you fall at a definite rate. Those are facts about gravity. But any "law of gravity" is a creation of the versatile human mind.

How we conceptualize gravity requires the informed use of imagination and intuition. Newton's "law of universal gravitation," which describes gravity as force acting across space, offers one conceptualization. Einstein's general theory of relativity, which describes gravity as the curvature of spacetime, offers another. As a logical structure, the former is contained as a limiting case within the latter. Whatever gravity *really is* ontologically we do not know, and perhaps we cannot know. But we do know that, from concepts such as force or spacetime curvature, specific predictions in the conceptual world can be made and tested against the real world, by stepping off a roof or tracking a light ray skimming by the Sun. Creativity for the concepts, logic for the inferences, data for the comparison, then iterating—these are elements essential for doing science.

Science is a hybrid of poetry and logic, intuition and mathematics. Our definitions, principles, and laws are statements of observed patterns that we have compressed into words and equations. Equations are precise, but they apply to conceptual representations, or models, of real things. If words must always adhere rigidly to precise definitions, it would be difficult to discover in mass, for instance, a form of energy. Definitions expand with experience.

Words carry multiple shades of meaning, giving the soil of poetry—and of physics—their fertility. Poetry uses ambiguity to say more than the words themselves. The poet may write, for instance, that love is a river, a razor, a hunger, a flower.[15] The question for poetry is not, "Which metaphor is *correct*?" Each one is *correct within its context*, but the poet does not spell out those contexts. That is left to our personal experience and imagination. We accept this as the method of poetry. However, if love were a science (and it is not![16]), then as scientists we would start from this ambiguity and try to spell things out: Under what circumstances is love a razor, a river, a hunger, a flower?

Physics as the Poetry of Nature

The Society of Physics Students used to distribute a lapel button that declared PHYSICS IS THE POETRY OF NATURE. Poets exploit the flexibility of language to create impressions that go beyond words. Physicists sometimes find themselves confronting similar situations. The challenge for physics is to prevent the flexibility of words from carrying us into a state of confusion. Wave-particle duality offers a dramatic example of a fruitful response to ambiguity.

We can engineer with electrons to make electric lights and semiconductors for the computer industry, but we still don't know what an electron really is. The only languages that come close to describing electrons are the mental pictures of waves and particles. Waves spread out and particles are localized, so these mental pictures are contradictory. Unfortunately for those who insist on mutually exclusive choices, real electrons sometimes behave indistinguishably from waves, and in other circumstances they behave as particles.

In experiments or applications in which electrons behave like particles (e.g., television picture tubes), the wave model is irrelevant. In situations where electrons act like waves (e.g., electron microscopes), the particle model is irrelevant. So far no one has been clever enough to invent a single model in terms of which all the doings of electrons can be understood. But although we do not know what electrons "really" are, we do know what they are like, and under which circumstances they are like that. Particles and waves are mental pictures gleaned from our macroscopic experiences with billiard balls and ocean surf. When we carry these concepts into the microscopic world of the atom—where we have no direct experience—we should not be astonished to find that neither model, by itself, adequately describes everything that electrons do.

In 1949 Niels Bohr described two kinds of truth, a "simple truth" for which the opposite statement is false, and a "deep truth" for which the opposite statement is also true.[17] This remarkable insight came from his confrontations with wave-particle duality. In physics or any other science, as in life, not every premise is either true or false. Furthermore, premises in physics are almost always, if not always, expressed through metaphors and analogies. Logicians do not like the use of metaphors or analogies in arguments, but we can only explain unfamiliar things in terms of things we already understand.

