This Month in Physics History

January 1998: The accelerating expansion of the universe

In the mid-1990s, two competing teams began observing supernovas with the goal of pinning down the rate at which the expansion of the universe was slowing down. Much to everyone's surprise, they found just the opposite: the expansion was not slowing down, but speeding up, driven by a mysterious unseen force. In early 1998, the researchers announced these strange results that shook up the field of astrophysics.

In 1917, as he was developing his theory of general relativity, Einstein added an arbitrary constant term to his equations in order to keep the universe static and unchanging, as it was then believed to be. Without this term, an initially static configuration of matter in the universe would tend to be pulled together under gravity; the cosmological constant was needed to counteract that tendency and keep the universe from collapsing.

However, in 1929, Edwin Hubble looked at the redshifts of faraway galaxies and found that the rate at which an object is receding from us is proportional to that object's distance from us. The universe was actually expanding, not static at all. The cosmological constant looked unnecessary, and Einstein then abandoned it, calling it his greatest blunder.

After Hubble's discovery, for the next few decades most scientists believed that there was no cosmological constant. It was assumed that matter dominated the universe and would eventually cause the expansion to slow down. Depending on just how much matter there was in the universe, it might eventually collapse in a big crunch, or go on expanding forever, but more and more slowly.

Research concentrated on determining the history of the expansion of the universe by looking at extremely distant objects. Comparing the redshift of these objects with their distance gives a measure of how fast the universe is expanding.

But getting accurate distances to faraway objects is difficult. One way to do this is to find so-called standard candles, objects whose intrinsic brightness is known and thus can be compared with their apparent brightness to give a measure of their distance from us. Type Ia supernovas are just such objects. They occur when a white dwarf star that is part of a binary system attracts some extra mass from its companion star. When the white dwarf reaches a particular mass (about 1.4 times the mass of the sun), it explodes. These supernovas are extremely bright, visible billions of light years away. Since all type Ia supernovas explode when they reach the same mass, they make good standard candles. By the mid-1980s automated searches had begun to find these rare events.

In the late 1980s, a team called the Supernova Cosmology Project, led by Saul Perlmutter at Lawrence Berkeley National Laboratory, began their search for type Ia supernovas.

Starting in the mid-1990s, a second team, called the High-Z Supernova Search, led by Brian Schmidt of the Australian National University and Adam Riess of the Space Telescope Science Institute, worked on a competing effort.

The research teams used both ground-based telescopes and the Hubble Space Telescope in the race to find supernovas billions of light years away and use them to measure the (presumed) slowing of the expansion of the universe.

By late 1997, supernova data were piling up, and both groups were noticing that the distant supernovas were fainter than expected, indicating that the universe's expansion is actually speeding up, not slowing down.

In January 1998, at a press conference held during the Washington, DC meeting of the American Astronomical Society, the Supernova Cosmology Project team announced that they had analyzed 40 supernovas and found that the universe's expansion would continue forever, and that the data could be explained by a cosmological constant.

After that press conference, one reporter picked up on the incredible news that there were signs of accelerating expansion and a mysterious force pushing the universe apart ever faster, while most simply reported that there would be no big crunch.

In February, the High-Z team presented their supernova data at a conference, also showing that the expansion of the universe is accelerating. Now it was clear that some strange, unseen antigravity force was driving the universe apart. Both teams soon published papers in refereed journals. These findings were completely contrary to everyone's expectations, but with the two competing teams finding the same shocking result, they had to be taken seriously.

Later that year cosmologist Michael Turner coined the term "dark energy" to describe the mysterious force, in analogy with the invisible dark matter that makes up most of the matter in the universe.
Science magazine called the accelerating universe the "Breakthrough of the Year" in December 1998.

Now, more than ten years after the discovery, further results have confirmed that the expansion of the universe is accelerating, but the bizarre dark energy remains a mystery.

One candidate for dark energy is a cosmological constant, just as Einstein predicted (though with a different value). Quantum theory predicts that vacuum fluctuations, virtual particles that flit into and out of existence, provide energy to empty space. Unfortunately, the energy density associated with these vacuum fluctuations is, according to theoretical calculations, a whopping 120 orders of magnitude greater than the energy density cosmologists measure. Other suggestions for the dark energy have been made, and further studies are underway, but for the most part, scientists remain in the dark.

