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Gravitational radiation experiments at the University of Reading and the Rutherford Laboratory

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Abstract. The results are reported of a search for short pulses of gravitational radiation, using two split-bar detectors 30 km apart. The detectors have masses of 625 kg each and are capable of millisecond resolution over a broad band around 1200 Hz. Pulses imparting energy of $\frac{1}{2}$ to $1\,kT$ to each bar, and coincident within ± 1 ms, were indistinguishable in trace characteristics from pulses due to thermal noise; and the number in the bin registering coincidences within ± 2 ms (ie 308 in total), was indistinguishable from the numbers in bins of the same timewidth but registering coincidences with time differences of up to ± 10 ms between the two detectors.

1. Introduction

After a decade of exploratory development, Joseph Weber announced that he observed coincidences between detectors designed to register gravitational radiation and situated 1000 km apart (Weber 1969). This, and a succeeding paper suggesting that the source was to be located at the centre of our Galaxy (Weber 1970), stimulated several groups to repeat the experiments (Logan 1973). Among them was our own, which started in 1970 and has now been operational for about a year. In common with the experimental groups other than Weber's, we have failed to detect any pulses which give energy to detectors 30 km apart, other of course than random noise effects at a level of about $\frac{1}{2}\,kT$. Our experiment is presented in greater detail elsewhere (Allen and Christodoulides 1975) and only a brief summary of the main results is given here.

2. Summary

2.1. *Chief properties of the detectors*

The detectors are located in relatively isolated huts, one near Reading (Sonning) and the other at the Rutherford Laboratory, separated by a distance of 30 km. Mechanically, the bars are of aluminium alloy, 46 cm in diameter and 150 cm long, with a total mass of 625 kg each. The construction follows the split-bar principle suggested by P Aplin of Bristol University: two cylinders, half the length of the 'bar', are cemented together via piezoelectric transducers at the plane of maximum strain (in contrast to Weber's detector which is a single 150 cm bar with transducers cemented around the periphery).

Two factors enter into the sensitivity of the system to mechanical impulses: β the ratio of the electrical energy in the transducers to the total energy in the bar, and Q the overall quality factor of the bar. As compared to a solid bar, our Q is naturally less by a considerable factor (about 20) due to mechanical losses in glue and transducers; but the value of β is much higher and the product βQ is about 10 times higher than that for the Weber detectors.

Electrically, the system is converted into a relatively broad-band (600 Hz bandwidth round a central frequency of 1180 Hz) detector by a notch filter (Drever 1971, paper presented at the International Conference on Gravitation and Relativity, Copenhagen; see also Buckingham and Faulkner 1972). The amplified outputs from the bar and from the filter are fed into a shift register (Drever *et al* 1973); when the filter output exceeds a threshold level the signal arrests the register. When this occurs at Sonning the contents of the register are then transmitted in digital form via a telephone link to the Rutherford Laboratory, and if there has been a trigger at the Rutherford detector, also within ±10 ms, the traces from both ends are displayed on an oscilloscope and photographed. Figure 1 shows some typical results from applied forces giving 1 kT to each bar simultaneously and from a typical random noise coincidence. The threshold was set at $\frac{1}{2}$ kT for the Rutherford Laboratory and 0·8 kT for Sonning. Calibration of the system, using timing pulses at 60 kHz from Rugby radio station, was carried out three to four times weekly for most of the period of operation.

