Chapter 6

The Coulomb And Ampère-Maxwell Laws In The Schwarzschild Metric, A Classical Calculation Of The Eddington Effect From The Evans Unified Field Theory

by
Myron W. Evans,
Alpha Foundation's Institutute for Advance Study (AIAS).
(emyrone@oal.com, www.aias.us, www.atomicprecision.com)

Abstract

The Schwarzschild metric is used in the Evans unified field theory to calculate the slowing of the speed of light and angle of deflection of light by a gravitating object such as the sun. Thus, Einsteins well known gravitational explanation of this effect in terms of the photon mass is completed within the context of a unified field theory in which electromagnetism is considered to be at once particulate and undulatory.

Key words: Evans unified field theory; gravitational lensing; diffraction of light

by gravitation; Eddington experiment; Schwarzschild metric.

6.1 Introduction

The diffraction of electromagnetism by gravitation appears to be precisely explained for the sun and some stars by the Einstein/Hilbert gravitational theory of general relativity [1]. The theory is however incomplete, as Einstein pointed out, because it does not involve classical electromagnetism. In consequence there are anomalous gravitational shifts which cannot be explained by the Einstein Hilbert theory [2]. The latter explanation is based on the gravitational attraction of the photon by the sun, and was originally verified by Eddington et al. [3]. In this paper the diffraction of electromagnetic waves by mass is calculated both in classical electrodynamics and with the Einstein/Hilbert theory using the Evans unified field theory [4]– [10]. The structure of the latter theory is based solidly on universally accepted Cartan differential geometry [11], the homogeneous and inhomogeneous equations of classical electrodynamics being derived from the first Bianchi identity. The relation between the potential and the field is derived from the first Cartan structure equation, and all the wave equations of physics are derived from Cartans tetrad postulate, which links Cartan differential geometry to Riemann geometry and which is a universally accepted fact of geometry like the Pythagoras Theorem.

The Coulomb and Ampère-Maxwell laws from the Evans unified field theory are set up in Section 6.2, the charge current density being calculated using the Schwarzschild metric for the sake of illustration. Other metrics can be used if preferred. In Section 3 the slowing of the speed of light by the suns gravitational attraction is calculated straightforwardly with the Einstein/Hilbert field theory directly from the Schwarzschild metric and the result is compared with that of Newtonian dynamics. This is part of the Evans unified field theory, which reduces to the Einstein/Hilbert field theory when the torsion form of Cartan vanishes [4]– [10]. Another part of the Evans field theory is then used to calculate straightforwardly the refraction expected in classical electrodynamics by the slowing of the speed of light. This is a first qualitative calculation using the suns equatorial radius, a calculation which may refined and extended within the context of the unified field theory.

6.2 The Coulomb and Ampère-Maxwell Laws From The Unified Field Theory

The Coulomb and Ampère-Maxwell laws in the unified field theory are derived from the first structure equation of Cartan:

$$T^a = D \wedge q^a \tag{6.1}$$

and the first Bianchi identity:

$$D \wedge T^a = R^a{}_b \wedge q^b. \tag{6.2}$$

Here $D\wedge$ denotes the covariant exterior derivative:

$$D\wedge = d\wedge + \omega^a{}_b\wedge \tag{6.3}$$

where $d\wedge$ is the exterior derivative of Cartan. In Eq.(6.3) $\omega^a{}_b$ is the spin connection, T^a is the torsion form, and $R^a{}_b$ is the Riemann form. Eqs.(6.1) and (6.2) become the homogeneous field equations using the basic ansatz:

$$A^a = A^{(0)} q^a \tag{6.4}$$

where $A^{(0)}$ is a primordial quantity with the units of volt sm^{-1}, and A^a is the vector potential of the unified field theory, a vector valued one-form.

