

Weber Reports 1660-Hz Gravitational Waves from Outer Space

Joseph Weber of the University of Maryland believes he has observed gravitational waves from extraterrestrial sources (*Phys. Rev. Letters* **22**, 1320, 1969). The gravitational-wave detectors, sensitive to 1660 Hz, were stretched over a 1000-km baseline between the Maryland campus and Argonne National Laboratory; they showed 17 significant coincidences during the first three months of this year. The signals imply a mean gravitational-radiation energy density of about 10^{-32} gram/cm³ over a bandwidth of about 0.1 rad/sec.

What could cause such strong gravity waves? Although there is no obvious explanation for the strength, waves could come from supernovas, a pair of spiraling neutron stars, or matter falling into "black holes."

Weber has been working on gravitational-wave detection over the past ten years with modest support from the National Science Foundation. His search for gravitational waves has been considered "one of the most long-shot and least-likely-to-succeed of any experiments," he said. "I expected to find them, but not so frequently." Thinking he would find two or three events a year, he was surprised to find roughly one a week.

"It's hard for me to believe that there won't be skeptics," he said. "But so far they haven't shown up."

The data are directional, but a few more months of running time may change the direction, Weber says. He does feel that the data are consistent with a source or sources in our own galaxy.

Antennas. Weber developed the theory of gravitational radiation antennas early in 1959. His antenna is an elastic body that can be deformed by the dynamic derivatives of gravitational potentials and have its normal modes excited. The antenna measures precisely the Fourier transform of certain components of the Riemann curvature tensor averaged over its volume (*PHYSICS TODAY*, April 1968, page 34).

In earlier experiments Weber and his collaborators produced and detected dynamic gravitational fields in the laboratory. The new experiment was

designed to look for collapsing star systems, which sweep through 1660 Hz during a collapse.

The detectors are a pair of aluminum cylinders 153 cm long and 66 cm in diameter, suspended by wire on acoustic filters in a vacuum chamber. The cylinder oscillates in response to the Riemann curvature tensor. Then piezoelectric crystals, which are bonded to the cylinder surfaces, convert normal-mode oscillations to an output electric field. The detectors are both arranged with their maximal response in the north-south direction. Relative displacements of the end faces of 10^{-14} cm and strains of a few parts in 10^{16} are routinely measured by the array.

A telephone line transmits the rf

output of the Argonne detector to Maryland. This output and that from the Maryland detector are coupled to a two-channel coincidence detector. If the rectified output of the two detectors crosses a given threshold in the positive direction within 0.44 sec, Weber calls the event a coincidence. At Maryland he also operated a 61-cm and a 96-cm-diameter detector, which were not coupled to a coincidence counter.

During an 81-day period he observed 17 significant two-detector coincidences, five three-detector coincidences and three four-detector coincidences. On 20 March Weber found a pair of three-detector coincidences that could occur accidentally every 70 million years. Low signal-to-noise ratio

U. OF MD. PHOTO BY BILL CLARK



GRAVITATIONAL-WAVE DETECTOR. Joseph Weber of the University of Maryland inspects the suspension of one of the aluminum antennas used to detect waves from extraterrestrial sources. This one is 96 cm in diameter and 153 cm long. It oscillates in response to the Riemann curvature tensor. Weber observed coincidences between detectors in Argonne and Maryland, along a 1000-km baseline.

accounts for the small number of three- and four-detector coincidences.

The detectors do not appear to be showing seismic or electromagnetic disturbances, Weber believes. He has shown with a seismic array that earthquakes and other earth motions do not generally register on his antennas. Because one of the detectors has an inherent 11-sec time lag for gravitational disturbances, it discriminates against electromagnetic signals.

Weber wants to pin down the directional effects over the next year, improve time resolution and change the frequencies of his detectors. In earlier experiments Weber had used the earth itself as a detector and looked for quadrupole oscillations, using as gravimeter a harmonic oscillator with a very weak spring constant; the period would be 54 min or more. He would like to put such a gravimeter on the moon.

What could be producing the gravity waves? Weber would not hazard a guess. He did note, though, that about 90% of the nearby matter in our galaxy is invisible. "If our intuition is

based entirely on the light we see and the radio signals and the x rays, then it's not altogether surprising that there should be some things that we didn't expect."

