NEW SOURCE FOR DYNAMICAL GRAVITATIONAL FIELDS

J. Sinsky and J. Weber*
Department of Physics and Astronomy, University of Maryland, College Park, Maryland
(Received 13 February 1967)

We describe a new source for dynamical gravitational fields consisting of an acoustically stressed volume of matter. The very-near-zone dynamical gravitational fields are measured as a function of distance and azimuthal angle, using apparatus responsive to the curvature tensor. The high frequency of 1660 cycles per second implies a new regime for gravitational technology.

Einstein[1] and Eddington[2] considered the gravitational radiation from a spinning rod. As the angular velocity increases, the dynamical fields and radiation increase. As the peripheral velocity of the rod begins to approach the sound velocity, rupture will occur because of the large stress at the center. The length of such a rod is about 10^{-7} gravitational wavelengths at the rod rotation frequency. As a result, the radiation available from a rod is many orders too small to detect.

Some years ago it was suggested[3] that the acoustic stress in a solid would serve as a more effective radiator. Under certain conditions of operation, a piezoelectric source would have stress components which do not change sign every acoustic half-wavelength. This makes dynamical gravitational field sources possible with linear dimensions approaching a gravitational wavelength, using terms in the stress tensor which are linear in the time-dependent pressure. A second possibility is to use the quadratic terms in the stress tensor. In that case a piezoelectric material would not be essential, and again, a source with linear dimensions of order of gravitational wavelengths is possible.

As a preliminary step in development of such sources, we have constructed an acoustically stressed source for 1660-cps gravitational fields. This experiment measured the dynamical near-zone gravitational fields as a function of distance and azimuthal angle, using the detection apparatus already described[4] for measurement of the Riemann tensor. While post-Newtonian effects are not observed, the experiment does define a new regime of gravitational technology.

The tidal gravitational fields are dynamical in character and well understood. The present experiment involved, therefore, an upward extension in frequency from the tidal cycles per day of the Cavendish experiment to the region of 1.66 kc/sec.

The detector is an aluminum cylinder 154 cm long and 60 cm in diameter. The generator is a second aluminum cylinder 154 cm long and 20 cm in diameter. Both generator and detector were suspended in separate vacuum chambers. The generator was driven electromagnetically by means of ceramic piezoelectric crystals bonded to its surface. Its frequency was controlled by controlling its temperature, using a closed-loop servo system. By this means, strains of 0.45×10^{-4} were maintained for several weeks. The distance between cylinders with their axes coaxial was varied and the change of detector output recorded. A second series of experiments involved lateral displacement of the cylinders and observation of the changes in detector output.

The detector output is a voltage which appears at the output terminals of quartz piezoelectric crystals bonded to the cylinder surface. In order to improve the signal-to-noise ratio, a superconducting inductance is employed for resonance with the strain gauge capacitance. Solution of the boundary value problem of the cylinder and piezoelectric crystal enables calculation of signal and noise output. Figure 1 is a plot of the calculation of the predicted output power of the detector versus measured power increase as a function of distance between coaxial cylinders and of lateral displacement of the cylinders. For the closest distance the agreement between theory and experiment is 3.5% with a probable error of 10%.

The detector responds to a kT of energy over its relaxation time of 30 sec. The driving power for the generator consisted of 100 W of electromagnetic energy at the detector frequency. Extreme precautions were therefore required to avoid acoustic and electromagnetic leakage. Over 25 orders of power attenuation were in fact achieved.