The antisymmetric field tensor of the unified field theory is a vector-valued two form which is derived from the potential using the Cartan structure equation:

$$\begin{aligned} d\wedge F^a = \mu_0 j^a &= -A^{(0)}\left(q^b \wedge R^a{}_b + \omega^a{}_b \wedge T^b\right), \\ F^a &= d\wedge A^a + \omega^a{}_b \wedge A^b. \end{aligned} \tag{6.5}$$

Therefore electrodynamics becomes a geometrically based theory as required by the basic philosophy of general relativity. Finally the temporal and spatial dependence of the electromagnetic field tensor is determined by the first Bianchi identity of differential geometry:

$$\begin{gathered} D\wedge T^a = R^a{}_b \wedge q^b \\ \downarrow \\ D\wedge F^a = R^a{}_b \wedge A^b \end{gathered} \tag{6.6}$$

This equation is the homogeneous field equation (HE) of the Evans unified field theory and the current j^a is the homogeneous current. The HE is a condensed version of the Gauss law applied to magnetism and of the Faraday law of induction, which are known to hold to high precision in the laboratory. The experimental data in the laboratory therefore [4]– [10] imply that there is no interaction between gravitation and electromagnetism measurable by the Gauss and Faraday laws in the laboratory, i.e. the homogeneous current vanishes within instrumental precision in the laboratory:

$$j^a \sim 0. \tag{6.7}$$

However in a cosmological context gravitational fields may become very intense, and the homogeneous current is non-zero in general.

The inhomogeneous field equation (IE) of the Evans unified field theory is obtained by Hodge dual transformation [4]– [10] of the HE, giving:

$$d\wedge \widetilde{F}^a = \mu_0 J^a = -A^{(0)}\left(q^b \wedge \widetilde{R}^a{}_b + \omega^a{}_b \wedge \widetilde{T}^b\right) \tag{6.8}$$

The IE is a condensed summary of the properly covariant inhomogeneous laws of electrodynamics, the Coulomb and Ampère-Maxwell laws. In general the inhomogeneous current J^a is made up of both spacetime curvature and torsion, reflecting the interaction of electromagnetism and gravitation. In order to describe gravitational lensing in general, the HE and IE must be solved simultaneously with given initial and boundary conditions. This is in general a problem for the computer.

However, if a minimal prescription is used, i.e. if it is assumed [4]– [10] that the electromagnetic geometry of the IE is described by:

$$\left(q^b \wedge \widetilde{R}^a{}_b + \omega^a{}_b \wedge \widetilde{T}^b\right)_{e/m} = 0 \tag{6.9}$$

then the IE reduces to:

$$d \wedge \widetilde{F}^a = -A^{(0)} \left(q^b \wedge \widetilde{R}^a{}_b\right)_{grav} . \tag{6.10}$$

Eq.(6.10) is a combination of the Coulomb Law:

$$\nabla \cdot \mathbf{E}^0 = -\phi^{(0)} \left(R^0{}_1{}^{10} + R^0{}_2{}^{20} + R^0{}_3{}^{30}\right) \tag{6.11}$$

where

$$\mathbf{E}^0 = E^0_x \mathbf{i} + E^0_y \mathbf{j} + E^0_z \mathbf{k} \tag{6.12}$$

and the Ampère-Maxwell law

$$\nabla \times \mathbf{B}^a = \frac{1}{c^2} \frac{\partial \mathbf{E}^a}{\partial t} + \mu_0 \mathbf{J}^a \tag{6.13}$$

where the components of the current term are given by:

$$J^1_x = -\frac{A^{(0)}}{\mu_0} \left(R^1{}_0{}^{10} + R^1{}_2{}^{12} + R^1{}_3{}^{13}\right) \tag{6.14}$$

$$J^2_y = -\frac{A^{(0)}}{\mu_0} \left(R^2{}_0{}^{20} + R^2{}_1{}^{21} + R^2{}_3{}^{23}\right) \tag{6.15}$$

$$J^3_z = -\frac{A^{(0)}}{\mu_0} \left(R^3{}_0{}^{30} + R^3{}_1{}^{31} + R^3{}_2{}^{32}\right) . \tag{6.16}$$

The electric and magnetic fields appearing in the Ampère-Maxwell law are:

$$\mathbf{E}^a = E^1_x \mathbf{i} + E^2_y \mathbf{j} + E^3_z \mathbf{k}, \tag{6.17}$$

$$\mathbf{B}^a = B^1_x \mathbf{i} + B^2_y \mathbf{j} + B^3_z \mathbf{k}. \tag{6.18}$$