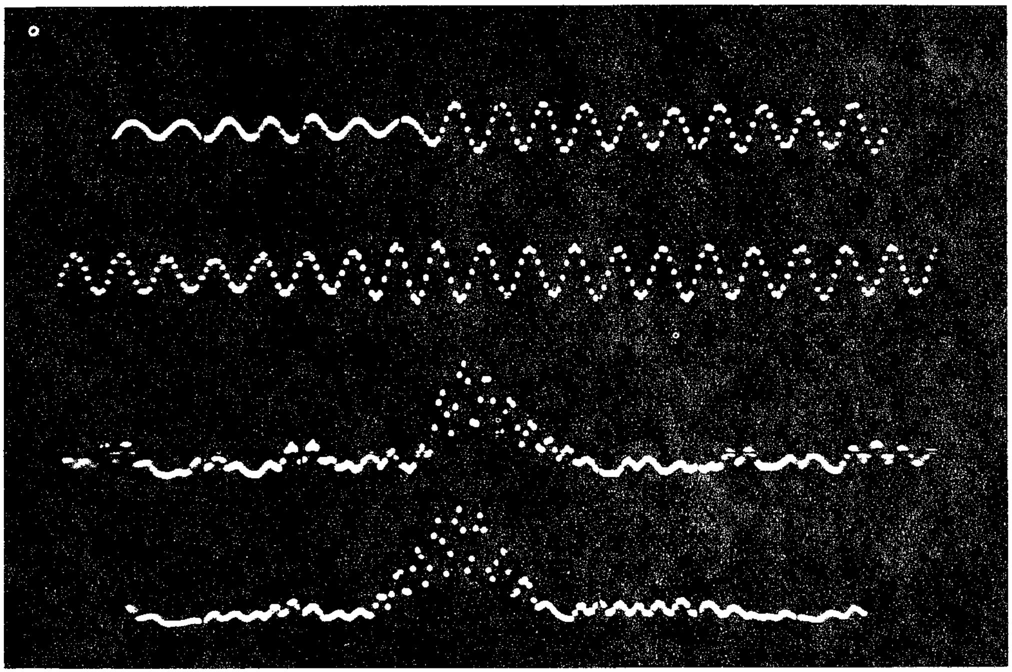
2.2. *Experimental procedure*

Random coincidences within ±2 ms were photographed at a rate of about 1 per day. The system also recorded coincidences in bins 4 ms wide, for a range of -14 to $+18$ ms delay between the Sonning pulses and those at the Rutherford Laboratory. The photographed coincidences (±10 ms) were timed to within ±1 s. No coincidences were observed which could be ascribed to gravitational radiation impulses. The histogram of coincidences between the eight bins showed no difference outside statistics between the bin recording prompt coincidences and the bins recording delayed coincidences. Neither was any preferred time found on a sidereal timescale for the occurrence of coincidences.

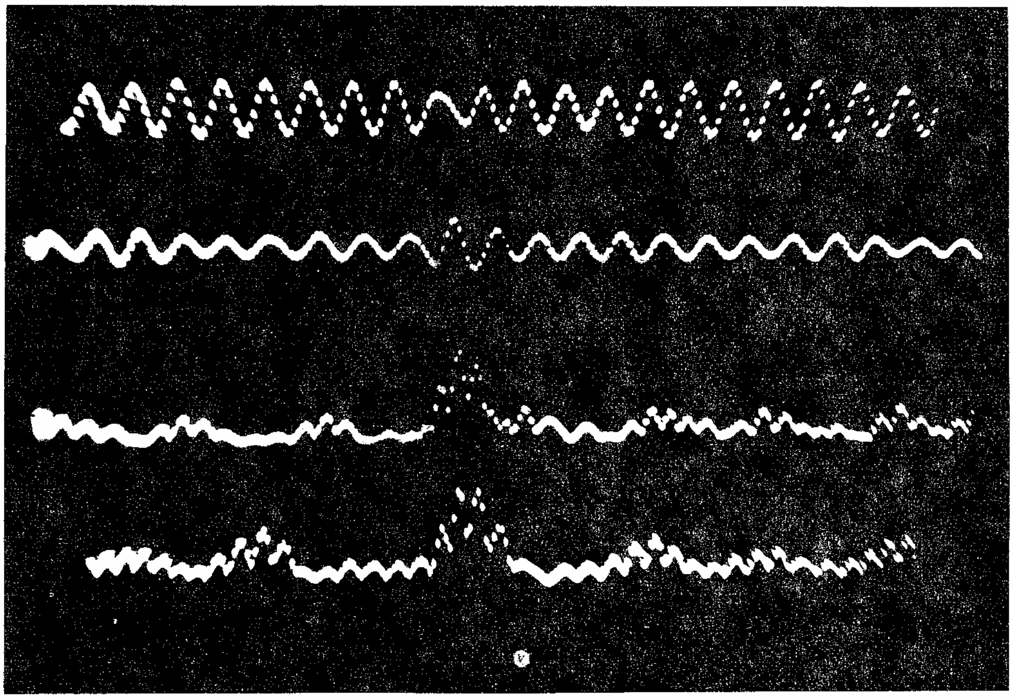
A brief account is given below of some of the problems encountered and of the techniques developed in the construction and operation of the bars.

3. Bar construction

Preliminary work was done on deciding which glue to use to avoid excessive losses which would drastically reduce the overall Q. Aluminium bars of 2 in diameter and 15 in length were cut at the middle and reassembled using the glue under investigation, by heating under compression. The mating faces were machined as flat as possible. Various glues were examined, such as black wax, pitch, sulphur, sulphur–pitch mixtures and Araldite (Devcon), before it was decided that PVA sheets, which could be kept as thin as 0·0005 in, had the advantage of low mechanical losses and enabled the construction and dismantling of bars at temperatures low enough (~120 °C) so as not to damage the transducers. Accordingly, the first bar (Sonning) was built using PVA as glue. Later, a glue was supplied to us by the Glasgow University group (of unknown nature, possibly Araldite CT-200 by CIBA-GEIGY, to be referred to as 'Glasgow glue'). This was found



(*a*)



(*b*)

Figure 1. Photographs of the signals from both detectors. In each photograph the top trace is AC voltage output of the Rutherford bar, the second trace is the same from Sonning, the third is the filtered and rectified signal from Rutherford, and the fourth is the same from Sonning. Each cycle corresponds to 0·85 ms. Time increases from left to right. (*a*) shows 1 *kT* calibration pulses applied to both bars; (*b*) shows a coincidence caused by the thermal noise of the bars.

to be even better than PVA and had to be heated only to about 100 °C to form strong bonds at low thicknesses. This glue was used in the construction of the second (Rutherford) detector.

