Gravitational Effects of Celestial Bodies on High Energy Elementary Particle Processes

Essay written for the Gravity Research Foundation by

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Summary:

Absorption of gravitation by electromagnetic radiation, causing radiative decay of the photon into three or more photons, and emission of gravitational energy by elementary particles of vanishing rest mass, are shown to emerge from established gravitational and quantum electrodynamic theories.

Such elementary particle processes, in spite of certain general restrictive principles, can be produced by gravitational fields of celestial bodies.

Theoretical foundations of these processes are analized and necessary new experiments indicated. Other interesting phenomena are discussed.

The quoted results are rigorous and up until now unpublished, unless otherwise mentioned.

a gravitational field cannot be screened." (2) This statement appears somewhat misleading, if temporarily varying fields are considered. In this essay it will be shown, that in spite of the equivalence principle, gravitational fields of large masses can have perceptible effects on elementary particle processes. For this purpose one should first realize, that for the investigation of gravitational forces acting on elementary particles, some kind of gigantic spatio-temporal magnifying glass is at our disposition. (3) Indeed, giving the contemplated falling system a large initial velocity alters the gravitational forces acting at each spot in a way which can be easily calculated e.g. from the equations given by J. Weber (4). The calculation shows, that some of them are increased by the factor $1/1(1 -(v/c)^{2})^{2}$. This fact expresses a merely demonic property of gravitation, as it implies the domination of its forces for high velocities over electrical and other forces. This and other facts, as the definite relation between gravitation and the masses of the elementary particles should encourage scientists who gave up hope on this subject because of the smallness of its effects.

Having remarked on the potential powers of gravitation, we shall now reveal its weakness. Inserting the highest actually observed velocity of elementary particles with finite rest mass into the above formula, we obtain a factor of nearly a billion squared increasing some of the gravitational forces. Nevertheless, accelerations acting on a falling system having this initial velocity and sizes of 10^{-11} cm are not larger than those at the earth's surface. An observer in this system, moving only less than an inch/sec slower than light, would pass the earth, flattened due to the Lorentz transformation to a thumb's breadth within a billionth of a second. This demonstrates the power of the equivalence principle to make gravitational effects undetectable. It would be too speculative to use higher, unobserved velocities to obtain a more satisfactory case.

One recognizes that there is hardly a chance of finding measurable effects in the small, by merely extending the formalism of General Relativity, in first quantization, to these regions. Unfortunately up to the present, the many outstanding attempts for second quantization of the gravitational field also leave us without suggestion for an observation. A great hope to achieve this appeared in the meson spin 2 theory, developed by Belinfante, Feynman, Gupta, Thirring and others and recently brought to perfection by Feynman. This theory, whether it is realized in nature or not, would give the most detailed description of gravitational processes in the small and therefore let us expect more results. Indeed, investigations about the measurability of the geometrical quantities connected with gravitation, (6) might even suggest the possibility that some of the events computable from meson theories can perhaps not be determined at all by a limited number of measurements. Unfortunately also from this theory no practical results could be deduced. We are standing of course at the beginning of development, but if this situation persists one will be forced to take either the attitude that these theories are right and there do not exist measurable gravitational effects in the small, or that as it happened in electrodynamics, new yet unknown events occur. The latter leaves open a wide range for speculations and indeed many such ingenious speculations have been made and also experiments have been suggested - yet again until now without practical result. Experimental progress is to be expected by realization of the ideas suggested by Dicke, Schiff, Weber and others and by experiments with artificial sattelites. The latter are a practical realization of the falling system mentioned, in which an observer has the privilege to remain free of gravitational forces and as was seen, even to return alive, different from the case in the old fashioned Einstein lift. Yet all these progresses will improve our knowledge directly, only in large or semi-microscopic regions. Because of the mentioned demonic property of gravitation the microscopic domain of the elementary particle processes is of greatest interest. While single elementary particle processes are energetically not significant, by the choice of an appropriate experimental setup in which many such processes happen, substantial deviations from habitual conditions can be achieved. This is best demonstrated by the example of the atomic bomb, where the elementary particle process, the fission of the Uranium nucleus, in single events was hard to discover, yet in large numbers even hard to control. Controlled elementary particle processes, however, constitute one of scientists' greatest hopes for a bright future of mankind. If it becomes possible to absorb gravitation in a single elementary particle process, already a big step is made.