In order to proceed in this minimal approximation the Riemann elements appearing in equations (6.11) to (6.18) must be calculated for a given metric such as the Schwarzschild metric [12] (SM). The SM is well known to be the first solution discovered of the Einstein/Hilbert field equation of 1915 - the spherically symmetric solution to:

$$G_{\mu\nu} = 0 \tag{6.19}$$

and known as the vacuum solution. Here $G_{\mu\nu}$ is the Einstein field tensor. The SM therefore describes the spacetime around a gravitating mass of any kind. In the Eddington experiment this is the sun of mass M and in general relativity M is a parameter of curved spacetime. The SM is a metric solution corresponding to the Riemann geometry used by Einstein and Hilbert. In the notation of differential geometry this is:

$$R^a{}_b \wedge q^b = 0 \tag{6.20}$$

$$T^a = 0 \tag{6.21}$$

$$\widetilde{R}^a{}_b \wedge q^b \neq 0 \tag{6.22}$$

Eq.(6.20) is the first Bianchi identity of Riemann geometry used by Einstein and Hilbert. The identity is true if and only if the connection is symmetric in its lower two indices: if and only if the torsion tensor vanishes. It is this geometry that was used by Einstein in his explanation of the Eddington experiment [13]. The explanation by Einstein [13] was based on the gravitational attraction of a photon of mass m a distance r from the sun of mass M. This is a purely dynamical explanation without reference to classical electromagnetism. In this paper we give a fuller explanation than Einstein/Hilbert in terms of generally covariant unified field theory [4]– [10].

The SM is given in spherical polar coordinates by [11, 12]:

$$\begin{aligned} ds^2 = \left(1 - 2\frac{GM}{rc^2}\right)(cdt)^2 - \left(1 - 2\frac{GM}{rc^2}\right)^{-1} dr^2 \\ -r^2 d\theta^2 - r^2 \sin^2\theta d\phi^2 \end{aligned} \tag{6.23}$$

where G is Newtons universal gravitational constant and where c is the speed of light, a universal constant. The velocity v_0 of an object in orbit around the sun is given in the frame of the observer by:

$$v_0 = \frac{dr}{dt} = \frac{\left(1 - 2\frac{GM}{rc^2}\right)^{1/2}}{\left(1 - 2\frac{GM}{rc^2}\right)^{-1/2}} \frac{dr'}{dt'} = \left(1 - 2\frac{GM}{rc^2}\right)_{v'}. \tag{6.24}$$

For a photon:

$$v_0 = \left(1 - 2\frac{GM}{rc^2}\right)c. \tag{6.25}$$

Therefore the photon appears to be slowed by:

$$\frac{v_0}{c} = 1 - 2\frac{GM}{rc^2}. \tag{6.26}$$

From this result the observed diffraction of light by the sun can be calculated with the general relativistic theory of gravitation of Einstein and Hilbert. The Evans theory reduces to this theory when:

$$q^b \wedge R^a{}_b + \omega^a{}_b \wedge T^b \longrightarrow 0 \tag{6.27}$$

$$T^a \longrightarrow 0, \tag{6.28}$$

so the Einstein/Hilbert field theory is a well defined limit of the Evans unified field theory [4]– [10], a limit in which classical electrodynamics is not considered at all.

Einsteinś explanation of the Eddington experiment is accepted because it is repeatable for some stars to within 0.02% uncertainty. The corresponding Newtonian result is calculated from the Newton inverse square law:

$$\mathbf{F} = -\frac{mM}{r^2}\mathbf{k}. \tag{6.29}$$

Integrating Eq.(6.29) we obtain:

$$v^2 = 2\frac{MG}{r}. \tag{6.30}$$

This gives:

$$c^2 - v^2 = (c-v)(c+v) = c^2\left(1 - 2\frac{MG}{rc^2}\right) \tag{6.31}$$

and:

$$\left(c^2 - v^2\right)^{1/2} = c\left(1 - 2\frac{MG}{rc^2}\right)^{1/2} \tag{6.32}$$

If $v << c$ then:

$$v_0 = c - \frac{v}{2} \sim \left(1 - \frac{mG}{rc^2}\right)c. \tag{6.33}$$

Therefore the Newtonian result is half the result from the Schwarzschild metric.

