TRYING TO ROCK WITH GRAVITY'S VIBES

Both heavy metal and laser light play a role in the search for gravitational radiation. Maybe if physicists move into the desert, they'll find it.

By DIETRICK E. THOMSEN

Whoever does not believe that faith can rule the hearts of scientists might contemplate the story of gravitational waves. It is a faith based on mathematical reasoning, yet it is interesting to see how the work of a single person, Joseph Weber of the University of Maryland, could turn the logic completely around.

For decades physicists either did not believe gravitational waves existed or believed them too weak ever to be detected. In the 1950s, Weber convinced himself that a detector could be built, and in the 1960s he built one. Now, although they have not yet seen, physicists believe. In the last decade detectors have proliferated from their beginnings in College Park, Md., to such exotic places as Glasgow and Guangzhou, not to mention southern California. Occasional rumbles that look like gravitational waves have been seen in some of these detectors, beginning with some reported by Weber in 1969, but so far never an unequivocally confirmed instance.

The latest detector proposal, aired at the recent meeting in Baltimore of the American Astronomical Society by Kip S. Thorne of California Institute of Technology in Pasadena, is to decorate the desert with two five-kilometer-sized examples. Truly, as several scientists have said, scientific laboratories are the cathedrals of the twentieth century.

Gravitational waves are gravity's analog to electromagnetic waves, such as light and radio. They are waves of undulating gravitational forces that move through space carrying energy. Just as radio waves provoke in an antenna a response that generates a current by which the receiver can decipher whatever information the wave may be carrying, so gravitational waves should provoke a response in bodies they encounter. Astronomers hope that they will be an entirely new medium for investigating the universe.

Einstein's general relativity theory predicts gravitational waves. For decades after the theory's publication in 1917, physicists tended to read the prediction in one of two ways: Either the prediction contains a self-canceling provision that renders the existence of the waves moot, or the waves do exist, but their power is so microscopic that detection is hopeless.

In the 1950s Weber convinced himself that the waves do exist and that there is a possibility of detecting them. The style of detector he built is basically an aluminum bar designed to resonate with a wavelength calculated to be produced by some particular astrophysical cataclysm, say the collapse of the orbit of a binary star, or a lopsided supernova explosion, whatever seems likely and frequent enough. The typical Weber bar is about a meter in diameter and one or two meters long. Passage of a gravitational wave should cause a minute vibration in the bar, one that displaces its surface by about 10^{-16} centimeter, about the width of an atomic nucleus. Piezoelectric sensors measure this motion. Weber started in life as an electrical engineer, and it may be that experience that made him more confident than most physicists that such circuitry could be engineered, but engineer it he did.

The first Weber detector, according to Thorne, has since been followed by detectors at: Stanford University, the University of Rochester (New York), Louisiana State University at Baton Rouge, a University of Rome—CERN collaboration, Perth (Western Australia), University of Tokyo, Beijing, Guangzhou and Moscow. Perhaps the most exotic is Vladimir Braginsky's installation in Moscow, which uses a 10-kilogram single crystal of sapphire. More than simply proliferating, Thorne points out, gravitational wave detectors have increased their sensitivity by a factor of 10,000 over a decade.

Meanwhile a second type of detector, usually associated with the name of Robert L. Forward, one of the first of Weber's students to become interested in the gravity wave business, has developed. This design illustrates explicitly the quadrupole nature of gravitational waves. The simplest waves are dipole waves, something vibrating on one axis, up and down or back and forth. Einstein's prediction definitely carries a self-cancellation feature for dipole waves. The simplest possible gravitational waves are quadrupoles.

A quadrupole wave stretches something along one axis, say north-south, at the same time compressing it along an axis 90 degrees away (east-west), then compresses north-south while stretching east-west and so on back and forth. To track this motion one might set up test masses at the ends of a cross and measure their displacements relative to one another along the two axes. Or, as is usually done in practice, one dispenses with the cross and uses a single right angle.

The test masses are equipped with mirrors, and any displacements are measured by interference of laser light. There are two methods, the Michelson interferometer and the Fabry-Perot interferometer. In the Michelson case laser light is split by a half-silvered mirror and sent at right angles down the two arms. Reflected from the test masses, the beam is recombined. If the two distances are the same, the light will interfere constructively and show up bright. If the distances are unequal, the light will interfere destructively and be darker, perhaps totally dark. In practice, multiple reflections are used to amplify the effects of small motions of the test masses. In the Fabry-Perot style, two mirrors are set up in each arm to form resonant reflecting cavities for the light. The laser is tuned and locked to one of these. If the other gets out of tune by some change in their relative lengths, that will show up in the interference pattern.

