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My Year as the SPS AZC Representative

— Contributed by Krystle Williams, University of Rochester

(L-R) Edward Greve, Cheri Hall, and Krystle Williams, during the 2006 SPS Council meeting in College Park, MD.

During 2006 I had the distinct pleasure of being the Associate Zone Councilor Representative to the Executive Committee; it was an amazing task that continued my involvement with the Society of Physics Students (SPS) National Council past my term as Associate Zone Councilor (AZC) of Zone 2—and what a year it was! Long before the Council meeting in September, I had the chance to represent SPS in different arenas. In retrospect this was a daunting task, since in essence I was representing each and every one

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Motorcycle Maintenance and the Art of Physics Appreciation

— by Dwight E. Neuenschwander

Curious budding scientists examine a classic change of state experiment involving liquid nitrogen ice cream at a Southern Nazarene University SPS event. Christina wrote in appreciation, "I really enjoyed your show. I liked it when the liquid exploded. I like when the chemical changed."

All photos appearing in this article are courtesy of the author.

How many people driving a car every day carry in their minds a mental image of the mechanics, thermodynamics, and electromagnetism that make their machine possible? Our society is saturated with technological applications of science. Yet most people you encounter in the laser-equipped grocery store checkout line, waiting in the clinic for their MRI, or sitting next to you on the airplane, seem amazingly uncurious about how any of this stuff works. How quickly the marvelous becomes commonplace and taken for granted!

Some perceptible progress has been made towards science being claimed as the intellectual heritage of everyone. Practically everybody has some mental picture of the Earth as a planet orbiting a star, agrees that human genetics gets encoded in helical molecules, and assumes that floods and earthquakes have geophysical causes. But although science has revealed a breathtaking vision of the universe and our place in it, here again the typical citizen, by and large, seems unreflective about it all. How quickly the astonishing becomes mundane! Henry David Thoreau exaggerated only mildly when he lamented that[1]

Nature has no human inhabitant who appreciates her...

Why this lack of wonder and curiosity? It does not start out this way. I have evidence to suggest that second and third graders are the world's most promising scientists. Wonder and curiosity about the physical world bubble forth as spontaneously from them as their desire to

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AIP Member Societies: American Physical Society • Optical Society of America • Acoustical Society of America • The Society of Rheology • American Association of Physics Teachers • American Crystallographic Association • American Astronomical Society • American Association of Physicists in Medicine • AVS, The Science and Technology Society • American Geophysical Union ***Other Member Organizations:*** Sigma Pi Sigma, Physics Honor Society • Society of Physics Students • Corporate Associates

KRYSTLE WILLIAMS
2006 SPS Associate Zone Councilor Representative

Hi, my name is Krystle Williams and I'm originally from Trinidad and Tobago, although I have called upstate NY my home for the last five years, having developed a perplexing affinity for snow. I'm entering my second year in the Biophysics graduate program at the University of Rochester, Rochester, NY. I graduated in 2006 from Colgate University with a concentration in physics, where my involvement with SPS began and I am currently serving my third year on the SPS National Council as the Zone 2 Associate Councilor.

I'm a proud member of the Kielkopf Lab, where we primarily study proteins involved in alternative splicing through different biophysical methods such as x-ray crystallography (which lets my inner physics geek run wild when I collect x-ray data at a synchrotron- particle accelerator, awesome!). When I'm not doing research I can probably be found planning social events for gradate students as the GSS Social Chair, watching bollywood movies, building snowmen in random places or playing steeldrum with a local band.

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MY YEAR AS THE SPS AZC REPRESENTATIVE

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of us—every student—and I hope I did a good job!

My first official charge came with an invitation from the American Institute of Physics (AIP) Advisory Committee on Physics Education. This committee had never had a student representative present, and perhaps recognizing the valuable input a student may be able to contribute, they called on SPS to send a student representative. It was a one day meeting that sought to address AIP's various policies and programs concerning education. It was a thrill to be part of the policy making process, and to see the amount of attention that AIP affords education, which consisted of several areas, one of which was the SPS. I hoped my contributions were practical and helped AIP know more about the students' needs. The AIP committee members were truly concerned about offering students the best opportunities available. At the end of the day I was very pleased to be part of one particular policy-making aspect: the committee voted unanimously to add a student representative permanently to its annual advisory meeting!

Also in 2006, the American Institute of Physics celebrated its 75th anniversary, and they did so with flourish. AIP called upon its student membership to be part of their celebrations. My participation came in the form of the 75th Anniversary video. By far, this was my favorite project as an SPS student representative. To meet with the interviewers, I flew out to New York City for an hour-long interview that was immensely enjoyable. It was the most physics-filled trip I have ever taken, because I had the most amazing conversations with almost everyone I encountered, including my taxi cab driver! Once I had told him the reason for my trip he asked me the ultimate "so-you're-a-physicist" question. You know, that question that everyone asks you when they find out you are a physics major? Actually, I can think of a couple more like "so can you explain relativity to me?" or "are you crazy?" On this particular day, the cab driver, Dave, asked me "So what's the deal with this quantum physics thing?" Of course I had to oblige! One thing led to another and soon enough we were deep in a conversation about my summer research in biophysics. It's always a great day when I get to talk about physics with a non-physicist, especially one like Dave who was so fascinated!

Finally September rolled around and it was time for the SPS National Council meeting. The council is one of the best things about SPS because it really gets students involved in the entire process. I always think of it as a "of the people, by the people, for the people" atmosphere, because a significant percentage of the council is students. Not only are students benefiting from the opportunities afforded by SPS but the council enables us to really have a say in what goes on in the Society. This was my second year on the council and this time I had the added bonus of meeting with the Executive Committee to discuss council activities. At Council, Zone Councilors and Associate Zone Councilors of each zone meet to discuss their zone's activities, such as outstanding chapters. Another council activity is the opportunity to serve on a separate committee which focuses on a certain aspect affecting the SPS. This is one of the more time-consuming activities that we undertake but it is one of the most rewarding. At the end of the day each committee presents to the rest of the council what they have accomplished. I served on the "Under-represented groups in Physics" committee and we felt reasonably accomplished this year, as we had begun talks and planning for a conference to be held on minorities in physics. Other committees included 'ComPADRE, The Nucleus, and the Scholarship Clearinghouse,' 'Ethics Recommendations from the 2004 Congress,' and '[Sigma Pi Sigma] Congress 2008.' It was exciting to see some returning Councilors, two of which had taken last years Council by storm with a surprise presentation on their idea for the Sigma Pi Sigma Congress theme. They were back serving on the Congress committee, hammering out the details for their theme which will be used at the 2008 Congress. On the last day of the Council meeting, it was my duty to coordinate the election of the next AZC Representative to the Executive Committee, which was my last official task.

Serving on the SPS Council for the last two years was indeed a great experience. Contributing to the physics community is something I have come to appreciate and will continue to do for a long time. Though I know that my official time is over, I will definitely be involved with SPS for more years to come, if they allow me to—and remember, physicists have a lot more perseverance than most, so I'm not going anywhere!

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Motorcycle Maintenance and the Art of Physics Appreciation

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play. For years my university's chapter of the Society of Physics Students has conducted "physics circuses" with local elementary schools. Working with their teachers, we invite the children to submit written questions in advance. The 2nd and 3rd graders ask the same kinds of profound questions that drive fundamental scientific research. Here is a sample, in their own spellings:[2]

What makes light?
— Christy

How can the planets obet the sun
when they're on nothing?
— Robby

1 how does the sun stay up?
2 how does the wrod move urand?
3 how does trees grow??
4 how did dinosarze live?
— Michael

I wont too how gravtae wroks.
and how doss the sun shin.
and how mene stars are thar in
the hol wrlld.
— Kevin

I want to know if space ever ends, how magnets work, how lightning acrus, how electricity works, how sound works, if numbers ever end, how clowds acru.
— Chris

how dus the electricity gite throw the plug?
— Nikki

Why are all people different?
— Erin

These are the same questions that drive fundamental research in science! Our Einsteins, Curies, and Feynmans never stopped asking such "childish" questions. Thoreau said,[3]

Children, who play life, discern its true law and relations more clearly than men, who fail to live it worthily, but who think that they are wiser by experience, that is, by failure.

The minstrels sang as much a century later:[4]

Watch children playing,
They seem so wise.

These delightful little people also write revealing thank you letters. From a class of third graders:

I really enjoyed your show. I liked it when the liquid exploded. I like when the chemical changed. How did you think about being a scientist. A few days ago I was thinking and I got some food and made an experiment but it turned brown. The same day I made an experiment with milk and my mom told me to pour it out.
— Your friend, Christina.

...Please come back again and see us. We would be happy if you did. I was thinking that if I were to be a scientist I could be in your class. It would be lots of fun. Do you have another place?
— Your friend, Tasha

We hope that Christina will keep on experimenting. We hope that Tasha will still want to be a scientist when she reaches college. But we know that, statistically, they will not. Among the many difficulties that Christina and Tasha must overcome to keep their curiosity alive, two of the most formidable may grow from their first impressions of science as a formal academic subject.