Figure 2 is a schematic diagram of the experiment including a schematic diagram of the

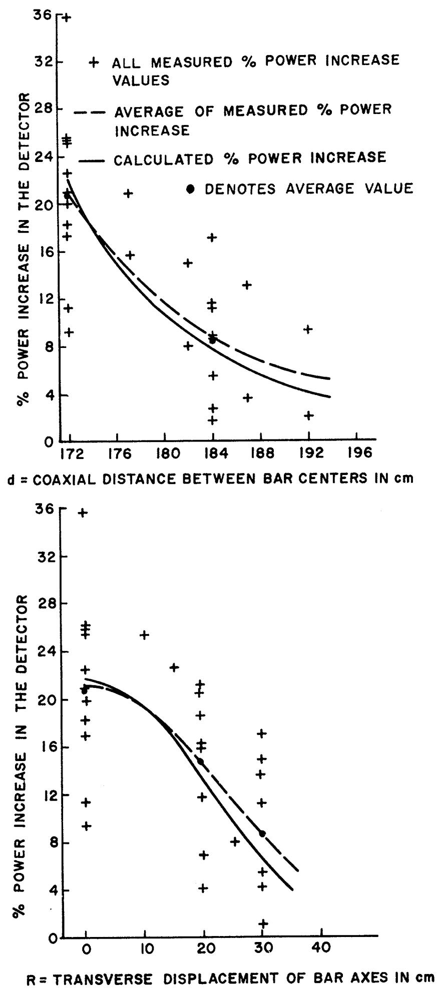

FIG. 1. Percent power increase in the detector versus coaxial and transverse distance between bars.

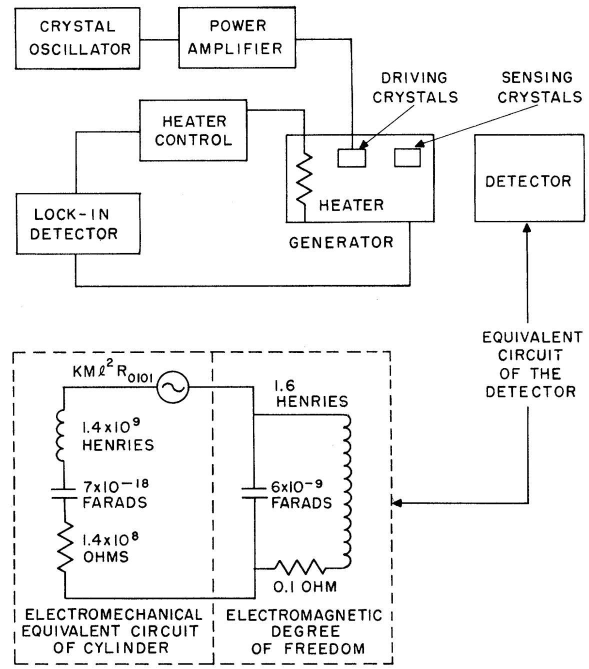

FIG. 2. Schematic diagram of the generator and the detector.

equivalent circuit of the detector. The lowest compressional mode of the detector is coupled to an electromagnetic degree of freedom having a very high Q, or quality factor. We discovered that all of the leakage above the noise threshold was associated with the electromagnetic degree of freedom. Thus by detuning the electromagnetic part from the detector, various sources of leakage could be identified and remedial action taken. It was discovered that a structure induced by weight stresses on Teflon made it slightly piezoelectric, and this was a major source of acoustic coupling through transmission line supports. Fused quartz and polyethylene fittings were finally employed.

In summary, this new regime in gravitational technology is characterized by dynamical sources consisting of volume integrated stresses, communications at kilocycle frequency between source and detector with center to center separation as great as 184 cm (end-face to end-face separation of 30 cm), cryogenic technique to improve coupling and noise performance, and system stability permitting continuous operation for many weeks.

We note that in this experiment electromagnetic fields are employed to produce stresses. The vacuum gravitational interaction then couples energy to an electromagnetic output circuit. Thus we may think of output photons as being produced from input photons via the gravitational interaction. This kind of coherent process is capable of upward extension in frequency for a variety of other experiments.

It is our pleasure to acknowledge the contributions of Dr. David M. Zipoy who performed noise analyses, prepared a computer program, and designed the suspension. Dr. Robert L. Forward suggested use of aluminum and designed the vacuum chamber. We are also deeply appreciative of the assistance of Mr. Jerome V. Larson and Mr. Reginald Clemens in carrying out the data processing required for this experiment.