Physics History

This Month in Physics History
APS News Archives

Historic Sites Initiative
Locations and details of historic physics events

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Economic Theories not Scientific

I congratulate H. Eugene Stanley for his very illuminating Back Page (*APS News*, December 2008) on the role of physics in the current financial crisis. I wholeheartedly agree with him regarding the contention that physicists are responsible for it. That is simply a red herring, introduced to shield those who are truly responsible.

On the other hand, I disagree with his characterization of economics as a science. Current economic theories are essentially political, and insofar as I can discern are divorced from a number of well established scientific facts: that resources are finite, for instance. While we see criticisms of capitalism as being incapable of recognizing the worth of things that cannot be valued in units of currency, such as clean air and water, biodiversity, and human dignity among others, the same can also be said of other recent economic theories such as Marxism and Maoism.

Because economic theories are essentially political, they tend to be ideological, putting them in the same category as religion. Which as we all know is the antithesis of science.

Stanley's intuition that an overconnected system is disadvantageous is correct in my opinion. Since the introduction of requirements for quarterly reporting, listed corporations have largely abandoned long-term planning, focusing instead on short-term results to please the analyst-priests. In addition, programmed trading enhances the connectivity, providing a substantial positive feedback response. A simple fix would be to introduce significant but random delays in large programmed trades, in an effort to partially decouple them.

Stephen Schiff
Aldie, VA

Malthus Still Relevant

The Back Page on Econophysics by H.E. Stanley does not mention an equally or even greater failure. Malthus warned of the problem, but prematurely. Today only a few lonely voices are heard, when it should be clear that "solving" the energy problem without simultaneously addressing the population growth is counterproductive. The most important contribution Physics can make is promoting the importance of considering all the interacting parts, rather than developing a technical fix for one part while ignoring its effect on the whole.

Elmer Eisner
Houston TX

Correction Offered to Science and History of Cosmic Acceleration

As a member of the High-Z Supernova Search Team (HZT), I think it is worthwhile to correct both the science and the history that were described in "This Month in Physics History" that appeared in the January *APS News*.

On the science, Type Ia supernovae are not standard candles: their luminosities vary by a factor of 3. Sorting the bright from the dim by the shape of their light curves to get precise distances was introduced by HZT member Mark Phillips in 1993.

Similarly, absorption by interstellar dust can mimic dimming that is due to accelerated expansion. Riess, Press, and Kirshner developed a solution to this problem, published in 1996, which was essential to the analysis of distant supernovae submitted by Riess and HZT to the *Astronomical Journal* on March 13, 1998. This paper was accepted on May 6, and published in September 1998. The Supernova Cosmology Project also developed an effective way to measure dust absorption to individual supernovae, but not until 2003. Their article on cosmic acceleration was submitted to the *Astrophysical Journa*l on September 8, 1998 and appeared in the June 1999 issue.

On the history, the January 1998 AAS meeting was not the time and place where the world learned we live in an accelerating universe. At the AAS press briefing, 5 speakers, including Peter Garnavich from HZT, concurred that we live in a low density universe that would expand forever. In that public setting, no one claimed that the universe was accelerating [see, e.g. John Noble Wilford, *The New York Times*, Jan 9, 1998 "New Data Suggest Universe Will Expand Forever".] The first clear public statement that evidence from supernovae indicated cosmic acceleration took place in February 1998, at the Dark Matter meeting in Marina Del Rey. Alex Filippenko of HZT said "the dimness of the supernovae–pointing to unexpectedly large distances–implies that cosmic expansion has actually sped up in the years since the stars exploded." This triggered a flood of public attention, including an interview of HZT member Adam Riess on The News Hour. Cosmic acceleration seemed like news to the world in

February. Not January.

