The widening search for gravity waves

Experiments are being set up around the world to try to confirm Joseph Weber's observations of gravitational radiation

by Dietrick E. Thomsen

One of the questions facing cosmologists today is what might be called the Weber problem: Using antennas tuned to 1,661 hertz, Joseph Weber of the University of Maryland has detected bursts of gravitational radiation (SN: 6/21/69, p. 593) that seem to come from the center of our galaxy. Theorists assumed out of hand that these bursts were representative of a source that radiates a broadband spectrum (a large range of frequencies) simply because that is the most likely kind of gravitational radiator that theory can picture. Extrapolating the flux that Weber receives to a broadband spectrum and assuming a source that radiates equally in all directions, theorists determine that its production requires wholesale destruction of the mass at the center of the galaxy.

At the Fourth Cambridge Conference on Relativity, held in June at the Massachusetts Institute of Techology, Weber underlined the gravity of the Weber problem by providing observational evidence that the theorists' assumption is correct: The source is a broadband radiator.

Recently Weber set up a detector at the University of Maryland that responds to 1,030 hertz. This has been operating in conjunction with a 1,661-hertz antenna at Argonne National Laboratory to see if they would respond simultaneously. In five days of operation four accidental coincidences would be expected according to the statistics of the antennas. Fifteen coincidences were recorded. "One ought to say this is a positive result," Weber observes. "Whatever it is extends over a bandwidth at least 600 hertz."

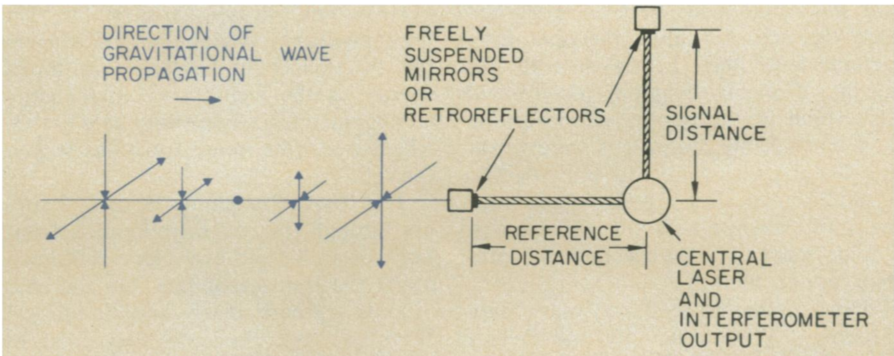
One way to solve the Weber problem, which was suggested by C. W. Misner of the University of Maryland, is to assume that the radiation is beamed in Weber's direction, thus considerably lessening the total energy output necessary. This could be so if the emanation were gravitational synchrotron radiation (SN: 4/29/72, p. 284). The possibility of such synchrotron radiation is disputed, especially by Remo Ruffini of Princeton University (SN: 6/3/72, p. 363), but if the radiation is synchrotron radiation, it should be highly polarized.

Weber has set up an experiment to test for this polarization. It consists of a disk with instrumentation to measure strain along radii at right angles to each other. A polarized gravitational wave will induce different strains along the different radii. Weber says an analysis of his published data indicates the source is probably not polarized, but he has set up the polarization experiment, nevertheless, just in case.

Another aspect of the Weber problem is that Weber's findings have not yet been confirmed by an independent experiment similar to his own. At least three other experiments are on the air, at Bell Telephone Laboratories in Holmdel, N. J., at the University of Glasgow and at the European Space Research Institute in Frascati, Italy, but they have not been going long enough to give definitive results.