6.3 Refraction Of Electromagnetic Radiation By Gravitation

It is first shown that the elements of the Riemann tensor appearing in equations (6.11) to (6.16) are self-consistently the non-vanishing elements of the Riemann tensor from the Schwarzschild metric. These elements are:

$$\begin{aligned} R^0{}_{101} = \;& e^{2(\beta-\alpha)}\left[\partial_0^2\beta + (\partial_0\beta)^2 - \partial_0\alpha\partial_0\beta\right] \\ & + \left[\partial_1\alpha\partial_1\beta - \partial_1^2\alpha - (\partial_1\alpha)^2\right] \end{aligned} \tag{6.34}$$

$$R^1{}_{212} = \; re^{-2\beta}\partial_1\beta/r^2 \tag{6.35}$$

$$R^1{}_{313} = \; \left(1 - e^{-2\beta}\right)\sin^2\theta/r^2 \tag{6.36}$$

$$R^2{}_{323} = \; \left(1 - e^{-2\beta}\right)\sin^2\theta/r^2 \tag{6.37}$$

$$R^0{}_{202} = \; -re^{-2\beta}\partial_1\alpha/r^2 \tag{6.38}$$

$$R^0{}_{303} = \; -re^{-2\beta}\sin^2\theta\partial_1\alpha/r^2. \tag{6.39}$$

(Note that in ref. [12] these elements are given incorrectly in an otherwise useful book.) In the notation of Eqs.(6.34)–(6.39):

$$e^{2\alpha} = e^{-2\beta} = 1 - 2\frac{GM}{rc^2}. \tag{6.40}$$

Furthermore:

$$\partial_0\beta = 0, \quad \partial_0\partial_1\alpha = 0, \tag{6.41}$$

$$e^{2\alpha}\left(2r\partial_1\alpha + 1\right) = 1, \tag{6.42}$$

$$\partial_1\alpha + \partial_1\beta = 0. \tag{6.43}$$

From Eq.(6.42):

$$\partial_1\alpha = \frac{1}{2r}\left(e^{-2\alpha} - 1\right) \tag{6.44}$$

therefore:

$$\begin{aligned} R^0{}_{202} &= -re^{-2\beta}\frac{1}{2r}\left(e^{-2\alpha} - 1\right)/r^2 \\ &= -\frac{GM}{c^2r^3}. \end{aligned} \tag{6.45}$$

It follows that:

$$R^0{}_{303} = R^0{}_{202}\sin^2\theta \tag{6.46}$$

in the spherical polar coordinate system. Therefore:

$$R^0{}_{202} + R^0{}_{303} = -\frac{GM}{c^2r^3}\left(1 + sin^2\theta\right). \tag{6.47}$$

The $R^0{}_{101}$ element is given by:

$$R^0{}_{101} = e^{-4\alpha}\left(-\left(\partial_1\alpha\right)^2 - \partial_1^2\alpha - \left(\partial_1\alpha\right)^2\right) \tag{6.48}$$

where:

$$\partial_1\alpha = \frac{1}{2r}\left(\frac{1}{1 - 2\frac{GM}{rc^2}} - 1\right). \tag{6.49}$$

In the weak field limit

$$M \longrightarrow 0 \tag{6.50}$$

and the inverse square law of Newton must be obtained. In the weak field limit the Schwarzschild metric reduces to the Minkowski metric:

$$ds^2 = c^2dt^2 - dr^2 - r^2d\theta^2 - r^2\sin^2\theta d\phi^2 \tag{6.51}$$

of special relativity. The Newtonian limit of special relativity is the one where $v << c$, in which case the scalar curvature reduces to:

$$R = -2\frac{GM}{c^2r^3}. \tag{6.52}$$

Also in the limit of special relativity it is possible to raise and lower indices with the Minkowski metric, so we obtain:

$$R^{0}{}_{2}{}^{02} = \eta^{00}\eta^{22}R^{0}{}_{202} = -R^{0}{}_{202} \tag{6.53}$$

$$R^{0}{}_{3}{}^{03} = \eta^{00}\eta^{33}R^{0}{}_{303} = -R^{0}{}_{303}. \tag{6.54}$$

