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APS physics

More 2016 APS April Meeting coverage
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Advancing Beyond Advanced LIGO

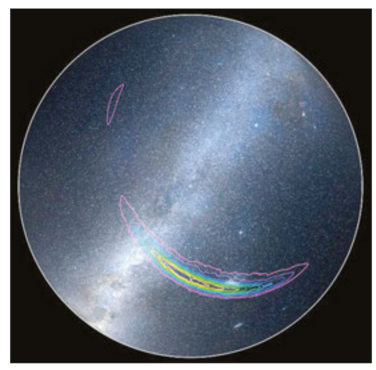
By Gabriel Popkin

2016 APS April Meeting — Members of the Laser Interferometer Gravitational-Wave Observatory (LIGO) Scientific Collaboration took a victory lap of sorts at the 2016 APS April Meeting in Salt Lake City, Utah. Talk after talk began with slides showing the now-famous signal from GW150914, the formal name for the September 14, 2015 detection of gravitational waves from two black holes that merged 1.3 billion years ago.

"For the first time when I present this talk, I can start with a discovery, not just upper limits," said Alessandra Corsi, an astrophysicist at Texas Tech University.

But speakers quickly pivoted to new astrophysics emerging from GW150914 and LVT151012, a second candidate event that appeared in LIGO data but did not reach the critical "5-sigma" statistical threshold needed to claim a true detection. Researchers also shared new ideas for peering deeper into the universe and increasing the frequency spectrum that gravitational-wave detectors can probe.

For astrophysics, GW150914 heralded a series of firsts — not just the first detection of a gravitational wave, but also the first proof that black holes form merging pairs (only inspiraling neutron stars had been previously seen), and the first evidence of black holes more than 25 times the mass of the sun. The large sizes of the merging black holes also revealed that their source stars were low in heavy elements, and that their spins were substantially lower than the maximum possible value allowed under general relativity.



LIGO

Contour lines show likelihood of where in the sky the black-hole merger GW159014 took place.

The finding has also allowed scientists for the first time to test aspects of general relativity in the "strong-field regime" — the highly warped regions of spacetime near extremely dense objects. Astrophysicists have used GW150914 to place more stringent limits on a number of general

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HAWC Charts the Gamma-Ray Sky

By Gabriel Popkin

2016 APS April Meeting — Researchers with the High Altitude Water Cherenkov (HAWC) Gamma-Ray Observatory unveiled a new map of the very-high-energy sky on Monday, April 18 at the 2016 APS April Meeting. The map includes data from the observatory's first year of full operation, and includes 40 sources, 10 of which have never been seen before in gamma rays with energies above a few hundred GeV.

"It's our deepest look at two-thirds of the sky," said HAWC's operations manager Brenda Dingus of the Los Alamos National Laboratory in New Mexico.

The observatory, which is located 4,100 meters above sea level near Mexico's Volcán Sierra Negra, sees gamma rays from the entire Northern hemisphere, though Earth blocks its views of part of the Southern hemisphere. It measures some of the highest-energy photons any experiment has detected — those reaching energies between 100 GeV and 100 TeV. By contrast, visible photons have energies of around 1 eV, and most previous gamma-ray survey instruments, such as NASA's Fermi Gamma-ray Space Telescope, are limited to photons in the hundreds of GeV range. The few other telescopes that can capture TeV photons see only a small patch of sky at a time and can observe only at night.

HAWC, by contrast, surveys two-thirds of the sky and observes 24 hours a day, giving it a uniquely broad view in both space and time. The observatory consists of an array of 300 7.3-meter-diameter tanks of purified water. It detects

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China's Proposed Heir to the LHC

By Sophia Chen

2016 APS April Meeting — His talk drew a modest crowd, but Xinchou Lou's excitement permeated the room. A senior fellow at China's Institute of High Energy Physics (IHEP), Lou presented China's plan for joining the ranks of international experimental particle physics: a circular collider 55 kilometers in circumference. It is designed to eventually achieve 100 TeV collisions and tentatively would be located 300 kilometers east of Beijing.

China seeks to make the proposed collider central to high-energy physics experiments from 2028 until 2055. With the Higgs boson observed and the Large Hadron Collider (LHC) approaching its maximum 14 TeV collision energy, the goal of the project is to keep high energy physicists thinking ahead, said Lou, who was recruited from the University of Texas at Dallas to be a project director for the collider. "I think this [project] will really energize our field," he said during the presentation.

Lou believes the time is ripe for a Chinese collider. He cited China's experience in building and operating the Beijing Electron-Proton Collider (BEPC) in the 1980s and its successor, BEPC II, which is still in use, while also pointing out that infrastructure and labor costs in China are low.

At the end of the presentation, one audience member echoed Lou's enthusiasm. "As a Chinese student working on high energy experiments in the U.S., if this is really happening and there are opportunities, I think people like me would like to go back to help," he said. "Plus, it [would be] close to my hometown."

IHEP

Rendering of the proposed CEPC

The project has the home-grown support necessary for its success, said Nima Arkani-Hamed, Lou's collaborator and the first director of IHEP's Center for Future High Energy Physics. "It's already tremendously boosted the morale of the under-35 crowd who are not sure what the future of [the] field might look like in the next 30 years," said Arkani-Hamed, who collaborates on the collider proposal and also gives topical lectures at Chinese universities. "It has also captured a place in the imagination of teenagers and twenty-year-olds in China."

Even so, China remains an underdog in the particle physics community. "They're the most recent country to enter into this game, so in that sense, they don't have the level of experience building large colliders of this scale that the U.S. or Europe has," said Ashutosh Kotwal, a Duke University physicist who coordinates U.S. physicists in the global effort to build a new collider and has collaborated with the Chinese group in the past. "But I'm happy that they have the ambition to do it."

The Specs

First proposed in 2012 by Yifang Wang at IHEP, the collider project, known as CEPC-SppC for Circular Electron-Positron Collider

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***Physical Review Fluids* begins publishing (see page 5)**

2016 Sakharov Prize Winner

By Sophia Chen

2016 APS April Meeting — Zafra Lerman knows far too well how the invisible hand of geopolitics can jerk scientists around. The Israeli-born chemist, who was awarded the APS Andrei Sakharov Prize this year for her work in human rights, organizes conferences that bring together scientists from opposing Middle East regimes — in an effort to establish peace.

"It was shocking to me when the Iraqis came with tears in their eyes," Lerman said in her presentation. They said, "All our life we studied, we learned, we heard about these monsters called Israelis, and suddenly they are human beings who are so nice. We would like to work with them. ... Once you see a person, this person is not your enemy."

Lerman organizes these conferences as president of the Malta Conferences Foundation. The Malta Conferences, which began in 2003, take place every two years, and have drawn well known attendees who range from Nobel Laureates such as physicist Claude Cohen-Tannoudji to Prince Hassan of Jordan. The most recent conference took place last November in Morocco.

Every other year, APS awards the Sakharov Prize to recognize a scientist's leadership and achievements in upholding human rights.

Zafra Lerman

At the moment, Lerman is putting together the next conference, to be held in 2017. The location has yet to be set. In addition to fundraising, one of her biggest challenges is finding a willing host country and jumping through all its bureaucratic hoops. "It's very difficult to find a country willing to give visas to scientists from Syria [and] Libya," she said.

Lerman's human rights career spans decades. Sébastien Francoeur, a physicist at the École Polytechnique de Montréal who chaired the prize committee, cites her long career as a reason why they chose her for the prize. The prize is "a recognition and also an encouragement to continue," he says.

During the final years of the USSR, Lerman would meet Soviet

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not gamma rays themselves, but showers of particles released when gamma rays hit molecules high in Earth's atmosphere. Inside the tanks, the particles from these showers release Cherenkov radiation — faint light emitted when a charged particle travels faster than the speed of light in its medium — which is then picked up by photomultiplier tubes. "It doesn't look like or work like any other observatory," said Dingus.

The HAWC map includes some known gamma-ray sources such as certain galaxies, the Cygnus cluster, and various regions of the Milky Way disk. But even when a source is known, the observatory can provide new information. For example, HAWC data suggest that a region in the Milky Way where researchers previously identified a single nebula named TeV J1930+188 may contain two or even three distinct gamma ray sources.

HAWC also observed gamma rays from the galaxy Markarian 501 mysteriously brightening and dimming over the course of several days in April. "We don't really know [where the] gamma rays are coming from," said astrophysicist Robert Lauer of the University of New Mexico, but he added that HAWC's nonstop coverage should enable him and his colleagues to better understand the process causing the variability.

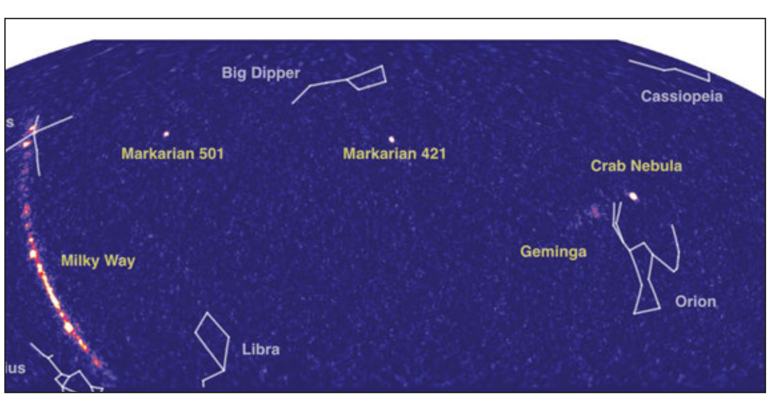
Meanwhile, with help from telescopes in other parts of the electromagnetic spectrum, project leaders are piecing together the sources of the abovementioned 10 detections that did not appear in previous TeV gamma-ray searches. Likely candidates include distant supernovas, stellar winds driven by pulsars like the one inside the Crab Nebula and high-energy jets that shoot out from black holes as they eat nearby matter. But project leaders aren't ruling out previously unknown objects.

