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Electromagnetic Energy from Gravitation

Summary. The geometric interaction of gravitation and electromagnetism in the Evans field theory is shown to lead to a new cross-current term which does not appear in the standard model, but which is, in theory, an important new source of electromagnetic energy. The structure of the new current term is developed with the Hodge dual of the homogeneous Evans field equation. Such a development shows that the new current term causes a tiny imbalance in the Faraday law of induction and Gauss law of magnetism. This gravitational effect (which does not exist in the standard model) changes the polarization of electromagnetic radiation in free space (or vacuum) and so can be detected in theory by looking for tiny changes in polarization of light grazing the sun in a total eclipse (Eddington type experiment), or in radiation grazing an intensely gravitating object such as a quasar or pulsar. This tests for the relic effect of gravitation on electromagnetism several billion years after the initial expansion event known as "Big Bang". This effect is expected to be very tiny, but very important to new forms of energy. So it must be looked for with the highest possible contemporary precision and the greatest experimental care. It is already possible, however, to amplify this current to useful levels, and reliable devices are available which achieve this aim.

Key words: Evans field theory, homogeneous Evans field equation, Hodge duality, electromagnetic current and energy due to gravitation, Faraday law of induction.

25.1 Introduction

Recently [1]–[30] the first objective (i.e. generally covariant) unified field theory has been developed based on differential geometry. The theory is known as the Evans unified field theory [31] (or simply as Evans field theory), an appellation intended to distinguish it from the standard model. It is already generally accepted [31], and for good reason, that the Evans field theory is a major advance from the standard model, bringing with it some important new technologies. In this note the homogeneous equation of the Evans field theory is developed into its Hodge dual [32, 33] in order to analyse a new current term which does not appear in the standard model, but which is in theory an important new source of electromagnetic energy from spacetime. In Section 25.2 the Hodge dual equation is deduced in tensor notation and written out in vector notation, whereupon it becomes clear that the new current causes a tiny imbalance of gravitational origin in the Faraday law of induction and the Gauss law of magnetism. In Section 25.3 suggestions are given for an experimental test of the theory by looking for tiny changes in polarization in electromagnetic radiation reaching a space or earthbound telescope/polarimeter after grazing the sun in a total eclipse (Eddington type of experiment) or after grazing an intensely gravitating object such as a quasar or pulsar in deep space.

25.2 Development of the Hodge Dual of the Homogeneous Equation of Evans Field Theory

In developing the Hodge dual [32, 33] some important mathematical details must be noted, because the development is taking place in a general four dimensional manifold (non-Minkowski spacetime). The starting point must therefore be the rigorous definition [32] of the Hodge dual in general relativity for the n dimensional manifold. The Hodge dual is obtained from the homogeneous Evans field equation [1, 30] in differential form notation:

$$d \wedge F^a = \mu_0 j^a \tag{25.1}$$

where $D\wedge$ is the covariant exterior derivative, F^a is the vector valued electromagnetic field two-form, j^a is the vector valued charge-current density three-form, and μ_0 is the S.I. permeability in vacuo. The current in Eq. (25.1) is defined by the wedge product [32]

$$j^a = \frac{1}{\mu_0}\left(R^a{}_b \wedge A^b - \omega^a{}_b \wedge F^b\right) \tag{25.2}$$

where $R^a{}_b$ is the tensor-valued Riemann or curvature two-form [32] and where A^b is the vector valued potential one-form. The latter is defined by the vector-valued tetrad one-form as follows [1, 30]:

$$A^b = A^{(0)} q^b \tag{25.3}$$

where $A^{(0)}$ is a C negative scalar with the units of the electromagnetic potential (tesla meters or webers per metre). As per standard practice [32] in differential geometry only the Latin indices of the tangent spacetime appear in Eqs. (25.1) - (25.3), the Greek indices of the base manifold are always the same on both sides of the equation and so can be omitted for ease of notation [32]. The homogeneous electromagnetic field equation of the standard model is the homogeneous Maxwell-Heaviside equation:

$$d \wedge F = 0. \tag{25.4}$$

In Eq. (25.4) $d\wedge$ is the ordinary (or flat spacetime) exterior derivative, and F is the scalar valued electromagnetic field two-form [32, 33].