The logical and empirical positivists said that "facts" are "applied to singular, particular occurrences" and from a pattern of facts come "laws."[18] But one has to exercise value judgments and actively search for the relevant facts; patterns are not there for the mere looking; promising hypotheses come from intuition and informed imagination. To paraphrase Robert Pirsig, your search for what's *true* is guided by your sense of what's *best*.[19] In a 1918 speech Albert Einstein made this point explicitly:

> *The supreme task of the physicist is to arrive at those universal elementary laws from which the cosmos can be built up by pure deduction. There is no logical path to those laws; only intuition, resting on sympathetic understanding of experience, can reach them.*[20]

The practice of science rests on aesthetic values such as elegance and simplicity. Questions worth asking must be recognized as valuable, which means that others are passed over. More hypotheses can be proposed than tested, so some must be discarded in advance. Physicists have found that starting with ideas that are beautiful and economical, and working outward from there, has consistently been a fruitful strategy.

The School of Athens is Still In Session

In Raphael's fresco *The School of Athens*, Plato and Aristotle are surrounded by a host of luminaries engaged in investigation, including Pythagoras, Epicurus, Zeno, Averroes, Euclid, and a constellation of others. Some figures are engaged in discussion. Some meditate in solitude. All exist within a community of critics and supporters, ready to sharpen one another's ideas. If there were no disagreements, and if meaning could not take on multiple shades, the world would be far less interesting. Each of us has a partial view to add to the discussion. But we are all like the blind men in the parable of the elephant.

I am glad to have you as my colleague and friend. I always learn more from my students than they learn from me. Thank you for taking my courses, for sharing your thoughts, and for listening.

Best wishes,
Prof N

Acknowledgments

Thanks to Devin Powell, Daniel Golombek, and SNU philosophy professor Dr. Brint Montgomery for insightful suggestions. I thank my student correspondent who shall remain publicly anonymous, and all the students from many sections of the Philosophy of Science and STS courses where the original discussions occurred.

References

[1] Max Planck's quantum hypothesis of 1900, that an oscillator has quantized energy, came from the thermodynamics of light in thermal equilibrium with matter, an instance of the breakdown of the classical equipartition of energy that had also been noted in predictions of the specific heats of gases. Albert Einstein's 1905 postulate of light "corpuscles," later called "photons," came from comparing the entropy of light to that of an ideal gas. For a short review of the second law, the Clausius inequality, and entropy, see "Elegant Connection in Physics: The Second Laws of Thermodynamics and Non-Conservation of Entropy," *SPS Newsletter* (June 1998), pp. 9-13.

[2] Peter Godfrey-Smith, *Theory and Reality* (University of Chicago Press, Chicago, 2003), Ch. 2.

[3] 1900 to 1948 began with the Planck hypothesis, and ended with Freeman Dyson's showing the equivalence of the quantum electrodynamics methods of Richard Feynman, Julian Schwinger, and Sin-itiro Tomonaga; see Silvan S. Schweber, *QED and the Men Who Made It* (Princeton University Press, Princeton, NJ, 1994).

[4] Albert Schweitzer, *Out of My Life and Thought* (Henry Holt & Co., New York, 1933, 1949), tr. by C.P. Campion. See also *Reverence for Life: The Ethics of Albert Schweitzer for the Twenty-First Century* (Meyer & Bergel, eds., Syracuse University Press, Syracuse, NY, 2002).

[5] Luther Standing Bear, *Land of the Spotted Eagle* (originally published 1933; University of Nebraska Press, Lincoln, NE, 2006), p. 165; Joseph Marshall III, The Lakota Way (Penguin Compass, New York, 2001), p. 49.

[6] Ann Cottrell Free, *Animals, Nature, and Albert Schweitzer* (Flying Fox Press, Washington, DC, 1988), pp. 47-48.

[7] The work of Temple Grandin is noteworthy in this regard. The People for the Ethical Treatment of Animals recognized her with the 2004 PETA Award. The citation read "Dr. Grandin's improvements to animal-handling systems found in slaughterhouses have decreased the amount of fear and pain that animals experience in their final hours, and she is widely considered the world's leading expert on the welfare of cattle and pigs." For a sample of her thoughts see T. Grandin, *Animals Make Us Human* (Mariner Books, Boston, 2009).