We asked two of Princeton's gravitation experts what might have caused Weber's observations. John Wheeler explained that in our galaxy alone supernovas occur every 30 to 300 years. If the mass of the collapsing star is less than the Chandrasekhar limit (about two solar masses), a white dwarf or neutron star results, and a pulse of gravitational radiation is emitted. If the mass is bigger, gravitational collapse occurs, and you get a black hole, which produces a pulse with a characteristic spectrum. Then the hole would not be heard from again unless matter floating through space fell into the hole; then another pulse would occur. Another possibility for a pulse is a pulsar "starquake," which some people believe explains the speeding up of the Vela pulsar over the "lost weekend" when nobody observed it.

Wheeler noted that Weber's events just might be due to gravitational waves (which travel at the speed of light) associated with earthquakes, but

he doubts it. He would, however, like to see directional measurements to make sure.

Robert H. Dicke commented that the source need not emit only a single pulse. If you had two neutron stars spiraling around each other they would emit gravitational waves, and their frequency would be increasing. These waves would sweep through Weber's detector, which is sensitive to a narrow band of frequencies.

We asked if one could check Brans-Dicke theory with gravitational-wave detectors. Because the theory requires both scalar and tensor fields, one could look for scalar effects. Unlike a tensor wave, which stretches a detector at right angles to the wave direction, a scalar wave produces stretch in all directions. So you could either do a polarization experiment or build a spherical detector and look for purely radial oscillations, which could only be excited by a scalar wave. Dicke and some Princeton colleagues tried such an experiment several years ago, using the earth as the spherical detector. They set up a gravimeter tuned for radial oscillations of the earth, but they did not observe any. —CBL

Matter Meets Antimatter in Akademgorodok

It is worth traveling halfway round the world to visit the antiworld of Andrei Budker. There, at his Nuclear Physics Institute in Akademgorodok, near Novosibirsk, he makes beams of antimatter collide with beams of matter, doing high-energy physics experiments on a low-energy physicist's budget. We spent a week in Akademgorodok, the Siberian science town, and had several pleasant visits with Budker and his wife Ludmilla at their home. At the institute we saw his latest venture, a 25-GeV proton-antiproton device, being built, toured his factory for mass producing accelerators, and looked at beams of positrons and electrons circling in one of his smaller storage rings.

Budker's given name was Gersh Itskovich, but as a boy he chose the name Andrei Mikhailovich, which all his many friends call him. As director of Akademgorodok's largest institute, Budker apparently has the freedom to try bold, new ideas, and he and his group have the imagination and daring to do so. The 25-GeV device is considered an experiment, not guaranteed to work entirely as planned. It is being built out of the institute's annual

operating budget, half of which comes from the Siberian branch of the Soviet Academy of Sciences. The other half comes from the sale of high-current electron accelerators, which he sells to customers at home and abroad. The model элит-3, for example, produces 100 amperes of 3-MeV electrons in 100-microsec pulses.

Budker speaks his mind. One evening in his garden we sat on a piece of driftwood from the Ob Sea while he spoke about physicists and their accelerators. Originally the institute scientific council planned to build both a 25-GeV proton-antiproton machine and a separate 3.5-GeV electron-positron machine. But, he said, "Machines should not rule physicists. We had a big argument when I asked why we should build both a proton and an electron machine when you can build one machine to do both. The answer was, 'It's not comfortable to have only one for both,' as if the main aim of the machine was to be comfortable. When I build a new machine the tunnel won't be big enough for visitors to walk around in."

Accelerators should not have a life of their own, he said. "Otherwise

they will become like the pyramids."

When you first think about it, a reliable accelerator seems important, he went on. "You push a button, and it works. It seems nice to have somebody else build the machine for the physicist. It only seems this way. Really, though, the mind of the physicist dies. Because of that, you see the fantastic cost of accelerators now." For research at the frontier of physics, physicists should make their own equipment, he says.

Budker was reminded of a story. "When people tell me that everyone knows accelerators cost a certain amount, and everyone knows that tunnels must be of a certain size, and everyone knows that the customary accelerator is a synchrotron, I tell them this story: Two women were talking. One said that England is an island. Her friend replied. 'That's nonsense. If that were so, everyone would know that England is an island.'"

25-GeV machine. What will the 25-GeV machine be like? Budker's group appears to be designing the machine as they go along. We were told of two possible designs. One is for VEPP-3, consisting of a synchrotron in-