Though it hasn't broken the high-energy record yet, HAWC detected a power-packed 60-TeV gamma ray — a photon more than four times as energetic as any human-made particle — coming from the Crab Nebula, which is a supernova remnant and a known gamma-ray source. And new data will soon push that number even higher, said astrophysicist Michelle Hui of NASA's Marshall Space Flight Center in Huntsville, Alabama. "More is coming."

"This is our announcement that we work as advertised," said Dingus. But she and her colleagues are already planning to increase HAWC's size and sensitivity, to capture even more gamma rays at the high end of the observatory's energy range. "We will see the highest-energy photon that has ever been seen," Dingus promised.

"This is really a triumph for HAWC," says Julie McEnery, project scientist for the Fermi telescope at NASA's Goddard Space Flight Center in Greenbelt, Maryland, and chair-elect of the APS Division of Astrophysics. McEnery says the two telescopes with their different energy ranges will together provide a more complete picture of gamma-ray sources than either can on their own. "We'll be able to combine Fermi data and HAWC data on every bright, energetic thing in the sky."

Gabriel Popkin is a freelance writer based in Mount Rainier, Maryland.



Sky map of high-energy gamma rays observed by HAWC. Many sources can be seen in the Milky Way and the extragalactic objects Markarian 421 and 501. Several well-known constellations are shown for reference.

This Month in Physics History

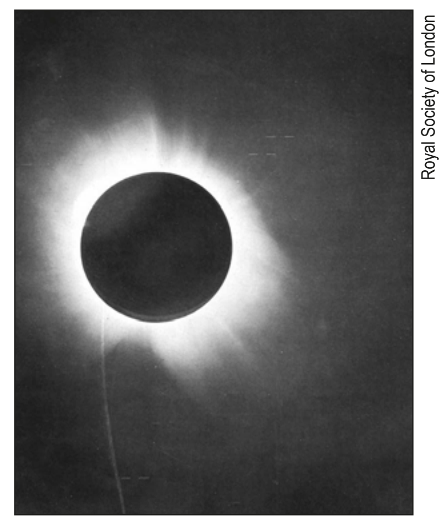
May 29, 1919: Eddington observes solar eclipse to test general relativity

When Albert Einstein published his general theory of relativity (GR) in 1915, he proposed three critical tests, insisting in a letter to *The Times* of London that if any one of these three proved to be wrong, the whole theory would collapse.

- Advance of the perihelion of Mercury
- Deflection of light by a gravitational field
- Gravitational red shift

Once he had completed his theory, Einstein immediately calculated the advance of the perihelion of Mercury, and he could hardly contain himself when GR produced the correct result. The next classical test was the deflection of light by a gravitational field, first performed by Sir Arthur Eddington in 1919.

Born to Quaker parents in December 1882, Arthur was just two years old when he lost his father to a typhoid epidemic that ravaged England. As a child, Eddington was enamored of the night sky and often tried to count the number of stars he could see. Initially Eddington was schooled at home, but when he did start attending school, he excelled so much in mathematics that he won a scholarship to Owens College in Manchester at age 16. He graduated with first class honors in physics, and promptly won another scholarship to attend Trinity College at Cambridge University.



One of Eddington's photographs of the May 29, 1919, solar eclipse. The photo was presented in his 1920 paper announcing the successful test of general relativity.

Eddington completed his M.A. in 1905. First he worked on thermionic emission at the Cavendish Laboratory, and then tried his hand at mathematics research, but neither project went well. He briefly taught mathematics before re-discovering his first love: astronomy. Eventually he found a position at the Royal Observatory in Greenwich, specializing in the study of stellar structure. By 1914 he had moved up to become director of the Cambridge Observatory; a Royal Society fellowship and Royal Medal soon followed.

During Eddington's tenure as secretary of the Royal Astronomical Society, Willem de Sitter sent him letters and papers about Einstein's new general theory of relativity. Eddington became Einstein's biggest evangelist at a time when there was still considerable wartime hostility and mistrust toward any work by German physicists. He soon became involved in attempts to confirm one of the theory's key predictions.

Since the masses of celestial bodies would cause spacetime to curve, Einstein predicted that light should follow those curves and bend ever so slightly. Isaac Newton had also predicted that light would bend in a gravitational field, although only half as much. Which prediction was more accurate? Scientists feared that measuring such a tiny curvature was simply beyond their experimental capabilities at the time.

It was Britain's Astronomer Royal, Sir Frank W. Dyson, who proposed an expedition to view the total solar eclipse on May 29, 1919, in order to resolve the issue. Eddington was happy to lead the expedition, but initially the venture was delayed. World War I was raging, and the factories were too busy meeting the country's military needs to make the required astronomical instruments. When the war ended in November 1918, scientists had just five months to pull together everything for the expedition.

Eddington took nighttime baseline measurements of the positions of the stars in the Hyades cluster in January and February of 1919. During the eclipse the sun would cross that cluster, and the starlight would be visible. Comparison of the baseline measurements of a star's position and the corresponding measurements made during the eclipse, when that star was just visible at the limb of the sun, would determine whether Einstein or Newton was right.

Then Eddington set sail for Principe, a remote island off the west coast of Africa, sending a second ship to Sobral, Brazil — just in case the weather didn't cooperate and clouds obscured the view. It proved to be a smart decision. Eddington's team was dismayed when heavy rains and clouds appeared on the day of the eclipse, although the skies cleared sufficiently by the time of the event to allow them to make their measurements. The Brazilian team had their own challenges: The tropical heat warped the metal in their large telescopes, forcing them to also use a smaller 10-centimeter instrument as backup.

Once the two teams had analyzed their results, they found their measurements were within two standard deviations of Einstein's predictions, compared to twice that for Newton's, thus supporting Einstein's new theory. News of Eddington's observations spread quickly and caused a media sensation, elevating Einstein to overnight global celebrity. (When his assistant asked how he would have felt had the expedition failed, Einstein is said to have quipped, "Then I would feel sorry for the dear Lord. The theory is correct anyway.")

Not everyone immediately accepted the results. Some astronomers accused Eddington of manipulating his data because he threw out values obtained from the Brazilian team's warped telescopes, which gave results closer to the Newtonian value. Others questioned whether his images were of sufficient quality to make a definitive conclusion. Astronomers at Lick Observatory in California repeated the mea-

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Washington Dispatch

Policy Update

Issue: Federal Budget

Section 300 of the Congressional Budget Act of 1974 provides a timetable (reproduced below) intended to ensure that Congress is able to finish its budgetary work by October 1, the start of the fiscal year. For more than two decades, Congress has not met the timetable, nor has the White House in the recent past. This year is no exception. The president submitted his budget request more than a week late, and neither the House nor the Senate was able to move a budget resolution by the April 15 deadline.

Although the House Budget Committee completed its work on schedule, the House Freedom Caucus, a group of several dozen Republican fiscal hawks, tied up floor action on the legislation, which it found to be too costly, even though it adhered to the spending limits in last December's two-year budget agreement. The Republican Senate leadership has refused to consider a Budget Resolution until the House has adopted its version. Although the likelihood of passage of a congressional budget resolution is small, it is worth considering several elements contained in the version that passed the Republican-controlled House Budget Committee 21 to 11 on a party-line vote.

The House language would eliminate the Department of Commerce and transfer basic research programs housed in the National Institutes of Standards and Technology (NIST) to the National Science Foundation (NSF) and those in the National Oceanographic and Atmospheric Administration (NOAA) to the Interior Department. It would severely constrain all federal applied and high-risk research funding, including support for Advanced Research Projects Agency - Energy (ARPA-E) and Energy Efficiency & Renewable Energy (EERE) in the Department of Energy.

In the absence of a Budget Resolution, House and Senate appropriators have begun work on funding bills based upon the total spending limit established last December. Still, given the short legislative calendar in a presidential election year and the objections of fiscal conservatives, it is unlikely that Congress will be able to meet the October 1 deadline and once again resort to a Continuing Resolution followed by an omnibus spending bill.

Standard Budget Timetable

First Monday in February	President's budget request
February 15	Congressional Budget Office: Economic & Budget Outlook Report
Six weeks after president's request	Congressional committees send Views & Estimates to Budget Committees
April 1	Senate Budget Committee reports Budget Resolution
April 15	Congress adopts Budget Resolution
May 15	House begins work on appropriations bills even if no Budget Resolution
June 10	House Appropriations Committee reports last appropriations bill
June 15	Congress completes reconciliation bill (if required by Budget Resolution)
June 30	House completes work on all appropriations bills
July 15	President's mid-session review of White House budget request
October 1	Fiscal year begins

Washington Office Activities

Advocacy

At the 2016 APS March Meeting, the APS Office of Public Affairs (OPA) helped 938 meeting attendees make an impact by sending the APS Contact Congress letter to their senators and representatives. The letter advocated for sustained science funding and requested Congress to ask the National Academy of Sciences to study the impact of child poverty on STEM performance.