[8] See J. Marshall III, Ref. 5, p. 51, for his account of "Bailey the beetle."

[9] Schweitzer autobiography, Ref. 4, pp. 104-105.

[10] Student letter, STS class week 7, Spring 2013.

[11] George Dyson, *Turing's Cathedral* (Vintage Books, New York, 2012), p. ix: "The stored-program computer, as conceived by Alan Turing and delivered by John von Neumann, broke the distinction between numbers that mean things and numbers that do things. Our universe would never be the same."

[12] Eugene Wigner, "The Unreasonable Effectiveness of Mathematics in the Natural Sciences," *Commun. Pure and Appl. Math. 13* (1960), 1-14, doi:10.1002/cpa.3160130102.

[13] Jacob Bronowski, *Science and Human Values* (Harper & Row, New York, 1965).

[14] David Hestenes, "Modeling Games in the Newtonian World," Am. J. Phys. 60 (8), 732-748 (1992).

[15] This example from "The Rose," written by Amanda McBroom, Fox Fanfare Music, Inc., BMI; sung by Bette Midler in the 1979 movie *The Rose* and in *Bette Midler Greatest Hits* (Atlantic Recording Corp., 1993).

[16] Richard Feynman wrote, "We must, incidentally, make it clear from the beginning that if a thing is not a science, it is not necessarily bad. For example, love is not a science." R.P. Feynman, *The Feynman Lectures on Physics* (Addison-Wesley, Reading, MA, 1963), Vol. 1, pp. 3-1.

[17] Niels Bohr, "Discussions with Einstein," in *Albert Einstein, Philosopher-Scientist*, Paul A. Schlipp, Ed. (MJF Books, New York, 1949), pp. 239-240.

[18] Rudolf Carnap, *Philosophical Foundations of Physics* (Basic Books, New York, 1966), p. 5.

[19] Robert Pirsig, *Zen and the Art of Motorcycle Maintenance: An Inquiry into Values* (William Morrow & Co., New York, 1974, 1999), pp. 293-297.

[20] Albert Einstein, "Principles of Research," *Ideas and Opinions* (Three Rivers Press, New York, 1954, 1982), pp. 226-227.

The First Astronomers

CONTINUED FROM PAGE 7

astronomers explain this in terms of the orbits of the planets around the Sun. The Yolngu people, thousands of years ago, came up with a different explanation.

When Venus rises before dawn, a rope is said to connect her to the island of Baralku. This rope is said to prevent her from moving too far away from the Sun.

Yolngu people say that if you look carefully, you can see this rope. They seem to be referring to the faint glowing line in the sky that astronomers call the zodiacal light, caused by interplanetary dust in the solar system. Although difficult to see in most parts of the world, it is easily visible in the clear dark skies and low latitudes of northern Australia.

Some Yolngu clans still hold an important Morning Star ceremony as part of the funeral process. This ceremony starts at dusk and continues to a climax as Banumbirr rises before dawn. During the ceremony, a "Morning Star pole" is used to help the participants communicate with their ancestors, with Banumbirr's help. The messages are said to be carried along the rope which connects Banumbirr to Baralku, where the ancestors live.

LEFT
Yonglu shows his Evening Star Rope. Photo courtesy of Ray Norris.

We can learn two important things from the Morning Star ceremony. One is that the Yolngu tradition includes the knowledge that Venus never moves far from the Sun. The other is that since Venus rises before dawn only at certain times (roughly once every 1.5 years), Yolngu people also keep track of the path of Venus well enough to predict when to start planning and hold the ceremony.

What of the Evening Star? When Venus rises after the Sun, it is not visible in the glare of the morning daylight. However, at those times of the year it sets after the Sun and then is visible as a bright star in the West after sunset—the Evening Star.