By antisymmetry:

$$R^{0}{}_{2}{}^{20} = -R^{0}{}_{2}{}^{02} = R^{0}{}_{202} \tag{6.55}$$

$$R^{0}{}_{3}{}^{30} = -R^{0}{}_{3}{}^{03} = R^{0}{}_{303} \tag{6.56}$$

and so:

$$R^{0}{}_{2}{}^{20} + R^{0}{}_{3}{}^{30} = -\frac{GM}{c^2 r^3}\left(1 + \sin^2\theta\right). \tag{6.57}$$

If we choose

$$\phi = \frac{\pi}{2}, \quad \theta = \frac{\pi}{2} \tag{6.58}$$

in the spherical polar coordinate system then the vector points along the y axis and:

$$R^{0}{}_{2}{}^{20} + R^{0}{}_{3}{}^{30} = -2\frac{GM}{c^2 r^3}. \tag{6.59}$$

Finally the Newton inverse square law is obtained from:

$$\nabla \cdot \mathbf{g} = -c^2\left(R^{0}{}_{2}{}^{20} + R^{0}{}_{3}{}^{30}\right) = -2\frac{GM}{r^3} \tag{6.60}$$

assuming that

$$R^{0}{}_{1}{}^{10} \longrightarrow 0 \tag{6.61}$$

in the weak field limit. From Eq.(6.60) we obtain:

$$\mathbf{g} = \frac{\mathbf{F}}{m} = -\frac{GM}{r^2}\mathbf{k} \tag{6.62}$$

which is the Newton inverse square law:

$$\mathbf{F} = -\frac{GmM}{r^2}\mathbf{k}. \tag{6.63}$$

Eq.(6.60) can be expressed as:

$$\nabla \cdot \mathbf{g} = -G\rho_m = -6.67 \times 10^{-11}\rho_m \tag{6.64}$$

and the Coulomb inverse square law as:

$$\nabla \cdot \mathbf{E}^0 = -\frac{1}{\epsilon_0}\rho_e = -1.129 \times 10^{11}\rho_e. \tag{6.65}$$

Here $\mathbf{g}$ is the acceleration due to gravity, ρ_{m_0} is the mass density in kgm^{-3}, is the charge density in Cm^3. In Eq.(6.65) $\mathbf{E}$ is the electric field strength in volt m^{-1} and ϵ_0 is the vacuum permittivity. From these well known equations it is clear that the electric field is twenty two orders of magnitude stronger in an earthbound laboratory than g for unit ρ_m and ρ_e. In the Evans field theory these laws are unified in terms of the scalar curvature R as follows:

$$\nabla \cdot \mathbf{E}^0 = -\frac{1}{\epsilon_0}\rho_e = -\phi^{(0)}R \tag{6.66}$$

$$\nabla \cdot \mathbf{g} = -G\rho_m = -c^2 R. \tag{6.67}$$

Here $\phi^{(0)}$ is a fundamental voltage, c is the speed of light in vacuo, and R is scalar curvature in inverse square metres. Therefore unification is achieved in terms of geometry, represented by scalar curvature R. This is the curvature of spacetime. The notions of mass density and charge density are replaced by geometry of spacetime.

The basic structure of Eqs.(6.66) and (6.67) is clear, but their interpretation requires reference to experimental data as follows.

If we use the Newtonian curvature R of Eq.(6.59) we obtain the Newton inverse square law (6.63) and also the Coulomb inverse square law:

$$\nabla \cdot \mathbf{E}^0 = 2\phi^{(0)}\frac{GM}{c^2 r^3} \tag{6.68}$$

from which the static electric field is given by:

$$\mathbf{E}^0 = \frac{\mathbf{F}}{e_1} = -\phi^{(0)}\frac{GM}{c^2 r^2}. \tag{6.69}$$