One of these obstacles is the perception, often verbalized to children before they can decide for themselves, that "Science is *hard*." The abilities of these same children to learn languages and music suggests that the "hardness" of science is overrated, and may be a symptom of other issues in the educational process. That question we must set aside for another day.

The second obstacle, and the one explored here, is the early impression that science is *dull*. "Dull" is more serious than "difficult."

Most of us were probably introduced to formal science around the sixth grade, when we met some form of a checklist Scientific Method. A contemporary version of it goes like this:[5]

Using Scientific Methods
1. Ask a question.
2. Make a hypothesis.
3. Plan a fair test.
4. Do your test.
5. Collect and record data.
6. Tell your conclusions.
7. Go further.

Such a checklist has value in emphasizing that science thinking must be organized so that you know what you know, and know what you don't know. But when such checklists morph into science as catechism, they give the false impression of science as a stern schoolmaster. Interest and curiosity are the first casualties. But this dour view of science does not square with the experience of practicing scientists. Most scientists see their work as an expedition filled with adventure and creativity. Their work is closer to that of the artist, and not the building inspector.

In 1974 Robert Pirsig chronicled in *Zen and the Art of Motorcycle Maintenance* a trip he took with his son Chris.[6] Beneath the surface was a philosophical journey as well. While visiting a friend who was a sculptor at Montana State University, Pirsig was shown a set of rotisserie assembly instructions. The professor of sculpture had spent a frustrating afternoon putting the rotisserie together, and wanted to see the instructions thoroughly damned. Finding nothing technically wrong, Pirsig took a broader view and said,[7]

What's really angering about these instructions is that they imply there's only one way to put this rotisserie together—their way. And that presumption wipes out all the creativity....

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Our awareness of the universe reminds us that we are in it as participants; we are not detached spectators of it. Robert Pirsig wrote, "On a cycle the frame is gone. You're in the scene, not just watching it anymore, and the sense of presence is overwhelming." Our cover story muses on the art of physics appreciation, from the formative role of the profound science questions asked by second-graders, to the sense of presence one experiences when standing next to a radio telescope collecting faint signals from across the universe.

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Science is not done by checklists of rigid rules. Not coincidentally, the same may be said of art. In *The Story of Art*, E. F. Gombrich put it this way:[8]

It is fascinating to watch an artist...striving to achieve the right balance, but if we were to ask him why he did this or changed that, he might not be able to tell us. He does not follow any fixed rules. He just feels his way. It is true that some artists or critics in certain periods have tried to formulate laws of their art; but it always turned out that poor artists did not achieve anything when trying to apply these laws, while great masters could break them and yet achieve a new kind of harmony no one had thought of before.

Science appreciation is not about following rigid rules. It's about creativity. It's about relationships. Returning to the rotisserie instructions, Pirsig continued:[9]

[It] presumes there's just one right way to do things and there never is....But if you have to choose among an infinite number of ways to put it together then the relation of the machine to you and... to the rest of the world, has to be considered, because the selection from among many choices, the art of the work, is just as dependent upon your own mind and spirit as it is upon the material of the machine...

Those second graders wanted to know what makes the sun shine, if space ever ends, if numbers ever end. These are the same questions that drove Hans Bethe and Albert Einstein and Emmy Noether.[10] But instead of an adventure in discovery, our budding scientists got a checklist. Checklists can be tested for on a quiz.[11] The spirit of adventure was trumped by another agenda. What happens when you have to wear somebody else's mind and spirit? Pirsig recalled how his former self, referred to in the third person as Phaedrus, began teaching rhetoric at Montana State:[12]

He was working on lecture notes at the time and was in a state of complete depression about them....

The text started with the premise that... rhetoric...should be taught as a branch of reason.... Elementary logic was introduced,... stimulus-response theory was brought in, and from these a progression was made to an understanding of how to develop an essay...

[Phaedrus] felt there was something wrong with it...He... felt that no writer ever learned to write by this squarish, by the numbers, objective, methodical approach....

Then one day Sarah, the department secretary, said in passing, "I hope you are teaching Quality to your students." Phaedrus assured her that he was. But the more he thought about it, the more he realized he could not answer the question, "What *is* Quality?" You *recognize* Quality when you see it, but you can't *define* it. Since you can't define it, you can't fit it into a structured system. That realization started Phaedrus on a long philosophical journey that took him past the point of madness. A motorcycle illustrates the principles.[13]

Motorcycles function according to the rules of reason. One way therefore to understand a motorcycle is through the logical analysis of its systems, with wiring diagrams and maintenance schedules. Pirsig called this world of underlying form the "Classic" mode of understanding. This way of seeing a motorcycle is essential when your alternator burns out. But there's also the "Romantic" mode of understanding. Here one appreciates surface impressions-the motorcycle's rugged grace, the gleam of the chrome, the joy of riding.

An apparent split between science and art seems to follow this Classic-Romantic fault line. Pirsig saw this split as destructive, and tried to bring the two modes of understanding together. As he and others have observed, this apparent split goes back to the beginning of Western thought.[14,15] The Greek philosophers were seeking what is *true*, above mere opinion. In the competition for the mind of mankind, they opposed the Sophist teachers of rhetoric, who taught *excellence*, one's judgement of what is *good*. The philosophers thought it necessary to introduce a distance between object and subject. Pirsig saw this detachment as the source of the disconnect between modern society and the natural world, between people and their machines and one another. Landscapes and wildlife become commodities; the sky is over us but we never look up; persons become objects, science a list of numbered instructions.

The link between the Classic and Romantic ways of seeing, the source of both, is Quality. Your search for what's *true* is guided by your sense of oneness with what's *good*. That guidance, that oneness, cannot be reduced to rotisserie instructions.

How does this guidance work? To maintain a motorcycle or to do physics, you must observe facts. But when the motorcycle won't start, or when your students are profoundly stumped by Faraday's law, you don't sit back and *passively* observe facts. *Which* facts are you going to observe? The color of the gas tank? The student's zip codes? The facts that are worth observing have to be *selected* on the basis of value.[16]

And Step Two of the checklist Scientific Method says "Make hypothesis." Although you can make an infinite number of hypotheses, you can never test them all, even though the checklist says you must. Therefore you have to reject some hypotheses in advance, through value considerations such as simplicity and elegance. The logic of science rests on a foundation of *aesthetic* values.

This reality has long been understood by master artists of physics, from Henri Poincaré writing about the selection of facts in 1908,[17] to George Sudarshan contrasting metaphors and analogies, laws and principles in 1998.[18] In a 1918 speech, Albert Einstein noted that the supreme task of science is to arrive at universal elementary laws that describe nature.[19] But, said Einstein,

There is no logical path to those laws; only intuition, resting on sympathetic understanding of experience, can reach them...

Einstein was talking about something deeper than reason: the *art* of doing physics. Combining intuition with evidence based reasoning, *science is the art of creating and testing a network of concepts in terms of which the universe becomes comprehensible*. Those concepts are creations of the human mind. That's the art. They must be tested against reality, then modified or replaced as necessary. That's the science. One cannot teach this craftsmanship, or gain a feeling for the work, by following fearfully the rotisserie instructions.

Pirsig observed how the true artist follows wherever Quality leads, even when the Quality path departs from the instructions. "*Sometime look at a novice workman or a bad workman and compare his expression with that of a craftsman whose work you know is excellent... The craftsman isn't ever following a single line of instruction. He's making decisions as he goes along....The material and his thoughts are changing together in a progression of changes until his mind is at rest at the same time the material's right.*"[20]

Where does the "objectivity" of science come in? It will not be found in the attitude of an Einstein pursuing his vision, for 10 difficult years, of gravitation as the curvature of spacetime. Objectivity will not be found in a Marie Curie standing day after day over noxious vats of melted pitchblende relentlessly pursuing trace amounts of radioactive elements. No, the

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objectivity of science does not go on pristine display in the focused dedication of the intense researcher.[21] It enters through the integrity of peer review, the rebar that gives the structure of science its robust strength. Passion for the craftsmanship drives the artist-researcher; skepticism drives the reviewer. When their minds meet, they are engaged in a conversation with Nature.

Craftsmanship requires the absence of detachment and the presence of authenticity. As Thoreau observed,[22]

It is a vulgar error to suppose that you have tasted huckleberries who never plucked them.

Authenticity in art or science begins with re-creating the work in the appreciator's own mind. In his 1956 essays *Science and Human Values*, Jacob Bronowski described *two* moments in the creative process:[23]

The poem or the discovery exists in two moments of vision: the moment of appreciation as much as that of creation;.... When...a theory is at once fresh and convincing, we do not merely nod over someone else's work. We reenact the creative act, and we ourselves make the discovery again.

This second creative event in physics does not always require one to learn vector calculus. It can be as direct as addressing the simple but fundamental question: "What are we doing when we solve a physics problem?" One answers, The art of physics compares the world of concepts to the world of empirical reality. But what does that mean for, say, the well-used textbook example of the block on the inclined plane?

