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The Question of Extended Energy-Mass Equivalence

and

Relativity

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September, 1996

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Abstract

The notion of extended energy-mass equivalence could be used to justify for extending Newtonian universal coupling to general relativity. On the other hand, binary star experiments have confirmed the necessary existence of the antigravity coupling in Einstein's equation. Thus, the extended universal coupling is not generally valid. It is shown that extended energy-mass equivalence is, in principle, not generally compatible with general relativity. As clarified by Einstein, the interpretation of his famous formula, $E = Mc^2$ is that energy-mass equivalence is only in the context of energy conservation. In particular, the electro-magnetic energy is not generally equivalent to mass. Thus, the investigation on gravitational effects due to different types of energy and tests for possibly different couplings would be necessary.

In 1946, Einstein [1] clarify the physical meaning of his famous formula,

$$E = Mc^2, \tag{1}$$

where E and M are respectively the energy and the mass of a particle, In his clarification, he makes clear the mass-energy equivalence is in the context of the conservation of energy. He wrote "The energy that belongs to the mass M is equal to this mass, multiplied by the square of the enormous speed of light-which is to say, a vast amount of energy for every unit of mass."

Such a clarification is needed because general relativity implies that energy and mass are <u>not</u> generally equivalence in terms of gravity. Although in Einstein's field equation [2,3],

$$G_{ab} = -KT_{ab}\ , \tag{2}$$

where G_{ab} is the Einstein tensor and T_{ab} is a sum of energy-stress tensors, all types of energy-stress tensor have the same coupling constant K, this does <u>not</u> ensure that energy and mass are equivalence in terms of gravity. In fact, the non-equivalence between different types of energy is inherence in general relativity Since the source of the Einstein equation is an energy-stress tensor in stead of just the mass in Newtonian gravity, the equality of the time-time components does not make two tensors equivalent.

For example, the trace of an electromagnetic stress tensor is zero; whereas that of an massive stress tensor is positive. This non-equivalence is explicitly manifested by the Reissner(1916)-Nordstrom (1917) metric [2,3],

$$ds^2 = (1 - \frac{2M}{r} + \frac{q^2}{r^2})dt^2 - (1 - \frac{2M}{r} + \frac{q^2}{r^2})^{-1}dr^2 - r^2\, d\Omega^2, \tag{3}$$

where M and q is respectively the mass and the charge of a particle at the origin of the coordinates, and r is the radial coordinate. Note that in metric (3) the gravitational components generated by mass and electricity have different signs, and furthermore very different radial coordinate dependences. The difference in signs

means cancelation, and the difference in their coordinate dependences means the cancelation is only partial.

Thus, metric (3) demonstrates that, in general relativity, the electromagnetic energy is not equivalence to mass. This is consistant with the requirement of special relativity that the photons are massless. Furthermore, while general relativity does not accept an infinite sheet of rest mass, a sheet of energy – light rays – is a common phenomenon. Although the Kreuzer experiment [4] and etc. manifest that the same gravity can be generated with different sources, in general relativity, energy and mass are not generally equivalence in terms of gravity. This means that the gravity of different types of energy should be investigated.

It should be noted the extended Newtonian universal coupling is an assumption which is independent of general relativity. As early as 1921, Pauli [5] pointed out that "The general theory of relativity does not provide a physical interpretation of the sign and numerical value of the gravitational constant, but takes these data from experiment." Thus, according to Pauli, in eq. (2) the source tensor T_{ab} instead of being just a sum of energy-stress tensors of different energy types, it is possible that

$$KT_{ab} = KT(m)_{ab} + \sum_{i=1} K^{(i)}T(E^{(i)})_{ab} \quad , \tag{4}$$

where $T(m)_{ab}$ is the energy-stress tensor of massive matter, $T(E^{(i)})_{ab}$ is the energy-stress tensor of the ith type, and $K^{(i)}$ is the coupling constant for the energy of the ith type.