Michelson types operate at Massachusetts Institute of Technology and Munich, Fabry-Perot types at Glasgow, Caltech and Paris, according to Thorne. In addition a Leningrad-Novosibirsk collaboration is working on a Forward-type detector. Forward's first was a tabletop model. The ones now functioning have arms ranging from one to 40 meters long. Weber detectors are narrow-band devices, being sensitive to a short range of frequencies on either side of a prime resonant frequency. The Forward type are broadband receivers, with a potential range, Thorne says, from 10 to 10,000 hertz.

Right now, Thorne says, "the Stanford bar detector sees events above Gaussian [random] noise, but there is no way to tell whether they are gravitational waves or not." What is needed is coordinated experiments. If two detectors at different locations record exactly the same signal at the same time, that would be very good evidence that something is coming from somewhere out yonder; a signal recorded in only one place could be some local effect. Weber recognized this long ago, and 15 years ago he set up a second detector at Argonne National Laboratory in Illinois to coordinate with the one in Maryland. Others have done similar things since, but there have been no generally accepted coincident readings. What is proposed now is a huge coordinated experiment.

This proposal, which Thorne, a theorist associated with the project, made public at the Baltimore meeting, is for a pair of large detectors in the desert. It would be a collaboration between Caltech and the Massachusetts Institute of Technology. Experimenters involved are Ronald Drever, Stanley Whitcomb and Robert Spero of Caltech and Rainer Weiss, Paul Lindsay and Peter Saulson of MIT. Thorne calls it "the world's largest hole in the atmosphere."

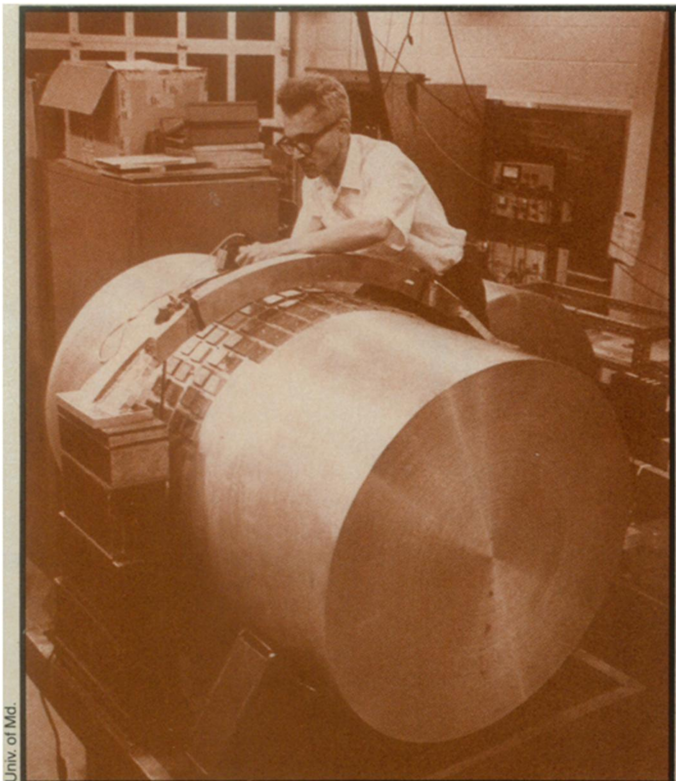
This proposal is for two Forward-type detectors with five-kilometer arms to be built at sites in the desert. Interferometric detectors have to work in a vacuum to suppress the effects of air both on the propagation of the laser light and the motions of the test masses. Thus, the detectors' arms would be vacuum tubes 48 inches in diameter evacuated to pressures of a millionth of the atmosphere or less.

The vacuum systems are estimated to cost $46 million. If construction could start in spring 1986, they could be finished by 1988. They could take various detectors, changing as the technology improves or as special functions develop. A minimal first detector (MFD) might have a laser of one watt and be sensitive to frequencies above 1,000 hertz; a possible later detector (PLD) might have a 100-watt laser and be sensitive down to 100 hertz.

