# LIGO project to provide a new window to the universe

■ **By Deborah Halber**
News Office

First there were optical telescopes. Then radio wave detectors and X-ray observatories gave researchers new "eyes" with which to view the cosmos. The next big window to the universe may be through gravitational waves.

Through a project called LIGO (Laser Interferometer Gravitational-wave Observatory)—a joint effort of the California Institute of Technology, MIT and a group of about 20 other institutions represented in the LIGO Scientific Collaboration supported by the National Science Foundation (NSF)—scientists expect to "see" the universe in a fundamentally new way.

Or with a whole new wave. In 1915, Einstein showed that accelerating masses, such as those occurring in an exploding star, create gravitational fields that radiate from their sources much like ripples spreading from a stone dropped in a lake. These fields, which warp the shape of space and time and travel at the speed of light, are called gravitational waves. They are difficult to detect because they interact so weakly with matter.

By the time they reach us, gravity waves, roaming through space since the beginning of the universe with little to dampen them, are minuscule disturbances in the space-time fabric.

Unlike electromagnetic waves such as radio waves or X-rays, gravity waves are not scattered as they travel. Scientists hope that this means they will open a unique window into the innermost and densest regions of space and provide information about violent events in the regions where they originated.

"What we're trying to do is actually explore nature in a way that is different," said Rainer Weiss, professor of physics at MIT and LIGO's integration scientist. "That's what's so exciting."

## AMBITIOUS UNDERTAKING

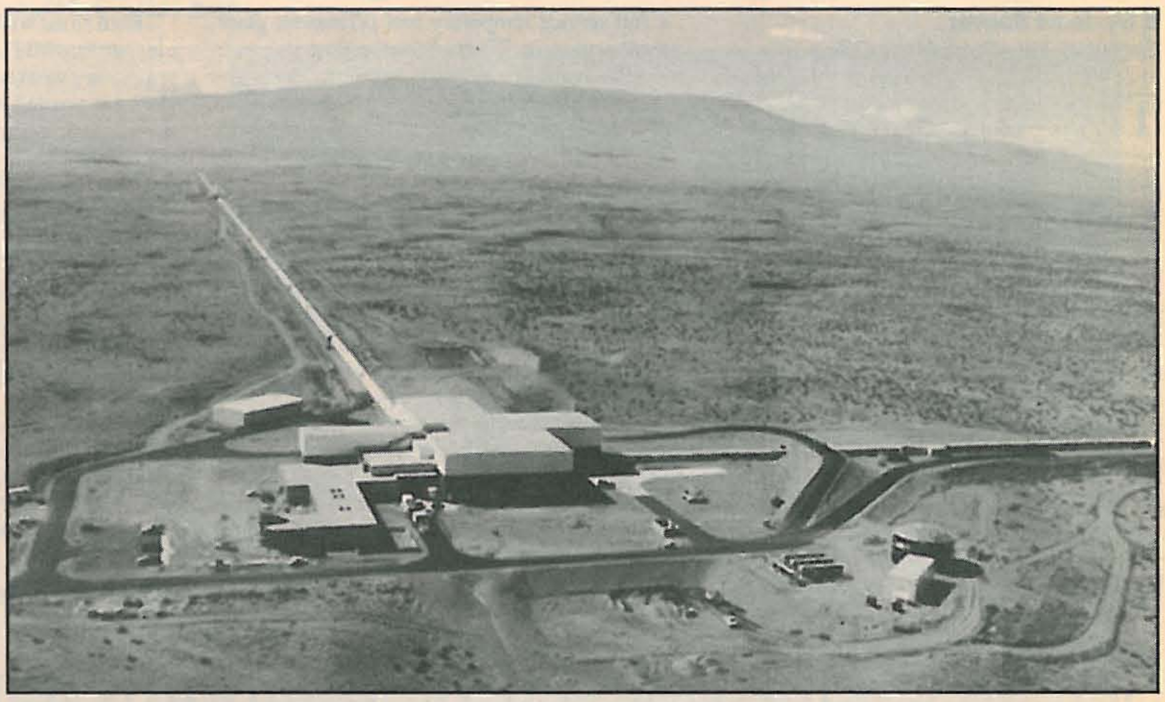
To date, researchers have indirect but strong evidence that gravitational waves actually exist. This came from radio observations of a binary stellar system consisting of a pair of compact stars made by 1993 physics Nobelists Russell A. Hulse and Joseph H. Taylor Jr. at the University of Massachusetts and Princeton University.

The system exhibits an energy loss best attributed to the radiation of gravitational waves. To detect gravity waves directly, researchers need an extremely sensitive instrument: one capable of a task tantamount to identifying a single, particular grain of sand on all of Cape Cod's beaches.

The unprecedented sensitivity required to directly detect gravitational waves has made the development of the detectors a first-rank technical challenge of such difficulty that it is sometimes met with skepticism.