On April 13, 2016, APS participated in the Science, Engineering, & Technology Working Group's "STEM on the Hill" Congressional Visit Day, which sent members of 34 different science organizations to Capitol Hill to advocate for science. OPA's Greg Mack accompanied Zachary Eldredge and David Somers, physics graduate students at the University of Maryland College Park, for meetings with the staffs of Senate and House members.

APS Panel on Public Affairs

The APS Panel on Public Affairs (POPA) subcommittees continued its work in preparation for the Panel's next meeting in June. Each subcommittee was tasked with reviewing previously approved statements for

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Transgender Physicists Face Fresh Challenges

By Sophia Chen

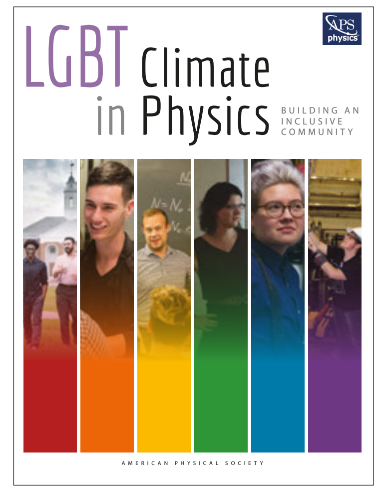
2016 APS April Meeting — While presenting the survey results of the APS report *LGBT Climate in Physics*, Elena Long mentioned that she can't fly through North Carolina anymore. "I can't use the Charlotte airport anymore because I could be arrested for using the restroom between my flights," said Long, a postdoc who works in nuclear research at the University of New Hampshire.

The reason? Long identifies as transgender, and North Carolina passed a law this March that requires transgender people to use public bathrooms that correspond to the sex on their birth certificates, instead of the gender with which they identify. Beyond airport layovers, transgender physicists like Long wouldn't be able to safely attend conferences in North Carolina without careful planning by APS.

And it is now a practical issue: APS is planning to hold its Division of Atomic, Molecular, and Optical Physics (DAMOP) meeting in Charlotte, North Carolina, in 2018.

The tricky part is that conference scheduling happens on long timescales, whereas legislation moves quickly. For big conferences, APS negotiates contracts with hotels and convention centers up to six or seven years in advance, said Kate Kirby, the chief executive officer of APS.

"When states suddenly adopt a law that is [discriminates against] particular groups, that puts us in a terrible situation," Kirby said. "Cancelling these contracts can cost a lot of money, hundreds of thousands of dollars. But I also don't like the idea of holding our meetings in a state where [participants] might feel uncomfortable."



In addition, it's hard to say whether the North Carolina law will still exist by the time the 2018 DAMOP meeting rolls around. Kirby pointed out that the vocal opposition from business leaders across the country has had some success in striking down these laws. For example, in March, the governor of Georgia vetoed that state's anti-LGBT (lesbian, gay, bisexual, and transgender) bill largely because of pressure from the business community. Advocacy groups such as the American Civil Liberties Union are also challenging the North Carolina law in court.

"I think we just have to look at it really carefully," Kirby said. "We could decide we can't do [DAMOP] in North Carolina, and then the whole thing gets repealed."

But other states also have similar discriminatory laws. In April, Mississippi governor Phil Bryant signed into law a bill that allows businesses to deny services to anyone who offends "sincerely held religious beliefs and moral convictions," he wrote in a statement. Opponents of the law say that it uses the pretext of religious protection to discriminate against the LGBT community. Legislators in Indiana, Massachusetts, Virginia, and Washington have also introduced bills that would limit transgender access to bathrooms.

Hannah LeTourneau, a recent physics graduate who attended the session and identifies as queer, acknowledges APS's logistical challenges in conference planning. But "people shouldn't need to be worried about [where to go to the bathroom] when they go to professional conferences," said LeTourneau, who works as an engineer for the Axion Dark Matter Experiment at the University of Washington.

However, conference venues

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International News

Dynamic Changes in Chinese Condensed Matter Physics: A Personal Journey

By Lu Yu

A half-century ago, modern condensed matter physics was almost nonexistent in China. During the past 30 years, especially since the beginning of the 21st century, the situation has changed dramatically. A number of outstanding young physicists from China with cutting-edge research achievements now have global recognition. How did this transition occur?

I was one of about 8000 Chinese scientists trained in the former Soviet Union for Diploma or Ph.D. degrees in the late 1950s and early 1960s. After returning to China, I was appointed a group leader at the Institute of Physics (IoP), the Chinese Academy of Sciences (CAS), even though I did not have a Ph.D. The lack of experience and scientific exchange was partially made up by intensive self- and mutual education. A group of almost starving young people passionately studied and disputed the latest results in the literature (fortunately, scientific journals were available at IoP).

Unfortunately, that joyful time did not last long. In 1966 the Cultural Revolution broke out in China, and normal research and education activities were almost completely stopped. In 1969, I was sent to the countryside to do manual labor, to be "re-educated" by farmers. Research work was out of question under those conditions.

Nevertheless, something magical happened after I returned from the countryside in 1971 — "Ping-Pong Diplomacy." Here, the exchange of table tennis (ping-pong) players between the United States and People's Republic of China (PRC) in the early 1970s marked a thaw in Sino-American relations that paved the way to a visit to Beijing by President Richard Nixon. Following the 'Ping-Pong' Diplomacy, China slowly started to open up to the West. C.N. Yang, T.D. Lee, and other American scientists of Chinese descent visited mainland China and gave lectures. We intellectuals "smelled" renewed opportunity to do research work again. There was no direct scientific exchange between the U.S. and China, but China was able to send a small delegation to attend the annual meeting of the Canadian Association of Physicists.

Although the scientific journals were not displayed in the library of IoP, they still arrived. They were just left unpacked. We rushed to the library and found with a big shock that during the Cultural Revolution in China, a genuine revolution was taking place in the studies of phase transitions and critical phenomena in the world. The strong feeling of lagging far behind urged us to take immediate actions: We started

Lu Yu

again the intensive process of self- and mutual-education with hunger and thirst; we read the important papers one-by-one and discussed them in detail at group seminars. It was not an easy job: the stacked lecture notes had thicknesses of the order 30 - 40 cm, but it was a genuinely exciting and enlightening time.

The main outcome was twofold. With Bailin Hao, we were able to make calculations of critical exponents for continuous phase transitions. We also accumulated enough materials for systematic lectures in that area and for a semi-popular book in Chinese on phase transitions and critical phenomena. The book was very well received by the Chinese scientific commu-

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Letters

Members may submit letters to letters@aps.org. APS reserves the right to select letters and edit for length and clarity.

Units and Constants

As with all "This Month in Physics History" articles, I thoroughly enjoyed the February 2016 issue on Amadeo Avogadro's life, struggles, and achievements. The fact that the Avogadro constant is one of the seven fundamental constants chosen to form the basis of the new International System of units (SI) is a testament to his accomplishments.

I would like to provide one clarification. While I'm extremely encouraged that the members and writers at APS have embraced an SI based on exact values of fundamental constants, the deed is not quite done yet. Barring some incredible event or discovery, the new SI will be officially adopted at the next (26th) meeting of the General Conference on Weights and Measures (CGPM) in the fall of 2018. "Soon the units will be defined by seven physical constants" would be more accurate.

David B. Newell
Gaithersburg, Maryland

More Thoughts on the SSC

I agree with statements in "A Brief Comparison of the SSC and LHC Projects" (*APS News*, February 2016) that the location (Texas) and military-industrial style of management helped to terminate SSC in 1993. But I think it would have been terminated independent of any type of management that was at SSC at that time. There was a great deal of political fighting during the 1992 elections and this termination was one of the results of that fight.

I also agree that if it were at the Fermilab site, it would be more probable that SSC would have survived. I was deeply involved in high-energy accelerator projects in the 1980s. I was project manager of the 3 Tev (UNK) collider under construction in Russia at the Institute for High Energy Physics in Protvino. From 1986 to 1990, progress on UNK construction was very good. U.S. Scientists provided that information to the U.S. Congress. At that time, competition between the USA and the USSR played a very important role in making decisions for new projects in the USA as well as in the USSR.

In 1991, following the collapse of the USSR, the budget for UNK was reduced to zero and construction was terminated by Russia. That political argument to build SSC disappeared. Personally, I believed that the USA would build SSC and moved from Russia to Texas in 1992. I was really surprised that the SSC was under attack and terminated in 1993, in spite of really good progress on construction.

The future of high energy physics and new possible accelerators were considered by the International Committee for Future Accelerators (ICFA) starting around 1976. On several workshops organized by ICFA during the 1970s and 1980s, consensus was achieved that new very big accelerators (VBA) could be built taking into account possible improvements in superconductors and superconducting magnets. ICFA considered the VBA as the next international project, but U.S. physicists took that idea and proposed SSC as a national project without international collaboration. This also simplified cancellation of the SSC later on.

In conclusion, in my opinion:

1. The U.S. lost leadership forever in high energy physics, which is the fundamental science about nature of matter and forces in the universe. Leadership went to Europe, most probably forever.
2. The SSC probably would have survived if it had been an international project and/or building on the Fermilab site and/or if Russia did not terminate construction on UNK.
3. Termination of the SSC could have been done independently of the type of management. The political motivation was very strong and cancellation was simplified by the increasing construction cost compared to the initial request at the approval time.