However, the Newton and Coulomb inverse square laws originate in different aspects of geometry. The former originates in curvature and the latter in torsion. The Newton law is obtained from the differential geometry:

$$q^b \wedge \widetilde{R}^a{}_b \neq 0 \tag{6.70}$$

$$T^a = 0 \tag{6.71}$$

with the constraints:

$$q^b \wedge R^a{}_b = 0 \tag{6.72}$$

$$D \wedge \omega^a{}_b = 0. \tag{6.73}$$

The Newton law is obtained from Eq.(6.70), which translates into Eq.(6.10) in the Schwarzschild metric. If it is assumed that there is a quantity $\mathbf{g}$ defined by R according to Eq.(6.67) then the inverse square law of Newton follows as Eqs.(6.62) and (6.63). The Newton law also follows, self-consistently, from the Evans wave equation in the non-relativistic limit. The quantity $\mathbf{g}$ may therefore be identified as the acceleration due to gravity.

The Coulomb law on the other hand is obtained from the geometry:

$$T^a \neq 0 \tag{6.74}$$

$$d \wedge \widetilde{T}^a \sim -q^b \wedge \widetilde{R}^a{}_b \tag{6.75}$$

which is an approximation to the IE [4]– [10]. It is seen that the spacetime torsion is zero in the Newton law and non-zero in the Coulomb law. However both laws have an inverse square dependence because both depend on scalar curvature R. The geometrical quantity common to both laws is $\widetilde{R}^a{}_b \wedge q^b$. In the Schwarzschild metric this gives Eq.(6.52). Therefore from Eq.(6.69) the force between two charges is:

$$\mathbf{F} = -\frac{e_1}{r^2}\left(\phi^{(0)}\frac{GM}{c^2}\right)\mathbf{k} = \frac{e_1 e_2}{4\pi\epsilon_0 r^2}\mathbf{k}. \tag{6.76}$$

By convention the Coulomb law of electrostatics is written without a minus sign and with a factor 4π in the denominator. The Newton inverse square law of dynamics is written with a minus sign.

From Eq.(6.76) we may express e_2 in terms of the parameter M:

$$e_2 = -\frac{4\pi\epsilon_0 G\phi^{(0)}M}{c^2} = -8.25 \times 10^{-38}\phi^{(0)}M \tag{6.77}$$

using:

$$\begin{aligned} 4\pi\epsilon_0 &= 1.112650 \times 10^{-10} J^{-1}C^2 m^{-1} \\ G &= 6.67 \times 10^{-11} m^3 kg^{-1} s^{-2} \\ c &= 2.997925 \times 10^8 ms^{-1}. \end{aligned} \tag{6.78}$$

Eq.(6.77) is a fundamental result which shows that charge in general relativity originates in spacetime. Eq.(6.77) means that for unit $\phi^{(0)}$ it takes 10^{38} units of mass to be equivalent to one unit of charge. This result has also been obtained self-consistently from the Evans wave equation [4]– [10]. The interpretation of this result is that in order for electromagnetism and gravitation to be mutually influential to any significant degree the homogeneous current j^a must be non-zero:

$$j^a = -\frac{A^{(0)}}{\mu_0}\left(\omega^a{}_b \wedge T^b + q^b \wedge R^a{}_b\right) \neq 0. \tag{6.79}$$

In the laboratory the Newton and Coulomb inverse square laws hold to within contemporary experimental precision so the interaction of gravitation and electromagnetism must be sought for in other ways. It is insufficient simply to change mass M in Eq.(6.77). If two charged objects of mass m and M are investigated in the laboratory then changing M has no effect on the Coulomb law to within experimental precision. This result means that the product $\phi^{(0)}M$ is a constant in the Coulomb law. Similarly, changing a charge on one of the two masses will have no effect on the Newton inverse square law. In the approximation used here this experimental fact has already been assumed in using the minimal prescription. In other words this calculation has been carried out in the approximation that the IE can be written as Eq.(6.10). This means that scalar curvature R is given by the Einstein/Hilbert theory and the SM. In this approximation it can be seen from Eq.(6.67) that the electric field has no influence on $\mathbf{g}$, as found experimentally.

