The Hunt for Gravity Waves

Wed, 19 Apr 2006 - As part of his general theory of relativity, Einstein predicted that mass should emit gravity waves. They'll be weak, though, so it would take very massive objects to produce waves detectable here on Earth. One experiment working towards their detection is the Laser Interferometer Gravitational-Wave Observatory (or LIGO). It should be able to detect the most powerful gravity waves as they pass through the Earth. And a space-based observatory planned for launch in 2015 called LISA should be stronger still.

Full article

Scientists are close to actually see gravitational waves. Image credit: NASA

Gravity is a familiar force. It's the reason for fear of heights. It holds the moon to the Earth, the Earth to the sun. It keeps beer from floating out of our glasses.

But how? Is the Earth sending secret messages to the moon?

Well, yes -- sort of.

Eanna Flanagan, Cornell associate professor of physics and astronomy, has devoted his life to understanding gravity since he was a student at University College Dublin in his native Ireland. Now, nearly two decades after leaving Ireland to study for his doctorate under the famous relativist Kip Thorne at the California Institute of Technology, his work focuses on predicting the size and shape of gravitational waves -- an elusive phenomenon forecast by Einstein's 1916 Theory of General Relativity but which have never been directly detected.

In 1974, Princeton University astronomers Russell Hulse and Joseph H. Taylor Jr. indirectly measured the influence of gravity waves on co-orbiting neutron stars, a discovery that earned them the 1993 Nobel Prize in physics. Thanks to the recent work of Flanagan and his colleagues, scientists are now on the verge of seeing the first gravity waves directly.

Sound cannot exist in a vacuum. It requires a medium, such as air or water, through which to deliver its message.

Similarly, gravity cannot exist in nothingness. It, too, needs a medium through which to deliver its message. Einstein theorized that that medium is space and time, or the "spacetime fabric."

Changes in pressure -- a thump on a drum, a vibrating vocal cord -- produce sound waves, ripples in air. According to Einstein's theory, changes in mass -- the collision of two stars, dust landing on a bookshelf -- produce gravity waves, ripples in spacetime.

Because most everyday objects have mass, gravity waves should be all around us. So why can't we find any?

"The strongest gravity waves will cause measurable disturbances on Earth 1,000 times smaller than an atomic nucleus," explained Flanagan. "Detecting them is a huge technical challenge."

The response to that challenge is LIGO, the Laser Interferometer Gravitational-Wave Observatory, a colossal experiment involving a collaboration of more than 300 scientists.

LIGO consists of two installations nearly 2,000 miles apart -- one in Hanford, Wash., and one in Livingston, La. Each facility is shaped like a giant "L," with two 2.5-mile-long arms made of 4-foot-diameter vacuum pipes encased in concrete. Ultra-stable laser beams traverse the pipes, bouncing between mirrors at the end of each arm. Scientists expect a passing gravity wave to stretch one arm and squeeze the other, causing the two lasers to travel slightly different distances.

The difference can then be measured by "interfering" the lasers where the arms intersect. It is comparable to two cars speeding perpendicularly toward a crossroads. If they travel the same speed and distance, they will always crash. But if the distances are different, they might miss. Flanagan and his colleagues are hoping for a miss.

Furthermore, exactly how much the lasers hit or miss will provide information about the characteristics and origin of the gravitational wave. Flanagan's role is to predict these characteristics so that his colleagues at LIGO know what to look for.

Due to technological limits, LIGO is only capable of sensing gravitational waves of certain frequencies from powerful sources, including supernova explosions in the Milky Way and rapidly spinning or co-orbiting neutron stars in either the Milky Way or distant galaxies.

To expand potential sources, NASA and the European Space Agency are already planning LIGO's successor, LISA, the Laser Interferometer Space Antenna. LISA is similar in concept to LIGO, except the lasers will bounce among three satellites 3 million miles apart trailing the Earth in orbit around the sun. As a result, LISA will be able to detect waves at lower frequencies than LIGO, such as those produced by the collision of a neutron star with a black hole or the collision of two black holes. LISA is scheduled for launch in 2015.

Flanagan and collaborators at the Massachusetts Institute of Technology recently deciphered the gravitational wave signature that results when a supermassive black hole swallows a sun-sized neutron star. It is a signature that will be important for LISA to recognize.

"When LISA flies we should see hundreds of these things," noted Flanagan. "We will be able to measure how space and time are warped, and how space is supposed to be twisted around by a black hole. We see electromagnetic radiation, and we think it's probably a black hole -- but that's about as far as we've got. It will be very exciting to finally see that relativity actually works."

But, he warned, "It may not work. Astronomers observe that the expansion of the universe is accelerating. One explanation is that general relativity needs to be modified: Einstein was mostly right, but in some regimes things could work differently."

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