We do not apply Newton's laws to a block on an inclined plane. We apply Newton's laws to a *conceptual representation* of a block on an inclined plane. The block is modeled as a particle, and its interactions with the rest of the world are modeled as forces and potential energies. Acceleration, mass, the particle, gravitational field, force, and energy are *concepts* that correspond to real world observables. The art of doing physics invents conceptual models, then compares their inferences against the real systems they are supposed to approximate.[24,25] This process, like the conceptualization and building and testing of a new motorcycle, stands a long way from the literal recitation of rules.

As Robert Pirsig said to Chris, taking care of a motorcycle is not hard if you have the right attitudes. It's having the right attitudes that's hard.[26] In today's society many of our fellow citizens assume science to be just another belief option. As physics appreciators we bear a responsibility to help them discover why science does not worship authority. The spirit of science says, "Is that so, eh? What's the *evidence*?" Reciting the evidence is easy; cultivating an environment where one has eyes to see it is hard, as the ongoing public conversation about greenhouse gases and climate change amply demonstrates.[27] Or to cite another contemporary example: whether or not the universe was designed by a cosmic intelligence, the question is meaningless *as science* because it invokes explanations that stand outside of nature. Science deals in explanations that operate *within* nature. Why is that central point so hard to get across to a public that starts looking for the nearest tower when fretting over cell phone reception?

Which brings us to everyday relevance in the appreciation of the familiar. The most engaging activity I have ever done with a class has each student dissect a cadaver. Unlike the biologists, we put our cadavers back together. I refer to my "Engine Cadaver Lab."[28] I don't know who has the most fun doing it, me or the students! Working in small groups, the students take apart and reassemble lawn mower engines. We examine how the engine applies physics concepts, from the moment of inertia of the flywheel to Faraday induction in the magneto; we compare systems in the human body to their engine analogs;[29] we learn what 5 ft-lbs of torque *feels* like; we visualize how a real engine actually works. As one who grew up tinkering with cars and motorcycles, I continually have to be reminded that few students today have ever worked on their own machines, even though they depend on them every day. What happened to the curiosity that so animated them as second graders twelve years before?

Happily, our engine cadaver lab, more than any other single activity I have ever done with students, gets them talking with animation. It also provides an opening for sobering discussions about the environmental impact of hundreds of millions of engines operating daily on our planet. We are *part* of the Earth, not detached spectators of it.

The photo on page three carries for me a summary of what a life with science appreciation is all about. While on a recent motorcycle trip from Arizona to Oklahoma, I pulled into the Very Large Array one evening at dusk. There I had the New Mexico desert all to myself. The vast silence was profound. The fading rays of sunlight painted the clouds as the first stars came out. I was not looking *at* the landscape; I was *in* it. Thoreau felt it too:[30]

I have, as it were, my own sun and moon and stars, and a little world all to myself...Why should I feel lonely? Its not our planet in the Milky Way?

I stood there for a long time, gazing into the sky, absorbing the solitude, alone without loneliness. There sat the machine that carried me so effortlessly across mountains and deserts; behind it another machine silently gathered faint signals from a galaxy halfway across the universe. Romantic awareness of earth and sky and light; Classical appreciation of the underlying forms that made possible the astronomical habitat, desert life, and the machines. It was a moment to live in and take with me always. It's not about the destination. It's about the journey. I wished Tasha were there. I wanted to say to her, Yes, we have a place for you here. Come and play.

— Dwight E. Neuenschwander, Editor

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OUTSTANDING SPS CHAPTERS FOR 2007

Please join us in congratulating all of the SPS chapters that attained outstanding chapter status for the past year. These are chapters active in SPS social activities, in presenting talks at local and national meetings, and whose members engage in physics outreach programs, as well as other activities. The Outstanding SPS Chapters for 2007 (with selected notes provided by the SPS Council and staff) are as follows:

ZONE 1

♦ University of Connecticut-Storrs

♦ Providence College

♦ Simmons College

"Simmons College hosted a Zone 1 meeting as a brand new chapter; and they are involved in a K-12 outreach program for elementary school girls called 'Strong Girls to Women.'"

♦ Southern Connecticut State University

ZONE 2

♦ Adelphi University

♦ University of Buffalo

♦ Colgate University

♦ Ithaca College

♦ SUNY at Brockport

ZONE 3

♦ Rowan University

♦ Juniata College

ZONE 4

♦ University of Maryland-College Park

♦ Old Dominion University

"ODU has quite a lot of activity; held a pumpkin drop analysis; great physics-related activities—very educational."

♦ Randolph Macon College

♦ University of Richmond

ZONE 5

♦ Furman University

♦ Guilford College

♦ University of North Carolina-Asheville

"UNC-Asheville had eight presentations by SPS members at meetings; had extensive outreach and volunter activity by SPS members; conducted lots of research, hosted great speakers and pizza parties; held Sigma Pi Sigma activities such as the Science Olympiad; hosted Super Saturdays, liquid nitrogen ice cream-making activities, and physics tutoring."

♦ University of North Carolina-Greensboro

♦ University of North Carolina-Wilmington

ZONE 6

♦ University of Central Florida

♦ Florida Institute of Technology

♦ University of Puerto Rico-Mayaguez

ZONE 7

♦ Denison University

"Denison has good K-12 outreach and has held an overnight holography workshop. Denison's efforts to involve alumni and other science clubs on campus is exemplary."

♦ Eastern Michigan University

♦ University of Michigan

"UM had about 40 new attendees participate in its new 'h-bar' event; it also hosted joint outreach with museum tour guides for prospective majors."

♦ Ohio University

♦ Wittenburg University

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Members of the University of Richmond SPS Chapter, an Outstanding SPS Chapter for 2006-07, are pictured at one of their liquid nitrogen ice cream socials.

SPS and APS Gearing Up for St. Louis Meeting

SPS and APS (American Physical Society) are planning a blow-out of student events for the April APS meeting in St. Louis, MO, April 12-15. There will be a Physics Jeopardy event, lab tours, a demonstration showcase, student research presentations, a physics Olympics competition, and an SPS zone meeting. Small chapter travel grants will be available on a limited basis—send your chapter's request to sps@aip.org by the Feb. 15 deadline. I hope to see you there!
— Gary White, SPS Director

Outstanding SPS Chapters for 2007

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ZONE 8

- ♦ Bradley University
- ♦ University of Louisville
- ♦ Middle Tennessee State University

ZONE 9

- ♦ University of Wisconsin-Platteville
- ♦ University of Wisconsin-River Falls

ZONE 10

- ♦ Louisiana State University-Baton Rouge
- ♦ Rhodes College
- ♦ University of Southern Mississippi

"USM conducted Absolute Zero and Conquest of Cold outreach campaign; held student/faculty jam sessions."

ZONE 11

- ♦ Coe College
- ♦ University of Northern Iowa

ZONE 12

- ♦ East Central University
- ♦ University of Missouri-Kansas City
- ♦ Southwestern Oklahoma State University
- ♦ William Jewell College

ZONE 13

- ♦ Abilene Christian University
- ♦ Angelo State University

"More SPS activity than any chapter in the country. Angelo State University had good SPS National-level participation: Marsh White, Blake Lilly; Intern; Scholarship; Outstanding Advisor."

- ♦ Texas State University

ZONE 14

- ♦ Mesa State College

ZONE 15

- ♦ Utah State University

ZONE 16

- ♦ Embry Riddle Aeronautical University

"Very active participation in local, zone, and national SPS activities. They are to be especially congratulated for becoming such a strong chapter very quickly after being formed (2003). Membership of 100+ after only two years is incredible, and the list of activities presented is commendable."

- ♦ New Mexico State University

ZONE 17

- ♦ University of Alaska-Fairbanks
- ♦ Central Washington University
- ♦ Green River Community College
- ♦ University of Oregon
- ♦ Seattle Pacific University
- ♦ University of Washington

ZONE 18

- ♦ California State University-Chico
- ♦ Hartnell Community College

♦

SPS Remembers Brent Joseph Janus

SPS-NASA Intern, 2002
Obituary, 1981 – 2007

SPS member and former National Intern Brent Janus passed away on November 27, 2007, due to complications from a respiratory infection. He was 26 years old.

Brent was a SPS National Intern in 2002, working with Dr. Larry Evans at NASA's Goddard Space Flight Center on the Near Earth Asteroid Rendezvous (NEAR) project. His team's work was later used for a display at the Smithsonian's National Air & Space Museum. A summary of his summer work is posted on the SPS Future Faces of Physics website (http://www.spsnational.org/programs/internships/2002/janus.htm).

Brent went on to graduate from Fort Lewis College in Durango, CO, in 2003, with dual degrees in physics and political science. Since that time, Brent has owned and operated his own web design business, while also working as an academic tutor and a research assistant.

