Imagine...

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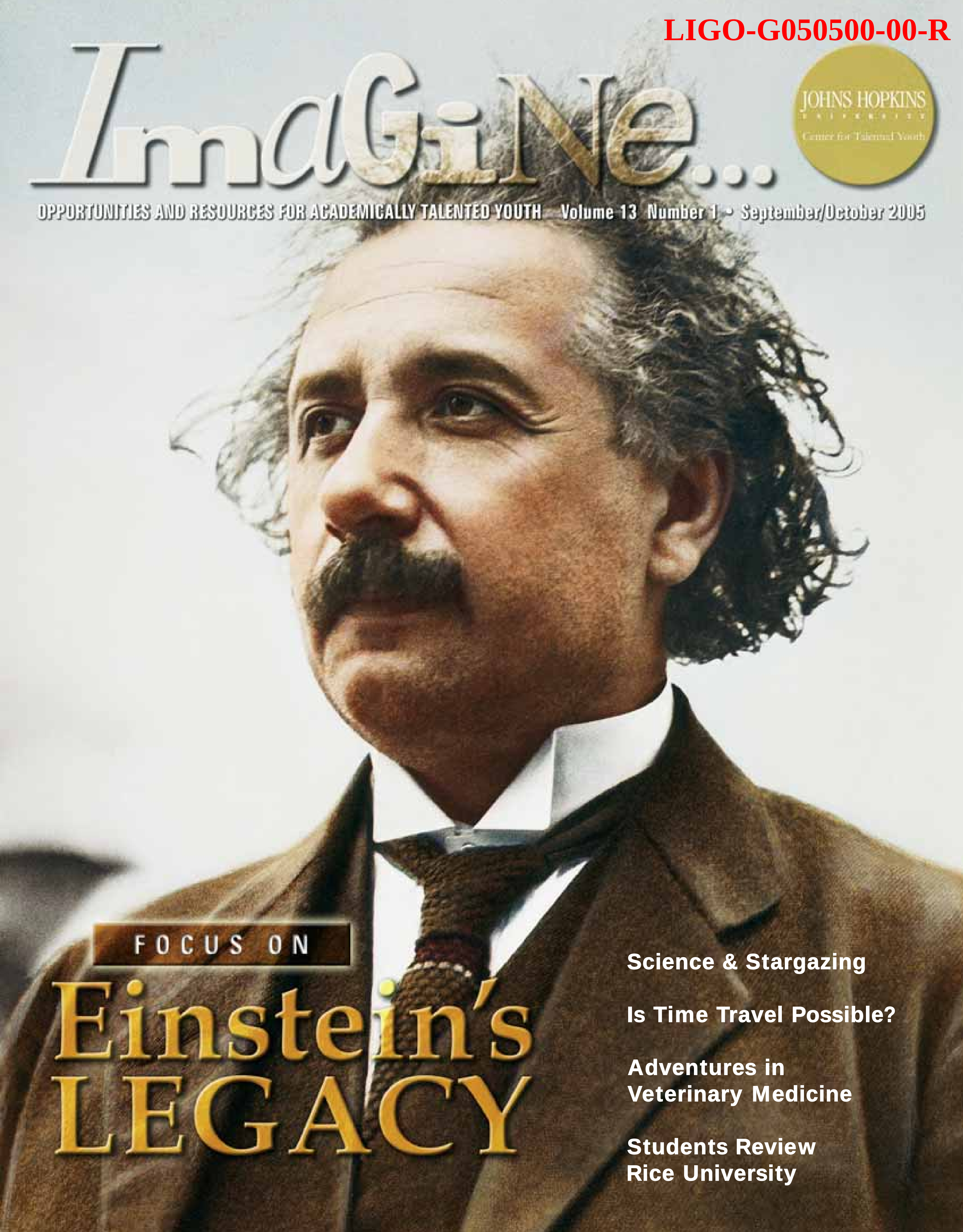

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In Search of Gravitational Waves
A SUMMER AT LIGO

by Nicky Virdone

Last summer, I had the chance to participate in research at one of the most prestigious universities in the nation. I have always loved math and science, so when my high school math teacher told me about an opportunity to work at Caltech as part of the LIGO (Laser Interferometer Gravitational-Wave Observatory) project, I couldn't pass it up.

Going into my internship, I knew very little physics. In fact, the only physics I had taken until then was during eighth grade. But I figured that since I was only a rising senior in high school, they probably wouldn't ask much of me.

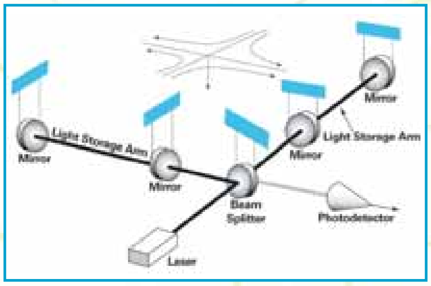
I quickly learned how wrong I was.