In March 1998, Saul Perlmutter was asked by *The New York Times* to explain his reluctance to assert cosmic acceleration at the AAS in January. According to the *Times*, "Describing their results in January, Dr. Perlmutter acknowledged that the evidence strongly suggested a cosmological constant, but went no further. 'We were trying to be very conservative until we had more observations'." Nobody claimed to have announced cosmic acceleration in January 1998. I think we should mark the dates of scientific discoveries from the submission of refereed publications, not commemorate the extrapolations of reporters who get ahead of prudent scientists in drawing reliable conclusions. I say we should have the anniversary on March 13! On this basis, I look forward eagerly to the next "This Month in Physics History."

References to the articles mentioned above can be conveniently found at
http://www.cfa.harvard.edu/~rkirshner/whowhatwhen/Thoughts.htm

Robert P. Kirshner
Cambridge, MA

Meeting Planners Need to Think Green

In this era of green thinking and friendliness to Planet Earth, I make a plea to all those who organize (APS and other) conferences. Surely, it makes sense, when deciding on a venue, to avoid far-flung corners of the US. Holding a major scientific meeting inevitably means that some participants will need to fly, but choosing Hawaii, for example, as a destination means that every participant will clock up thousands of air miles and be responsible for significant CO_2 emissions. Why not choose a major airline hub, or somewhere that is close to the workplace of many of the attendees? This will minimize the carbon footprint of the meeting, reduce costs associated with travel, and lessen the tedium of hours and hours spent confined in a metal tube.

Paula Rosen
Reading, Berkshire, UK

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of the storm. Further, as a resident of coastal Mississippi, I know of no citizen down here who does not prepare for the “unlikely event of a direct hit”, because we all know that it will happen several times a century. Everyone along the Gulf and Atlantic coasts will suffer from a hurricane eventually.

Improved flood models are required to assist our disaster planning. I know I speak for more than myself when I say that we welcome anyone with expertise in this area who is willing to do forensic studies on Katrina to determine which portion was natural and how much was manmade.

A. Louise Perkins
Long Beach, MS

Achievement not so New After All

One of the “Top Ten Physics News Stories of 2008” reported in the February *APS News* was the fascinating achievement of light passage through opaque matter. With my colleague Wayne Strange, I accomplished this feat over ten years ago through the use of polarization-selective optical phase modulation and synchronous detection. By scanning a helium-neon laser beam across the front surface of a cuvette containing a liquid of the opacity of whole milk under ambient illumination, we were able to map out the topographic features of various kinds of objects entirely hidden from view in the milky suspension [*Optics Communications* 144, 7 (1997)]. A detailed account of the experiment is given in my book *Waves and Grains: Reflections on Light and Learning* (Princeton University Press, 1998).

The same experimental technique enabled me and my colleague Jacques Badoz to detect and quantitatively measure for the first time the minute difference between the reflection of a left-and right-circularly polarized light beam by a naturally chiral medium [*Optics Letters* 17, 886(1992)] A personal account of this experiment is also included in *Waves and Grains*.

Mark P Silverman
Hartford, CT

Crucial to Help Pakistan with Science Education

The recent “Back Page” article by Wasif Syed called attention to the important challenge for Pakistan to expand and improve its science and engineering education and research programs. In an age when technology has come to dominate many important aspects of society, it is imperative for all nations and especially those in the developing world to place greater emphasis on advanced science and engineering education. For starters, there is an urgent need to develop homegrown solutions for critical problems in areas such as energy, agriculture, public health, and telecommunications. Unfortunately, there is often no infrastructure in these countries equal to the task. Perhaps partnerships with educational institutions in the developed world, together with funding from those countries, can jump start the growth of homegrown capacity. We are now participating in such an effort in Pakistan. Led by a group of young engineers, scientists, and entrepreneurs, the highly regarded Lahore University of Management Sciences (LUMS) has launched a new School of Science and Engineering (SSE). The SSE adds undergraduate, and eventually graduate, programs in basic science and engineering to existing programs in business, management, humanities, mathematics, and computer science at LUMS. The aim is nothing short of creating a world class research university with a rigorous science-based education program enhanced by an interdisciplinary research agenda. Dedicated to inclusiveness, the SSE maintains need-blind admissions and substantial financial aid, and is open to all, independent of gender, religion, or social status. The first class of 150 undergraduates entered in the fall of 2008, selected from a pool of about 7000 applicants. Clearly there is a deep hunger for high quality technical and scientific training, and the talent is certainly abundant. We, and about a dozen of our colleagues from U.S., European, and Asian universities and businesses, serve on an external Advisory Board for the SSE. It may be constructive for US agencies and Pakistan ministries to consider support for projects like this in Pakistan for higher education in general and science and engineering in particular.

