Chapter 2

First And Second Order Aharonov Bohm Effect In The Evans Unified Field Theory

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Abstract

The first and second order Aharonov Bohm effects are explained straightforwardly in the Evans unified field theory using the spin connection generated by electromagnetism as spinning spacetime.

Key words: Evans unified field theory; first and second order Aharonov Bohm effects.

2.1 Introduction

The class of first order Aharonov Bohm (AB) effects [1] (those due to a static magnetic field) can be defined as AB effects in which the wavenumber (κ) of a matter beam such as an electron beam is shifted by the electromagnetic potential A acting at first order in the minimal prescription:

$$\kappa \longrightarrow \kappa + \frac{e}{\hbar}A. \tag{2.1}$$

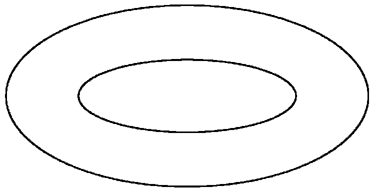

Figure 2.1: Area Overlapping

Here $-e$ is the charge on the electron and $\hbar$ the reduced Planck constant. Experiments on the AB effect can be summarized schematically with reference to Fig. 2.1, which defines one area within another as follows: In the well known Chambers experiment [2] for example the outer area is that enclosed by the interacting electron beams in a Young diffraction set up, and the inner area is that enclosed by an iron whisker within which is trapped a static magnetic flux density **B**. In the standard model, electromagnetism always is a theory of special relativity and:

$$\mathbf{B} = \boldsymbol{\nabla} \times \mathbf{A} \tag{2.2}$$

where **A** is the vector potential. The AB effect is observed in the Chambers experiment as a shift in the diffraction pattern of the electron beams, a shift that is proportional to:

$$\Phi = \int_s d \wedge A \quad (\texttt{outer}) \tag{2.3}$$

in which the surface integral is around the OUTER boundary defined by the paths of the two electron beams. This is despite the fact that **B** and therefore $\boldsymbol{\nabla} \times \mathbf{A}$ are confined to the INNER boundary [2]– [3] defined by the circumference of the iron whisker. The latter is placed between the openings of the Young interferometer. In the standard model, if B vanishes then so does $d \wedge A$. This is clearly stated in a standard textbook such as ref. [2]. Therefore in the standard model there cannot be regions in which $d \wedge A$ exists and in which B does not exist. Despite this simple inference it is often claimed confusingly that the first order AB effect is due to the effect of non-zero $d \wedge A$ where B is zero or that the AB effect is a pure quantum effect with no classical counterpart. Other attempts [2] at explaining the first order AB effect in the standard model rely on the classical concept of gauge transforming A. This confusion shows that the standard model does not explain the first order AB effect satisfactorily, or at all. This much is evidenced by over fifty years of theoretical controversy, all caused by the use of special relativity where general relativity is needed. The Evans field theory [3]– [6] is the first successful unified field theory that develops electromagnetism unified with gravitation as a correctly objective field theory of general relativity.

In Section 2.2 it is argued that the gauge transform theory of the standard model violates Stokes' Theorem in non-simply connected regions, and so is erroneous and unable to explain correctly the first order AB effect. In Section 2.3, the first order AB effect is explained correctly and straightforwardly using the spin connection of the Evans field theory. The latter is therefore preferred experimentally and mathematically to the standard model. Finally in Section 2.4 the second order or electromagnetic Aharonov Bohm effect is explained through the conjugate product of potentials in the Evans field theory, a conjugate product that defines the well known Evans spin field and which is observed in the inverse Faraday effect IFE [7]. The IFE is explained from the first principles of general relativity in the Evans unified field theory [3]– [6] but cannot be explained in the standard model without the empirical or ad hoc introduction of the conjugate product [8] in non-linear optics. Similarly for the second order AB effect which is implied by the well observed IFE.