Victor Yarba
North Aurora, Illinois

Einstein and Gravitons

In Emily Conover's stimulating article, "Gravitational Waves Caught in the Act" she notes, "The researchers also set a bound on the mass of the graviton—the hypothetical particle that transmits the gravitational interaction. …" I believe it is of general interest to point out that Einstein did not believe that there are gravitons, even though, as is well-known, he was the one who proposed light quanta that were later called "photons."

In general relativity, the so-called gravitational force is not a true force, unlike the Lorentz force in electrodynamics, but a pseudo-force. This is because one can make a coordinate transformation that will eliminate the gravitational pseudo-force at a point, and indeed, as Fermi later showed, it can be made to vanish along an arbitrary world line. Now when a photon strikes an electron, as in the Compton effect, it gives the electron a kick, so to speak, or more technically, a momentum transfer, and hence it exerts a true force that cannot be eliminated by a coordinate transformation.

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relativity's parameters, including the speed of gravitational waves and parameters related to the waves' phase evolution, but so far Einstein's theory continues to pass every test. "Don't believe the *New York Times* — we did not prove that general relativity is correct," said MIT physicist Salvatore Vitale. "We just found it's consistent with our data."

Though it resolved some mysteries, the gravitational wave detection also opened up new ones. "The question that's on everyone's mind" now that one black hole pair has been found is how many are out there, said Chad Hanna, an astrophysicist at Pennsylvania State University. Based on one detection and one candidate event, LIGO scientists have shrunk the theoretically predicted range of between 0.1 and 1,000 black hole mergers per cubic gigaparsec of space per year (one gigaparsec equals 3.26 billion light-years) to a somewhat narrower 2 to 400. While that's still a lot of wiggle room, Hanna said "0.1 is really off the table."

And more detections may soon constrain the rate further. LIGO's first observing run lasted from September, 2015 to mid-January, 2016 (project leaders decided after the September 14 find to extend the original end date by about a month), but so far the collaboration has published results only from data taken through early October. Collaboration members were tight-lipped about whether additional detections popped up in the more recently acquired data, promising an update within a month or two.

Gamma-ray intrigue

Those new results could also help resolve another mystery. Using the time delay between when the gravitational wave arrived at the twin Hanford, Washington and Livingston, Louisiana detectors, LIGO scientists narrowed the location of the black hole pair to a banana-shaped region that represents around 1.5% of the sky, equivalent to the angular size of around 2,500 full moons. Scientists with NASA's Fermi Gamma-ray Space Telescope then found in their data a candidate event from a region of sky that overlaps part of LIGO's region, occurring only 0.4 seconds after the LIGO signal began. Though the gamma-ray signal has a 2 in 1,000 chance of being spurious — making it far less than a 5-sigma event — Fermi scientists published it in February on the arXiv.

The possible coincidence of a gamma ray signal with GW150914 is intriguing, because leading theories do not predict that black hole mergers would produce electromagnetic radiation. Within days of the Fermi team's announcement, theorists had posted a pile of papers on the arXiv proposing explanations for the gamma rays.

But scientists are remaining cautious, because of the imprecise sky localizations of the two events, and because data from the European Space Agency's (ESA's) Integral satellite, which also looks for gamma rays, showed no hints of a detection. Right now scientists have "a big blob from LIGO, and a big blob from Fermi," Texas Tech's Corsi said. "I'm personally going to get convinced when I see more [gravitational wave and gamma-ray] associations."

Fermi team members are also remaining circumspect until LIGO releases more results. "We would not have reported this event just by itself, unless there was a gravitational-wave detection," explained Adam Goldstein of the Marshall Space Flight Center in Huntsville, Alabama. But, he added, the data are public, and "the most appropriate people to do this particular, difficult, detailed analysis is the instrument team, so there was particular pressure on us."

Gaining a better view

Even before they finish analyzing their latest round of data, gravitational-wave scientists are looking toward the future. LIGO is in the midst of a long-planned series of upgrades known collectively as Advanced LIGO; improvements include increasing the laser power in the detector arms, "squeezing" the laser light to reduce quantum uncertainty, and developing new mirror coatings to reduce thermal noise. The detectors will eventually capture gravitational waves from more than 25 times as much space as they did in the first observing run, which was already a more than 25-fold increase over their original sensitivity. By 2018, collaboration members expect dozens of detections per year.

And more detectors will soon join the network. The Virgo facility in Cascina, Italy is slated to come online late this year, though problems with the glass fibers that hold the detector's mirrors have caused delays. An underground, cryogenically cooled detector in Japan called KAGRA will become the world's most sensitive starting around 2018. And on March 31, officials from the U.S. National Science Foundation and India's Department of Atomic Energy and Department of Science and Technology signed a memorandum of understanding to build a LIGO clone in India. The synchronous operation of detectors around the world will greatly improve how precisely scientists can resolve the origins of gravitational waves.

Meanwhile, mindful of the time required to get a facility funded and built, researchers are already planning a "third generation" of detectors that could potentially scan almost the entire visible universe. The European Commission is studying the possibility of an experiment with 10-kilometer arms, proposed under the name "Einstein Telescope." Syracuse University's Stefan Ballmer noted that new facilities could deliver more bang for the buck by including two detectors with different orientations at one site, which would help scientists resolve gravitational waves' polarizations — something LIGO alone was not able to do for GW150914.

U.S. researchers also need to be thinking beyond LIGO, said Caltech astrophysicist Sheila Dwyer. She is part of a team preparing a proposal for a future facility, provisionally called "Cosmic Explorer," which would have 40-kilometer arms. "We have a clear path for the next five to seven years with Advanced LIGO. But people were figuring that out 10, 15 years ago," she said. "You have to think pretty far ahead."

Going into space

Amid the celebrations, astrophysicist Neil Cornish of Montana State University reminded his colleagues that there are some things LIGO and its earthbound partners will never do. Specifically, ground-based detectors cannot sense gravitational waves of frequencies below a few hertz, because they become swamped by seismic disturbances and the gravitational influence of objects moving on Earth.

To escape this noisy environment, scientists have for 20 years developed plans for the Laser Interferometer Space Antenna (LISA), which would orbit the sun behind Earth, and send laser beams among three spacecrafts at a distance of a million kilometers or more from each other. Such a detector could potentially capture thousands of signals per year from orbiting black hole and neutron star pairs, well before the final moments when ground-based detectors pick them up. "They're really complementary," Cornish said. "GW150914 would have been seen 5 to 10 years before in the LISA detector."

The ESA-led project has had more than its share of hiccups, however, with NASA initially committing and then in 2011 withdrawing as a partner. Currently a modified experiment called "evolved LISA," or eLISA, is slated to fly in the mid-2030s, though Cornish thinks the LIGO detection could inspire NASA to get back in the game—or push China, which has expressed interest in a mission, to partner with ESA or launch its own satellites. Either could shorten the wait for a functioning space-based observatory.

ESA's LISA Pathfinder mission, which launched late last year and has already demonstrated that mirrors inside the spacecraft can be kept stable enough, could also provide a rationale for moving faster, says Cornish.

Scientists are also pursuing a third gravitational wave search method that utilizes radio telescopes to search for small changes in the timing of rapidly rotating "millisecond pulsars" in our galaxy. Such changes are predicted to be produced by very low-frequency gravitational waves emitted from supermassive black hole pairs that result from mergers of distant galaxies. Project leaders predict a detection by early next decade.

One point of complete agreement among meeting attendees is that it's a great time to be a gravitational-wave physicist. "I'm excited about all of [the proposed gravitational-wave detectors]," said Gabriela González, a physicist at Louisiana State University and LIGO spokesperson. Though the ultimate funding levels for new experiments remain to be seen, she said LIGO's long-sought detection can only be a boost for the whole field. "We are more optimistic about the future now."

Gabriel Popkin is a freelance writer based in Mount Rainier, Maryland.

Education Update

Award for Improving Undergraduate Physics Education

Created by the APS Committee on Education, the award recognizes departments and programs that support best practices in education at the undergraduate level. Nominations for the award are being accepted until July 15. More information can be found at aps.org/programs/education/undergrad/faculty/award.cfm

Prize for a Faculty Member for Research in an Undergraduate Institution

This award honors a physicist whose research in an undergraduate institution has achieved wide recognition and contributed significantly to physics and who has contributed substantially to the professional development of undergraduate physics students. Learn more at aps.org/programs/honors/prizes/faculty-undergraduate.cfm

Excellence in Physics Education Award

This award recognizes and honors a team or group of individuals (such as a collaboration), or exceptionally a single individual, who have exhibited a sustained commitment to excellence in physics education. Learn more at aps.org/programs/honors/awards/education.cfm

APS Speakers Program features Physics Education Researchers

The APS Speakers Lists contain names, contact information, and talk titles of physicists who are willing to give talks on a variety of subjects, including physics education research (PER). Learn more at aps.org/programs/education/speakers/

Physical Review Fluids

Physical Review Fluids, the newest member of the APS family of journals, began publication on May 2. The online-only journal has called for research papers that "significantly advance the fundamental understanding of fluid dynamics."

The new journal is the first in the *Physical Review* series to focus exclusively on fluid mechanics and dynamics, and the editors aim to make it a premiere international fluids publication.

Gary Leal, a chemical engineer at the University of California, Santa Barbara who is one of two editors of the journal, says that carrying the established *Physical Review* name will "open [the journal] up to a broader potential readership than has traditionally been the case for fluid mechanics journals." Leal shares his role with John Kim, a mechanical engineer at the University of California, Los Angeles.