To make matters worse, once it was realized that gaining the requisite sensitivity would involve large baseline systems and thereby large costs and all the trappings of big science, new challenges became evident. The scientists in this field had to convince their colleagues that not only would the technology development succeed but also that the eventual scientific returns were worth the costs. Even with consistent support by the NSF, it took several decades to develop the scientific case. LIGO represents years of effort on the parts of Professor Weiss and many other scientists.

The decades of persistence paid off. Late last year, a first-of-its-kind instrument to search for gravitational waves was inaugurated in Livingston, LA. A twin facility exists in Hanford, WA. The $300 million LIGO project is the largest single enterprise ever funded by the NSF.



*An aerial view of the LIGO observatory in Hanford, WA.*

The detection concept is to measure the time it takes light to travel through the space distorted by the gravitational wave using precision interferometry. At each facility, laser light is injected from a central building into orthogonal tubes 2.5 miles long. Mirrors at the ends of the tubes reflect the light back to the central building.

A gravitational wave, should one happen along, will increase the light travel time in one arm while decreasing it in the other. This time difference is converted into a change in intensity and measured on photodetectors.

Among the cataclysmic cosmic events that should produce detectable gravity waves are compact stars (neutron stars or black holes) spiraling into companion compact stars, the collapse following a supernova, the characteristic oscillations of space-time when a black hole is formed or perturbed, the motion of nuclear fluid on the surface of a neutron star, or the waves produced by the Big Bang itself.

In addition to attempting to answer what Professor Weiss calls "sharp-shooter questions," for which there is a specific prediction, LIGO researchers and their instrument also will be open to "buckshot questions," which are more broad-based. "I think it's glorious to go looking, not knowing what you'll find," he said.

## THE SEARCH IS ON

The search for gravity waves is only around 40 years old and involves a handful of scientists around the world. Professor Weiss's interest was sparked early on, shortly after "acoustic bar" gravitational detectors were first proposed. By 1970, he had already come up with the concept of an interferometer-type detector.

In recently renovated space in Building NW17, there are huge metal tanks resembling a large distillery that will be used to develop the next generation of detector. The tanks and their connecting tubes contain "a few optics, a lot of light and very little air," according to David Shoemaker, senior research scientist for LIGO at MIT.

Because the effect of a passing gravitational wave is so small, causing only motions of the order of $10^{-19}$ (0.0000000000000000001) meters on the mirrors, every aspect of the instrument must perform at the limits of fundamental physics: the mirrors must show only Brownian motion, and the interferometric sensing must be limited by quantum effects.

In the future detectors presently under study, even Heisenberg's uncertainty principle comes into play.

## PLANNING AHEAD

The detectors, designed and constructed by Caltech, MIT and members of the LIGO scientific collaboration, are expected to record their first observations in 2002. Researchers already are preparing for the future with a more sensitive LIGO II, which is planned to be more sensitive by roughly a factor of 10.

Because the volume of space "seen" by the detector grows with the cube of the sensitivity, if only one event were detected during the first go-round, 1,000 events would be found with LIGO II.

In addition to US-based efforts, there is another interferometer planned in Australia and smaller units in Germany and Japan. In Italy, a detector called VIRGO is expected to come on line in 2002.

The ground-based detectors would be complemented by a space-based antenna planned for a decade down the road. LISA, the space-based project, a joint effort by the European Space Agency and NASA, would search for gravitational waves at much lower frequencies than the ground-based observatories. LISA would involve laser ranging between satellites three million miles apart in solar orbit.

Researchers expect to get dramatic results from LISA, as well as before LISA is up. "There is a reasonable chance that the currently planned ground-based interferometers will detect gravitational waves from astrophysical sources," Professor Weiss said. "Current estimates of source strengths and rates would predict a high probability of detection with the sensitivity improvements associated with LIGO II. Using the current knowledge of astrophysical phenomena, the LISA project is expected to make high signal-to-noise detections of massive black collisions throughout the universe.

"There is a strong chance," he added, "that gravitational wave detections will become a standard branch of observational astrophysics in the next two decades."

## Notes from the Lab

### CAPTURING $CO_2$ FROM POWER PLANTS?

One way to reduce emissions of greenhouse gases is to capture and permanently store the carbon dioxide ($CO_2$) emitted by electric power plants burning fossil fuels. However, current methods of capturing $CO_2$ are expensive.

Energy Laboratory researchers led by principal research engineer Howard Herzog have performed a methodical study of projected costs for capturing $CO_2$ from three types of power plants, two fueled by coal and one by natural gas. According to their analyses, capturing $CO_2$ could push up the cost of generating electricity from 3.3¢/kWh to 5.2¢/kWh at a natural gas plant and from 4.6¢/kWh to 6.0¢/kWh at a coal plant based on gasification.