2.2 Argument Against The Standard Model

Adopting the well known [9] notation of differential geometry the following three equations summarize the attempted description of the first order Aharonov Bohm effect in the standard model:

$$F = d \wedge A \tag{2.4}$$

$$d \wedge F = 0 \tag{2.5}$$

$$\kappa \longrightarrow \kappa + \frac{e}{\hbar} A. \tag{2.6}$$

Experimentally the observed Aharonov Bohm effect in an experiment such as that of Chambers is proportional to the magnetic flux (in weber) within the outer boundary of Fig 2.1 (the boundary defined by the paths of the electron beams):

$$\Phi = \int_S d \wedge A = \int_S F = \oint A \quad (\texttt{outer boundary}) \tag{2.7}$$

However, the magnetic flux density of the iron whisker is at the same time confined within the inner boundary

$$\Phi = \int_S d \wedge A = \int_S F = \oint A \quad (\texttt{inner boundary}) \tag{2.8}$$

and $d \wedge A$ is also confined within the inner boundary in the standard model. There is a contradiction between Eqs.(2.7) and (2.8) because the experimentally measured flux is given by Eq.(2.7) but the physical magnetic flux is given by Eq.(2.8). In a standard model textbook such as ref. [2], pp. 101 ff. an attempt is made to explain this contradiction in the first order Aharonov Bohm effect using the gauge transformation:

$$A \longrightarrow A + d\chi. \tag{2.9}$$

The standard model uses the Stokes Theorem to argue that:

$$\oint d\chi \neq 0 \quad ? \tag{2.10}$$

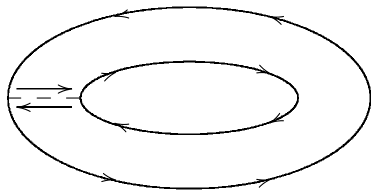

Figure 2.2: Integration Over Circumferences

in the region between the inner and outer boundary of Fig 2.1 and that the Aharonov Bohm effect is due to the integral over $d\chi$ in Eq.(2.10). However, the basis of electromagnetic gauge theory in the standard model is the Poincaré Lemma:

$$d \wedge (d\chi) := 0 \tag{2.11}$$

which is true for simply AND multiply connected spaces. The integrated form of the Poincaré Lemma is the Stokes Theorem:

$$\Phi = \int_S F = \int_S d \wedge (d\chi) = \oint d\chi := 0 \tag{2.12}$$

which is also true for multiply connected spaces [10]. The standard model [2] attempts to explain the first order AB effect by asserting INCORRECTLY that:

$$\Phi = \int_S F = \int_S d \wedge (d\chi) = \oint d\chi \neq 0. \tag{2.13}$$

In order to apply the Stokes Theorem to Fig 2.1 for example, a cut [10] is made to join the outer and inner boundaries as follows: and contour integration proceeds in one direction around the inner boundary, across the cut, in the opposite direction around the outer boundary, and back across the cut. Examples of such procedures are to be found in a standard textbook on vector algebra [10], in problems on the application of the Stokes Theorem.

We must look to general relativity and the Evans unified field theory for first correct explanation of the first order Aharonov Bohm effect.

2.3 Explanation of the First Order AB Effect in Evans Theory

In the correctly objective description of the first order AB effect [11] the electromagnetic field is defined by the first Maurer Cartan structure equation:

$$F^a = D \wedge A^a = d \wedge A^a + \omega^a{}_b \wedge A^b \tag{2.14}$$

where $D\wedge$ is the covariant exterior derivative, $d\wedge$ is the exterior derivative, $\omega^a{}_b$ is the spin connection in the well known Palatini formulation of general relativity [12,13] in which the tetrad $q^a{}_\mu$ is the fundamental field. (In the original Einstein Hilbert formulation of general relativity the metric is the fundamental field.) The electromagnetic potential field is the fundamental tetrad field within a primordial or universal scalar $A^{(0)}$, where $cA^{(0)}$ has the units of volts, and where c is the speed of light in vacuo:

$$A^a{}_\mu = A^{(0)} q^a{}_\mu . \tag{2.15}$$

It is seen that this gives a natural field unification scheme, because the metric used by Einstein and Hilbert is well known [9, 14] to be the dot product of two tetrads:

$$g_{\mu\nu} = q^a{}_\mu q^b{}_\nu \eta_{ab} \tag{2.16}$$

where η_{ab} is the Minkowski metric of the tangent bundle whose index is a. The latter becomes essentially a polarization index [3]– [6] in the Evans field theory. For example:

$$a = (1),\ (2),\ (3) \tag{2.17}$$

describes circular polarization where $((1), (2), (3))$ is the well known [15] complex circular basis. Again, it is well known [16] that the tetrad is developed into the spin 3/2 gravitino in supersymmetry theory, and that the Einstein Hilbert and Palatini variations of general relativity are inter-related by the tetrad postulate [9, 16]:

$$D_\nu q^a{}_\mu = 0. \tag{2.18}$$

One of the major inferences of the Evans field theory is that the tetrad field is the fundamental entity of objective (i.e. generally covariant) unified field theory, a unified field theory which satisfies the fundamental requirements of objectivity and general covariance in physics, the principles of general relativity. Electromagnetism in the standard model is a theory of special relativity, and is Lorentz covariant only. So the standard model is not a correctly objective theory of physics. This is the fundamental reason why it cannot describe the first order Aharonov Bohm effect, and gauge theory in special relativity [2] suffers from the same fundamental defect.

From Eq.(2.14) the magnetic flux in weber from the Evans field theory is defined as:

$$\Phi^a = \int_S F^a = \oint A^a + \int_S \omega^a{}_b \wedge A^b \tag{2.19}$$

and is in general the sum of two terms, one involving the spin connection $\omega^a{}_b$ of general relativity. It is $\omega^a{}_b$ that gives rise to the first (and second) order Aharonov Bohm effects. The fundamental reason is that the second term on the right hand side of Eq.(2.19) exists in the outer region of Fig 2.1 even though the magnetic flux density F^a is confined to the inner region and so is zero in the region between the inner and outer boundaries. The second term on the right hand side of Eq.(2.19) does not vanish, and gives rise to the AB effects. In the Chambers experiment, for example, the observed shift in the electron diffraction pattern is:

$$\delta = x \int_S \omega^a{}_b \wedge A^b \tag{2.20}$$

where x is a proportionality constant. The integration in Eq.(2.20) is around the outer boundary as required experimentally, the boundary defined by the diffracting electron beams in the Young interferometer of the Chambers experiment. The latter therefore observes the spin connection of the Evans theory directly. The spin connection is not present in the standard model, which has no explanation (Section 2.2) for the AB effects. The spin connection is a direct consequence of the major discovery of the Evans field theory that electromagnetism is the spinning of spacetime [3, 6, 17] - the spinning spacetime gives rise directly to the spin connection in the Palatini variation of general relativity.

The homogeneous field equation of the Evans field theory is [3]– [6]:

$$d \wedge F^a = 0 \tag{2.21}$$

implying that:

$$\omega^a{}_b = -\frac{1}{2}\kappa\epsilon^a{}_{bc}q^c. \tag{2.22}$$

In the complex circular basis:

$$\Phi^{(3)*} = \int_S F^{(3)*} = \oint A^{(3)*} - i\frac{e}{\hbar}\int_S A^{(1)} \wedge A^{(2)}. \tag{2.23}$$

From Eq.(2.23) it is seen that $F^{(3)*}$ and $A^{(3)*}$ are confined to the iron whisker (being in the Z axis of the iron whisker perpendicular to the plane of the paper), but $A^{(1)}$ and $A^{(2)}$ exist outside the iron whisker (i.e. in the plane of the paper) and interact with the electron beams. The observed fringe shift is proportional to $\Phi^{(3)*}$. The electron wavenumber is shifted by:

$$\kappa \longrightarrow \kappa + \frac{e}{\hbar}A^{(0)} \tag{2.24}$$

where

$$A^{(0)} = -i\left(A^{(1)} \wedge A^{(2)}\right)^{1/2}. \tag{2.25}$$

Here

$$eA^{(0)} = \hbar\kappa. \tag{2.26}$$

2.4 Electromagnetic or Second Order Aharonov Bohm Effect

The existence of the reproducible and repeatable inverse Faraday effect [3]– [6] implies that there is an electromagnetic or second order Aharonov Bohm effect. This is not a shift in the electron wave function but is due to magnetization by the Evans spin field $B^{(3)}$ [3]– [6]:

$$B^{(3)*} = -igA^{(1)} \wedge A^{(2)}. \tag{2.27}$$

In generally covariant unified field theory [3]– [6] the $B^{(3)}$ field is a fundamental manifestation of the fact that electromagnetism is spinning spacetime.