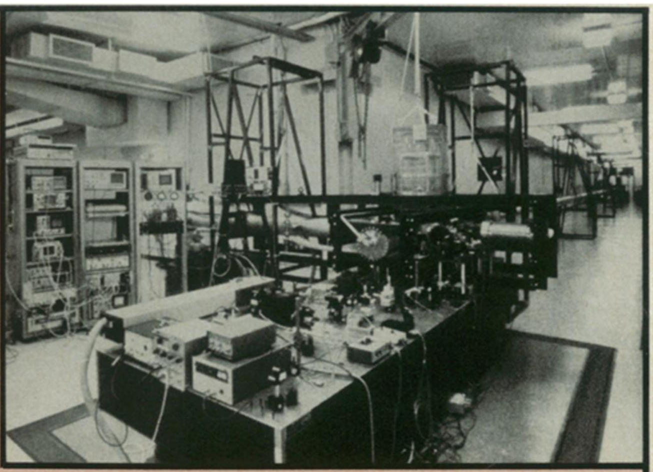
Two general types of sources are expected, burst sources and continuous ones. Supernovas are a typical kind of possible burst source. If a supernova explosion is perfectly spherical, it will not generate gravitational waves. The more aspherical it is, the more gravitational radiation it is likely to give. The Stanford bar, Thorne says, could barely see supernovas in our own galaxy. By the time they get to the PLD, astronomers might expect to see them in fairly distant galaxies. The collapse of a binary system involving two neutron stars might be seen by the MFD. The PLD might just be able to see one of the weirdest possibilities in general relativity, the collision of two black holes, if the ones involved each had 10 times the mass of the sun and were located at the edge of the observable universe. (We would be very uncomfortable if it happened close by.)

Periodic sources include pulsars and the periodic instabilities of neutron stars. Finally there is the question of a stochastic background of gravitational radiation that might be left over from the big bang, analogous to the well-known radio background attributed to the same source. Discovery of a gravitational wave background would have serious effects on cosmology and the theories of the shape and ultimate fate of the universe.

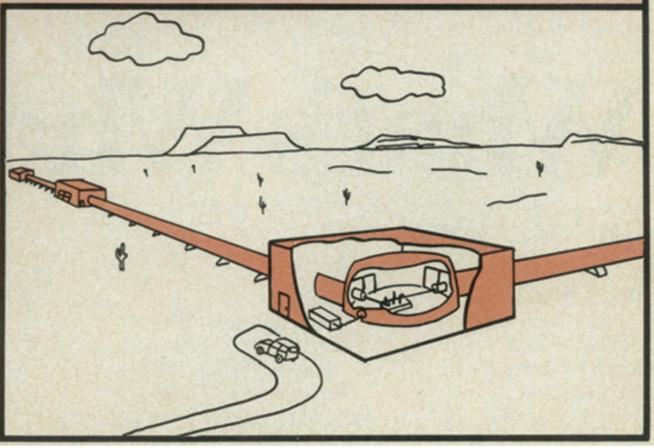
Thorne stresses that the information so derived would be "orthogonal" to that obtained from the electromagnetic radiation



Univ. of Md.



Stanley Whitcomb



Stanley Whitcomb

In a 1969 photograph (above), Joseph Weber adjusts one of his first gravity wave detectors. Caltech's interferometric detector (above, right) is the state of the art today. For the future, two interferometric detectors like the one sketched at right are proposed. They would have arms five kilometers long.

that ranges from gamma rays through light to long-wave radio. It comes from completely different physical processes and would tell very different things about the physics of those objects.

Study of gravitational radiation would also confirm some basic laws of physics. First the existence of the waves themselves. Second the speed of the waves. It is supposed to be the same as the speed of light, but is it? Then some properties of gravitons could be checked. Like all forms of radiation, gravitational radiation should have a particulate aspect. These particles are known as gravitons. The detection of gravitons as particles is far beyond the dreams of physicists right now, but study of the wave aspect could reveal some characteristics of the particles.

If gravitational waves do not come at the speed of light, that means gravitons have a mass, and the difference will give a measure of that mass. Study of the polarization of the waves can yield the spin of the graviton. It's supposed to be two, and a great deal of the formalism of Einstein's theory and every attempt to build on it depends on that number. Is it two?

Finally, astronomy has always been the science of serendipity par excellence, and in an area as strange as gravitational waves, serendipity could be working overtime. Thorne concludes, "I would say [we could find] something theorists haven't dreamed of." ☐

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The Apocalyptics: Cancer and the Big Lie — Edith Efron. The author, a research associate at the University of Rochester Center for Research in Government Policy and Business, explores how environmental politics controls what we know about cancer. "The Apocalyptics" (the extreme environmental movement), the author says, have misrepresented cancer as the by-product, for the most part, of post-World War II industry with nature "a Garden of Eden from which cancer had been largely banned." She argues that this theory is false and charges that scientists within U.S. cancer agencies ignored, denied or actively concealed the existence of massive literature on nature's carcinogens. S&S, 1984, 589 p., $19.95.