Brent was physically challenged with Spinal Muscular Atrophy, a form of Muscular Dystrophy. He never walked, and spent his life in a motorized wheelchair. Because of his physical limitations, he was not able to fulfill his dream of graduate school in physics, though he tried every avenue imaginable to continue his studies. He never stopped being a student of physics, even as his condition deteriorated. Others in his class report calling him from graduate school with tricky problems from quantum mechanics, Brent's favorite subject. Brent kept up with them, and was always able to help. In a way, Brent went to graduate school in mind if not in body.

Brent's passing represents a deep loss to the physics community that knew him. His potential was immense. It is a great injustice that his body was not able to take him where his mind could so easily have succeeded. His legendary sense of humor and helpful spirit will be missed.

Fort Lewis College is establishing a scholarship in Brent's name, for deserving physics students. Contributions may be made to Fort Lewis College Foundation at 1000 Rim Drive, Durango, CO 81301.

— Contributed by Dr. Ashley Steinhardt, Fort Lewis College

Physics News Update

The American Institute of Physics Bulletin of Physics News

— by Phillip F. Schewe

Number 841 #1, October 3, 2007

The Vacuum Strikes Back.

Modern physics has shown that the vacuum, previously thought of as a state of total nothingness, is really a seething background of virtual particles springing in and out of existence until they can seize enough energy to materialize as "real" particles. In high energy collisions at accelerator labs, some of the original beam energy can be consumed by ripping particle-antiparticle pairs out of the vacuum. Sometimes this process is the very reason for doing the experiment, but sometimes it is only a detriment.

For example, in the Large Hadron Collider (LHC), under construction at the CERN lab in Geneva, a major source of beam losses (particles exiting from the usable beam) for heavy-ion collisions is expected to be a class of event in which the counter-moving ions pass each other and don't interact except to spawn a pair of particles—an electron and positron—one of which (the positron) goes off to oblivion while the other (the electron) latches onto one of the ions.

This ion, bearing an extra electric charge, will now behave slightly differently as it races through the chain of powerful magnets that normally steer the particles around the accelerator. Going a certain distance, the modified ion will leave its fellows and smash into the beam pipe carrying the beams, thus heating up the pipe and surrounding magnet coils.

Fearing these future beam losses, accelerator physicists have sought to observe this effect at an existing machine, the Relativistic Heavy Ion Collider (RHIC) at the Brookhaven Lab on Long Island. And they found what they were looking for, a tiny splash of energy amounting to about .0002 watts, or about what a firefly puts out. The RHIC beam for these tests consisted of copper ions each carrying 6.3 TeV of energy (about 100 GeV per nucleon). According to CERN scientist John Jowett, this troublesome class of events, referred to as bound-free-pair production (or BFPP, the bound referring to the electron and the free to the positron), will be much more formidable at LHC than at RHIC.

First of all, the pair production scales as the atomic number of the nucleus (or the charge of the nucleus, denoted by the letter Z) raised to the seventh power. The LHC heavy-ion collisions will use beams composed of lead ions. The more highly charged nucleus and the larger energies (574 TeV per lead nucleus) mean the BFPP process should be some 100,000 times more prominent than in the test at RHIC.

This would amount to about 25 watts, the equivalent of a reading lamp. That doesn't sound like much but, when deposited in the ultra-cold (1.9 K) magnets of the LHC, it could bring them to the brink of "quenching" out of their superconducting state, interrupting the operation of the huge machine. (Bruce et al., *Physical Review Letters*, 5 October 2007.)

Number 841 #2, October 3, 2007

Gamma Rays From Thunderclouds have been observed by ground-based detectors, providing new insights into mechanisms for accelerating electrons to high energies, as high as 10 MeV, in the atmosphere. Ground observations of thundercloud gammas has been made before as part of monitoring regular nuclear plant operations. The new measurements, however, represent the first time that such gamma studies were made with detailed scientific objectives in mind, including determinations of particle species, arrival direction, and energy spectrum.

On the night of 6 January 2007, two powerful low-pressure air masses collided over the Sea of Japan. A nearby array of gamma detectors provided information on the energy and the timing of the gammas, which are the highest-category of electromagnetic radiation. The array is operated by the University of Tokyo and the Cosmic Radiation Laboratory of RIKEN in Japan. The gamma production, the researchers believe, works like this: an energetic seed electron, perhaps liberated from an atom by an intruding cosmic ray, ionizes many air molecules, which in turn are accelerated by the high electric fields present in the thunderclouds.

This flock of fast electrons can then emit gamma radiation (bremsstrahlung, or "braking radiation") as they are slowed by surrounding air. The gamma production actually occurs before the eventual lightning strike, says Teruaki Enoto of the University of Tokyo, and the reason for this is not entirely known.

Previous thundercloud-related gammas were studied by satellite and only measured very brief bursts, with durations of msec. By contrast, the Tokyo-RIKEN work indicates bursting behavior that could last for minutes, testifying to the quasi-static nature of the acceleration mechanism at work in the clouds. The electrostatic potential in the clouds might be as high as 10 million volts. (Tsuchiya et al., *Physical Review Letters*, upcoming article.)

Number 836 #1, August 21, 2007

Light-Driven Femtosecond Electricity.

Scientists in Canada foresee the use of electromagnetic fields of laser light for inducing and reversing tiny electrical currents along molecular wires without the use of a voltage applied across leads. They would accomplish this feat by shining special laser pulses containing light waves at two different frequencies onto a polyacetylene molecule which acts like a junction between two metallic leads on either side (see figure below).

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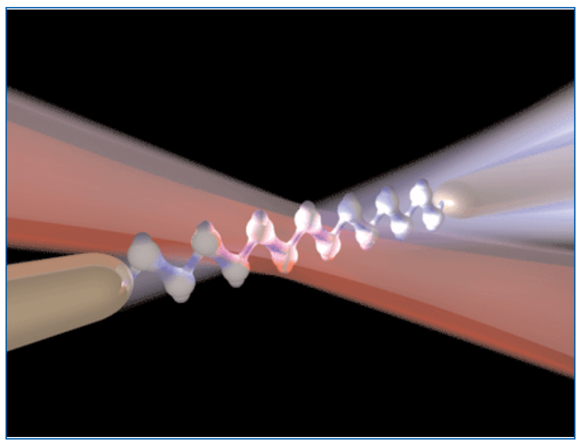


A two-color laser field can be used to efficiently induce directed currents along molecular wire junctions on a femtosecond timescale. The sign and magnitude of the current is controllable by varying laser parameters (figure by Michael Spanner).

Reported by: Franco et al. in Physical Review Letters
Figure courtesy of:
http://www.aip.org/png/2007/286.htm

Physics News Update (continued from page 8)

Depending on the exact frequencies used, the time duration of the pulse, and the relative phase relation between the two components of light, the induced pulse of electric flow could consist of as little as a single electron or many.

For the case of one electron set in motion by the 400-femtosecond pulse of laser light the resulting electrical "current" would be about 0.4 microamps. Why use light rather than voltage to drive electricity? Because the whole thing can be done on a femtosecond scale with lasers.

Ignacio Franco says that a potential use of laser-driven electricity would be in future optoelectronic devices such as ultrafast nanoswitches. (Franco, Shapiro and Brumer, *Physical Review Letters*, upcoming article.)

Number 838 #2, September 7, 2007

Curly Hair Gets Less Tangled Than Straight Hair.

The hair on people's heads (typically 100,000-150,000 hairs per head) comes in lots of shades, degrees of oiliness, and amounts of curliness. Jean-Baptiste Masson, who works at the Laboratory for Optics and Biosciences of the Ecole Polytechnique in France set out to study the problem scientifically. On the experimental front, he consulted hairdressers and got them to count tangles in people's hair. On the theoretical front, he devised a geometrical model of hair, hoping to explain the results mathematically.

Tangles, defined as groupings of hair that resist combing, proved to be almost twice as prevalent with straight hair than with curly hair. Masson explains this by saying that although straight hairs interact with each other less frequently the interaction is at great angles, and it is the relative angle between hairs that causes tangles. This in turn is a consequence of the surface properties of the hairs. One possible application of this work on hair, Masson says, is in designing velcro-like products.

For instance, the velcro properties could be changed by adding extra scales to the soft part of the velcro elements or by making the tension of the strings higher—the equivalent of making the strands straighter. Masson, whose main field of research is biophysics, expects his geometrical modeling might also be useful in the study of polymers and other filamentary materials in the biological world. (*American Journal of Physics*, August 2007.)

Number 838 #1, September 7, 2007

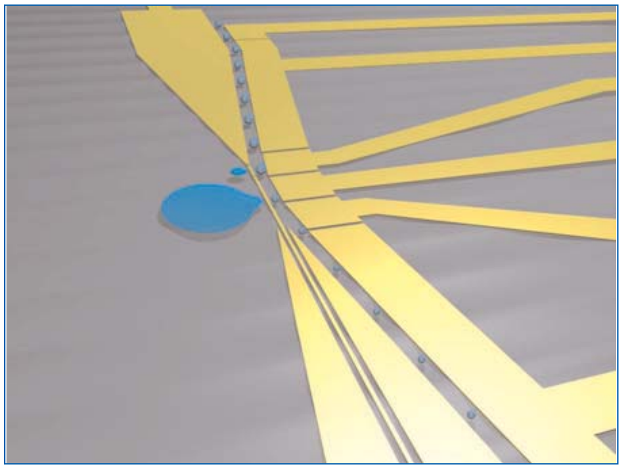
Acoustic Quantum Dots.