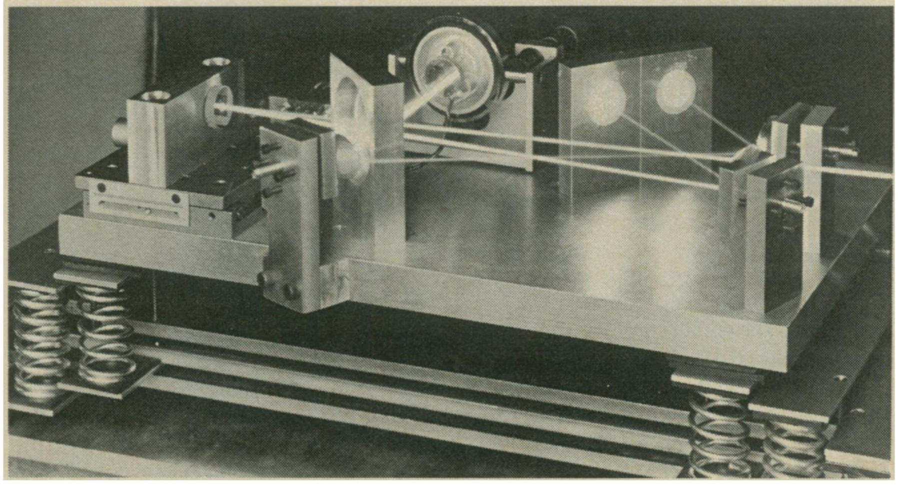
Weber's data depend on simultaneous responses of two antennas 1,000 kilometers apart. When these coincidences cannot be explained away by other causes they are considered positive records of gravitational radiation. Weber says some critics have suggested the reason he gets so many good ones is that the data are worked over by a "very concerned individual, namely myself." A colleague suggested he set up a way to process the data untouched by human hands.

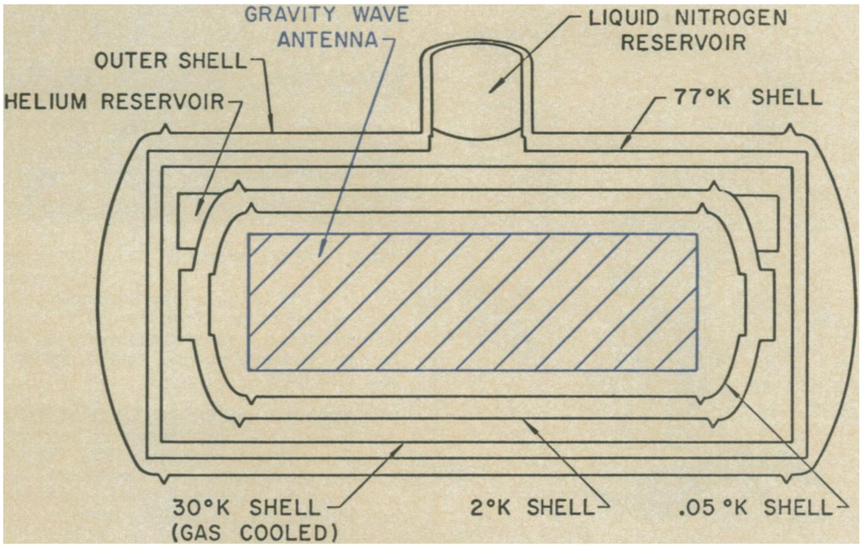
Weber arranged to record the data from the antennas on magnetic tape. A "hostile" computer programmer then went through it looking for concidences. They appeared. The programmer then



Hughes Research Laboratories

Moss' detector: Schematic shows orientation to detect gravitational wave moving in a particular direction. Detector itself was photographed during tests.





NASA-MTF/W. O. Hamilton

Series of shells for stepwise cooling surrounds LSU-Stanford bar detector.

inserted varying degrees of artificial time delay in the records of one or the other antenna. The more artificial delay, the fewer were the coincidences, the result that should appear if they are real. "This," says Weber, "is at least a result untouched by *my* hands."

There is a claim to an independent detection of gravitational radiation by an experiment quite different from Weber's. This was done by Dror Sadeh of the University of Tel Aviv and uses the earth itself as an antenna. If a gravitational wave passes through the earth, it will set up vibrations that, in principle at least, can be recorded by a vertical seismograph. Sadeh claims he has recorded gravity waves from the pulsar CP 1133 (SN: 4/1/72, p. 213). This is disputed by a group from the University of California at Berkeley, who tried to repeat the experiment and found nothing (SN: 5/6/72, p. 292).

Meanwhile a similar seismographic experiment was in place in a mine near Boulder, Colo. Judah Levine of the Joint Institute for Laboratory Astrophysics at the University of Colorado told the Cambridge meeting that although his group had been primarily looking for gravity waves from the Crab nebula pulsar, they had enough data of the noise around CP 1133 that when they received Sadeh's preprint they could take "a first crack at shooting him down." Their analysis revealed none of the signals Sadeh claims to have recorded.