The Yolngu people also have a story about the Evening Star, but it is puzzling. It says that when the Evening Star, named Djurrpun, is visible, it is the time to harvest raika, the lotus bulbs that grow in Arnhem Land. But that doesn't make sense—Venus would not be good for telling you when to harvest raika, as the time Venus sets changes from year to year, reappearing in the same apparent position only after a period of 584 days. Mathulu, we were told, was the owner of this story, and the only person who could explain it.

His story started: "A lady went out to a waterhole, and she sat collecting raika nuts. When Djurrpun sets just after the Sun, we know that raika, the nuts from the rushes in the river, are ready to be harvested." Then the conversation took an unexpected twist. From a bag, he produced a long rope.

"This is Laka, an Evening Star rope," Mathulu told us.

We were amazed. We had spent the last couple of years reading the literature on Yolngu culture and had never before heard of the Laka.

"It's a line of stars in the sky, and when the first star sets just after sunset, that's the time for the women to collect raika nuts," examined Mathulu.

He let us examine the rope, made of pandanus twine, twisted together with orange lorikeet feathers. Woven into the rope were the yellow-white marbles of the raika nuts.

"This Laka is a memorial to my grandmother, and we used it at her funeral to send her spirit off to the Evening Star. Like this." Together, he and a younger man translating for us demonstrated how a line of mourners held the rope on their heads, joining their spirits to that of their grandmother as they said farewell.

Walking back, we asked Mathulu which was the Evening Star. "That one," he pronounced confidently, pointing at the star Spica. Spica sets behind the Sun in October, just before the raika harvest. The anthropology books which identify Djurrpun as Venus were just plain wrong. Finally the puzzle was solved.

ABOVE
This sketch of a rock carving may depict two people reaching for a boomerang or for the moon. Photo courtesy of Ray Norris.

Acknowledgment

The editor adapted this story from materials provided by Cilla and Ray Norris.

Dream On

For more details on the work of Cilla and Ray Norris and their collaborators, visit their site, Australian Aboriginal Astronomy, at www.emudreaming.com.

We know that traditional aboriginal people were interested in the sky and used the stars for time keeping and navigation. They had a deep and extensive knowledge of the sky, and of the motion of the celestial bodies across it. Perhaps they were even making accurate measurements of the rising and setting places of the Sun. But we are only in the early stages of this study, and it is likely that far more lies undiscovered.

Why should we be interested in aboriginal astronomy? Personal curiosity, certainly. But it goes much deeper. If we succeed in uncovering ancient aboriginal astronomers, perhaps in a way we can give back to the aboriginal people some of that culture which our European ancestors destroyed.

Also we hope that, like music and art, astronomy can build an important bridge of understanding between indigenous and non-indigenous Australians. We all share the same sky and can't help being awed by the beauty and mystery of the glorious Milky Way stretching across the unknowable black heavens above us. We aim to promote a greater appreciation of the depth and richness of indigenous Australian cultures.

Ray Norris is an astrophysicist at the Australia Telescope National Facility (operated by Australia's Commonwealth Scientific and Industrial Research Organisation, or CSIRO). His wife, Cilla Norris, is an authority on possums, writing and teaching about the animals for the New South Wales Wildlife Information and Rescue Service (WIRES) and other groups.

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Corey, Christopher J., '04
Spigarelli, Robert P., '70
Strelchum, Thomas F., '82

Shippensburg University
○ Deardorff, Eugene A., '73
○ Imler, James H., '73

Siena College
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○ Smith, Paul J., '80

South Carolina, University of
Laster, Donald R., '59
○ Rosenfeld, Carl, '86
Safko, John L., '85

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Huh, Yung M., '03

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Booth, Don C., '74
Curry, James A., '92

Southern California, University of
○ Shigemitsu, Thomas M., '72

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Dickson, Richard L., '74
○ Van Loon, Timothy G., '74

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Berman, Leonard M., '86
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Stevens, Jr., Harold W., '71

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Watkins, Sylvia A., '46
Wells, Lois S., '53

St. Olaf College
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Kullberg, Craig, '69