A new experiment at the Cavendish Lab at the University of Cambridge is the first to controllably shuttle electrons around a chip and observe their quantum properties. A quantum dot restricts electrons to a region of space in a semiconductor so tiny as to be essentially zero-dimensional. This in turn enforces a quantum regime; the electron may only have certain discrete energies, which can be useful, depending on the circumstances, for producing laser light or for use in detectors and maybe even future computers.

A quantum dot is usually made not by carving the semiconductor into a tiny grain but rather by imposing restrictions on the electron's possible motions by the application of voltages to nearby electrodes. This would be a static quantum dot. It is also possible to make dynamic quantum dots—that is, moving dots that are created by the passage of surface acoustic waves (SAWs) moving through a narrow channel across the plane of a specially designed circuit chip (see figure above). The acoustic wave itself is generated by applying microwaves to interleaved fingered electrodes atop a piezoelectric material like GaAs. The applied electric fields between finger-electrodes induce a sound wave to propagate along the surface of the material.

These acoustic waves have the ability to scoop electrons and chauffeur them along the surface.

The tiny region confining the electron even as it moves is in effect a quantum dot. Such acoustic-based dynamic quantum dots have been made before, but according to Cambridge researcher Michael Astley, this is the first time the tunneling of the electrons (even single electrons) into and out of the quantum dots has been observed. This is an important part of the whole electron-shuttling process since one wants control over the electron motions and spins. If, moreover, electrons in two very close acoustic wave channels could be entangled, then this would present the chance to make a sort of flying qubit, which could be at the heart of a quantum computer. (Astley et al., *Physical Review Letters*, upcoming article.)



Electrons (blue blobs) are shuttled along a channel and across a chip under the control of surface acoustic waves. The electrons can tunnel out of the channel into reservoir of electrons (the larger blue blob).

Reported by: Astley et al in Physical Review Letters

Figure courtesy of:
http://www.aip.org/png/2007/289.htm

Number 834 #2, July 27, 2007 by Phil Schewe and Ben Stein

Laser Icemaking.

Physicists at the University of Goettingen have for the first time gotten supercooled water to freeze using pulses of laser light. Supercooling occurs when a sample of water is chilled down through its normal freezing point (0 C) without crystallization occurring.

This can happen in a small sample and if no "nucleation" site presents itself around which solid ice (a crystal structure) can form. The incoming laser pulse brings about an optical breakdown: some of the water molecules are ionized, creating a momentary plasma. The hot plasma expands and forms a vapor bubble that collapses very rapidly.

It is the pressure waves emitted by the tiny plasma and the bubble collapse which, the Goettingen scientists believe, trigger the rapid crystallization. Previously an acoustic equivalent of this process—sonocrystallization—had been seen, but this is the first time crystallization has been initiated by a laser pulse.

One of the researchers, Robert Mettin, suggests that laser icemaking can be extended to studying solidification of other materials. (Lindinger et al., *Physical Review Letters*, 27 July 2007.)

Elegant Connections in Physics

A Survey of Big Bang Cosmology, Part I: Cosmic Geography

— *by Dwight E. Neuenschwander*

In November 1915, Albert Einstein finished his decade-long struggle to develop the General Theory of Relativity (GR), in which he envisioned gravitation geometrically as the "curvature of space-time." Immediate observational confirmation for the theory was significant but slim. In 1915 this consisted of the successful accounting of the anomalous precession of Mercury's orbit. Tests of other early predictions, all on the solar system scale, would have to wait. Measurement of the deflection of light rays grazing the sun occurred with the 1919 total solar eclipse; measuring gravitational redshift and radar echo delay required high-speed electronics that appeared around 1960. Some measurements, such as gyroscope precession and gravitational waves, are only now being carried out for the first time.[1]

Despite limited early opportunities to test the theory, in 1917 Einstein hitched his wagon to the stars and brazenly launched modern cosmology by applying GR to the *entire universe*. In so doing he started a discussion that, over the next dozen years, blossomed into the genesis of big bang cosmology.

The years between 1900 and 1930 saw a confluence of observation and theory that matured cosmology into a science. On the theoretical side was the advent of GR. Newtonian cosmology was spectacularly inconsistent with Newtonian gravitation concerning the boundary conditions at infinity, and in 1917 GR offered a way out of the impasse. On the observational side, the realization that the spiral nebulae lay far outside the Milky Way galaxy was a necessary insight before modern cosmology could be possible. We take up a synopsis of the latter story here, and return to the former in subsequent installments of this series.

"...A CONGERIES OF INNUMERABLE STARS..."

In 1610, Galileo Galilei published *The Sidereal Messenger*, which offered humanity its first glimpse of the innumerable quantity of stars:[2]

> *"...the Milky Way itself...with the aid of the spyglass, may be observed so well that all the disputes that for so many generations have vexed philosophers are destroyed by visible certainty, and we are liberated from wordy arguments. For the Galaxy is nothing else than a congeries of innumerable stars distributed in clusters. To whatever region of it you direct your spyglass, an immense number of stars immediately offer themselves to view, of which very many appear large and conspicuous but the multitude of small ones is truly unfathomable."*

Not all the "disputes were destroyed by visible certainty," as we shall see. But from now on they would be resolved with data understood through theoretical models. By the end of the seventeenth century, the enormous successes of the Newtonian paradigm at the solar system scale gave Newtonian cosmologists, beginning with Isaac Newton himself, reason to turn with confidence to the large-scale structure of the universe. When Newton wrote the *Principia* in 1687, and republished its Book 3 as *A Treatise on the System of the World* in 1728, no mechanisms were known for turning stars on or off; presumably the universe was eternal. Euclidian space was the only geometry imaginable. Space was assumed infinite because an edge or boundary would raise more questions than it answered. The cosmos was thought to be essentially static because the stars exhibited little perceptible motion relative to one another. There was only one tiny problem. An infinite, static, eternal universe was *impossible to reconcile* with Newtonian gravitation.

Gravity only attracts; so why doesn't Galileo's "congeries of innumerable stars" collapse? To explain the non-occurrence of that catastrophe Newton invoked a symmetry argument. He suggested that the star population extends to infinity, with a uniform number density:[3]

> *"The fixed stars, being equally spread out in all points of the heavens, cancel out their mutual pulls by opposite attractions."*

Leaving aside the subtle (and fatal) question of such a system's instability against local density fluctuations, the model was also famously plagued with the so-called Olbers Paradox, first discussed by Edmund Halley in 1720, then J. P. de L. de Cheseaux in 1744, and Heinrich Olbers in 1823 (demonstrating that sometimes it pays to be third).[4] In an infinite universe populated uniformly with stars, every line of sight eventually terminates on a star. The stars far away appear dimmer than nearby ones, but there are more of them. For the stars in a spherical shell of given radius centered on the observer, the distance-dependent factors cancel, giving a each shell a common brilliance, not to mention infinite intensity when integrating over all shells.

Much of what Galileo saw through his small refractor and took to be stars turned out to be diffuse gas illuminated by starlight. A century later, Emanuel Swedenborg (1734), Thomas Wright (1750), Immanuel Kant (1755), and Jean Lambert (1761) commented on the existence of the fuzzy patches called "nebulae," not yet resolved into spirals or any other definite shape.[5] Whatever they are, about a hundred nebulae were listed by Charles Messier in his famous catalog "*Mémoires de l'Academie*," published in 1774. Thomas Wright had postulated that the Milky Way is a disc-shaped array of stars around us, and starry hosts might extend beyond our range of observation. In *An Original Theory or New Hypothesis of the Universe*, he wrote

> *"...That this [endless immensity] in all probability may be the real case, is in some degree made evident by the many cloudy spots, just perceivable by us, as far without our starry Regions...."*

William Herschel, a.k.a, Fredrich Wilhelm Herschel, was a musician who emigrated from Germany to England in 1759, having had enough of the Seven Years War. While teaching music in England he took up astronomy, and became one of the most skilled of telescope makers. Among his many astronomical accomplishments, Herschel attempted to map the Milky Way in a procedure he called "star gauging." By assuming the stars had the same intrinsic luminosities, he

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proposed relative distances to the stars from the relative intensities of their light that we receive on Earth. Thus he mapped the Milky Way by counting stars of various magnitudes, in hundreds of fields of view.

While making his systematic surveys of the sky Herschel discovered Uranus in 1781. This got him elected to the Royal Society, and he could devote his full time to astronomy, which was good for astronomy if not for music (CDs of his symphonies are available). Presented that same year with a copy of Messier's catalog, Herschel, with his sister Caroline, his steadfast partner in observing, began to systematically study the nebulae. Over the years they discovered thousands of them.