Prototype split bars were also built to check the degree of agreement between theoretically predicted and actual values of frequency and β. The results were rather disappointing, the frequencies being about 20% lower than predicted and β's down by a factor of 2. There is evidence to suggest that the discrepancies in frequency are caused by the azimuthal distortion of the aluminium faces in contact with the transducers. The low β's could be due to a slight deterioration of the electromechanical coupling coefficient k_{33} after the heating, but as changes of k_{33} during heating runs were found to be no more than 10%, it is suspected that the actual value of k_{33} for the transducers used was lower than that claimed by the manufacturers. In any case the relevant electromechanical coupling coefficient should not be k_{33} but, due to the geometry of the transducers (fairly flat discs), it should lie between $k_{33} = 0{\cdot}64$ and $k_t = 0{\cdot}48$, the thickness coupling factor for laterally clamped transducers.

The two full-scale bars built were almost identical and only the Rutherford bar will be described, with data relevant to the Sonning bar given in brackets where they differ. The Rutherford (and Sonning) bar consists of two aluminium cylinders of total weight 625 kg, length 74 cm each and 46 cm in diameter. The two halves were joined by sandwiching between them seven glass–transducer assemblies, one at the centre and the others on a regular hexagon at a distance of 15 cm from the centre. The mating faces of the aluminium were lapped to flatness within ±0·0001 in. The glue used was 'Glasgow glue' (PVA for Sonning). The transducers were PZT8 (Gulton G1408) of diameter 5 cm and thickness 2·4 cm (1·9 cm). Insulation from the aluminium was provided by glass discs, one on either side of each transducer, of diameter 5·4 cm and thickness 0·32 cm. These glass–transducer assemblies were constructed first and were ground to uniform thickness and flatness to within ±0·00005 in, the thickness of all assemblies being identical within this limit.

For the construction of each bar the two aluminium cylinders with the transducer assemblies and glue layers held in position were heated to 100±10 °C for 20 hours for Rutherford or 165±5 °C for 28 hours for the Sonning detector. During heating, the bars were under compression along their axes, the aim being to reduce glue thickness. Forces of around 800 lbf were used, resulting in pressures of 30 psi on the glass–transducer faces. When cooling down, the two halves were kept at the same temperature within ±0·5 °C to avoid freezing in of any strains due to differential expansion, which would lead to relaxation noise or damage to the transducers.

The final parameters of each bar are as follows (Sonning in brackets): frequency $f_0 = 1181$ Hz (1173 Hz), quality factor $Q = 7000$ (3400), measured $\beta = 0{\cdot}03$ (0·02) and $\beta Q = 200$ (70). A year after construction Q deteriorated to 4000 (2000) due to changes in either the glue or the transducers.

To minimize noise due to seismic or acoustic pick-up and temperature variations, both bars were enclosed in steel vacuum tanks (under vacuum of roughly 10 μm), which were resting on four piles of concrete blocks and rubber sheets at the bottom of 6 ft deep pits. Inside the tank the bar is suspended by steel wires from the middle of each aluminium half, the whole suspension system hanging from a 3 in diameter spring which in turn hangs from a plate resting on a pile of seven lead discs of 45 lb weight, separated by rubber sheets of 9 in diameter and $\frac{1}{4}$ in thickness.

A search for resonances revealed a few due to the tank and the suspension system. The tank was coated with an $\frac{1}{8}$ in thickness of 'Aquaplas' (a colloid of rubber and plastics) and resonances in the steel suspension wires were damped by using pieces of rubber. The only troublesome resonances remaining were at 461 Hz and 3945 Hz; these were finally removed from the output by electronic filters.

4. Electronics and data handling

The transducers are connected all in parallel for the Rutherford bar giving a total of 4200 pF, and in a series combination of three groups consisting of 2, 3 and 2 transducers in parallel for the Sonning bar giving 950 pF. Their outputs are fed to low-noise FET preamplifiers situated inside the vacuum tanks and run on lead–acid batteries to avoid pick-up (figure 2). These preamplifiers were constructed by Professor E A Faulkner's group at Reading University, with FET's specially selected for low noise. Their ultimate noise voltage referred to input is 1 nV Hz$^{-1/2}$.

