Fischbach *et al.* proceeded to interpret their gorgeous bibliographical discovery as a fifth force, coupled to baryon number, and exerted by the strata underlying Eötvös' laboratory. In idealized conditions (flat terrain and strata), and for a force with an intermediate range much smaller than the radius of the Earth, this interpretation is incorrect[6,7]. Indeed, if the equivalence principle is largely correct, all weights in Fig. 2 are parallel and directed along the truly vertical direction: $\vec{g}_N + \vec{d}$. The surface of a quiet sea and, on the average, the superficial land strata, are in isostatic equilibrium orthogonal to $\vec{g}_N + \vec{d}$. Barring local inhomogeneities, a force whose source is this nearby underlying matter is directed in the same direction $(\vec{g}_N+\vec{d})$ as the torsion wire of the balance: it cannot produce a torque around it, QED. A relatively short-range force, exerted by the inhomogeneous surroundings of the experiment, may be responsible for the observed effects, a possibility that is hard to pin down. Although malicious rumour has it that Eötvös himself weighed more than 300 pounds, unspecific hypotheses are not, *a priori*, particularly appealing.

Toying with logic and vectors, we have not really understood Eötvös' non-null results. It is conceivable that some uninteresting variable is disguising itself as baryon number, B. There is a rough correlation, R.H. Dicke points out (Chu, S.Y. and Dicke R.H. *Phys. Rev. Lett.* **57**, 1823; 1986), between B and inverse density, ϱ^{-1}, for several of the substances tested by Eötvös. Temperature gradients in the apparatus could perhaps result, via air currents within its enclosure, in a correlation with ϱ^{-1}. (To avoid this and other systematic effects, Eötvös flipped the positions of all pairs of materials, and averaged the results.) A second and more 'fundamental' explanation[9] can be found in terms of a force with a long range much greater than the radius of the Earth. Such a force originates, like gravity, from the Earth as a whole, and it is directed along $\vec{g}_N$. Its effects are equivalent to a material-dependent modification of gravitational mass: Eötvös' balance is sensitive to them. The value of α required by this explanation is plotted in Fig. 1 as the dotted line. By what is presumably a monumental coincidence, there is one point on this dotted line, at $\lambda \simeq 4\times10^{10}$ metres, that falls in a narrow window not disallowed by astronomical observations. This literally far-fetched interpretation[9] of Eötvös' results would correspond to an attractive force, approximately coupled to proton + neutron (or neutron + electron) number, and mediated by the exchange of a new scalar or tensor particle of mass some 22 (!) orders of magnitude lighter than the electron. Finally, it may well be that the many experiments now in progress do not reproduce Eötvös' results, and we must turn for good this page of the fifth force saga. In that case, Eötvös and collaborators would have carried their secret to their graves: how to gather ponderous evidence for something like baryon number decades before the neutron was found. ☐

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Astronomy

Detecting gravitational waves

from David Blair

WHEREAS electromagnetic waves are seen everywhere, gravitational radiation has not been detected. Huge laser-interferometer experiments are being planned to detect gravitational waves (see *Nature News and Views* **321**, 378; 1986), but the technology of cryogenic resonant bar gravitational-wave antennas, the first form of detector to be proposed, has at last reached the stage where long-term coincident operation of several widely spaced sensitive antennas has been achieved. Preliminary, but null, results for the first three-way coincidence experiment have recently been reported*.

In 1960 Joseph Weber (*Phys. Rev.* **117,** 306) outlined the basic design for a resonant bar gravitational radiation antenna. Since the early 1970s a world-wide network of cryogenic resonant bars has been under development. All, following Weber's original design, use highly vibration-isolated metal bars, but now use a low acoustic-loss aluminium alloy or niobium, and are cooled to liquid helium temperatures. In principle a resonant bar antenna is simple: a gravitational wave induces a small phase and amplitude change in the thermal vibration of the antenna. This can be measured above the thermal noise if the quality, or Q, factor is high enough, and if the vibration sensor is sufficiently sensitive. (Q measures the acoustic loss of the antenna. High Q means low damping, and consequently near-perfect, low-noise oscillation.)

The three operating antennas, at CERN near Geneva (operated by the University of Rome), at Stanford University and at Louisiana State University, have a sensitivity to the Riemann curvature or strain amplitude of between 8×10^{-19} and 3×10^{-18}. This sensitivity is sufficient to see most predicted transient gravitational radiation events in the Milky Way galaxy (such as supernovae and the coalescence of binary black holes or neutron stars), but is insufficient to see more distant events in the Virgo cluster and beyond. Because events in our Galaxy are likely to be rare, it was not surprising that no events have been observed. But the results do demonstrate the power of multiple coincidence analysis to reject seismic noise (W.O. Hamilton, Louisiana State University). Although the individual antenna 'event rate' was 60–70 per day (measured by a predetermined threshold crossing), no triple coincidences were observed, and the nearest two-antenna coincidence had a 0.9-second time difference. As gravitational radiation should travel at the velocity of light, this coincidence must be attributed to chance. However Hamilton emphasizes that the results are "extremely preliminary". With two more antennas expected to begin soon (at the University of Western Australia and the University of Maryland) there is hope that nearly continuous monitoring in the frequency range 700–1,000 hertz will soon become possible. With information from timing and antenna orientation, reasonable directional information should be attainable once signals are detected.

Why are such promises taking so long to be realized? The answer is that nobody, not even the experimentalists themselves, appreciated the difficulties. A whole range of new technology has had to be developed, including a new generation of low-noise direct current superconducting quantum interference devices. These devices are now used as the amplifiers for the superconducting vibration sensors on the antennas that are now operating. Meanwhile, groups in Moscow, Perth and Tokyo have developed parametric transducers, which use superconducting microwave techniques to read out the antenna vibrations, and very high Q-factor antennas. The Perth group reported a Q-factor in their niobium antenna of 2.3×10^{8}. After a 'knock', this bar will ring for more than one day.

Everyone is working to push the sensitivity towards 10^{-20} and to push up the antenna bandwidths from the present 1–10 to several hundred hertz. This can be achieved if the transducer impedance can be better matched to the antenna. ☐

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