Leal said that, in addition to traditional topics, the journal will embrace interdisciplinary areas, such as fluids research relevant to biology and medicine and to collective motion, like flying and swimming. The first issue already

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Science Meets Politics: A Complicated Relationship

By Gabriel Popkin

2016 APS April Meeting — Ever since its birth, science has mixed with politics, sometimes for good and sometimes for ill. But speakers at an invited session at the 2016 APS April Meeting organized by the Forum on Physics and Society agreed that U.S. science policy has taken a troubling turn in recent years, and called on scientists to reassess their role in the political conversation.

Spencer Weart, historian emeritus at the American Institute of Physics, traced scientists' involvement in two of the 20th and early-21st centuries' most contentious issues: nuclear energy and climate change. In the case of nuclear energy, scientists came down on both sides, some emphasizing its dangers and others promoting its use. As a result, nuclear bomb testing went underground and was then phased out altogether, while nuclear fission became a significant player in the global energy landscape.

But the nuclear industry has also become much more intensely regulated than nearly any other, and its once-rapid growth in the U.S. and other developed countries has largely stalled. "You could call that a success or failure, depending on your point of view," Weart said.

On climate change, by contrast, nearly all scientists agree that climate change is real, humans are causing it, and politicians need to take action. Yet a well-funded counter-movement, aided by a small number of scientists willing to publicly contradict the majority, has cast doubt on the scientific consensus and prevented a robust political response, Weart said.

"This is the first time as far as I know in the history of the world that there have been major groups of people viciously attacking individual scientists because of their scientific views," Weart said of the climate change debate. "And [the attacks are] not just by anybody, but by leaders of one of our major political parties."

Scientists' involvement in such charged issues has at times led to better decision-making, but it may have also cost scientists some of the bipartisan support they used to enjoy, Weart said, citing polls showing that conservatives' trust in scientists has eroded in recent years.

Rush Holt, a physicist who

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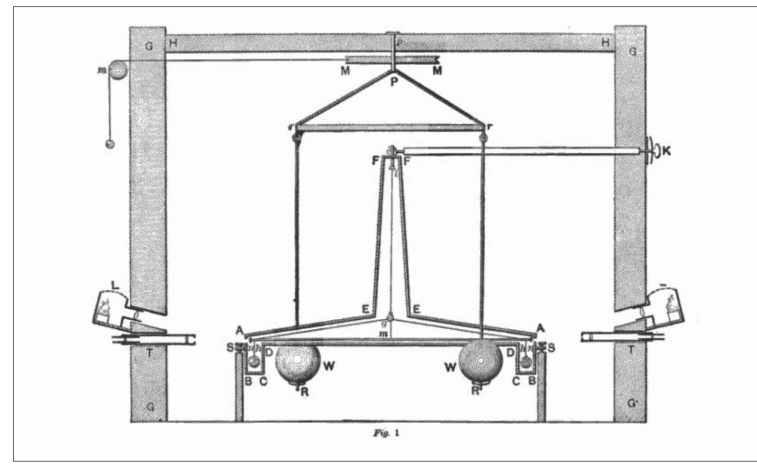
Attracting New Ideas for Measuring Big G

By Gabriel Popkin



wikimedia commons

Henry Cavendish started the search for an accurate measurement of big G with his torsion balance in 1798, shown here in a drawing from his paper reporting the results.

2016 APS April Meeting — The gravitational constant, also known as "Big G", is a bit of a black eye for physics. While precision measurements have enabled physicists to add ever more decimal points to most fundamental constants, G is barely known better today than it was more than two centuries ago, and at times its uncertainty has gone up instead of down. Currently, G is known to only around 47 parts per million, according to the International Council for Science's Committee on Data for Science and Technology (CODATA), making it the fundamental constant with the largest uncertainty.

In an invited session at the 2016 APS April Meeting, presenters reviewed past attempts to measure the constant and shared ideas for breaking the impasse. Physicists from all fields were urged to contribute to the effort by applying to participate in a National Science Foundation-sponsored "Ideas Lab," a new initiative for funding innovative research.

Isaac Newton introduced G in 1687 with his law of universal gravitation. But the first person to attempt to measure G was Henry Cavendish in 1798. He designed a torsion balance in which two small "test masses" are suspended from a wire that is then gently twisted, and the gravitational attraction between each of those masses and two much larger "source masses" are pitted against the wire's restoring force. The torsion balance is "one of the greatest ideas" for measuring the gravitational constant, said Stephan Schlamminger of the National Institute of Standards and Technology (NIST). "It brought physics a big step forward." And augmented by electronic control systems, it remains the state of the art for precision gravity experiments.

It's not that people haven't tried other things. Schlamminger described various experiments using pendulums and balance beams, but none have improved over the torsion balance. Gravity is very weak relative to other forces, Schlamminger explained, and experiments cannot be shielded from outside gravitational influences.

Recent developments in cooling and trapping of atoms have enabled new approaches to the old problem, however. Guglielmo Tino of the University of Florence in Italy described a method known as "accurate measurement of G by atom interferometry," or by its Italian acronym MAGIA. Tino and his colleagues put rubidium atoms in two different quantum states with different momentums and tossed them up vertically in the presence of source masses. They then used the falling atoms' interference patterns to determine their accelerations, and ultimately derive a value for G.

Atoms provide natural advantages, Tino said: Their masses are known to high accuracy, and their positions can be measured very precisely using lasers. But he admitted that, compared to the torsion balance (described by Cavendish as "very simple"), "the MAGIA apparatus is not very simple," requiring high vacuum and precisely tuned lasers. Tino's team published a result in 2014 with an uncertainty of 150 parts per million — relatively large but within striking distance of torsion balance results. He thinks he can improve his experiment and further reduce the uncertainty by one or possibly even two orders of magnitude.

Christian Rothleitner of the Physikalisch-Technische Bundesanstalt in Germany proposed measuring the gravitational constant by simultaneously dropping three corner-cube reflectors as test masses, and measuring their gravitational accelerations using a laser interferometer. The setup would eliminate many sources of error present in other free-fall experiments, such as the moon and sun's changing tidal influences and the gradient in Earth's gravitational field. A prototype of Rothleitner's proposed device has been built at the University of Luxembourg, and all that's missing is funding to carry out the experiment, he said.

The problems with G go beyond large uncertainties, Schlamminger said. Some G-measuring experiments also disagree with each other and with the CODATA value. That suggests undiscovered systematic errors, and an International Union of Pure and Applied Physics working group is coordinating an effort to have labs around the world ship experimental setups to each other and repeat each other's experiments, to better understand and hopefully reduce such errors. The first such repetition is in preparation at NIST.

But entirely new experimental approaches are also needed, Schlamminger added, especially from those outside the gravity research community. He urged all physicists help "reinvigorate the field" by applying to NSF's Ideas Lab. "Measuring Big G is a great thing to do at a small institution, because you only need a tabletop experiment," Schlamminger said. "It's metrology, it's fun and you learn a lot."

Preliminary proposals are due May 16, and "ideas should be risky," Schlamminger added. "They should not be ones that will work for sure, because then someone will have already tried it."

Montana State University Achieves Gender Parity in STEM Hiring

By Sophia Chen

2016 APS April Meeting — Since 2012, Montana State University has hired 72 new tenure-track faculty in science, technology, engineering, and mathematics (STEM) — and 36 of those hires were women. "Fifty percent. That's equality," said Jessi Smith, an MSU psychology professor, during a press conference at the 2016 APS April Meeting. Smith trained hiring committees to confront their own biases in job candidate selection.

She credits the achievement to an hour-long intervention that she and her colleagues developed that trained committees to recognize implicit biases to avoid subconsciously stereotyping candidates. They also arranged for candidates to discuss the university's work-life climate, confidentially, with a faculty member not on the hiring committee. They based their intervention on rigorous testing and systematically measuring the outcomes.

After the intervention, Smith said, a hiring committee member was 6.3 times more likely to make an offer to a woman candidate, and those women candidates were 5.8 times more likely to accept the offer.

The training is just a small step in changing the culture in STEM, Smith said. Scientists need to step away from the idea that science comes from innate talent, both because many underrepresented minorities are stereotyped as not having it, and because science requires hard work, she said. "This is not asking diverse people to assimilate to existing science culture, because that's not actually diversity," she said. "That's just more people who think the same way."

To meet diversity goals, departments need to be more deliberate in involving social science experts and research, explained Smith. "The solution is not throwing the kitchen sink at diversity, taking a survey, and hoping something will stick," she said.

Diversity matters because it spurs innovation, Smith said. To be more inclusive, physics departments need to recognize that scientists' personal lives affect their professional decisions, said Elizabeth H. Simmons, a physicist and dean at Michigan State University who also participated in the press conference. "Everyone we work with has other dimensions in their lives," she said.

Smith and her colleagues have published an article on their work in the April issue of *Science* magazine.

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may have ways to work around the bathroom laws. One possibility, Long said, is to arrange in advance for the facility to designate temporary gender-neutral bathrooms.

Conference attendance isn't the only issue facing LGBT physicists. "All of these considerations — it's a mess," Long said. "Particularly as a young career physicist trying to figure out where I want to go, hopefully for a tenure track position ... it's hard to figure out what state I can actually live in."

A discussion about conference planning followed Long's presentation about the *LGBT Climate in Physics* report, which was published in March 2016 by the ad hoc APS Committee on LGBT Issues. The committee used survey responses from 324 LGBT physicists, most of whom work in academia, and found that over one-third of respondents considered leaving their workplace or school in the past year.