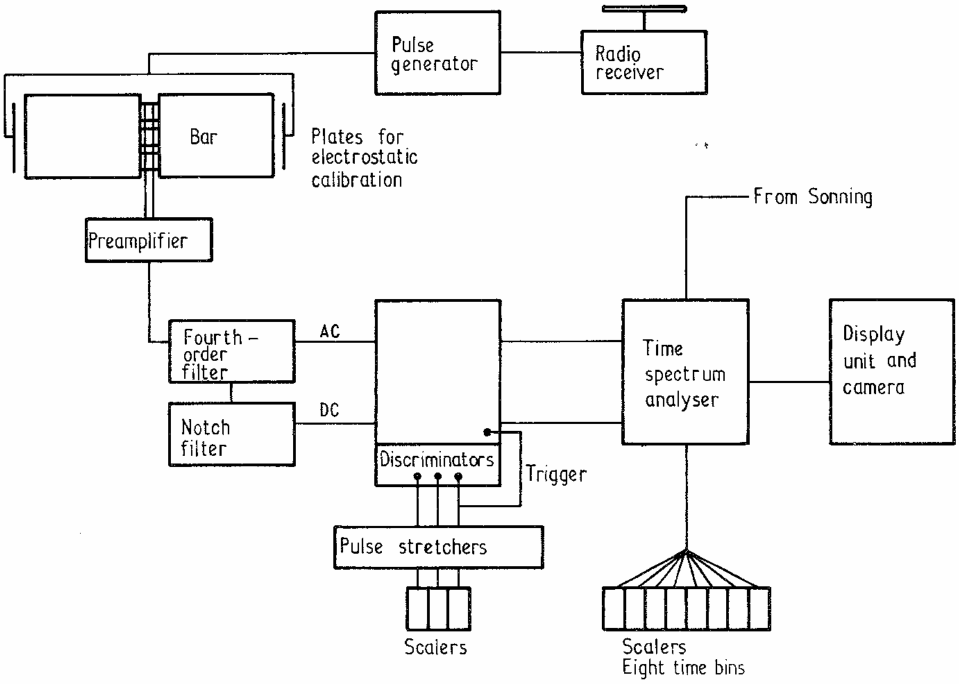


Figure 2. Block diagram of the system at the Rutherford Laboratory. That at Sonning is identical but without the time spectrum analyser, display unit, camera or the eight time scalers.

The preamplifier output (of the order of 1 mV) is then passed through a fourth-order filter which limits the bandwidth between 460 Hz and 4 kHz, at which frequencies the gain is almost zero to remove the two mechanical resonances left in the support system. Next, the signal is passed through a notch filter centred at the resonance of the bar to remove the resonance and give an overall broad-band response with a $Q_M \sim 5{\cdot}3$, as defined by Buckingham and Faulkner (1972). The expected signal sensitivity was close to the observed $\frac{1}{50}\,kT$ ($\frac{1}{30}\,kT$ for Sonning), this being the mean energy in the bar as observed through the transducers (ie mean energy in transducers divided by β).

The two detectors are 30 km apart and are connected via a data link. The rectified output of the notch filter is integrated with a time constant of the order of 1 s to provide a reference voltage level. When the rectified signal exceeds this by a predetermined factor, the system is triggered. When this happens at Sonning, the signal within ±20 ms of the trigger, sampled every 50 μs, is sent via the line, in digital form, to the Rutherford station. If after correction for the delay in the line, there has not been a trigger at the Rutherford end within ±10 ms of that at Sonning, the Sonning pulse is simply counted. If however there has been a trigger within ±10 ms, then the traces from both detectors, within ±10 ms of the Sonning trigger, are displayed on an oscilloscope screen and photographed (figure 1). A dial registering time in seconds is also photographed to time the event.

In addition the event is classified in one of eight bins, each of 4 ms width, depending on the time difference between the two triggers. All but the central prompt coincidence bin provide a random coincidence rate since any gravitational coincidence should be well within ±2 ms, considering the fast response of the system.

The discrimination levels are set so as to have about one pulse per minute from Sonning (dictated by the total transmission time of 1·7 s for each 40 ms event), and about 10 pulses per minute at the Rutherford Laboratory. These rates lead to about one coincidence per day in each of the eight 4 ms bins. The discrimination levels correspond to energies of 0·5 kT and 0·8 kT for the Rutherford and Sonning detectors respectively.

Both detectors are calibrated in coincidence three to four times per week. To achieve this, two 60 kHz radio receivers are used to provide triggering pulses at 1 s intervals, as received from the Rugby station. These then trigger pulse generators which apply standard −20 V pulses of 0·42 ms duration on electrostatic plates (12 in diameter and at 6 mm distance from the bar ends). These give energy of 1 kT to each bar, and have been checked to be synchronous to within about 0·1 ms. The outputs of each bar are photographed at the beginning of each film to provide a record of sensitivity and synchronization (figure 1).

As a guide to rejecting pulses due to electrical pick-up, the AC output of each bar is also displayed and photographed in addition to the filtered and rectified output (figure 1). In this way spurious pulses which were seen to have left the energy of the bar unchanged were rejected. The rate of such spurious pulses was found to be about one per 10 h at each end.

5. Results and conclusions

The system has been in operation for $1\frac{1}{2}$ yr. Data were collected for the last 11 months with an observation efficiency of 63 % giving a total observation time of 7 months. This time was found to be evenly distributed on a sidereal histogram of 12 1 h bins. The same was found to be evenly distributed on a sidereal histogram of 12 1 h bins. The same was found to be true for solar time provided that bins 12 h apart were added together.

A total of 2583 events were counted in the eight time bins, of which 1614 of coincidences within ±10 ms were photographed. The distribution in the eight time bins is given in figure 3(*a*). There were 308 coincidences within ±2 ms (bin 4) of which 167 were found from photographic analysis to have been coincidences within ±1 ms. A histogram of these against sidereal time is given in figure 3(*b*). No significant excess above average was found as indeed was the case for similar histograms of coincidences