Messier had suggested that 29 of his nebulae held no stars. However, with his excellent telescopes Herschel was able to resolve 18 of these into what we now call "globular clusters," most of which seem to congregate in the direction of Sagittarius, suggesting we are not surrounded by them; and in 1790 he found a nebula that contained a central star surrounded by what appeared to be a gaseous atmosphere. Today we call the latter "planetary nebulae" in which the star has puffed off its outer layers. However, with the persistence of some diffuse nebulae (think of the Orion or the Crab nebulae), Herschel became convinced that not all nebulae would be resolved into stars.[6]

A distinctive spiral shape for a nebula was first seen in M51 in 1845 by William Parsons, third Earl of Rosse, with "Leviathan," his 72-inch telescope that surpassed Herschel's 48-inch instrument as the world's largest at the time, and remained so for the next seventy years.[7] Few believed his remarkable drawings of spirals until photographs offered confirmation.

What are the Spirals?

In his *General Natural History and Theory of the Heavens* of 1755, Immanuel Kant proposed two far-reaching ideas.[8] One hypothesized that stars and their planets form in the condensation of some of the nebulae.[9] His second hypothesis suggested that some of the nebulae are "island universes," galaxies in their own right, of which the Milky Way happens to be the example in which we reside. Kant wrote, "It is much more natural and reasonable to assume that a nebula is not a unique and solitary sun, but a system of suns."[10] Kant's "island universe" hypothesis was at the time pure speculation, and raised a controversy that continued until 1924.

Kant was a formidable philosopher, though not trained in advanced mathematics. So he could not express his concepts in the language of mathematical models that could lead to testable quantitative inferences. That step was taken in 1796 by Pierre-Simon Laplace, who made quantitative the nebula collapse concept as the mechanism of solar system formation.[11] After 1845 it was suggested that in the vortex of the spiral nebulae we are seeing solar system formation in progress. Until 1924 astronomers tended to be either Kantians or Laplacians. Kantians supposed that the nebulae were "island universes," other galaxies like the Milky Way. Laplacians supposed that the nebulae, especially the spirals, were solar systems under construction.

The Island Universe hypothesis received its first observational support from the inexhaustible William Herschel. In two papers of 1784 and 1785 he presented the results of his "star gauging" surveys from 683 regions over the sky. In some fields he would see only one star, in others there would be hundreds. His map of the Milky Way shows roughly a wheel-shaped region with the Sun placed near the center. The Milky Way, according to Herschel's map, was not infinite in extent. So if the Milky Way was just a proper name for the universe, that would offer a sharp contrast to the assumptions of Newtonian cosmology. In any case, the galaxy's finite size supported the island universe notion.

Herschel's early map is all the more remarkable because he did not entertain the notion of absorption of light by interstellar dust, or allow for diverse luminosities among stars. The ubiquitous John Michell had shown in 1767 that the stars could not all have the same luminosity.[12] For instance, the stars in the Pleiades appear with unequal brightnesses, yet their grouping gives every appearance of the members being close proximity to one another.

The main problem was measuring distances with any reasonable accuracy and precision. Stars are so far away that distances to only a very few nearby ones can be measured by parallax using the Earth's orbit diameter as the baseline. Such a trigonometric parallax was first published by Friedrich Wilhelm Bessel in 1838, finding 0.31 seconds of arc for 61 Cygni, which puts it about 10 light-years (LY) from Earth.[13] These incredibly skinny triangles are good for probing distances on the order of less than 100 LY.

Herschel hoped to use as a distance calibrator the parallax of "optical double stars," two stars that happen to lie on essentially the same line of sight. Herschel proceeded to catalog all the optical double stars he could find. He was not successful in using them as distance indicators, but he did show for the first time (with Castor in Gemini, in 1804) that gravitationally bound true binaries occur, where one star orbits another, and therefore Newton's laws apply outside the solar system. Herschel's quest for binaries also showed that some of his true binary stars had differing brightness, whereupon he reluctantly acknowledged that stars exhibit diverse luminosities.

As Herschel began to question his own assumptions for mapping the Milky Way, he began to doubt the island universe model. The Laplacian scenario of the spirals being stars condensing from nebulae seemed to receive dramatic support with the sudden appearance in 1885 of a bright new star, or "nova," seen in M31, the Andromeda nebula.

Throughout the 19th century, estimates for the size of the Milky Way ranged from about 6,000 to over 20,000 LY.[14] These were Herschel's figures early (1785) and later (1806) in his star-gauging career. Several other surveys were attempted by other astronomers. For instance, Giovanni Celoria in 1879 proposed a finite galaxy of two or more concentric rings. Not until 1900 was the first map of the Milky Way drawn that endows it with spiral arms. This was done by Cornelius Easton, who placed the Sun in the center and the spirals off to the sides.[15] Karl Schwarzschild estimated the galaxy to be about 10 kpc (1 pc = 3.26 LY) in diameter, 2 pc thick, with the Sun at the center. Jacobus Cornelius Kapteyn and Pieter J. van Rhijn in 1920, and Kapteyn again in 1922, put the diameter of the galaxy about double Schwarzschild's, and the latter survey put the Sun about 3 kpc off-center.[16]

But even if the Milky Way was a spiral, it was not yet clear whether the spiral nebulae were sovereign galaxies, or merely satellites of the Milky Way. By the time Easton drew his Milky Way spi-

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ral, over 100,000 spiral nebulae had been found. I suppose it is hard for us nowadays to appreciate how difficult it must have been at that time to be asked to stretch one's mind around the vastness of space required for the spiral nebulae to be as remote and large as the island universe required. In addition, the brightness of the "new stars" (novas), such the Andromeda event of 1885 and Tycho's nova of 1572, overwhelmed the imagination if they were supposed to occur in other, distant island universes not part of the Milky Way (although by 1920 there was talk of there possibly being more than one kind of nova). The astronomer and historian Agnes Clerke perhaps echoed this reluctance accurately when she wrote in *A Popular History of Astronomy During the Nineteenth Century* (1890), "No competent thinker, with the whole of the available evidence before him, can now, it is safe to say, maintains any single nebula to be a star system of coordinate rank with the Milky Way."[17] If that sentiment was right, then the Milky Way was the universe. As late as 1922 when H. G. Wells ambitiously wrote *A Short History of the World*, it was still possible to think of the spirals as solar systems in the process of forming:[18]

> *"The telescope reveals to us in various parts of the heavens luminous spiral clouds of matter, the spiral nebulae, which appear to be in rotation about a centre. It is supposed by many astronomers that the sun and its planets were once such a spiral, and that their matter has undergone concentration into its present form."*

Standard Candles and Redshifts

If a "standard candle" were available, then the ratio of received flux to the candle's intrinsic luminosity would give a fairly accurate measure of the distance to it, thanks to the inverse square diminishment of light intensity. The first reliable standard candles were provided in 1908 by Henrietta Swan Leavitt, after working for four years with photographic plates from Harvard's new Arequipa observatory in Peru.[19] The plates carried images of light from Cepheid variable stars residing in the Small Magellanic Cloud. She reinforced her results with more data in 1912.[20]

All stars exhibit some mechanical vibrations, and several kinds of variable stars exist. Cepheids are massive, young stars that take this periodic swelling to such amplitudes that the oscillations in the star's surface area give its luminosity measurable periodicity. Cepheids are bright enough to probe intergalactic distances, and have periods that range from 2 to 40 days.[21] However, their average luminosities vary from star to star. For the 1908 paper, from the Arequipa plates Leavitt found and measured hundreds of variable stars. Of these she highlighted sixteen Cepheids for which she could say, "It is worthy of notice [that] the brighter variables have the longer periods." Her discovery of the period-luminosity relation of the Cepheids, with its subsequent tentative calibration via statistical methods by Henry Norris Russell[22], Einar Hertzsprung[23], Harlow Shapley,[24], and Ralph Wilson[25], released the brake on measuring deep space distances.

Compared to distance measurements, velocity measurements of nebulae were relatively robust. About 1912 Vesto Melvin Silpher, working with the 24-inch refractor at the Lowell Observatory, started measuring the spectra of several dozen spiral nebulae. Percival Lowell, the observatory director, expected these studies to show that spiral nebulae were indeed solar systems being formed.[26] But Silpher, who had previously analyzed the spectra of the planets, became convinced that the spirals were not planetary systems, but full-fledged galaxies, because their spectra were more like those of stars.

Silpher's spectra were also the first empirical evidence of a systematic redshift among the nebulae. By 1922 he had collected data from 41 nebulae. Of these, 36 showed redshifts, fractional stretches of wavelength that ranged up to $\Delta\lambda/\lambda \approx 0.006$. Only five nebulae showed blueshifts, the largest being Andromeda with $\Delta\lambda/\lambda \approx -0.001$. If these red and blue shifts were interpreted as Doppler effects due to relative motion between the source and our own system (and not due to other interpretations, such as Fritz Zwicky's "tired light" hypothesis), then to first order in velocity, the Doppler effect for light gives $\Delta\lambda/\lambda \approx v/c$. The dominance of redshifts suggested that the spirals, whatever they were, are not gravitationally bound to the Milky Way galaxy. The significance of this pattern would become apparent after 1917, increasingly so throughout the 1920s, and would be understood as a *cosmological* redshift.