It can be seen that there is a new vector-valued current three-form, j^a, present in the Evans field theory, which is a rigorously objective theory of physics. Conversely, in order that physics be a rigorously objective subject, one we can all agree upon, this current term has to be recognised to exist in physics. By inspection of the structure of Eq. (25.1) the new current three-form is non-zero if and only if the Christoffel connection [32] is asymmetric in its lower two indices. If the Christoffel connection is symmetric in its lower two indices the torsion form vanishes, and the Evans field reduces to the Einstein gravitational field. The latter therefore becomes independent of electromagnetism when the Christoffel symbol becomes symmetric. In this limit the Christoffel symbol of the decoupled electromagnetic field can only be anti-symmetric: the electromagnetic field has become self-consistently independent of the gravitational field. It follows that electromagnetism and gravitation can be mutually influential if and only if the Christoffel symbol is asymmetric. This is of basic importance and can be regarded as a new and rigorously objective law of physics. When the two fields are independent the only possibility is:

$$d \wedge F^a = 0, \tag{25.5}$$

$$j^a = \frac{1}{\mu_0}\left(R^a{}_b \wedge A^b - \omega^a{}_b \wedge F^b\right) = 0, \tag{25.6}$$

and the current term in Eq. (25.1) vanishes.

The Evans field theory indicates therefore that this current MAY be non-zero. The Evans field theory does not imply that the current MUST be non-zero, only experiment can distinguish between these two theoretical possibilities. However the Evans field theory implies objectively and geometrically that the electromagnetic field must be a vector-valued two-form, F^a, not a scalar valued two-form,F, as in the standard model. This means that we must reject the standard model as being unobjective and incomplete. An early sign of this incompleteness was the inference [34] of the fundamental Evans spin field, denoted $\boldsymbol{B}^{(3)}$, whose origin is now understood [1, 30] to be the complex circular index $a = (3)$ of the tangent spacetime of Evans field theory. This index does not exist in the standard model, which therefore cannot be used to analyse the Evans spin field, a well known observable [1, 30] of the inverse Faraday effect. Reliable experimental devices are already available which indicate that the current, j^a, is non-zero [35]. These devices produce potentially very important energy savings which cannot be explained qualitatively by Maxwell Heaviside theory, Eq. (25.4). As yet, these devices provide only qualitative indications, but these are important indications for several good reasons, both fundamental and technological. At electronic scales in a circuit taking electromagnetic energy from spacetime the curvature of spacetime becomes very large. Indeed, in the limit of a point electron the scalar curvature is infinite (infinite spacetime compression). So it is not surprising that the new current is significant at electronic scales because it is directly proportional to the Riemann curvature for a given tetrad. These important concepts do not exist in the standard model, and there is no indication in the standard model that electromagnetic energy can be obtained from spacetime.

The general definition of the Hodge dual is given by Carroll [32]:

$$A_{\mu_1 \ldots \mu_{n-p}} = \frac{1}{p!} \epsilon^{\nu_1 \ldots \nu_p}{}_{\mu_1 \ldots \mu_{n-p}} A_{\nu_1 \ldots \nu_p} \tag{25.7}$$

Eq. (25.7) maps from a p-form of differential geometry to an (n-p)-form in a general n dimensional manifold. The general Levi-Civita symbol is defined [32] in any manifold to be:

$$\widetilde{\epsilon}_{\mu_1 \mu_2 \ldots \mu_n} = \begin{cases} 1 \text{ if } \mu_1 \mu_2 \ldots \mu_n \text{ is an even permutation} \\ -1 \text{ if } \mu_1 \mu_2 \ldots \mu_n \text{ is an odd permutation} \\ 0 \quad \text{otherwise} \end{cases} \tag{25.8}$$

The Levi-Civita tensor used in the definition of the Hodge dual is however [32]:

$$\epsilon_{\mu_1 \mu_2 \ldots \mu_n} = (|g|)^{1/2} \, \widetilde{\epsilon}_{\mu_1 \mu_2 \ldots \mu_n} \tag{25.9}$$

where $|g|$ is the numerical magnitude of the determinant of the metric. This procedure is necessary to define a valid tensor, Eq. (25.9), whose indices can be raised or lowered using the metric tensor for the general manifold. These mathematical details are important for numerical computation of the Evans equation (25.1). In the general manifold the metric and inverse metric tensors are defined by the Kronecker delta:

$$g^{\mu\nu} g_{\nu\sigma} = \delta^{\mu}_{\sigma} \tag{25.10}$$

Tensor operations such as contraction, symmetrization, and so on are unchanged in the general manifold from their equivalents in Minkowski spacetime, but in the general manifold the tensor $g^{\mu\nu}$ is not the same as the tensor $g_{\nu\sigma}$, and as we have just argued, the Levi-Civita symbol is not the same. These details can however be easily coded into a form that can be used routinely to evaluate the new current by computation. In this way the amount of electromagnetic energy available from spacetime can be estimated in a given circuit design.

In order to clarify the meaning of Eq. (25.7) some examples are given as follows.