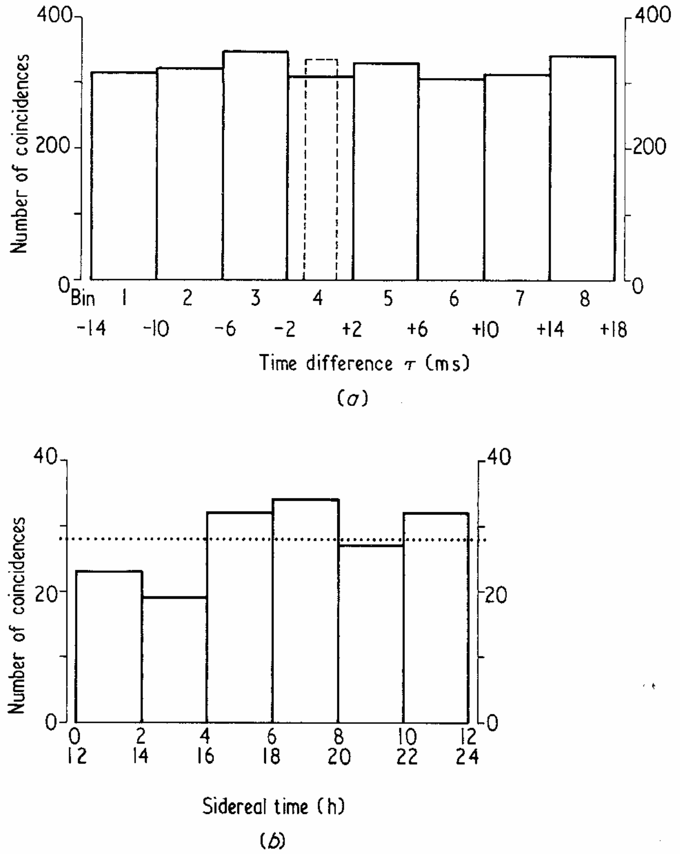


Figure 3. (*a*) Coincidence with time differences between the two pulses ranging from −14 to +18 ms (average 324). A total of 2583 were observed of which 308 were within ±2 ms. Also shown are the coincidences within ±1 ms, 167 in total. (*b*) The 'prompt' coincidences (within ±1 ms) arranged in a sidereal time histogram (average 28). Bins have a width of 2 h and those differing by 12 h were added together.

within ±0·5 ms or ±2 ms. Sidereal and solar times differed by up to 21 h during the experiment and any excess of pulses from one direction in space should have been apparent.

All pulses photographed were below roughly 1 kT except for some spurious ones (~10) which were rejected either because they did not coincide with a pulse from the detector within ±1 ms or as electrical interference identified as described in § 2.

Allowing for the lower masses of our detectors as compared to Weber's, we can say that the discriminator levels used correspond to about 1 kT on Weber's scale. It has to be concluded that at this level no statistically significant excess of coincidences was observed which could be due to gravitational radiation. If there are some such coincidences obscured by statistical variations between bins in the histogram of figure 3(*a*), their rate must be less than 1 per 12 days. In an analysis of the energy sensitivity of Weber's system (Christodoulides 1975; see also for examination of sources of noise and optimization of frequency bandwidths and discrimination thresholds), the discrepancies between our results and those of Weber *et al* (1973) are discussed further. The main conclusion, as illustrated by figure 3(*a*), is that the coincidences, coincident within 1 ms, are indistinguishable in trace characteristics from those in adjoining bins, representing delays up to ±10 ms, while the numbers registered in the 'coincident' bin are statistically consistent with the number registered in neighbouring bins.

As stated in the introduction, negative results have been previously reported by several groups. These groups vary in experimental techniques and methods of calibration, and detailed comparison is not justified. As will have been gathered from the foregoing, our experiment has in general followed the pattern of the Glasgow group (Drever *et al* 1973). The overall sensitivity to gravitational radiation is comparable: our sensitivity, in terms of kT, is one half that of the Glasgow detectors, but the mass is roughly twice as great. The chief difference is that our two detectors are 20 miles apart, rather than being housed in the one laboratory as at Glasgow.

We must conclude that unless Weber is detecting pulses of a narrow spectrum and near his frequency of 1661 Hz, all attempts to verify his claims of gravitational radiation have failed.

6. Acknowledgments

In this work we have been greatly assisted by R D Downs of the Rutherford Laboratory who designed and supervised the construction of the link, and by two research students, D Munro and J Whitney in the maintenance of the link. The amplifier and notch filter were provided by Dr M J Buckingham and Professor E A Faulkner of Reading University. Dr Buckingham also contributed to the work during the first year. We acknowledge support in part from the Science Research Council.

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No gravity waves to be found in Berkshire

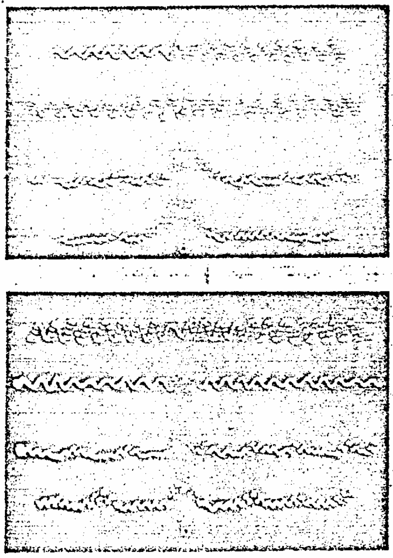
Jo Weber's claim, made first in 1969, that he has detected and continues to detect gravitational waves has suffered a further blow. For another experiment, this time by Dr C. Christodoulides and Professor W. D. Allen of Reading University and the Rutherford Laboratory, has failed to detect the radiation.

Published in a recent issue of *Journal of Physics A* (vol 8, p 1726) Allen and Christodoulides' results support those of the other groups that also began work after Weber's initial announcement—the groups at Bell Laboratories, Glasgow, Moscow, and Munich.