---

*Work supported in part by the U. S. Air Force Of-

fice of Scientific Research.

[1]A. Einstein, Sitzber. Kgl. preuss. Akad. Wiss. 1916, 688; 1918, 154.

[2]A. S. Eddington, Proc. Roy. Soc. (London) A102, 268 (1923).

[3]J. Weber, General Relativity and Gravitational Waves (Interscience Publishers, Inc., New York, 1961), Chap. 8.

[4]J. Weber, Phys. Rev. Letters 17, 1228 (1966).

MASS EMPIRICS*

Julian Schwinger
Harvard University, Cambridge, Massachusetts
(Received 13 April 1967)

The following is an empirical observation about the mass spectra of the baryon octuplet and the baryon resonance decuplet: The respective fractional mass splittings are identical.

The precise meaning of this statement refers to a particular phenomenological description of the mass spectra. First, let the various particles be represented by fields (or sources, or state vectors) that are constructed from the third-rank unitary tensor ψ_{abc}. The decuplet is associated with a totally symmetrical tensor, and the octuplet is contained in the matrix

$$N_{ad}=\sum_{bc}\epsilon_{bcd}\psi_{abc},$$

where ϵ is the totally antisymmetric symbol. Next, define a quantity H_3, which acts additively on single indices and on pairs of indices in ψ_{abc}, with the basic values +1 for a single 3 index; -1 for an antisymmetrical 12 index pair; 0 otherwise. With the exception of Λ, all particles under consideration are eigenvectors of H_3. The eigenvalues are displayed in Table I. Our phenomenological mass formula for these particles is

$$M=M_0+\Delta H_3,$$

where M_0 and Δ are fixed within the octuplet or the decuplet.

Table I. Eigenvalues of H_3 for members of the octet and decuplet.

Particle	H_3
N	-1
Σ	1
Ξ	2
N^*	0
Y_1^*	1
Ξ^*	2
Ω	3

The following octuplet assignments,

$$(M_0)_8=1065\tfrac{1}{3}\text{ MeV},\quad \Delta_8=126\tfrac{1}{3}\text{ MeV},$$

give the masses (in MeV) $N=939$, $\Sigma=1192$, and $\Xi=1318$, which is an accurate reproduction of the data[1] particularly if one keeps in mind the difficulty in attributing a central mass to an electromagnetically split multiplet, lacking a completely satisfactory theory of such splittings.[2] The fractional mass splitting for the octuplet[3] is now defined,

$$(\Delta/M_0)_8=\frac{126\frac{1}{3}}{1065\frac{1}{3}}=0.1186.$$

The decuplet mass values $N^*=1238$, $Y_1^*=1358$, $\Xi^*=1532$, and $\Omega=1674\pm3$, are consistent with the uniform spacing

$$\Delta_{10}=147\text{ MeV}$$

and

$$(M_0)_{10}=1238\text{ MeV}.$$

The content of our observation is now evident in the value of the decuplet fractional splitting

$$(\Delta/M_0)_{10}=147/1238=0.1187.$$

---

*Publication assisted by the U. S. Air Force Office of Scientific Research.

[1]A. Rosenfeld et al, Rev. Mod. Phys. 39, 1 (1967).

[2]There is an electromagnetic mass formula that uses the analogously defined H_1, but the situation is more complicated and will not be discussed here.

[3]For completeness we add some remarks about Λ. The expectation value of H_3 for this particle is $\frac{1}{3}$, which gives the mass 1107(0.4). That falls short by 8 MeV $\sim\Delta_8/16$, which also measures the inadequacy of the Gell-Mann–Okubo formula. To improve the phenomenological mass formula, define H_{123}, which acts only on index triples. It assigns the value unity to a single 3 index combined with an antisymmetrical 12 index pair, and is 0 otherwise. The additional term needed in M/M_0 is $\frac{4}{5}(\Delta/M_0)^2H_{123}$.