Robert Jaffe
Cambridge MA

Alvin L. Kwiram
Seattle WA

Kirshner’s Account of Cosmic Acceleration History Challenged

As one of the five people who participated in the January 8, 1998 AAS press release session described by Robert Kirshner in his letter that appeared in the February 2009 *APS News*, I must disagree with the notion that cosmic acceleration was not suggested during that session. My press release for that session states "Astrophysicists announced today new predictions of the ultimate fate of the universe obtained by calculating the characteristic or maximum size of very distant radio galaxies. Reports being presented by Dr. Ruth A. Daly, and Dr. Erick Guerra, both of Princeton University, in Princeton, New Jersey, to the American Astronomical Society meeting in Washington, DC, suggest that the expanding universe will continue to expand forever, and will expand more and more rapidly as time goes by." The press release goes on to say "The apparent size, or distance from hotspot to hotspot, of a high redshift radio galaxy is a clue to which of the competing models of the nature of the universe is most likely. A relatively small size at great distance from Earth would suggest a universe that will halt its current expansion and recollapse; a larger size suggests a universe that will continue to expand forever, but at an ever decreasing rate; an even larger size suggests the universe will continue to expand, and will expand at a faster and faster rate. The current work finds that at high redshift the galaxies are very large, with widely separated radio hotspots. Thus, the universe will continue to expand forever and will expand at a faster and faster rate as time goes by." Clearly, the acceleration of the rate of expansion of the universe was indeed suggested at the January 8, 1998 AAS meeting press release session.

The press release is available at http://www.princeton.edu/pr/news/98/index1.html under "The Ultimate Fate of the Universe" (1/8/1998) and at http://www.bk.psu.edu/faculty/daly.

Ruth A. Daly
Reading, PA

Your January column "This Month in Physics History" gave what I thought a fair and balanced account of the discovery of the accelerating universe, including the contributions of both research groups, so I was surprised at Robert Kirshner's letter responding to it in the February issue. Having reviewed his fine book, *The Extravagant Universe*, in the *New York Times Book Review* and edited a *SLAC Beam Line* article on the research written by Gerson Goldhaber of Lawrence Berkeley Laboratory, I feel in a good position to comment further.

The column might indeed have delved more deeply into the experimental techniques involved—and Kirshner cited a few of the specific contributions of his High-Z Supernova Search team. Omitted from both accounts, however, was the central role of Saul Perlmutter of the LBL Supernova Cosmology Project in pioneering the core technique used by the two groups. This method involves taking successive photographs with a CCD camera of the same patches of night sky about four weeks apart during the new moon; by comparing individual pixels in this wide field of view, researchers can identify candidate supernovae for further observation during the next few months on dedicated telescopes. By following a supernova's light output over this period, they can obtain the correction factor Kirshner mentions and thereby establish the supernova as a valid "standard candle."

The LBL team, composed mostly of experimental particle physicists familiar with manipulating vast quantities of data, felt equal to this daunting task. But many astronomers and astrophysicists figured that the technique would never work. Thus the High-Z group found itself playing catch-up in the mid-1990s after the LBL team showed that it *did* work.

I vividly recall sitting in the front row at a UC Santa Cruz physics colloquium on 8 December 1997, when Perlmutter gave the first public (beyond Berkeley) presentation of the results that attracted so much attention a month later. Having just edited Goldhaber's article and been primed on the significance of this research by my UCSC colleague Joel Primack, I was sitting on the edge of my seat, waiting for the numbers, which came only in the last few minutes of the talk. Based on 38 Type Ia supernovae analyzed until then, Perlmutter said, they could conclude that the universe was open: it had only about 30 percent of the critical mass density needed to slow the Hubble expansion to zero. I don't recall him making any further conclusions, but Primack was not so reluctant. In the ensuing discussion period, he stood up and pointed out that these results implied the previously unthinkable: the need for a cosmological constant.