Each of Allen's and Christodoulides' two detectors, one of which was set up at the Rutherford Laboratory, the other at Reading, followed a design (also employed by the Glasgow group) due to Dr Peter Aplin of Bristol University. The detectors are made from 1·5 m long cylinders sliced in two across their axes, the two halves being joined by piezoelectric transducers bonded between them. In this position the transducers very efficiently transform ringing along the axes of the cylinders into electrical signals.

The electrical output from the ringing of the detectors is shown in the figures below. In each figure the output of the Rutherford pair of cylinders makes the first trace; the Reading pair makes the second. Each cycle of the ringing takes about 0·8 msec. The traces are of an amplitude corresponding to the thermal energy $\frac{1}{2}kT$ of each ringing mode; they represent movements of a small fraction of a nuclear diameter in the ends of the cylinders.

In figure a the two traces are disturbed simultaneously by a calibration pulse given electrostatically to the ends of the bars. The output of the electronics (designed to filter out the resonance of the bars) is shown in the third track (for Rutherford) and the fourth (for Reading), and clearly shows the effect of the calibration pulse.



In figure b a similar pulse occurs in both detectors but this time the pulse is natural. The question arises whether this is an incident gravitational wave hitting both detectors simultaneously (simultaneously because gravitational waves should move at the speed of light; at that speed it takes only one tenth of a ringing cycle to get from Reading to the Rutherford) or whether it is a coincidence of "noise" caused by random thermal movements in each bar. Random coincidences like these should occur at the same rate whatever delay is applied between the signals from each pair of cylinders—whereas coincidences induced by gravitational waves would vanish for any delay other than zero. The rate of coincidence Allen and Christodoulides found was independent of delay and so due only to noise.

The remaining question is whether as (Professor Allen puts it) "God claps his hands" when He makes gravity waves. Only Weber's detector is sensitive to waves which come in long (tenth-second) bursts with a slow rise and fall in intensity; the newer detectors have been sensitive only to much shorter (millisecond) bursts.

US space biologists hitch a Soviet ride

The Soviet biosatellite (no 782 in the Cosmos series), recently placed in orbit, is providing extra research facilities for US space biologists. They have supplied four experiments plus a number of specimens. The last American biological research spacecraft was launched in 1969, and, without using Soviet payloads, US biologists would have to wait until the 1980s for the Space Shuttle. Other countries involved in the experiments are France, Romania, Czechoslovakia, Hungary and Poland.

Cosmos 782 is carrying a centrifuge, which creates a force equivalent to the Earth's gravity at its revolving rim. The majority of experiments seem designed to study the effect on living organisms of different conditions, varying from normal gravity to weightlessness. The organisms include tortoises, which have relatively highly organised cardiovascular and nervous systems; and fruit flies, whose ageing and genetic mechanisms are of interest.

Soviet and American scientists have prepared tumour cells grafted on to carrots to see what will happen under different gravity conditions in space. In ground-based experiments the Americans have found that increased gravity can retard tumour growth, while simulated weightlessness increases it. Another joint experiment will study fertilised fish eggs at different stages of their development—to see when space factors tell.

Pure strains of rats, supplied by the Czechs, are being used to study infection in space. And biologists from France, Rumania and the USSR have collaborated on an experiment to study the biological effects of heavy nuclei radiation on single-cell organisms and seeds.

It now appears that the Soyuz 20 craft, launched last month to link up with the Salyut 4 space station, is also a biosatellite. According to press reports it is carrying turtles, fruit flies, cacti, and gladioli bulbs to provide information for the design of cosmonaut life-support systems. Its programme is apparently being linked with that of Cosmos 782.

Guzzlers may have a make-and-break circuit

Somehow, people and animals know how much they need to eat. American biologists researching into the mechanism of this instinctive regulation have now discovered a biochemical manoeuvre which causes rats to triple the amount of food they take at a sitting. It seems to involve an important part of the brain circuits which control eating behaviour (*PNAS*, vol 72, p 3740).

The area of the brain known as the hypothalamus contains the brain cells that regulate feeding. And the brain transmitter noradrenaline is involved in making animals eat; injections of noradrenaline in the hypothalamic area make rats start eating.

However, the doses of noradrenaline used to elicit eating in earlier experiments have been huge—much larger than the amounts occurring naturally in the rats' brains. Robert Ritter and Alan Epstein of the University of Pennsylvania wanted to discover the effect of realistic doses. In particular, they wanted to know exactly which behaviour was affected and in exactly what way. For instance, after animals have been deprived of food for a while, they make it up by eating more. They do that by taking more food at one go, not by increasing the frequency of meals.

Ritter and Epstein looked at the effect of meal size by arranging an apparatus that would inject a small dose of noradrenaline into the rats' brains each time they started to eat. In that way they managed to drive up the animals' food intake by more than 200 per cent.

Doses of noradrenaline that small failed to start an animal eating, so Ritter and Epstein suggest that two mechanisms are at work. One is a hunger mechanism, switched on by noradrenaline; the other is a satiation mechanism suppressed by it. They believe they were seeing the effect of the latter.