House of Waves

LIGO, which was built by scientists from Caltech and MIT, has two observatories: one in Hanford, Washington, and the other in Livingston, Louisiana. Together, they are designed to detect gravitational waves, which are caused by motions of matter that shift the curvature of space-time. Space-time is the continuum of four dimensions, three of space and one of time, in which events occur. Albert Einstein predicted in his general theory of relativity that the quick acceleration of large masses distorts space-time and generates waves. If detected, these gravitational waves could alert scientists to distant catastrophic events, such as supernovas or collisions of black holes, that would otherwise go unnoticed.

The two observatories consist of identical L-shaped arms, each two and a half miles long. A beam-splitter divides a laser beam and sends each half down an arm, where it is reflected back by a mirror suspended at the ends. A transiting gravitational wave would gently shake the suspended mirrors at the end of each tunnel and generate a modulation in the beams, which would be detected when they recombine at the vertex of the L.

By the time gravitational waves reach Earth, they are so weak that the disturbance of space-time is hundreds of millions of times smaller than the width of an atom. Therefore, these detectors have to be sensitive enough to measure lengths as small as 1/100,000,000,000,000 of a human hair. Year by year, LIGO scientists continue to improve the sensitivity of the interferometers. Greater sensitivity will improve the odds of detecting a gravitational wave.



This diagram shows the main elements that will detect a gravitational wave.

The Creep Property

I was the youngest person working on a team supervised by Dr. Riccardo DeSalvo. Each person in the group has his or her own job, from working on the shape of the mirror that reflects the laser light, to creating the springs that will hold the mirror steady, to building a test interferometer. Walking through the halls of Caltech among these brilliant scientists, I was intimidated to say the least.

On my first day, Dr. DeSalvo sat me down and started talking about what he wanted me to do. "I want you to build an oven," he said. My mind was overwhelmed with thoughts and questions, though I only managed to whimper, "Excuse me?" Dr. DeSalvo is known to have a great sense of humor, so I assumed he was joking.

He wasn't.

The rest of that day, he explained to me the task at hand: to measure the creep property of a metal alloy called maraging steel. Creep is a measurement of how an alloy deforms under strain over time. It is most likely to occur under high temperatures. The group I work with at LIGO uses maraging steel for the spring that suspends the mirrors inside the interferometer vacuum chamber. Although the springs will not be subjected to high temperatures, the metal still has a creep property that can be measured, allowing scientists to pre-

Aerial view of the LIGO Livingston observatory. Each arm is more than two miles long.

A view of the interferometer's interior. This shot shows the vertex of the L.

LIGO staff install a mode-matching mirror and suspension into a vacuum chamber.

All photos courtesy of LIGO.

dict how much the springs will droop over time.

Instead of telling me exactly how to approach this task, Dr. DeSalvo asked me how *I* thought it should be done. At first I absolutely hated this way of teaching, but it turned out to be the reason that I learned so much. I would suggest something, and if it was way off, Dr. DeSalvo would guide me to the easiest way. Together we decided to build an oven that would heat up to 200°C (~400°F) and would house a spring made of maraging steel that would hold a payload of around 63 kilograms (~139 pounds).

Under Construction

I spent the rest of my summer building the oven. I was responsible for every detail, from the metals we used to the size of the screws. Dr. DeSalvo let me do everything. This was the first time I ever used power tools!

The oven was made of circular aluminum plates with insulation that can withstand temperatures up to 400°F. Inside the cylinder-shaped oven is a maraging steel spring with a payload hung from a small hole in the center. The oven was heated by a commercial temperature controller that stabilized the inside of the oven to whatever temperature I input.

After some trial and error, we decided that the most efficient way to measure the creep of the metal was to excite, or agitate, the spring into oscillation and take an average of many payload vertical position measurements. We started taking measurements at 40°C (86°F). After several days at this temperature, we increased the temperature to higher levels, and then brought it down to 40°C. These measurements took place throughout the school year. For each temperature, we waited until the position stabilized (around two weeks) and measured at several temperatures.

Up to 190° C, the spring showed a small initial drooping, then stabilized. Above 190°, the data showed a definite, continuous creep of the payload's vertical position. This data will be useful in predicting what the spring will do over many years. Overall, the experiment ran very well and produced useful data. I spent this summer analyzing this data and writing a paper on our findings.

This experience has been amazing for me. I was so scared my first day on the job, but now I am extremely comfortable tackling problems that seemed impossible. Before this, I would have never guessed I could handle such a task. Dr. DeSalvo refused to hold my hand yet was right behind me making sure I was going in the right direction. I am sad that my days at work in LIGO are coming to an end, but when LIGO detects its first gravitational wave, I will be thrilled to know that I played a small part in making it possible. ■

Nicky Virdone, 18, graduated in June from Mayfield Senior School in California. In her free time, she enjoys listening to music, playing softball, and watching musicals with her friends. Nicky now attends UCLA, where she plans to major in bioengineering.

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The oven that Nicky built to test the creep property of a metal alloy. The temperature controller sits on the table; the payload hangs below. Inset: A view of the oven's interior.