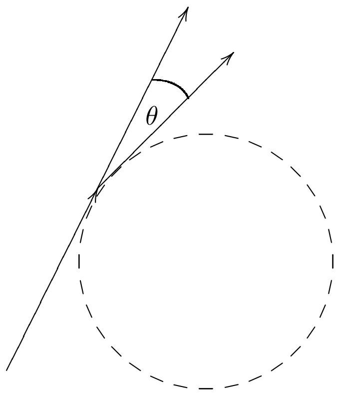

Figure 6.1: Refraction

To obtain such an influence one must use the geometry defined by the most general Bianchi identity of differential geometry [4]– [12]:

$$d \wedge T^a = -\left(\omega^a{}_b \wedge T^b + q^b \wedge R^a{}_b\right) \tag{6.80}$$

$$d \wedge \widetilde{T}^a = -\left(\omega^a{}_b \wedge \widetilde{T}^b + q^b \wedge \widetilde{R}^a{}_b\right). \tag{6.81}$$

In this geometry the torsion and curvature are both non-zero. The corresponding field equations in this geometry are:

$$d \wedge F^a = -A^{(0)}\left(\omega^a{}_b \wedge T^b + q^b \wedge R^a{}_b\right) \tag{6.82}$$

$$d \wedge \widetilde{F}^a = -A^{(0)}\left(\omega^a{}_b \wedge \widetilde{T}^b + q^b \wedge \widetilde{R}^a{}_b\right). \tag{6.83}$$

Only in this situation will electromagnetism have any effect on gravitation and vice-versa. The Newton and Coulomb inverse square laws are only approximations to these more general laws. The approximation is excellent in the laboratory but not in general in cosmology.

In the approximation to the IE given by Eq. [10], it is possible to estimate the angle of refraction in the Eddington experiment from the fact that the speed of the photon has been slowed from c to v. The resultant angle of deflection (Fig. (6.1)) from general relativity is:

$$\theta = \frac{4MG}{rc^2} \tag{6.84}$$

and this result has been verified experimentally to one part in 100,000. The same precision is obtained from the IE as a refraction problem (Fig (6.2)). With reference to the geometry of Fig (6.2) we obtain:

$$\frac{\sin(r-\theta)}{\sin r} = \frac{c}{v} = \left(1 - \frac{2MG}{rc^2}\right)^{-1}. \tag{6.85}$$

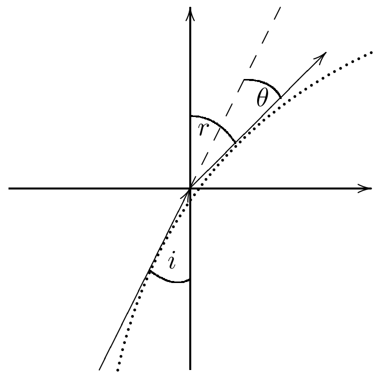

Figure 6.2: Refraction & Defraction

Using the formula:

$$\sin(r-\theta) = \sin r \sin\theta - \cos r \cos\theta \tag{6.86}$$

in the limit $\theta << 1$ radian we obtain

$$\theta \sim 1 + \tan r + \frac{2MG}{rc^2} \tag{6.87}$$

The result of general relativity is finally obtained using:

$$1 + \tan r = \frac{2MG}{rc^2}. \tag{6.88}$$

This means that the equivalent angle of refraction is almost exactly $-45°$. The minus sign means rotating in a certain direction, which is arbitrary. In other words the Eddington effect is explained using the IE to one part in one hundred thousand by using a set of axes inclined at almost exactly 45° to the incident light. This is an explanation based on classical electrodynamics within a unified field theory, and is missing entirely from Einsteinś analysis.

In the case of the sun therefore the approximation, Eq.(6.10), to the Evans field theory is justified within contemporary instrumental precision, meaning that our minimal prescription is in this case an excellent approximation. In the latter it has also been assumed that there is no gravitational torsion present, only gravitational curvature, and this again is an excellent approximation, the suns gravitation produces curvature and in the weak field limit is described by the Newton inverse square law. However, for objects such as pulsars, which are much more intensely gravitating than the sun, departures from this approximation must be expected, leading to anomalous gravitational shifts as observed experimentally [2, 4]– [10].

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