St. Peter's College
Lopez, Jose L., '07

Stetson University
○ Williams, David C., '69

Stony Brook University
Cravens, Thomas E., '69
○ Garrett, Randy, '99
Shlesinger, Michael F., '69
Shteyman, Alan G., '11

SUNY at Albany
Bono, Paul C., '77
Coppola, Richard A., '66
○ Landi, Peter C., '88
○ Sanders, Stephen J., '71
○ Sullivan, Joseph M., '67
Walikis, Rosemary, '62

SUNY at Binghamton
Calistri-Yeh, Millie, '89

SUNY at Brockport
Gentile, John P., '01

SUNY at Buffalo
Snyder, David J., '88

SUNY at Fredonia
○ Bicknell, Paul A., '75

SUNY at Geneseo
♦ King, Paul M., '92

Syracuse University
Barroll, Sara D., '46
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○ Lehmann, William L., '47
○ Richman, Gilbert C., '48

Tennessee-Chattanooga, University of
○ Mathis, Joe T., '61
○ Visser, Jon R., '63
Wingo, Kenneth W., '74

Tennessee-Knoxville, University of
Breeding, J.E., '61
Cooper, David A., '68
○ Crume, E.C., '68
○ Fleming, Edward R., '67
Hill, Jackie T., '73
Hinsdale, Sandra Jo, '65
○ Hubisz, John L., '64
Jarratt, James S., '67
○ King, Philip W., '68
○ Lewis, Rex D., '61
Reeves, Charles A., '68
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Young, Glenn R., '72

Texas A&M University-College Station
♦ Burrow-Ludlow, Janet, '76
Gruben, James H., '72
Wheeler, Bob L., '77

Texas Christian University
Campbell, Russell C., '79
Hilley, Larry L., '63

Texas State University
Berry, Richard E., '63
Borst, Walter L., '85

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Lagasse, Chris, '06
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Smith, Stanley G., '78

Texas-Arlington, University of
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The College of New Jersey
Deak, Melvin L., '79

Thiel College
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○ Barker, Thomas E., '98
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Toledo, University of
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Towson University
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Transylvania University
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Miller, John H., '50
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Azar, Jamal J., '67
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Livengood, C.D., '62

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William Jewell College
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○ Schneider, Robert S., '80

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○ Diesslin, Blaine R., '71
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Wisconsin-Whitewater, University of
Zagorski, William G., '71

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Bernacki, Stephen E., '70

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Wyoming, University of
○ Bunch, Wilbur L., '49
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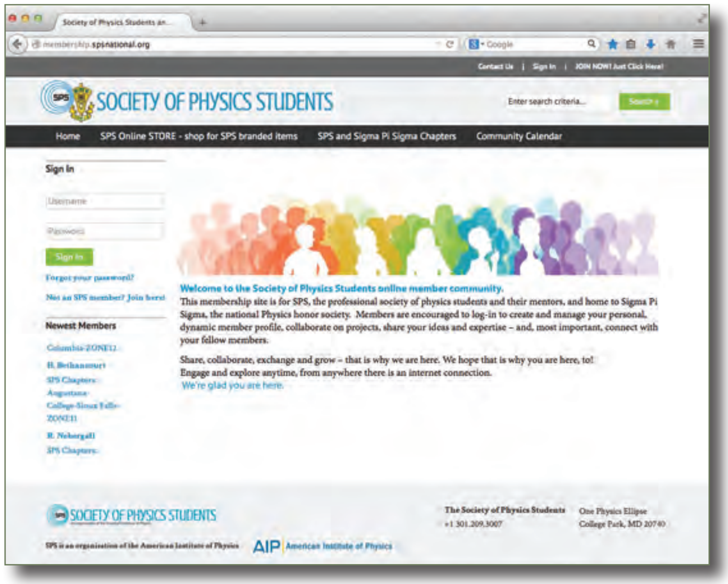

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