Levine presented a similar null result regarding the Crab nebula pulsar. They had concentrated on this one because it has the fastest period of the known pulsars. Theoretically, the faster a pulsar's period, the stronger should be its gravitational radiation. Levine reported that a million seconds of observation at the theoretically indicated frequencies of 60.4 and 30.2 hertz indicate that if any change due to gravity waves occurred in the length of their seismograph it was less than one part in 8×10^{17}. "As far as we're concerned that's about the end of the Crab nebula," he declares.

Another method for detecting gravitational waves that differs greatly from Weber's aluminum bars is to use optical interferometry driven by a laser. The basic design of such an instrument, as described by Gaylord Moss of Hughes Research Laboratories, is similar to a Michelson interferometer. A beam of light is split by a half-reflecting plate so that part of it goes through the plate and part is reflected at a 90-degree angle to its original direction. Both of the beams are reflected back by mirrors at the end of a certain path length, and they are recombined at the half-reflecting plate. If the length of one path differs from the other in such a way that the beams go out of phase with each other they will interfere destructively. If the path lengths are such that the beams come back in phase, they interfere constructively. If one of the mirrors at the ends of the paths moves, a succession of light and dark fringes will appear. For detecting gravity waves, this means that if one mirror is attached to a mass that is free to move under the influence of the waves, the passage of the waves can be read out of the changes in the fringes.

Weber considered this idea at one time. Robert L. Forward of Hughes, one of Weber's early collaborators, recalls that one day in 1964 Weber telephoned him with the suggestion. "I thought Joe was losing his marbles," says Forward. To record gravitational waves that way would require measuring shifts of a billionth of the width of one fringe. This requires an extremely coherent light source, one that was beyond the technology of that time. Introducing Moss to the Cambridge meeting, Forward said: "I present to you the man who made the laser that can do it."

Meanwhile, Weber-type bar antennas are being set up in a number of places. Some of these are intended to be as close a copy of Weber's original as they can be in the hope of seeing exactly what he sees. For example, Heinz Billing of the Max Planck Institute in Munich says: "We deviated only in minor points, improvements that seemed obvious and not dangerous." Other single-bar antennas, differing more or less from Weber's, are planned at IBM in Yorktown Heights, N.Y., and the University of Rochester (the latter to work in coincidence with Holmdel).

All, including Weber, are attempting to increase the sensitivity of detectors. One way to do this is to cool them almost to absolute zero (less than a tenth of a degree K.), thus getting rid of the background noise of thermal vibrations. This is the option taken by a joint experiment between Louisiana State University at Baton Rouge and Stanford University. Within a year, says William O. Hamilton of LSU, the group hopes to have an antenna set up on each campus for coincident operations. Supercooling is also the choice of a group at the Istituto di Fisica "G. Marconi" in Rome. Guido Pizzella says they expect to have their dewar (cooling chamber) ready by 1973 and that they are ordering an aluminum bar five feet in diameter by ten feet long. At the University of Saskatchewan a somewhat smaller supercooled bar is planned. For additional isolation from disturbance it will be buried underground about 15 miles from Saskatoon.

Another innovation is the so-called split-bar detector. Weber's prototypes have piezoelectric crystals attached to their surfaces to transduce the mechanical vibrations of the bars into electrical signals. Cutting the bar in half and putting the transducer between the halves could increase sensitivity, many think. As W. Douglas Allen of the University of Reading in England says, it gets "more strain energy of the aluminum into the transducer." Three split-bar detectors are now operating at the University of Glasgow, and two more are being built. According to Ronald W. P. Drever, the Glasgow investigators hope to space them 1,000 miles apart. A split-bar detector is also planned at Frascati.

Considering all this activity leads people to believe that confirmation of Weber's work, if it is to come, should not be long arriving. It should soon also be possible to learn more details of the gravity-wave signals: their pulse shapes, frequency spectrum, polarization, etc. As the chairman of one of the sessions, R. V. Pound of Harvard University summed it up: "The next three or four years should be decisive." ☐