While they found that attitudes about LGBT vary from site to site, the committee also found that 40 percent of respondents felt pressured to hide their sexuality, and over 20 percent reported experiencing exclusionary behavior such as sexual harassment, homophobic comments, or expectations of incompetence.

Long also pointed out specific challenges facing transgender physicists, such as a lack of health benefits and being forced to "out" themselves on a CV because they are unable to change their names on publications accepted before their transition.

In the report, the committee recommended that APS establish a Forum on Diversity and Inclusion, to be launched by the lgbt+ Physicists grassroots group, the APS Committee on the Status of Women in Physics, and the APS Committee on Minorities in Physics. It's important for all three groups to work together, Long said, because their report found that someone who falls under multiple disadvantaged identities — for example, an LGBT physicist who is also a racial minority, a woman, or disabled — encounters the most discrimination. "A lot of those people can't separate where the harassment is coming from," Long said. She said that it makes more sense for the three groups to approach these cases collectively.

The forum may organize sessions at conferences, Long said, and also work on figuring out how to update transgender physicists' names on publications. She hopes to encourage more senior physicists to be involved. More broadly, the report says,the Forum would work broadly to advance diversity and inclusion of all historically marginalized groups in physics.

The APS Council has formally endorsed the report, which contains a number of recommendations for developing advocacy efforts and implementing LGBT-inclusive mentoring programs. "Work has already begun, for example, with the APS Code of Conduct at meetings" Kirby said. "APS staff will now seek to respond to the other recommendations."

Sophia Chen is a freelance writer based in Tucson, Arizona.

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hints at this promised diversity, with papers that explore the flow of sediment in rivers, the transport of energy by ocean waves, and the splashing of droplets of cornstarch and other shear-thickening liquids.

Physical Review Fluids is endorsed by the APS Division of Fluid Dynamics. This backing means that the journal will publish several items from the division's annual meeting, including invited papers from plenary talks and a collection of eye-catching images and videos known as the Gallery of Fluid Motion. Researchers who publish in *Physical Review Fluids* are also eligible to receive the François Frenkiel award, an annual prize that recognizes the contributions of a young scientist to the field of fluid mechanics.

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served for 16 years in the U.S. House of Representatives and is now chief executive officer of the American Association for the Advancement of Science, shared a somewhat more optimistic take on the role scientists can play in politics. While acknowledging that few policy makers have deep scientific expertise, Holt added that "You don't have to be a professional scientist to understand the rudiments of science."

Policy makers represent the people that elected them, so scientists should focus on helping the public better understand how scientists evaluate evidence and come to conclusions, Holt said. He emphasized that this is different from the commonly used but largely ineffective strategy of simply presenting the public with more facts. "Our goal should be to equip and empower nonscientists to deal with the issues they confront, to understand the benefits of this empirical way of thinking, and to develop a reverence for evidence and the ability to handle evidence on their own."

The science-policy discourse has changed as policy makers have become less insulated from public opinion, agrees Michael Lubell, director of public affairs at APS. "Members of Congress are increasingly worried about what their constituents think—they will watch your behavior and voting patterns more than 25 years ago."

But Lubell took issue with Weart's assertion that the public's trust in science has actually fallen. He cited soon-to-be-published results from a poll conducted by the nonprofits Research!America and Science Counts that show that at most four percent of the public is anti-science. (Science Counts has received APS support and Lubell is a senior advisor to the group.)

"People do trust scientists," he said.

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and Super Proton-Proton Collider, is still in its initial design phase. The acronyms in its name reflect two distinct project stages. The first stage, CEPC, tentatively will begin construction in 2021 and will collide electron and positrons at energies up to 250 GeV beginning in 2028. [By comparison, the current record-holder for most energetic electron-positron collider, the Large Electron-Positron Collider (LEP) at CERN reached 209 GeV in 2000.] Lou said they intend this electron-positron collider to be a Higgs, W, and Z boson factory. A high production rate will allow them to both confirm theory and look for new physics. In addition, they will study bottom, charm, and top quarks produced in the collisions. This collider will be in operation until 2035, when construction on the second stage begins.

The second stage, a proton collider planned to start at 70 TeV collisions and upgrade to 100 TeV, would begin construction within the same tunnel starting in 2035. After expected completion in 2042, this collider will be used to look for physics beyond the Standard Model. From the first electron-positron collisions to the final proton-proton measurements, the collider's experiment lifetime will span from 2028 until 2055.

By first constructing an electron-positron collider and later replacing it with a proton-proton collider, the Chinese are following a design strategy that CERN has used in the past. Before the LHC began construction, its tunnel housed the LEP. This cuts costs, while also allowing time for the complicated research and development needed to build the proton collider. The biggest technical challenge, Lou said, will be to develop the high-field superconducting magnets that accelerate the protons close to the speed of light. This proton collider's magnets will need to produce fields of 20 T. (By comparison, each of the LHC's most powerful magnets can produce 8 T. CERN has developed prototype magnets that can achieve over 13 T.)

Another technical challenge, said Kotwal, will be dealing with synchrotron radiation in the electron-positron collider. This radiation, which all charged particles emit when accelerated in a curved path, could heat up the collider tunnel and break its vacuum. In addition, the experiment would need to make up for the energy lost through radiation. Kotwal said the extra energy used to cool down the tunnel and to compensate for the electron's radiated energy would be on the order of the power use of a small town.

Competing Colliders?

Two other future colliders share the table with the Chinese plan: the International Linear Collider (ILC) in Japan and CERN's Future Circular Collider (FCC) in Europe. Lou said that because the Chinese collider would probe lower energies than the ILC, whose initial collisions are planned for 500 GeV, their group considers the two projects complementary. In addition, Kotwal pointed out that because the ILC design is complete and ready to build, experiments at ILC will likely precede China's.

However, the Chinese collider's goals do overlap with European FCC plans. The projects have similar time frames and are designed to answer the same big particle physics questions. These colliders have billion-dollar price tags— should the world have two?

According to Kotwal, the question isn't relevant yet because this competition is beneficial during the design stage. The particle physics community benefits from more scientists being involved, he said. "Let's just collaborate and do our homework together."

In addition, Arkani-Hamed pointed out that too much focus on the competition between the colliders can slow down the actual physics research. "One aspect of this discussion that I find a little odd, especially among people in the West, is this idea we have to be perfectly kumbayah, in lock-step with each other, internationally deciding everything all at the same time," he said. "This has not worked out in the last 10, 15, 20 years. It hasn't given us projects that have gone ahead with great momentum."

However, the Chinese collaboration recognizes that with other collider proposals on the table, their collider may not pan out as planned, Lou said. "We fully support a global effort for the circular collider program, even if eventually the big machine is not built in China," he said during the talk.

Full Steam Ahead

In addition to 12 million yuan (1.9 million USD) in seed money from IHEP over the next three years, the group recently submitted a proposal to the Ministry of Science and Technology within the Chinese government for 50 million yuan (7.7 million USD).

Yuanning Gao, a Chinese physicist at Tsinghua University who leads the collider's fundraising efforts, is optimistic about the proposal. "The central government really thinks that China should initiate an international project," he said. According to Gao, next year they plan to ask the government for 1 billion yuan (154.6 million USD), which will go to research and development of the collider.

The timing is perfect for China, Arkani-Hamed said. Its government wants to prove itself in the international community, and high energy physics needs an ambitious new collider. When geopolitical and science goals line up perfectly, he said, "you should just go for it."

Lou echoed this sentiment after his talk. "China is still a developing country," he said. "It hasn't done any big science projects. People look at us and want to know, 'Are you serious?'" Fifty-one PowerPoint slides later, at the very least — he clearly was.

Sophia Chen is a freelance writer based in Tucson, Arizona.

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dissident scientists in dark alleys after midnight.

"I would collect their CVs to bring back to the U.S. on their behalf," she said. On her trips to the USSR, she held seminars in attics; she distributed scientific magazines. She even took a crash course in Russian to avoid needing a translator.

Incidentally, Lerman also knew Andrei Sakharov, the Soviet dissident nuclear physicist for whom the prize is named.

"We need a critical mass of scientists to start a chain reaction for peace," Lerman says.

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surement during the 1922 eclipse, and got similar results, as did the teams who made measurements during the solar eclipses of 1953 and 1973. Each new result was better than the last. By the 1960s, most physicists accepted that Einstein's prediction of how much light would be deflected was the correct one.

Eddington succumbed to cancer in November 1944 after a long illustrious career. In addition to his many scientific contributions, he once penned a lyrical parody of *The Rubaiyat of Omar Khayyam* about his famed 1919 expedition:

Oh leave the Wise our measures to collate
One thing at least is certain, LIGHT has WEIGHT,
One thing is certain, and the rest debate –
Light-rays, when near the Sun, DO NOT GO STRAIGHT.

Further Reading:

Douglas, A. Vibert. *The Life of Arthur Eddington*. Thomas Nelson and Sons, 1956.

Dyson, F.W.; Eddington, A.S.; Davidson, C.R. (1920) "A determination of the deflection of light by the sun's gravitational field, from observations made at the solar eclipse of May 29, 1919," *Philosophical Transactions of the Royal Society A* 220: 571-581.

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clarity, relevance, context, and endurance and determining if each still provided outreach and advocacy opportunities for the Society. In 2016, there are seven APS statements up for review.