Note that, while the Newtonian universal coupling can be considered as based on the atomic structure of massive matter, there is little theoretical basis to extend this coupling to other form of energy-stress tensors if whose trace are zero. Nevertheless, the notion of extended energy and mass equivalence could be considered as a justification for extending the Newtonian universal coupling. Perhaps, this could explain why the extended interpretation that any type of energy is equivalence to mass even in terms of gravity, is prevailing [6,7] although both Einstein and Pauli disagree with such an interpretation. Thus, the extended Newtonian universal coupling remains an assumption since it also lacks a conclusive experimental support.

Moreover, for some energy-stress tensors, it may be possible to have the antigravity coupling [8,9], i.e. $K^{(i)} = -K$ for some energy types. An antigravity coupling is not allowed in Newtonian theory of gravity because such a coupling in the Poisson equation of gravity would lead to contradiction to Newtonian third law

of mechanics. But, in general relativity the equation of motion is the geodesic equation which is not related to any coupling constant of gravity. The fact that static electromagnetic energy does not "fall" under the influence of gravity, does not imply that the gravity coupling to electromagnetism is zero. Thus, the coupling constants for some massless matter and massive matter can be different. In conclusion, general relativity is, in principle, not necessarily compatible with the extended universal coupling.

In 1991, the necessary existence of the anti-gravity coupling was predicted [9]. Its existence is confirmed surprisingly by the Taylor-Hulse [10] and other binary pulsar experiments [11,12]. Based on these experiments, analysis [8] shows that the Einstein equation must be modified to the following:

$$G_{ab} = -K\{T_{ab}(m) - t_{ab}(g)\} , \tag{5}$$

where $T_{ab}(m)$ is the energy-stress tensor for massive matter and $t_{ab}(g)$ is the gravitational energy-stress tensor. In the modified eq. (5) the extended universal coupling is violated since the coupling of tensor $t_{ab}(g)$ has a different sign. When gravity is weak, tensor $t_{ab}(g)$ is of second order of deviations from the flat metric. It is also concluded that only for weak and stationary gravity, the linearization of eq. (2) is valid in mathematics. Thus, the eq. (2) is only an approximation of eq. (5) for the case of stationary and weak gravity.

The confirmation of the antigravity coupling means that the exended Newtonian universal coupling is <u>not</u> generally valid. Therefore, experimental tests of the couplings for each type of energy would be necessary.

One may ask does the accurate equivalence of masses from different kinds of matter [4,13-15] constrain the gravity coupling to electromagnetism? Obviously, the answer is yes because of the electromagnetic structure of matter. On the other hand, in terms of gravity, energy and mass may not be equivalent unless they are related to the same form of energy-stress tensor. Thus, if gravity of matter is due to the resulting mass, general relativity would require some cancelations among diverse gravitational effects, in particular those violate mass equivalence, from different types of energy in matter. Such cancellations make simple minded modeling almost impossible. Thus, without a thorough understanding of all the interactions involved, it would be very difficult to determine such constraints quantitatively in theory.

Moreover, one might ask whether general relativity is consistent with special relativity from which eq.

(1) is derived. According to Einstein's clarification [1], eq. (1) is not a general relationship for the equivalence between mass and any type of energy, since E is the total energy of a particle. The interpretation of Einstein's eq. (1) is only that mass can be converted to energy (possibly a certain combination of different energy types). Then, that the electromagnetic energy is not equivalence to rest mass, can still be compatible with eq. (1). For instance, the total energy of an atom includes the nuclear energy. The difficulty between eq. (1) and the inequivalence of electromagnetic energy and mass can be resolved if the nuclear energy is also not equivalent to mass. It is interesting to note that this would require the established fact in physics that the nuclear force must have a small isospin dependence [16].

In summary, the interpretation [6,7] that any type of energy is equivalent to mass is not valid. Experiment supports eq. (2) only as an approximation for the static and weak gravity [8,9,17]. Moreover, since Newtonian universal coupling is not generally valid, investigations on the gravitational effects of different energy types and experimental tests of the coupling constant for each energy type would be necessary.

ACKNOWLEDGEMENTS.

The author gratefully acknowledges stimulating discussions with Benson P. Ho and C.C. Lo. This work is supported in part by Innotec Design, Inc., U.S.A.

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