Flexibility in the size of a meal taken at any given time has obvious adaptive advantages, they point out. It enables animals to take full advantage of food sources only sporadically available.

NEW SCIENTIST (11 Dec. 1975, p.631)

Search for gravity waves

Generations of physicists are familiar with the dictum that no new find should be allowed to stand until confirmed by an independent investigator. An example of the need for confirmation is the well known search for quarks. A second, which has received equal publicity, is the attempt to confirm a claim that gravitational radiation from near the centre of our galaxy has been detected on earth.

The chase started in 1969 when Professor Joseph Weber announced that two metal bars, spaced 1000 km apart, had simultaneously absorbed gravitational energy from that region of the universe. A number of groups started work immediately on similar experiments to confirm Weber's experiments, including one at the University of Reading and the Rutherford Laboratory. Indeed the latest published results come from that group, in a paper by W D Allen and C Christodoulides appearing in the November 1975 issue of *J. Phys. A: Math. Gen.* (p1726). In common with other groups, Allen and Christodoulides had to conclude that they were unable to confirm Weber's results.

The search for gravitational radiation has certainly stimulated some original instrument research. Allen and Christodoulides used a technique in which the detectors were two aluminium bars spaced 30 km apart, each weighing 625 kg. Each bar was split in half and any energy absorbed by them detected by a number of piezoelectric transducers cemented between the two halves. To check that an 'event' detected in one of the bars was not spurious, the event was transmitted via a telephone link to the other detector and checked for coincidences. The threshold for triggering a transmission was an energy of 0·5–1 kT absorbed in either bar. Because of the fast response of the system, coincidences for the detection of gravitational radiation would have to be well within ±2 ms so that if gravitational radiation were received, the number of events recorded around the ±2 ms coincidence mark would be higher, by a statistically significant amount, than the coincidences from random events with larger time differences.

The result, after a total observation time of seven months spread over nearly a year, and after recording 1614 coincidences within ±10 ms of each other, is that there is no significant difference between the number of random events recorded and those that could be due to gravitational radiation, nor is there any excess of pulses from any one direction in space. The authors can only claim that all attempts to verify Weber's claims have failed.

There will still be room for discussion over sensitivities and the relative merits of different experimental techniques. Other groups too, perhaps, may try again with improved techniques and instruments, and the benefits to the science of measurement will not be immaterial. For the time being, Weber's results stand on their own but even if he should be proved in error in the end, much useful instrument experience will have been gained ◻

Light scattering in Brazil

By Professor R J Elliott

Light scattering studies have developed exponentially over the last decade as lasers have become readily available. The third international conference on light scattering in solids held in Campinas, Brazil on 28 July–1 August showed the diversity of materials which are now studied in this way.

The scientific programme was arranged by Dr Worlock from Bell Laboratories and proved diverse and stimulating. The results on amorphous materials, liquid and plastic crystals, magnets and superionics were reviewed. Several papers demonstrated the wealth of detail now accessible from resonant Raman scattering in favoured crystals like cuprous oxide. Light scattering studies of electron–hole droplets evoked considerable interest. New and related techniques were also discussed such as photon correlation methods for excitations of very low frequency and at the other end of the spectrum the possibility of x-ray Raman scattering using a synchrotron source.

The extreme diversity of phenomena studied sometimes led to a rather superficial treatment of the underlying physics. But this is inevitable in a conference on an experimental technique and is offset by other advantages to workers in the field, who see the full range of possible applications.

It was only possible to hold a major international meeting on this scale in South America because of generous support from the Federal Government Agencies and from the state of Sao Paulo. Almost all of the dozen British participants obtained travel assistance from the conference. The meetings were smoothly organized and the hospitality was lavish. Professor Rogeiro Leite and his colleagues from the University of Campinas worked unstintingly and the success of the conference was a tribute to their effort.

In addition to the scientific interchanges at the conference, participants from abroad were able to see something of the effort which is now being made to stimulate scientific and technological research in Brazil, to parallel the economic expansion. At the University of Campinas, Professor Sergio Porto and Professor Regeiro Leite are establishing major groups in optics and semiconductors. Smaller developments are taking place at Sao Carlos, Rio de Janeiro, Recife, Brazilia and many other centres. If these projects come to fruition, Brazil will be a major centre of research in solid state physics. We may expect to see more Brazilian physicists working in this country, while for British scientists there are increased opportunities for scientific visits and even a few jobs for those willing to work in an exotic country ◻

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at lower beam current; this has led to their predominant use for treatment directly with the electron beam, for which high energies (10–35 MeV) are essential to give adequate penetration.

These medical developments provided an important stimulus for NPL to consider extending its calibration service to higher energies. However, industry also uses high energy radiations on a large scale for radiation processing and sterilization, and the increasing interest in improved accuracy, partly for economic and partly for technical reasons has led to requests for a suitable calibration service for dosemeters capable of measuring large amounts of radiation. At the other extreme, there have been demands from the nuclear power industry for calibrations of radiation monitors of the type that can measure the low intensity gamma radiation outside the concrete shielding surrounding nuclear reactors.