Atoms of Silence: An Exploration of Cosmic Evolution — Hubert Reeves, translated from French by Ruth A. Lewis and John S. Lewis, foreword by Victor F. Weisskopf. A nuclear astrophysicist here presents a poetic picture of the evolving universe and the evolution of life to its culmination in human consciousness. Weisskopf indicates that "this book succeeds in showing that man and nature, the atoms and the stars are all one great adventure ... which we must protect lest it be destroyed by the misuse of power we have gained from our deeper understanding of the universe." Originally published in France in 1981. MIT Pr, 1984, 244 p., illus., $14.95.

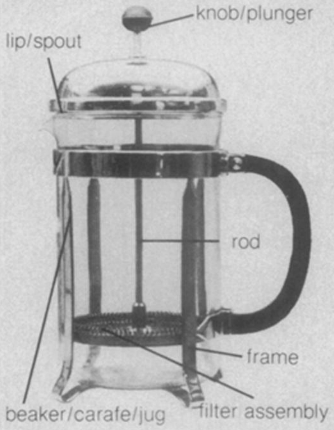
Handbook of Synfuels Technology — Robert A. Meyers, Ed. Presents chapters on each of the synthetic fuels technologies that are now either on stream, at pilot plant or demonstration plant level. Technologies developed in other countries are described along with the latest U.S. systems. McGraw, 1984, 816 p., illus., $89.50. (See p. 74)

Newton at the Bat: The Science in Sports — Eric W. Schrier and William F. Allman, Eds. Thirty-five essays about science and sports selected from SCIENCE 84 magazine, intended for those who may have wondered if a curve ball really drops just before it gets to the batter, why the golf ball has dimples and why the boomerang keeps coming back. Explores such topics as aerodynamics, physics and biomechanics and their application to various sports. The body in relationship to sports is discussed — the architecture of the knee, growing pains of young athletes and what makes muscles work. Scribner, 1984, 178 p., illus., $14.95.

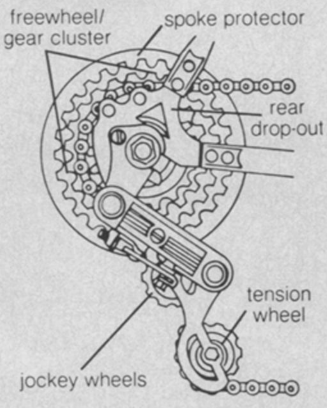
The Robot Revolution — Tom Logsdon. Discusses the many ways in which robots and computers have been combined to help enhance the efficiency of our productive society. Traces the history of robots and speculates about the future of robotics. S&S, 1984, 207 p., illus., paper, $9.95.

Total Eclipses of the Sun — J.B. Zirker. Explores for the amateur and professional astronomer the physical reasons for the occurrence of solar eclipses, their durations and paths of totality. Explains how eclipses have been used in scientific investigations and describes recent experiments. Van Nos Reinhold, 1984, 210 p., illus., $22.50.

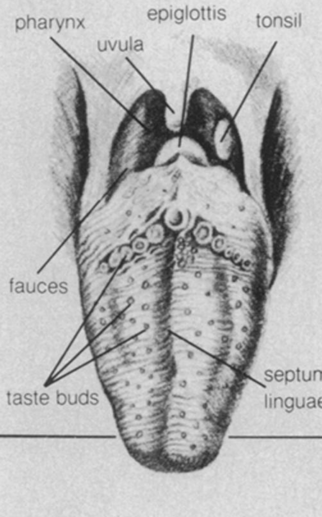
Infusion Maker



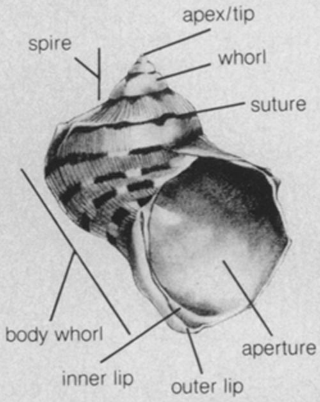
Rear Section



Tongue



Univalve Shell



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