To be fair to Kirshner and the High-Z team, these preliminary LBL data could not yet rule out dimming of the supernovae light due to absorption by intervening dust—which his group could eliminate by making observations at three different wavelengths. But in early 1998, when these astonishing results began to surface in press accounts, the High-Z team had a statistically weak sample of only about 10 supernovae, while the LBL group by then had accumulated over 40. Nobody—at least not in the particle physics community—would have accepted the momentous conclusion of an accelerating universe as valid based on such a single small sample had there not been another, independent result with significantly better statistics. In the final historical analysis, it was the joint results of both teams, each covering weaknesses in the other's analysis, that convinced the wider scientific community so rapidly about such an unexpected, revolutionary result.

Historians of science find these priority disputes rather tiresome, but then we don't have any Nobel prizes at stake!

The current dispute about the discovery of the accelerating universe reminds me of my favorite adage: “One of the most difficult things to divide is success.”

Michael Riordan
Santa Cruz, CA

APS Copyright Policy Still No Good

When I saw that a new APS copyright policy was announced, I was happy for a moment ... until I discovered the “new” policy continues to be that APS takes your copyright and keeps it (although now giving back some limited rights.)

The commercial publishers in the world–by which I mean the ones that actually pay their authors–do not take an author’s copyright. It is odd that the APS, which doesn’t pay, demands transfer of copyright on the grounds that “we must have this to continue to provide quality publications.” Must? Commercial publishers do not require transfer of copyright, but APS does?

And I’m left the same question: Since APS inherently can’t defend the intellectual property rights of physicists in this case, because of their conflict of interest: who will?

Geoffrey A. Landis
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Letters to the Editor

Accelerating Universe: Who Knew What When?

Ed. Note: *We featured the accelerating universe in our "This Month in Physics History" column in January. This was followed by a series of letters in February and April. With the two letters below, we close our discussion of the history of how this discovery was made.*

Michael Riordan's letter to *APS News* (April 2009) contained a vivid account of the scene as Saul Perlmutter presented the results of the Supernova Cosmology Project at a Santa Cruz colloquium in December 1997. His narrative of Saul reporting evidence for low cosmic mass density and unlimited expansion is fully consistent with what both the High-Z Team and the SCP said in January 1998. This confirms the point I was trying to make in my February 2009 letter to *APS News*: that the persuasive evidence for something qualitatively different–cosmic acceleration–came just a little later. February 1998 if you like Alex Filippenko's conference talk at the Dark Matter meeting, March 1998 if you like the High-Z Team's *Astronomical Journal* submission. Ruth Daly's point in her letter to *APS News* is that ideas about acceleration were in the air in January, mine is that data of adequate precision to make the case in a refereed journal were just ahead.

Riordan makes three additional points. He says that Saul Perlmutter pioneered the technique of taking successive photographs four weeks apart in the dark of the moon to discover supernovae, that experimental particle physicists "familiar with manipulating vast quantities of data" felt up to the task of finding supernovae in digital images from CCDs while astronomers did not, and that the SCP result had "significantly better statistics" than the High-Z Team result. Each deserves a brief factual response.

Saul Perlmutter led the SCP with determination, but he did not invent the rhythm of the moon, which approximately matches the 21-day rise time of supernovae and leads to a four week cycle for efficient searches. This pattern of observing in the dark of the moon was pioneered by Caltech's Fritz Zwicky, starting in the 1930's. Monthly spacing of the search was used extensively in the Calan/Tololo search in Chile to find objects for scheduled follow-up. This set of data on nearby supernovae was used by both groups to establish the reality of cosmic acceleration. Monthly searches were employed, but not invented, by the SCP.