The "Great Debate"

Scientific controversies are not settled by verbal debates, but by evidence. Nevertheless, a debate can be useful for focusing the issues. The National Academy of Science's annual William Ellery Hale Lectures featured for 1920 a "debate" between Harlow Shapley of the Mt. Wilson Observatory, and Heber D. Curtis of the Lick Observatory. Their topic was "The Scale of the Universe." The island universe model may have seemed far-fetched in 1890, but by 1920 much informed opinion was swinging in its favor.

In the 1920 Debate,[27] Curtis was the Kantian. He had spent much of his time at the Lick Observatory photographing and measuring the spirals. Shapley was the Laplacian. Using Leavitt's Cepheid variables—and several extrapolations beyond them—Shapley attempted to measure the size and shape of the Milky way, and obtained answers so large that he became convinced that the Milky Way was the entire universe. Among his extrapolations, on one end of the distance scales Shapley lumped RR Lyre stars (older periodic stars with pulsation periods less than a day) along with W Virginis stars (with periods similar to the Cepheids but different chemical compositions and ages)[28] into a single period-luminosity relation; on the other end of distance scale he valiantly attempted to use entire star clusters as standard candles. It would take Walter Baade and others, working into the 1950s, to sort out the different kinds of variable stars and complete separate calibrations for all of them.

Shapley argued that the Milky Way was essentially the Universe. He put its diameter at some 200,000 LY with the Sun about 65,000 LY from the center, with the globular clusters hovering about the center. Curtis cited for these dimensions about 32,000LY and 10,000 LY respectively (the modern value is over 100,000 LY for the diameter of the visible disc and roughly 25,000 LY for our distance from the center). The upshot was that Shapley's Milky Way was thought to be so enormous that it was essentially the entire Universe; at best the spirals were satellites of it. Curtis' universe, in contrast, shrank the Milky Way down to a size where it might be but one of many spiral nebulae. That two leading astronomers could come to quite different conclusions shows that the measurements were tedious and difficult, and

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filled with compounded uncertainties. Improved technology in the form of larger telescopes, and thus less ambiguous data, was just around the corner.

The ink was barely dry on Wells' 1922 book of world history when the new 100 inch telescope at Mt. Wilson saw first light. This instrument was able to resolve individual stars within some of the spiral nebulae. On the night of October 4, 1923, Edwin Hubble took another round of time exposures of the Andromeda spiral nebula, looking for novae, and confirmed when comparing that night's run to previous plates that Andromeda held a sample of Henrietta Leavitt's Cepheid variable stars.[29] Hubble's measurements and Leavitt's period-luminosity relation put the distance to Andromeda on the order of a million LY, an order of magnitude more remote than the outer regions of even Shapley's swollen Milky Way (modern, re-calibrated distance: ~2 MLY). The Kantian-Laplacian question of the spirals was settled. The spiral nebulae were galaxies.

Hubble's paper reporting the results was read by Henry Norris Russell at the December/January 1924-25 meeting of the American Association for the Advancement of Science. *The New York Times* beat the peer-reviewed journals to press with an article on November 24, 1924 that said, "Dr. E. Hubble confirms view that spiral nebulae are stellar systems." Before the AAAS meeting, Hubble broke the news to Shapley in a letter. Cecilia H. Payne-Gaposchkin recalled being in Shapley's Harvard office when the letter arrived. Shapley held it out to her and said, "Here is the letter that destroyed my universe."[30] Hubble's student Allan Sandage would later recall, "What are galaxies? No one knew before 1900. Very few people knew in 1920. All astronomers knew after 1924."[31]

Return to Einstein and 1917

Whether the universe was a "gas" of individual stars or of nebulae, in 1917 the boundary conditions at infinity and cosmological kinematics were still open questions. At the largest scales the distribution seemed to be reasonably isotropic and homogeneous. As we will discuss in the next installment of this series, Newtonian gravitation was wonderfully inconsistent with the cosmological boundary conditions at infinity. The redshift measurements of the time gave speeds small compared to light, suggesting the contents of the universe to be static in the main. Seeking consistency with contemporary data, in his 1917 cosmology Einstein took his model universe to be static, homogeneous, and isotropic. Most remarkable, Einstein solved the problem at infinity by abolishing infinity, by postulating a spherical closed geometry! However, to his chagrin he found that to make the model work he had to modify his original equations by introducing a "cosmological constant," Λ, that effectively opposed gravity to maintain a static universe. The 1917 paper[32] started a discussion that, through the work of mathematicians and astronomers in Russia, England, Belgium, America, Holland, and elsewhere, led by 1930 to an observational and theoretical understanding that the universe is expanding.

After the expansion of the universe was discovered, Einstein urged that Λ be dropped and his equations restored to their pristine form. However, Λ could not be so jauntily dismissed. A nonzero Λ remains a *logical* possibility within GR, thereby allowing the *most general* version of the field equations. But Λ remains an enigma: what principle determines its value? If nonzero, must Λ be a *fundamental* constant, or could some non-gravitational physics produce an *effective* Λ?

As a serious contender for the latter, consider that most of the universe is "empty" space, or "vacuum." The vacuum, practically by definition, has zero energy density. But according to quantum theory, "zero" means only that the *average* energy vanishes—there are always statistical fluctuations about the average. They would arise through the continual production and annihilation of virtual particle-antiparticle pairs. If these statistical processes endow the energy density of the vacuum with a nonzero variance, in an expanding universe it would eventually dominate the cosmic energy density budget. These vacuum fluctuations could provide an *effective* cosmological constant.

Unfortunately for our present understanding, all attempts to *calculate* an effective Λ from quantum theory give answers that are ridiculously larger than observational limits on Λ allow. This dilemma must be taken seriously today because two independent lines of recent research lead to the conclusion that a non-zero Λ, or something mimicking it, seems to account for about 70 percent of the energy density of the universe! This exciting development reveals a crisis of incompatibility between GR and quantum theory, which separately have proved to be our most successful theories. In our next article we return to 1917 and see how Λ entered cosmology.

Acknowledgments

Any short telling of a topic as rich in personalities and events as the history of cosmology will skim the surface at best. I am indebted to Professor Virginia Trimble for priceless suggestions, criticisms, and much-appreciated advice. Any errors that may remain are my own.

References

[1] For a comprehensive comparison of GR to evidence see Clifford Will, *Theory and Experiment in Gravitational Physics* (Cambridge, 1981, 2000). Gravitational wave interferometers are now being realized; see the Fall 2005 *Radiations* which describes how your screen saver can help analyze LIGO data. The Gravity Probe B experiment, measuring the geodetic and frame-dragging effects on orbiting gyroscopes, released initial results earlier this year; see http://einstein.stanford.edu/ .
[2] Galileo Galilei, *Siderus Nuncius* (1610), Tr. by A. van Helden (Univ. of Chicago, 1989), p. 62.
[3] Newton in the *Principia*, quoted by E. R. Harrison, *Cosmology* (Cambridge, 1981), p. 10.
[4] J. D. North, *The Measure of the Universe: A History of Modern Cosmology* (Dover, 1965), Ch. 1; see also Charles W. Misner, Kip S. Thorne, and John A. Wheeler, *Gravitation* (Freeman, 1973), p. 756; and Edward Harrison, "Olbers' Paradox in recent times," *Modern Cosmology in Retrospect*, edited by B. Bertotti, R. Balbinot, S. Bergia, and A. Messina (Cambridge, 1990), p. 33.
[5] North, Ref. 4, p. 3 offers a brief survey. The original sources are E. Swedenborg, *Principia Rerum Naturalium* (Dresden, 1734), tr. by J. R. Rendall and I. Tansley as *The Principia* in two volumes (London, 1912); T. Wright, *An Original Theory, or New Hypothesis of the Universe, founded upon the Laws of Nature, etc.* (London, 1750); I. Kant, *General Natural History and Theory of the Heavens* (1755), tr. by W. Hastie (Glasgow, 1900); J. Lambert, *Kosmologischen Briefe* (Augsburg, 1761). See also the collection of Bertotti et. al, ref. 4.
[6] North, Ref. 4, Ch. 1. For biographies of the Herschels see M. A. Hoskin, *William Herschel and the Constructions of the Heavens* (Oldbourne Press, 1964) or C. A. Lubbock, *The Herschel Chronicle* (Cambridge, 1933).
[7] North, p. 7.
[8] Kant :Bef http://www.friesian.com/kant.htm#note-1 .
[9] Swedenborg suggested a similar idea a few years earlier; cf. North, p. 7.
[10] George Johnson, *Miss Leavitt's Stars: The Untold Story of the Woman Who Discovered How to Measure the Universe* (Norton, 2005), p. 59.