It was these requirements that led to the specification of the purpose-built machine manufactured by Radiation Dynamics Ltd. An energy range from 2–20 MeV covers the whole of the medically useful range of high energy x-ray energies, and extends sufficiently high for extrapolation to be made to the highest energies used for electron therapy. Accurate control can be exercised on the beam energy when the beam is deflected by a 'pretzel' analysing magnet into a separate experimental room. Beam pulse lengths can be varied from 5 ns to 3 µs at rates from 1·6 to 480 Hz, and a single pulse facility has been incorporated to allow for pulse radiolysis measurements.

The very wide range of intensities to be provided by the future calibration services make necessary the provision of a correspondingly wide range of electron beam currents. Maximum pulse currents of 4 A for short pulses and 700 mA for long pulses are available, giving a maximum mean current of about 0·5 mA; this is quite typical of the beam from an industrial processing LINAC. At the other end of the scale a pulse current as small as 0·1 µA has been achieved in the analysed beam giving a mean current of about 80 pA at maximum duty cycle; under these conditions it is envisaged that protection-level dosemeters can be calibrated in the direct x-ray beam.

Of corresponding importance to the machine is the new national primary standard of absorbed x-ray dose, at present being assembled. This consists of a graphite calorimeter in which the energy deposited by a radiation beam in a block of graphite is measured by matching its temperature rise by that produced by heating with a small known electric current. Other calorimeters for electron beam calibrations are envisaged and appropriate transfer devices are being planned.

The cost of the whole project, machine plus building, was less than £350000. It was formally opened on 27 October 1975 by Dr G Schuster, the Director General of Research, Science and Education of the Commission of the European Communi-

Rutherford Laboratory

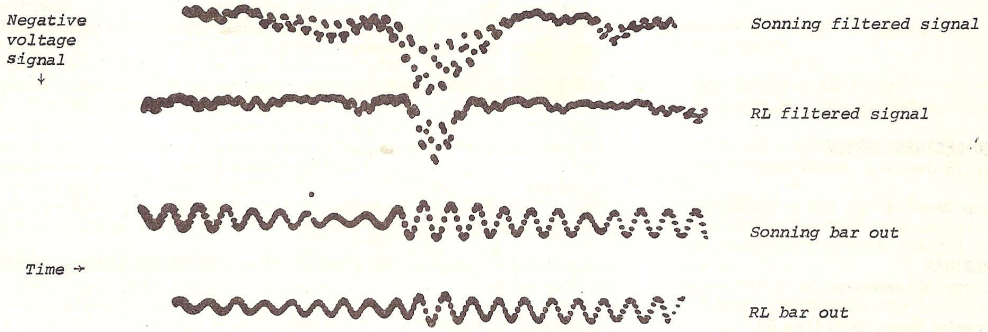
21 January - 4 February 1974

bulletin 2

A MATTER OF SOME (?) GRAVITY

For several years now, the experiments of Joseph Weber have intrigued physicists. If the gravity familiar in everyday life is not constant in time but is subject to tiny ripples due to the arrival of gravitational waves, then, if they are of sufficient intensity, it should be possible to detect them. Accelerated electrical charges radiate, and in turn the resultant radiation accelerates charges, as we all know from the TV transmission and reception. The laws of gravitational forces are similar to Coulomb's law for electrostatic forces: so it is plausible that accelerated masses should radiate. The oustanding question is whether it is possible to detect such radiation.

Weber says he can: two detectors set up near Chicago and near Washington show coincidences at rates significantly above the random rate (i.e. the rate when the signal from either detector is subject to time delay). Other workers have so far (i.e. over a period over about a year) failed to substantiate Weber's claim. A new local detector is now in operation: a detector at the Rutherford Laboratory is in coincidence with a detector at Sonning near Reading. Both detectors are of the split bar type proposed by Aplin of Bristol: they have a lower Q (ring time) than Weber's bar, but higher efficiency and much greater bandwidth. The picture below shows a calibration pulse (i.e. a genuine coincidence!) initiated from the time signal from Rugby. This time signal triggers an electrostatic pulse which gives the required very small hammer blow to the bar. This causes the bar to change its original oscillation which arises from Brownian noise, in either phase or amplitude. The output is handled by a filter and finally emerges in the form of a pulse.



The response of the Sonning bar is piped over the telephone line to RL, where it is displayed, together with the response from the RL bar, on an oscilloscope. The top two traces show the filtered response to an input energy of l kT ($\frac{1}{2}$ kT, the thermal noise in the bar, sets a lower limit to sensitivity). The bottom two traces show the corresponding actual bar response.

Pictures such as the above have been collected for about two months, and the collection will continue over the next several months: together with the exploration of alternative methods of signal recovery.

LADIES - YOUR ATTENTION PLEASE

A film entitled "Screening for Breast Cancer" is being shown in the Lecture Theatre on 31 January and repeated on 1 February. Full details are given in 'Internal Events' on page 2 of this Bulletin.

LIBRARY NOTICE

TRANSLATIONS Would people who are fluent in any foreign language and would be prepared to provide occasional translations, please contact the Librarian on Ext. 6668.

JANUARY SALES The Library will have more superseded and surplus books for disposal. As the last advert produced an embarassing number of avid readers, books will be available from Monday 21 January in the reading room and will be restricted to two books per person.

LECTURE THEATRE BOOKINGS

All Lecture Theatre bookings should in future be made through H F Norris, Room 42, Ext. 484.