As a follow-on activity to the release of the 2015 APS Statement on Earth's Changing Climate, the POPA Energy and Environment Subcommittee began preliminary activities on a workshop that will provide basic-level training on how to design and plan the development of a greenhouse gas inventory for the Society. The APS Physics and the Public Subcommittee continued to review data emerging from a recent survey on overcoming obstacles in recruiting teachers in the physical sciences. Following the fourth global Nuclear Security Summit held in Washington, DC in early April, the POPA National Security subcommittee convened to discuss initiatives and APS future activities that could contribute to the international dialog.

A template for study proposals can be found online, along with a suggestion box for future POPA studies: aps.org/policy/reports/popa-reports/suggestions.

ANNOUNCEMENTS

Distinguished Traveling Lecturer Program in LASER SCIENCE

The Division of Laser Sciences (DLS) of the American Physical Society invites applications from schools to host a lecturer in 2016/2017. Lecturers will visit selected academic institutions for two days to give a public lecture open to the entire academic community and meet informally with students and faculty. They may also give guest lectures in classes related to Laser Science. The aim is to bring distinguished scientists to colleges and universities in order to convey the excitement of Laser Science to undergraduate students.

- Applications should be sent to the DTL committee Chair Rainer Grobe (grobe@ilstu.edu) and to the DLS Secretary-Treasurer Joseph Haus (jwhaus@udayton.edu). **The deadline for application for visits in Fall 2016 is May 30.**
- Detailed information about the program and the application procedure is available on the DLS-DTL home page: **physics.sdsu.edu/~anderson/DTL/**

Lecturers for 2016/2017:

Laurie Butler, University of Chicago
Hui Cao, Yale University
Jim Kafka, Spectra Physics
Wayne Knox, University of Rochester
Christopher Monroe, University of Maryland
Luis A. Orozco, University of Maryland
Carlos Stroud, University of Rochester
Linda Young, Argonne National Lab

APS physics

Reviews of Modern Physics

Colloquium: Search for a drifting proton-electron mass ratio from H_2

W. Ubachs, J. Bagdonaite, E. J. Salumbides, M. T. Murphy, and L. Kaper

Looking back into 10-12 billion years of cosmic history this Colloquium summarizes what is presently known about the proton-to-electron mass ratio and its variation with time. The hydrogen spectra of quasars and how they reveal fundamental information on some of the most important constants in physics and cosmology are reviewed.

journals.aps.org/rmp

2017 APS Prizes & Awards

These APS Prizes and Awards recognize achievements across all fields of physics. Please consider nominating deserving colleagues for the following:

Julius Edgar Lilienfeld Prize
Nomination Deadline: July 1, 2016

George E. Valley Prize
Nomination Deadline: July 1, 2016

APS Medal for Exceptional Research
Nomination Deadline: August 1, 2016

Serving a diverse and inclusive community of physicists worldwide is a primary goal for APS. Nominations of qualified women and members of underrepresented minority groups are especially encouraged.

LEARN MORE
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APS physics

2016 APS National Mentoring Community Conference

OCTOBER 21 - 23, 2016
at the University of Houston
Houston, Texas

go.aps.org/nmc-conference

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nity, in that all copies of the three earlier editions were sold out, and the fourth one is under preparation. Many young colleagues told us later that they benefited a lot from reading that book.

Another important event took place in 1975: An American delegation of solid state physicists visited China in September and October for almost one month. The delegation was led by Charles Slichter from the University of Illinois, and included four physics Nobel Laureates: John Bardeen, Nicolaas Bloembergen, Ivar Giaever, and Bob Schrieffer. The delegation spent three full working days at IoP and obtained quite a good picture of the actual situation. I happened to be the interpreter of Bob Schrieffer's talk on solitons and could present my joint work with Hao on the critical exponent calculation. Our American colleagues were very much impressed as evidenced by their comments in the published official report *Solid State Physics in the People's Republic of China* (National Academy of Sciences, Washington, DC, 1976). To tell just a small episode: During Bob's lecture at IoP, I reminded him, beyond my interpreter's duty, when the key word of his talk — "Soliton" — escaped from his mind temporarily. For me that was nothing special, as I had read his paper in advance. However, Bob was quite pleased and told the story to several friends, including Stig Lundqvist from Sweden, who would later invite me to join the staff of the International Centre for Theoretical Physics (ICTP) in Trieste, Italy.

In 1978 I got permission to travel abroad again after a 17-year interruption, and went to Brussels to attend the Solvay Conference, where I met Phil Anderson, Leo Kadanoff, Mike Fisher, and many others. Later I visited Bert Halperin's group at Harvard for more than a year. That was an inspiring experience of true re-education to gain fresh feeling of frontline research. Bert jokingly called me his "senior postdoc." "Senior" is true, as I am 4 years older than he, but I do not have a Ph.D. at all. In 1983 I met Stig Lundqvist at IoP in Beijing, and as mentioned above, he kindly initiated my involvement with ICTP, an event which changed my professional life in a fundamental way. In 1985, before joining ICTP, I received a heavy-weighted letter from Abdus Salam, the founding director of ICTP saying: "We would like the condensed matter activities in developing countries to be enhanced through your presence here at the Centre. … We all look forward to a second revolution in condensed matter activity in developing countries with your appointment and through your influence." One can imagine how much pressure and drive was there for me from this kind of anticipation.

The ICTP and its sister organization, the International School for Advanced Studies (SISSA), have played a tremendous role in promoting science and education in developing countries, especially after China suffered badly from isolation and destructions during the Cultural Revolution. Thousands of young Chinese scientists visited ICTP-SISSA as postdocs, trainees in the Italian laboratories, associate members, participants of schools/conferences, and many of them used it as a stepping stone to the broad international arena. During my tenure at ICTP (lasting almost 17 years), I did my best, under Salam's supervision and following his advice, and that token contribution was well recognized by colleagues. In 2007, I was awarded the American Institute of Physics John T. Tate Medal for International Leadership in Physics, established for non-Americans. Abdus Salam also received the same award earlier, in 1978. I felt greatly honored and pleased, as I was trying very hard to follow his steps.

In 2002 I returned back to China after retirement from ICTP. Instead of enjoying a relaxed pensioner's life, I have been still actively involved in research-related activities. However, my role changed dramatically: no longer as a research leader or a science organizer, but rather as a senior adviser, a friend for researchers of different age groups, and a "cheerleader." In that position I personally witnessed the dramatic changes in Chinese science, and in condensed matter physics, in particular.

At the end of February 2008, I was invited by Nanlin Wang at IoP to join their group meeting, where the latest report (in Japanese) of the Hosono group's discovery of 26 K iron pnictide superconductors was discussed. In less than a week, the first paper written by that group appeared on the arXiv, giving rise to the heat wave of research on iron-based high-temperature superconductivity worldwide. Soon afterwards several Chinese groups followed up, pushing the superconducting temperature to the highest record, as *Science* commented, "New superconductors propel Chinese physicists to the forefront."

Surely, these tremendous changes did not come out of blue: strong government support (the budget of NSF China has been increasing by10 to 15 percent annually for the last 10 to 15 years), the large inflow of well-trained scientists (a few thousand for the last 10 years), and the substantial improvement in research facilities are the key prerequisites for materializing the quantal transition. As Abdus Salam said, "Scientific thought is the common heritage of the Mankind."

The scientific exchange during the Cultural Revolution was rather limited, but it was crucial for our scientific survival and for research continuity. The personal contacts established then were extremely helpful for recovering our scientific careers and building up successful international collaboration after China's opening up to the outside world. The international exchange, especially the helping hand offered to us when we were under severe isolation, is a most indispensable factor for this current success. We Chinese scientists will never forget it!

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So if there were gravitons, they too would give kicks to particles they interacted with, and hence would exert true forces. Thus if one wants to stick with the view about the gravitational interaction that emerges from Einstein's general relativity, one has to reject gravitons. This no-graviton view of Einstein could help to explain why there has been no success in the numerous, and mathematically impressive, efforts to quantize general relativity. For Einstein then, gravitational waves are classical waves that one should not attempt to quantize.

However, this is by no means the end of the story, because these classical gravitational waves that LIGO so remarkably detected are solutions to the linearized Einstein gravitational field equations. If one plugs these linearized solutions into the exact field equations, one finds there are true energy-momentum source terms that result due to the nonlinear structure of the exact equations. The LIGO theoreticians have yet to tell us what is the physical meaning of these classical quantities? Do they really exist, or are they just mathematical artifacts? If they do, can they eventually be detected as well?