1. In a three dimensional manifold (space) a one-form is the Hodge dual of a two-form. This is the well known result that an axial vector is dual to an

antisymmetric tensor. However, it seems not to be well known that this result is true for the general three dimensional space as well as Euclidean or flat three dimensional space. From Eq. (25.7) we obtain:

$$^*A_{\mu_1} = \frac{1}{2!}\epsilon^{\nu_1\nu_2}{}_{\mu_1}A_{\nu_1\nu_2} \tag{25.11}$$

when $p = 2, n = 3$. Re-labelling indices we obtain:

$$^*A_\rho = \frac{1}{2}\epsilon^{\nu\mu}{}_\rho A_{\nu\mu}. \tag{25.12}$$

Eq. (25.12) is the generalization to non-Euclidean space of the familiar Euclidean:

$$^*A_k = \frac{1}{2}\epsilon^{ij}{}_k A_{ij}. \tag{25.13}$$

2. In a four-dimensional manifold a one-form is dual to a three-form:

$$^*A_{\mu_1} = \frac{1}{3!}\epsilon^{\nu_1\nu_2\nu_3}{}_{\mu_1}A_{\nu_1\nu_2\nu_3} \tag{25.14}$$

or:

$$^*A_\mu = \frac{1}{6}\epsilon^{\mu\rho\sigma}{}_\mu A_{\nu\rho\sigma} \tag{25.15}$$

with $n = 4, p = 3$.

3. In a four-dimensional manifold a three-form is dual to a one-form:

$$^*A_{\mu_1\mu_2\mu_3} = \epsilon^{\nu_1}{}_{\mu_1\mu_2\mu_3}A_{\nu_1} \tag{25.16}$$

or

$$^*A_{\mu\nu\rho} = \epsilon^\sigma{}_{\mu\nu\rho}A_\sigma \tag{25.17}$$

with $n = 4, p = 1$.

4. In a four-dimensional manifold a two-form is dual to a two-form:

$$^*A_{\mu_1\mu_2} = \frac{1}{2}\epsilon^{\nu_1\nu_2}{}_{\mu_1\mu_2}A_{\nu_1\nu_2} \tag{25.18}$$

or

$$^*A_{\mu\nu} = \frac{1}{2}\epsilon^{\rho\sigma}{}_{\mu\nu}A_{\rho\sigma} \tag{25.19}$$

with $n = 4, p = 2$.

The indices in the Levi-Civita tensor defined by Eq,. (25.9) are raised or lowered with the appropriate metric tensor of the general manifold, for example:

$$\epsilon_{\sigma\mu\nu\rho} = g_{\sigma\kappa}\epsilon^\kappa{}_{\mu\nu\rho} \tag{25.20}$$

This is an important difference from the Levi-Civita tensor of Minkowski spacetime, but here again computer code is easily written provided that the mathematical fundamentals are precisely defined. Some important inferences can be made without resorting to computation.

Eq. (25.1) in tensor notation is [1, 30, 32]:

$$\partial_\mu F^a{}_{\nu\rho} + \partial_\nu F^a{}_{\rho\mu} + \partial_\rho F^a{}_{\mu\nu} = \mu_0 \left(j^a{}_{\mu\nu\rho} + j^a{}_{\nu\rho\mu} + j^a{}_{\rho\mu\nu} \right) . \tag{25.21}$$

This is ideal for computation, but the equivalent Hodge dual equation, which we develop as follows, is ideal for physical inference. Using Eq. (25.15):

$$\begin{aligned} {}^*j^a{}_\sigma &= \frac{1}{6}\epsilon^{\mu\nu\rho}{}_\sigma j^a{}_{\mu\nu\rho} \\ &= \frac{1}{6}\epsilon^{\nu\rho\mu}{}_\sigma j^a{}_{\nu\rho\mu} \\ &= \frac{1}{6}\epsilon^{\rho\mu\nu}{}_\sigma j^a{}_{\rho\mu\nu} \end{aligned} \tag{25.22}$$

so the Hodge dual of the right hand side of Eq. (25.21) is $3_{\mu_0}{}^*j^a{}_\rho$. This Hodge dual current is a vector valued one-form. Similarly the Hodge dual of the left hand side of Eq. (25.21) is found using Eq. (25.19):

$$\begin{aligned} {}^*F^a{}_{\mu\sigma} &= \frac{1}{2}\epsilon^{\nu\rho}{}_{\mu\sigma} F^a{}_{\nu\rho} , \\ {}^*F^a{}_{\nu\sigma} &= \frac{1}{2}\epsilon^{\rho\mu}{}_{\nu\sigma} F^a{}_{\rho\mu} , \\ {}^*F^a{}_{\rho\sigma} &= \frac{1}{2}\epsilon^{\mu\nu}{}_{\rho\sigma} F^a{}_{\mu\nu} . \end{aligned} \tag{25.23}$$

