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1952

ON THE DESIGN OF A PARTIAL INSULATOR FOR GRAVITATION

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SUMMARY

The theory of Gamow, according to which the fundamental process of gravitation is the emission and absorption of system of two neutrinos between the interacting bodies, is described, and original developments of it are presented. This gives us the only hint at present of the essential nature of gravitational forces between atomic nuclei. The problem of finding a gravitational insulator is then reduced to that of finding an absorber for neutrinos, and a plan of research to this end is outlined.

It is useless to discuss the problem of insulating gravitation until it is clearly understood of what gravity consists. For this purpose there have been designed several theories, of which that of Einstein is the most famous. The key to our problem, however, lies in the interaction of gravitation with individual atoms and atomic nuclei, and so far it has proved impossible to bring Einstein's theory down to this microscopic level. Although the theory describes the effects of gravity in the large, it tells us little about the essential nature of gravitons, the particle-like entities responsible for gravitational interaction, other than that they move with the velocity of light. To consider further how these gravitons interact with nuclei, and hence how gravity interacts with matter, one must appeal to the modern quantum theory of elementary particles.

This theory teaches us that such particles affect each other by means of a field which itself is composed of particles. Thus, for example, it is supposed that nucleons (protons and neutrons) in a nucleus interact via a field which itself gives rise to particles which may be identified as mesons. Similarly, electric charges interact by means of an electromagnetic field which itself is composed of particle-like entities called photons, and bodies interact by means of a gravitational field.

which itself is composed of gravitons.

It was pointed out by Gamow¹ in 1947 that these gravitons may be made to fit very nicely into the scheme that has been devised to describe nuclear forces. This is the only hint we have as to the nature of the fundamental process that is involved when bodies affect each other by gravity. The theory is that a graviton consists of the superposition of two neutrinos, particles postulated by Pauli and Fermi to describe β -radioactivity, i.e. the spontaneous emission of an electron or a positron by a nucleus. The existence of neutrinos is now well established and the idea that a gravitational field is composed of them is very fruitful. It not only relates our problem to the whole scheme of nuclear physics but also enables us to understand the fundamental processes, upon the nuclear scale, responsible for gravitational interaction. Our problem of shielding against a nebulous thing like gravity becomes the problem of shielding against the much more clearly understood neutrinos.

It follows, then, that a proton or neutron, or indeed the nucleus of any atom, is surrounded by a cloud of mesons, electrons, and neutrinos, and that another nucleus will have its motion affected if it moves into this cloud. Exchange of energy between two such nuclei then occurs when a particle from the cloud around one of them attaches itself to the cloud around the other. A meson exchange gives rise to nuclear forces, an electron and neutrino exchange is simply the emission of a β particle and its ultimate absorption by another nucleus. Conservation of the angular momentum tells us that an odd number of neutrinos cannot be exchanged, and that the most important possibility is that neutrinos be exchanged two at a time. Such an exchange may describe gravitation.

We now show by general arguments, without giving detailed calculations, that this process is quite capable of describing the chief properties of gravitation. In the first place, neutrinos, like the photons which compose the electromagnetic field, are without any rest-mass---their energy is due entirely to their motion, which takes place with the velocity of light. This gravitation is propagated with the velocity of light, in agreement with Einstein's theory.

Secondly, this common characteristic of photons and neutrinos leads immediately to Coulomb's law, on the one hand, and Newton's law of gravitation on the other. In the case of two interacting electrically charged particles, for instance, the force between them is proportional to the product of their charges e_1, e_2 and could depend on r , the distance between them, and perhaps even on c (the velocity of light) and h (Planck's constant). Since the photon has no intrinsic mass there is no other physical quantity upon which this force could depend. Thus the electrostatic force is

$$F_e \sim e_1 e_2 r^x h^y c^z \quad (1)$$

where x, y, z are unknown. Since the following dimensional argument does not take account of possible numerical factors like π we have written \sim instead of an equality.

Substituting into (1) the dimensions of the physical quantities involved

$$\begin{aligned} F_e &\sim [MLT^{-2}] & h &\sim [ML^2T^{-1}] \\ e_1 e_2 &\sim [M^2T^2] & c &\sim [LT^{-1}] \\ r &\sim [L] \end{aligned}$$

and equating powers of M, L, T we have immediately $x = -2, y = 0, z = 0$

so that $F_e \sim \frac{e_1 e_2}{r^2}$

which is Coulomb's law. Similarly also the gravitational force between two nucleons of mass M is

$$F_g \sim \frac{GM^2}{r^2} \quad (2)$$

where G is the gravitational constant.