In the following it will be shown that, in spite of the equivalence principle, there exists a bridge between our established gravitational and elementary particle theories and the unknown domain of the gravitational interaction with elementary particles. For this purpose we have to review two other gravitational effects, which appear like violations of the equivalence principle. G. Mie (7) already in 1920 realized the problem connected with a small electrically charged body falling in a gravitational field. Because of its acceleration it should radiate electromagnetic energy, but the equivalence principle does not accept forces on the body because it is small. Yet the electromagnetic field is of large extensions and so radiation cannot be excluded. DeWitt (8) established that indeed electromagnetic radiation occurs.

The author (8) showed that particle waves of equal rest masses and different spins propagate differently in gravitational fields. To this there corresponds in astronomy the deviation of spinning planets from their geodesic orbits. (9)

Both these effects are again immeasurably small. The author (10) showed, that applying the mentioned magnifying glass to the first case and letting an elementary particle of highest initial velocity fall, would increase the radiation energy in the direction of motion due to the Doppler effect by another factor of $1/\sqrt{1-\beta^2}$. But a detailed calculation gave a result that even for highest energies is still hard to distinguish from other disturbing factors. The second result makes one even realize that a charged particle with spin ought to radiate even, if the first mentioned radiation did not exist, because it deviates from the geodesic and therefore in its rest frame is accelerated. The same would be true if the particle possesses only a magnetic moment instead of a charge. It was then tried to ascribe such properties to the neutrino. Here another property of particles like the neutrino and the photon shows up, which one might call as well demonic. A strange paradox occurs if one considers a neutrino or a photon of finite energy but of arbitrarily small rest mass and magnetic moment. In the direction of motion the particle would then emit a finite radiation while propagating in a gravitational field. This radiation may, depending on the rest mass chosen, be very soft and unobservable, but produces in the course of propagation of the particle a measurable energy loss. Neutrino energies cannot be measured exactly but one could try the same reasoning to the photon. A review of the existing experimental material showed a gap of our knowledge. Whenever light which had passed gravitational fields of large celestial bodies was examined it showed a red shift.

mentioned spin 2 meson theory. Here no problems about unmeasurable quantities occur and, like the result for classical radiation, it can be considered quite reliable. A decay of the photon into three photons as result of the absorption of gravitation here takes place. The calculations involved in the solution of this problem are the most complicated. Simpler problems like the scattering of light on light remained unsolved for decades. But at present already some estimates can be made and it appears that for light of very short wavelength also this part of the effect may well come into detectable range.

Recently in a discussion with Prof. J. A. Wheeler it was made clear that also gravitational radiation may come here into play. This is astonishing because the amount of gravitational radiation from the planets orbiting around the sun is negligibly small. Light has a very small mass compared to the planets. But here the author's consideration of the vanishing magnetic moment comes into play, only that it is replaced by a mass. Gravitational radiation has some remote similarity to electromagnetic radiation and so, also here a contribution to the effect by emission of gravitational energy is to be expected.

To conclude, we have various indications that a very interesting and important physical process in connection with the gravitational field exists and until now no experiment to contradict it. On the other hand also no other hopeful experiments giving information on the interaction of gravitation with elementary particles exist. When Faraday made his discovery about the connection between light and magnetism, he had probably less theoretical reasons for the experiment; yet it was also much easier to perform. Also further theoretical investigations may give more insight into the discussed problem.

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On the development of the subject treated in the essay:
It is based on three unpublished works of the author, one at the Univ. of Vienna im May 59, the other two at Cern, Geneva. and on the author's latest works at the Institute of Field Physics. Publications have not yet been made except a lecture at the Hoboken seminar on gravitation, where the subject was discussed with most leading scientists in this field. The subject became one of the most discussed and the author is in continous contact with leading scientists at Palmer Physical Lab., Princeton N.J. CERN, Geneva, Brandeis Univ. and others to inform them about new results.