It follows that

$$\begin{aligned} \partial^\mu \ {}^*F^a{}_{\mu\sigma} &= \frac{1}{2}\partial^\mu \left(\epsilon^{\nu\rho}{}_{\mu\sigma} F^a{}_{\nu\rho} \right) , \\ \partial^\nu \ {}^*F^a{}_{\nu\sigma} &= \frac{1}{2}\partial^\nu \left(\epsilon^{\rho\mu}{}_{\nu\sigma} F^a{}_{\rho\mu} \right) , \\ \partial^\rho \ {}^*F^a{}_{\rho\sigma} &= \frac{1}{2}\partial^\rho \left(\epsilon^{\mu\nu}{}_{\rho\sigma} F^a{}_{\mu\nu} \right) . \end{aligned} \tag{25.24}$$

and re-arranging dummy indices it follows that the Hodge dual of the left hand side of Eq. (25.21) is $3\partial^\mu \ {}^*F^a{}_{\mu\sigma}$. Therefore the complete Hodge dual equation is found to be:

$$\partial^\mu \ {}^*F^a{}_{\mu\nu} = \mu_0 \ {}^*j^a{}_\nu . \tag{25.25}$$

In field theory the Hodge dual is written with a tilde instead of an asterisk so we obtain:

$$\partial^\mu \widetilde{F}^a{}_{\mu\nu} = \mu_0 \widetilde{j}^a{}_\nu . \tag{25.26}$$

The equivalent equation in the standard model is well known [1],[30, 32], [33] to be:

$$\partial^\mu \widetilde{F}_{\mu\nu} = 0 \tag{25.27}$$

Eq. (25.27) is a combination of the Gauss law of magnetism and the Faraday law of induction:

$$\nabla \cdot \boldsymbol{B} = \boldsymbol{0}, \tag{25.28}$$

$$\nabla \times \boldsymbol{E} + \frac{\partial \boldsymbol{B}}{\partial t} = \boldsymbol{0} \tag{25.29}$$

The Evans field theory is more richly structured, notably, the presence of the tangent spacetime index a means that there are more states of polarization and more field components than in the standard model. One of these polarization states or fields is the Evans spin field observed in the inverse Faraday effect [1, 30]. The vector structure of Eq. (25.26) is as follows:

$$\nabla \cdot \boldsymbol{B}^a = \mu_0 \widetilde{j}_0^a, \tag{25.30}$$

$$\nabla \times \boldsymbol{E}^a + \frac{\partial \boldsymbol{B}^a}{\partial t} = c\mu_0 \widetilde{\boldsymbol{j}}^a, \tag{25.31}$$

so there is an additional charge density due to gravitation in the Gauss law of magnetism and an additional current density due to gravitation in the Faraday law of induction. It may be deduced that in the presence of gravitation, the circular polarization of an electromagnetic wave is changed because the right hand sides of Eqs. (25.30) and (25.31) are no longer zero. In other words circularly polarized solutions of Eqs (25.28) and (25.29) are no longer true for Eqs. (25.30) and (25.31). This deduction assumes, of course, that j of Eq. (25.1) is non-zero, and this can only be determined experimentally. The existence of reliable devices as described already strongly suggests, however, that j^a is non-zero.

25.3 Eddington Type Experiment

In order to observe the expected changes in circular polarization predicted theoretically in section 25.2 a source of intense gravitation is needed to maximize the cross-current j^a. Then changes in polarization are observed in theory in electromagnetic radiation grazing this source of gravitation. One such possibility is to look for polarization changes in light grazing the sun during a total eclipse. The instrument needed for this observation is a high accuracy polarimeter mounted on a telescope: either a space telescope or an earthbound telescope. The polarization of light grazing the sun would be compared with the polarization of light from the same source but in the absence of the gravitating object, in this case the sun. The experiment could be repeated for electromagnetic radiation reaching the earth from a source with an intervening intense gravitational field, such as that of a quasar or pulsar. Several variations on this experiment are possible in contemporary cosmology, in each case the objective of the experiment would be to evaluate the effect of gravitation on the polarization of electromagnetic radiation.

Other types of experiments have been suggested recently [36] in order to look for the mutual effects of gravitation and electromagnetism. The governing principle of each experiment is to initially balance a given design and to look for changes in the balance with high precision apparatus. For example to look for changes in a high precision gravimeter due to intense pulses of electromagnetic radiation. On an electronic scale in a given circuit design, we expect to see significant effects, as argued already in Section 25.2.

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