Replacing eyes with computers to find supernovae in digital data was an important development. In 1988, Danish astronomers used their 1.5m telescope at the European Southern Observatory to search for supernovae. They took digital images each month of galaxy clusters, registered the new images with the old, scaled the sky, convolved the images to match atmospheric blurring, and subtracted to find new stars in distant galaxies. All this manipulation of data was done in real time at the observatory. By astronomers.Their discovery of SN 1988U, a Type Ia supernova at the cosmologically interesting redshift, z =0.31, was reported in *Nature*. I wrote the "News & Views" explaining the importance of this work. Experimental particle physicists invented their own methods, but pixel-by-pixel subtraction to find supernovae for cosmology was carried out first by Danish astronomers (who didn't think it was very difficult.) If their detector had been a little bigger, perhaps they would have found cosmic acceleration.

Finally, comparing the error ellipses shows that the statistical uncertainty in the values of Omega_lambda and Omega_matter from the High-Z Team in our September 1998 AJ paper was every bit as good as that from the SCP in their June 1999 Ap J paper, despite our having a smaller sample of high redshift objects. That's because we had a larger sample of low-redshift objects from both Calan/Tololo and the Center for Astrophysics, an object-by-object way of determining the reddening to each supernova, and a larger fraction of excellent measurements from the Hubble Space Telescope. A bigger sample does not always yield a more precise answer.

All of us have had a great scientific adventure in learning that the universe is accelerating. That thrill of discovery is part of the fun of doing science, and it is based on a long sequence of contributions by many minds and hands. That long chain of cooperation is what I'd call success.

Robert P. Kirshner
Cambridge, MA

* * *

Riordan Responds

Having read and reviewed his book, I am well aware of most of the details Kirshner discusses in his letter. But I don't think they invalidate my two principal assertions:

• that a group of mostly particle physicists led by Perlmutter (yes, building on prior work by Kirshner and other astrophysicists) pioneered the use of Type 1a supernovae to serve as precision standard candles in measuring the expansion rate of the Universe; both the LBL and High-Z teams subsequently employed such a technique to find that the Hubble expansion was not decelerating as expected, but instead accelerating.

• that by early 1998, the results of neither group alone were sufficient for cosmologists to conclude that this momentous conclusion was true; both were needed because they addressed important weaknesses in the others' analyses.

Taken together, however, the two observations were quite convincing.

Michael Riordan
Santa Cruz, CA

Letter Condemns Attacks on Iranian Students, Universities

During the last week, members of the Iranian security forces in plain clothes have attacked universities and many student dormitories in Iran. In one of the dormitories in Tehran, several students have been killed. In solidarity with the university professors and students in Iran, the Iranian-American Physicists (IrAP) Network Group Board of Directors wishes to express its outrage and condemn such violent attacks on the universities and student dormitories.

IrAP Board of Directors

Ed. Note: *APS News received the letter above on June 22 from IrAP President Mostafa Hemmati of Arkansas Tech University.*

Molten Salt Reactor Will Solve Energy Problems

Our country will need lots more electric power in the foreseeable future. Back-of-the-envelope calculation shows that all green "alternative" sources combined–wind, solar, etc–are not going to cut the mustard, because of inherently low energy densities. If foreign oil and dirty coal are out, the only way left is the dreaded "nuclear option." Here is where physicists ought to step up to bat. They consider themselves knowledgeable about energy alternatives…but how many know that before 1969 this country did successful proof-of-concept research into a liquid fluoride thorium reactor that offered improved safety and efficiency, 1/30th the waste volume (compared to a uranium reactor), reduction of high-level waste storage requirements from over 10,000 years to around 300 years, reduced target-value to terrorists (due to non-production of weapons material), cheaper construction costs and raw materials (over 1000 times the fuel reserve), etc.? After 1969, dominated by technically-uninformed, fear-driven nuclear revulsion, America curtailed research and even junked half-completed nuclear plants, with the result that today South Africa has more imaginative nuclear designs than we do. The US needs to put "stimulus" funds into researching nuclear power innovations, rather than coasting on 1940-era designs. And who will advocate such funding, if not you as a physicist? Protecting your grant? Speak up, if you have the guts and dare to boast of the "moxie"! The silence is deafening.

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