At those costs, carbon capture promises to be a less expensive near-term option for carbon mitigation than switching to solar and perhaps nuclear power. With technological advances expected by 2012, incorporating capture could add less than 1¢/kWh to the cost of electricity. Increasing power plant efficiency could reduce the cost of capture substantially.

The researchers are now performing more rigorous analyses of how $CO_2$ capture compares to other carbon mitigation options under various assumptions about the future. This research was supported by the DOE.

**Nancy Stauffer, Energy Lab**

### NEXT-GENERATION BAR CODE

MIT researchers are working on the next generation of the Universal Product Code (UPC), better known as the bar code found on most manufactured products.

Professors Kai-Yeung (Sunny) Siu and Sanjay Sarma of mechanical engineering with Dr. David Brock of the Laboratory for Manufacturing and Productivity are designing an industrial application that will employ low-cost, electromagnetically coupled tags to improve product tracking and supply chain management. Using this system, tagged products will be identifiable to reader devices which are themselves hooked up to a computerized local area network (LAN). The LAN can be connected to the Internet, allowing objects to be traced from anywhere in the world.

The bar code's limitation as it currently stands is that it has to be manually scanned—on the shelf the code is useless. By replacing bar codes with electromagnetic tags, companies will be able to monitor product movement continually, from manufacture to disposal, in real time. Eventually, shoppers will bypass checkout counters altogether as the prices of their tagged purchases are automatically debited from their accounts on their way out the door.

This project is administered by the Auto-ID Center (AIDC), a consortium of academic and industry partners of which Professor Siu is director. It will be featured at an MIT Industrial Liaison Program conference April 12-13 called "Smart World in the New Millennium." For more information, go to <http://ilp.mit.edu/ilp/conferences/current.html>.

**Charles Schmidt, MIT Report**

*This column features summaries of MIT research drawn from several sources. If you have an item to suggest, send it to Elizabeth Thomson, News Office assistant director for science and engineering news, Rm 5-111, or <thomson@mit.edu>.*

# Talk probes dangers of chemical in movie

■ **By Deborah Halber**
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In the new hit movie *Erin Brockovich,* the main character discovers a cover-up involving contaminated water that causes devastating illnesses among residents in a California community. A visiting scientist at MIT says that the chemical responsible, chromium (VI), is a growing global health issue.

Avi Bino, a chemistry professor at the Hebrew University of Jerusalem who is currently conducting research at MIT, spoke March 22 on "Models for the Interaction of Carcinogenic Chromium (VI) with DNA" as part of the MIT chemistry department's Inorganic Chemistry Seminar Series.

Chromium has three main forms: chromium (0), chromium (III) and chromium (VI). Some chromium (III) compounds are an essential nutrient that occur naturally in the environment. Chromium (VI) is a known carcinogen. Manufacturing or disposal of products or chemicals containing chromium, or burning of fossil fuels release odorless, tasteless chromium (VI) into the air, soil and water. Workers exposed to chromium (VI) have an increased risk of lung cancer; high doses have been associated with birth defects. "Chromium (VI) is bad news for biological systems," Professor Bino said.

Chromium is produced by burning coal and fossil fuels, stainless steel plating, chrome plating and leather tanning, among other processes. As a result of the efforts of the real-life Erin Brockovich, Pacific Gas & Electric Co. settled with plaintiffs in 1996 for $333 million, the largest settlement ever paid in a direct-action lawsuit in US history.

"Chromium is ubiquitous," Professor Bino said. "It is becoming more and more ubiquitous as we dump millions of tons of chromium all over the place. In the last decade, millions and millions of tons have been dumped into rivers, soil, the oceans and the atmosphere."

Some of the first plants in the country to produce chromium as a byproduct were in Madison County, NJ, and the chromium mud they created was dispersed all over the country, he said. It's estimated that 200,000 tons of chromium, 5 percent of which is chromium (VI), is in the New York area alone, he added.

"Releasing chromium (VI) into the atmosphere or onto the ground is totally forbidden, but for many years, some of those factories didn't comply," said Professor Bino, who noted that his expertise is not ecology or cancer. "The problem is not confined to a certain plant—it is becoming global because of emissions to the atmosphere. Chromium (VI) comes down with rain and we breathe it." He cited estimates that 75,000 tons of chromium (VI) are emitted globally every year through manufacturing processes, plus about another 18,000 tons from natural sources such as volcanoes.

"Usually, chromium (VI) is reduced to chromium (III) and nothing happens," Professor Bino said. "The problem is when it gets into the body as chromium (VI). It can be absorbed through the skin or inhaled. Then it can penetrate the cell, bind to DNA and cause genetic damage."

Because exposure to chromium (VI) happens mostly from breathing workplace air or ingesting water or food from soil near waste sites or industries that use chromium, Professor Bino suggested that the air and water surrounding every chromium (VI)-emitting plant be monitored.