(continued on page 14)

A Survey of Big Bang Cosmology, Part I: Cosmic Geography

(continued from page 13)

[11] P. S. Laplace, *Mécanique Céleste*, in five volumes, 1799-1825.
[12] North, p. 4.
[13] Bessel was the first to publish a triangulation parallax result. That same year Thomas Henderson, working at the Cape of Good Hope, measured the parallax of Alpha Centauri; and Friedrich Struve in Russia measured a parallax for Alpha Centauri and Vega. See George O. Abell, David Morrison, and Sidney C. Wolff, *Exploration of the Universe*, 6th ed. (Saunders 1993) Ch. 21; also North (ref. 4.).
[14] V. Trimble, "The 1920 Shapley-Curtis Discussion: Background, Issues, and Aftermath," *Publications of the Astronomical Society of the Pacific* **107**, 1133-1144, Dec. 1995.
[15] *ibid.*; also North, p. 9.
[16] *ibid.*
[17] Johnson,, ref. 10, p. 60.
[18] H. G. Wells, *A Brief History of the World* (Macmillan, 1922) p. 5.
[19] H. S. Leavitt, "1777 Variables in the Magellanic Clouds," *Annals of the Astronomical Observatory of Harvard College*, **60**, No. 4, 87-108 (1908).
[20] Edward C. Pickering, "Periods of 25 Variable Stars in the Small Magallenic Cloud," *Harvard College Observatory Circular* **173**. Although this paper was published under Pickering's name as the Director of the Observatory, the first sentence says, "The following statement regarding the periods of 25 variable stars in the Small Magellanic Cloud has been prepared by Miss Leavitt."
[21] See any introductory text; e.g., Abell et. al., (ref. 13), Ch. 29; Niel F. Comins and William J. Kaufmann III, *Discovering the Universe*, 5th ed. (Freeman, 2000), Ch. 11; Michael A. Seeds, *Horizons: Exploring the Universe*, 6th ed. (Brooks/Cole, 2000), Ch. 12.
[22] H. N. Russell, *Science* **37**, 651 (1913),
[23] E. Hertzsprung, *Astron. Nachr.* **196**, 201 (1913).
[24] H. Shapley, *Astrophysical Journal* **48**, 89 (1918).
[25] R. E. Wilson, *Ap. J.* **35**, 35 (1923); Ap. J. 89, 218 (1939).
[26] V. Trimble, "H_0: The Incredible Shrinking Constant 1925-1975," *Pub. Ast. Soc. Pacific* **108**: 1073-1082, Dec. 1996, p. 1076; also North, ref. 4, p. 142.
[27] For a thorough and lively account, see Trimble, ref. 14. Johnson, ref. 10, Ch. 6, provides an engaging synopsis.
[28] Cepheids are "Population I" and W Virginis stars are "Population II" stars.
[29] Hubble's colleague, Milton Lasell Humanson, may have been the first to detect Cephids in M31, while Shapley was the Mt. Wilson director. See refs. 26 and 17.
[30] Trimble, ref. 14, pp. 1142-1143.
[31] Johnson, ref. 17, p. 98.
[32] A. Einstein, "Cosmological Considerations on the General Theory of Relativity," pp. 177-188 in the Dover reprint of original papers by Einstein, Lorentz, Weyl, and Minkowski: *The Principle of Relativity*, tr. by W. Perrett & G. B. Jeffrey (Dover, 1952). The original article appeared as "Kosmologische Betrachtungen zur allgemeinen Relativitätstheorie," in *Sitzungsberichte der Preussischen Akad. d. Wissenschaten*, 1917.

Motorcycle Maintenance and the Art of Physics Appreciation

(continued from page 4)

Notes

This article borrows excerpts from two of the author's talks, "Conversations with ghosts" [*Am. J. Phys.* **69** (3), 251-254 (2001)], presented at the Summer 2000 AAPT Summer meeting; and "There is no 'Art,' there are only artists," <http://preview.tinyurl.com/23taj2>, presented at the Summer 2006 AAPT meeting.

References

[1] Henry David Thoreau, *Walden* (first published in 1854, my copy by Houghton Mifflin Co., 1960), p. 138.
[2] Questions from pupils in the second and third grade classes of Northridge Elementary School, the second grade of Wiley Post School, and Bethany Elementary School, all in the Oklahoma City area. These samples of questions were gathered in the early and mid 1990s. Tasha has probably graduated from college by now. I wonder if she became a scientist?
[3] Thoreau, Ref. 1, p. 66.
[4] Lyric excerpt from "The Morning," track 3 of *Days of Future Passed* by the Moody Blues (Decca Records, 1967).
[5] This checklist comes from *Scott Foresman Science*, Vol. 4 (Pearson Education Inc., 2007), p. 312.
[6] Robert M. Pirsig, *Zen and the Art of Motorcycle Maintenance* (William Morrow & Co., 1974, 1999).
[7] Pirsig, Ref. 6, pp. 166-167.
[8] E. F. Gombrich, *The Story of Art* (15th Ed., Phaidon, 1995), p. 35.
[9] Pirsig, pp. 166-167.
[10] Hans Bethe first worked out in 1938 the nuclear reactions that power the Sun; in 1917 Einstein published the first modern cosmological model, featuring a closed, finite universe, a paper that started a discussion that led twelve years later to the genesis of big bang cosmology; in 1918 Emmy Noether published what is now called "Noether's Theorem" that relates conservation laws to symmetries. Noether was well known to mathematicians for her work on abstract algebra.
[11] I mean this literally. On my son's first day of sixth grade, when he had his first middle school science class, he was given a checklist "scientific method" and instructed to memorize it for the next day's quiz. I'm a PhD physicist and don't have the checklist memorized, so why sixth graders had any real reason to memorize it escapes me. It was reduced to fodder for a quiz, and therefore made the first whack at detaching that former second grade scientist from the authentic practice of science, just as he was learning the conceptual frameworks that would allow him to answer some of those profound second grader's questions. It seems that the making of such guidelines by the students themselves, *after* they have put a question to nature and have some experience to reflect over, would be more meaningful than having The Method presented as it were on tablets of stone.
[12] Pirsig, Ref. 6, pp. 180–182.
[13] ibid., pp. 73–74
[14] ibid., pp. 371–375.
[15] George Kennedy, *The Art of Persuasion in Greece* (Princeton University Press, 1963), Ch. 1.
[16] Pirsig, p. 281.
[17] Henri Poincaré, *Science and Method* (1908, Barnes & Noble, 2004).
[18] Tony Rothman and George Sudarshan, *Doubt and Certainty* (Basic Books, 1998).
[19] Albert Einstein, "Principles of Research," address delivered at a celebration of Max Planck's 60th birthday, 1918. Reprinted in *Ideas and Opinions* (Crown Publishers, 1954, 1982), pp. 224–227.
[20] Pirsig, pp. 166–167.
[21] Of course, the craftsman physicist practices internal "peer review" before sending the paper to the editor. One may be motivated by the beauty of one's idea, but like the builder of a motorcycle prototype, one rides it hard to see where it will break in order to fix that weakness. For a thorough and recent example of this process, see W. M. Wood-Vassey et. al, "Observational Constraints on the Nature of Dark Energy: First Cosmological Results from the ESSENCE Supernova Survey" (*Ap. J.* 666: 694-715, Sept. 10, 2007). The group describes their understanding of systematic error sources and estimates the contribution of each one, in a section called "Sources of Systematic Error." These include bias in differential image photometry, CCD linearity, photometric zero-point calibrations, bandpass uncertainty, K-corrections (transforming the magnitude in the observed filter to the magnitude in the rest-frame filter), galactic extinction, biased selection effects, supernova evolution, gravitational lensing, "gray" dust, and others. Even the most passionate researcher, if a true craftsman, puts hard questions to his or her own work, anticipating problems and answering them, before the work ever goes to external peer review. But to describe this important caveat in the text would have broken up the flow of its point.
[22] Thoreau, p. 120.
[23] Jacob Bronowski, *Science and Human Values* (Harper, 1956, 1965), p. 19.
[24] ibid, Ch. 2.
[25] David Hestenes, "Modeling Games in the Newtonian World," *Am. J. Phys.* 60 (8), 732-748 (1992).
[26] Pirsig, p. 410.
[27] Sharon Begley, "The Truth About Denial," *Newsweek*, August 13, 2007, pp. 20-29.
[28] "Engine Cadaver Lab" poster presentation, AAPT Summer 2003 meeting, Madison, WI.
[29] For example, the engine analog to the respiratory system includes the air cleaner, intake manifold, etc.
[30] Thoreau, pp. 90, 92.

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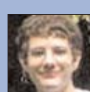

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All SPS members are invited to participate in the 2008 Sigma Pi Sigma Quadrennial Congress! This meeting will be held at the Fermi National Accelerator Laboratory (Fermilab), in Batavia, IL, November 6-8, 2008. We believe that this is the only national physics meeting specifically designed to bring undergraduates, practicing physicists and physics alumni together to address common concerns for the discipline and for society. The Congress, which is themed Scientific Citizenship: Connecting Physics and Society, will be held jointly with a regional SPS meeting.

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