Frank R. Tangherlini
San Diego, California

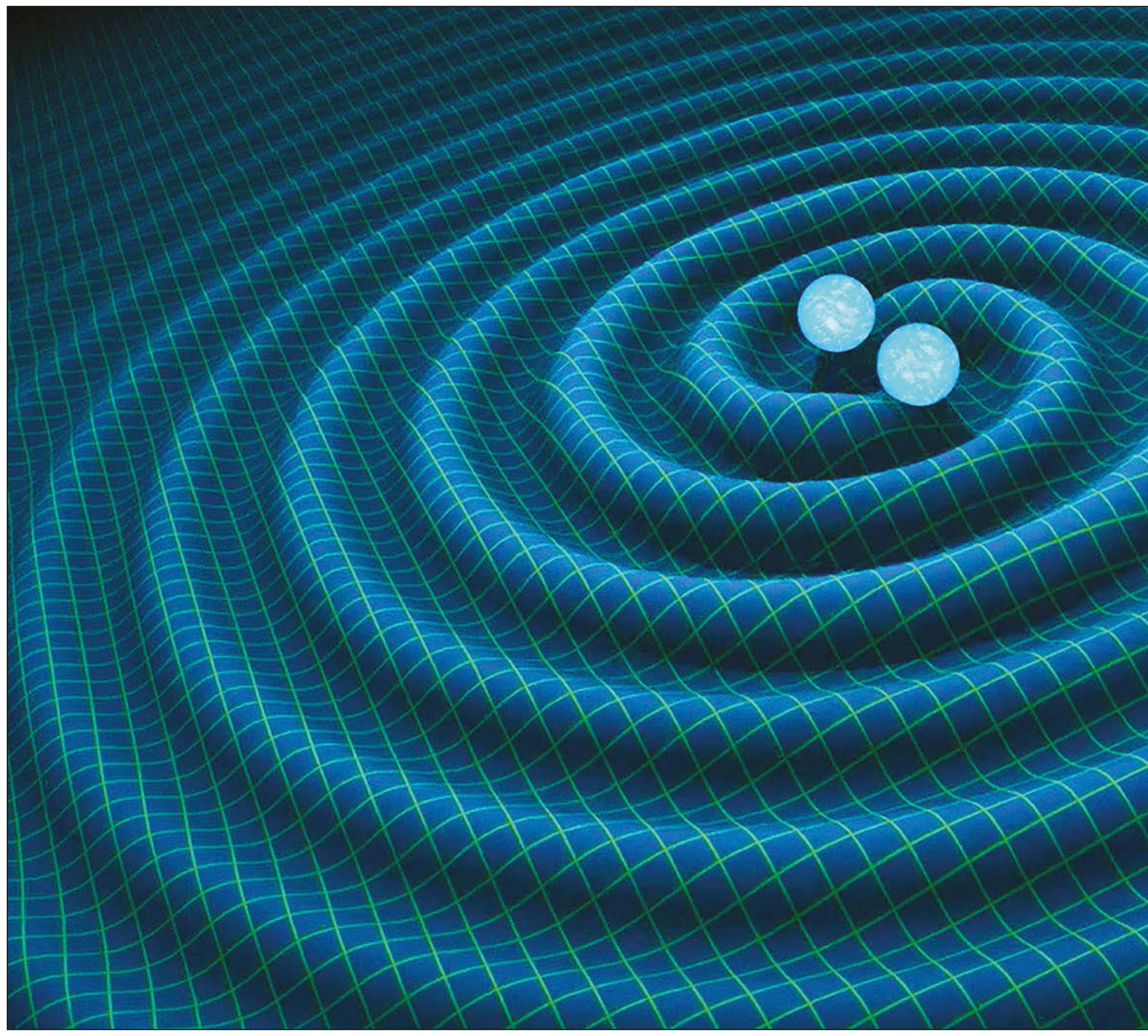
The Back Page

Finding Beauty in the Darkness

By Lawrence M. Krauss

On Thursday, February 11, 2016, the LIGO Collaboration announced their stunning discovery of gravitational waves. For several months there had been growing anticipation of a possible discovery, which I was pleased to have helped fan in social media. Not only were the media better prepared as a result, but the excitement in the press was palpable in the days leading up to the announcement, which was covered around the world. Nevertheless, the questions I most often received, both in advance and afterwards, included "what good is it?", or, "What will it do for me?" I wrote this piece shortly after the discovery to stress the cultural impact of science and its importance in enhancing the simple joy of being human. This is particularly important in light of efforts by the U.S. Congress to require funding for science to pass a "national interest" test—namely to justify scientific research by its immediate impact on defense, or technological innovation. In this sense my piece was meant to add to the beautiful words of Robert Wilson, when he was asked by a Senate committee if Fermilab would aid in the security of the country. His response was brilliant, and worth remembering:

"*It has only to do with the respect with which we regard one another, the dignity of men, our love of culture.. Are we good painters, good sculptors, great poets? I mean all the things we really venerate in our country and are patriotic about….it has nothing to do directly with defending our country except to make it worth defending.*"



NASA

Would gravitational waves have been directly observed if the funding had to pass a "national interest" test?

With presidential primaries in full steam, with the country wrapped up in concern about the economy, immigration and terrorism, one might wonder why we should care about the news of a minuscule jiggle produced by an event in a far corner of the universe.

The answer is simple. While the political displays we have been treated to over the past weeks may reflect some of the worst about what it means to be human, this jiggle, discovered in an exotic physics experiment, reflects the best. Scientists overcame almost insurmountable odds to open a vast new window on the cosmos. And if history is any guide, every time we have built new eyes to observe the universe, our understanding of ourselves and our place in it has been forever altered.

When Galileo turned his telescope toward Jupiter in 1609, he observed moons orbiting the giant planet, a discovery that destroyed the Aristotelian notion that everything in heaven orbited the Earth. When in 1964 Arno Penzias and Robert Wilson of Bell Laboratories detected radio waves emitted by celestial objects, they discovered that the universe began in a fiery Big Bang.

One hundred years ago, Albert Einstein used his newly discovered general theory of relativity (which implies that space itself responds to the presence of matter by curving, expanding or contracting) to demonstrate that each time we wave our hands around or move any matter, disturbances in the fabric of space propagate out at the speed of light, as waves travel outward when a rock is thrown into a lake. As these gravitational waves traverse space they will literally cause distances between objects alternately to decrease and increase in an oscillatory manner.

This, of course, is far from the realm of human experience. In the absence of alcohol, your living room doesn't appear to shrink and grow repeatedly. But, in fact, it does. The oscillations in space caused by gravitational waves are so small that those ripples in length had never been seen. And there was every reason to suspect they would never be seen.

Yet on Thursday, the Laser Interferometer Gravitational-Wave Observatory, or LIGO, announced that a signal from gravitational waves had been discovered emanating from the collision and merger of two massive black holes over a billion light-years away. How far away is that? Well, one light-year is about 5.88 trillion miles.

To see these waves, the experimenters built two mammoth detectors, one in Washington State, the other in Louisiana, each consisting of two tunnels about 2.5 miles in length at right angles to each other. By shooting a laser beam down the length of each tunnel and timing how long it took for each to be reflected off a mirror at the far end, the experimenters could precisely measure the tunnels' length. If a gravitational wave from a distant galaxy traverses the detectors at both locations roughly simultaneously, then at each location, the length of one arm would get smaller, while the length of the other arm would get longer, alternating back and forth.

To detect the signal they observed they had to be able to measure a periodic difference in the length between the two tunnels by a distance of less than one ten-thousandth the size of a single proton. It is equivalent to measuring the distance between the earth and the nearest star with an accuracy of the width of a human hair.

If the fact that this is possible doesn't astonish, then read these statements again. This difference is so small that even the minuscule motion in the position of each mirror at the end of each tunnel because of quantum mechanical vibrations of the atoms in the mirror could have overwhelmed the signal. But scientists were able to resort to the most modern techniques in quantum optics to overcome this.

The two black holes that collided, which the LIGO experiment claimed to have detected, were immense. One was about 36 times the mass of our sun, the other, 29 times that mass. The collision and merger produced a black hole 62 times our sun's mass. If your elementary arithmetic suggests that something is wrong, you're right. Where did the extra three solar masses disappear to?

Into pure energy in the form of gravitational waves. Our sun will burn for 10 billion years, with the intensity of over 10 billion thermonuclear weapons going off every second. In the process, only a small fraction of its total mass will be turned into energy, according to Einstein's famous equation, $E=mc^2$. But when those black holes collided, three times the entire mass of our sun disappeared in less than a second, transformed into pure energy. During that time, the collision generated more energy than was being generated by all the rest of the stars in the observable universe combined.

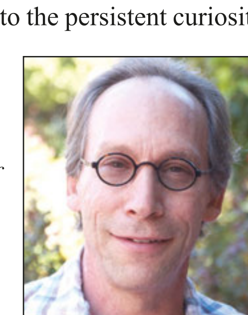
Too often people ask, what's the use of science like this, if it doesn't produce faster cars or better toasters. But people rarely ask the same question about a Picasso painting or a Mozart symphony. Such pinnacles of human creativity change our perspective of our place in the universe. Science, like art, music and literature, has the capacity to amaze and excite, dazzle and bewilder. I would argue that it is that aspect of science — its cultural contribution, its humanity — that is perhaps its most important feature.

What more can we learn about the universe from a stupefying experimental feat observing a stupefying wonder of nature? The answer is anyone's guess. Gravitational-wave observatories of the future will be able to explore the exotic features of black holes. This may shed light on the evolution of galaxies, stars and gravity. Eventually, we may be able to observe gravitational waves from the Big Bang, which will push the limits of our current understanding of physics.

Gravitational waves emerge from near the "event horizon" of black holes, the so-called exit door from the universe through which anything that passes can never return. Near such regions, for example, time slows down by a huge amount, as anyone who went to see the movie "Interstellar" knows. (Coincidentally the original treatment for "Interstellar" was written by Kip Thorne, one of the physicists who helped conceive of the LIGO experiment.)

Ultimately, by exploring processes near the event horizon, or by observing gravitational waves from the early universe, we may learn more about the beginning of the universe itself, or even the possible existence of other universes.

Every child has wondered at some time where we came from and how we got here. That we can try and answer such questions by building devices like LIGO to peer out into the cosmos stands as a testament to the persistent curiosity and ingenuity of humankind — the qualities that we should most celebrate about being human.



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