In Fermi's β -ray theory, however, one postulates the existence of an interaction constant g , which may be determined from measurements of the intensity of β -ray spectra, and which plays the same role in the production of neutrinos from nucleons that the electric charge plays in the production of photons from charged particles.

The dimensions of g are $[ML^5T^{-2}]$ and its value is²

$$g = 2 \times 10^{-49} \text{ erg cm}^3 \quad (3)$$

One may show that the force between two nucleons due to exchange of neutrino pairs is proportional to g^4 , although the electrostatic force between two protons is proportional to e^2 . The difference is due to the fact one may think of the latter as due to the emission and absorption of a photon (two processes) while the former is

due to the emission and absorption of two neutrinos (four processes). In addition the force between two nucleons may depend on h , M , and c , previously defined, so that

$$F \sim \frac{g^4}{r^2} h^x M^y c^z$$

or $[MLT^{-2}] = [ML^5T^{-2}]^4 [L]^{-2} [ML^2T^{-1}]^x [M]^y [LT^{-1}]^z$

From this it follows as before that

$$1 = 4 + x + y$$

$$1 = 20 - 2 + 2x + z$$

$$-2 = -8 - x - z$$

or $x = -11, y = 5, z = 5$

and $F \sim \frac{g^4}{r^2} \frac{M^5 c^5}{h^{11}}$ (4)

Comparing (4) with (2), we see that to regard this force as a gravitational force requires us to write

$$\begin{aligned} g^4 &\sim G h^{11} M^{-6} c^{-5} \\ &= G \left(\frac{h}{Mc}\right)^6 h^5 c \end{aligned} \quad (5)$$

a very remarkable relation between gravitational and nuclear constants. With the numerical values

$$\begin{aligned} G &= 6.7 \times 10^{-8} \text{ cm}^3 \text{ gm}^{-1} \text{ sec}^{-2} & h &= 6.5 \times 10^{-27} \text{ cm}^2 \text{ gm} \text{ sec}^{-1} \\ \left(\frac{h}{Mc}\right) &= 1.3 \times 10^{-13} \text{ cm} & c &= 3 \times 10^{10} \text{ cm} \text{ sec}^{-1} \end{aligned}$$

we have $g \sim 10^{-51} \text{ erg cm}^3$, which should be compared with (3). Considering the enormous numbers which appear in the numerical evaluation, and the fact that extra numerical factors do not show up in a dimensional argument, the fact that the values are even of the same order of magnitude is most remarkable. Further, since Fermi's theory is well established for β disintegration, one may ask the question, "If the force (4) derived from Fermi's theory is not gravitation, what is it?" It cannot be discarded as "small" for it is a force like gravitation and, on the above rough arguments, even stronger than it.

We are now in the position to tackle on a much sounder basis the problem of insulating against gravity, for on the above argument, the root of the problem is to

study the interaction of neutrinos with matter. Any substance that absorbs neutrinos will absorb also the affect of gravity, and allow us to insulate against it.

We already know that neutrinos pass very easily through ordinary matter, which corresponds, of course, with the fact that gravity passes also. But the fact that neutrinos are produced means also that they can be absorbed, and it is known that this absorption increases with the density and thickness of the absorber. We may therefore suggest the following plan of research

- (1) to take accurate measurements, with a Warden or other type gravimeter, of the acceleration of gravity when the densest possible alloys are used as a shield, to see if this shielding effect can be detected.
- (2) to measure the value of gravity near a very strong β^- particle emitter, to see if the accompanying neutrinos affect the reading.
- (3) to measure the gravitational force between two β^- particle emitters
- (4) to investigate further, by photographic plate or other techniques, the absorption of neutrinos by ordinary matter.
- (5) to attack the problem of producing alloys of greater and greater density, with the ultimate aim of producing substances as dense as that found in white dwarf stars.
- (6) to develop the above theory quantitatively, including all numerical factors.

If this theory stands up to all tests that can possibly be made of it, we shall understand definitely the fundamental process of gravitation, a necessary step in the solution of the problem of how to insulate ourselves from this ubiquitous force.

References.

1. G. Gamow - Phys. Rev. 71, 550 (1947)
2. E. Fermi Elementary Particles (Yale 1951) p. 43 (in this reference our constant g is called g_1)