The latter gives rise to the spin connection in Eq.(2.14), and the second term in this equation gives the $B^{(3)}$ spin field using Eqs.(2.22) and (2.27). The magnetization of the inverse Faraday effect is to second order in the potential, so gives rise to a second order electromagnetic Aharonov Bohm effect (EAB) [3]– [6]. In a Chambers type experiment the EAB would be due to a circularly polarized electromagnetic beam directed between the interfering electron beams but isolated from the electron beams. The resulting fringe shift would be proportional [3]– [6] to the magnetic flux:

$$\Phi^{(3)*} = \mu_0 \int_S M^{(3)*} \quad (\texttt{outer}) \tag{2.28}$$

where integration again occurs around the outer boundary in Fig 2.1. The EAB has important consequences for RADAR and stealth technology because objects can be detected outside the width of the RADAR beam using the EAB.

2.5 Discussion

The explanation of the EAB is simply that the second term on the right hand side of Eq.(2.14) exists when it is arranged experimentally that the first term, the exterior derivative of the potential, is zero. This explanation means that an electromagnetic beam of given diameter will interact with an electron placed outside the electron beam. If so, the diameter of the electromagnetic beam must be defined. In the standard model there is no answer to this question because the standard explanation of the AB effects violates the Poincaré Lemma. The latter is identically zerofor any function in both simply and non-simply connected spaces because:

$$\boldsymbol{\nabla} \times \boldsymbol{\nabla} := 0 \tag{2.29}$$

is an identity independent of the function or topology. A laser beam at visible frequencies has a definite diameter and color, it can be focused or expanded, reflected and so on. However, the term $\omega^a{}_b \wedge A^b$ is invisible, for the first time in physics it is seen that there is something more to an electromagnetic beam than $d \wedge A^a$. Similarly the Chambers experiment shows that there is something more to a magnetic field than the curl of a vector potential. Again, this is the $\omega^a{}_b \wedge A^b$ of general relativity, caused by the spinning of spacetime itself.

The beam diameter must therefore have been defined by the way that the beam was originally created, or radiated by the source charge-current density J^a in the inhomogeneous Evans field equation (IE):

$$d \wedge \widetilde{F}^a = \mu_0 J^a. \tag{2.30}$$

For example if the beam is radiated by a non-relativistic electron in a circular orbit, the diameter of the beam is the diameter of the orbit. A laser is more complicated than this but this illustration gives the principle. The circling electron causes a spacetime spinning. The radiated magnetic and electric components of the laser beam are confined within the laser beam diameter by Eq.(2.30) and its Hodge dual in free space, the homogeneous Evans field equation (HE):

$$d \wedge F^a = 0. \tag{2.31}$$

The invisible term ${\omega^a}_b \wedge A^b$ exists both inside and outside the laser beam and outside the laser beam interacts with the electron in the Aharonov Bohm effect.

So what we see as the visible laser beam is defined by the exterior DERIVATIVES of F^a, its Hodge dual $\widetilde{F}^a$, and the potential A^a. The exterior derivative summarizes the time and space variation of these entities within the diameter defined by the circling electron in the source term J^a of Eq.(2.30). Outside of this diameter there is no visible radiation. However, the spacetime spinning indicated by ${\omega^a}_b \wedge A^b$ exists outside the visible laser beam because spacetime itself exists outside the laser beam. The spatial and temporal variations of A^a are also confined within the beam diameter. Only ${\omega^a}_b \wedge A^b$ exists outside the beam, and this contains no spatial or temporal variations of A^a. In the Chambers experiment the latter interacts with an electron at first order, and the second order AB is indicated by the existence of the inverse Faraday effect (IFE). This is the first correct explanation of the Aharonov Bohm effects, the important new principle at work is that the diameter of a beam of electromagnetic radiation is always defined by spatial and temporal variations of the potential, electric and magnetic fields. Similarly a static magnetic field is defined by the curl of a magnetic potential inside the iron whisker or solenoid, but spacetime outside the iron whisker is spun by the magnetic field. A useful analogy is to think of the electromagnetic beam or iron whisker as a stirring rod and the spinning spacetime as the whirlpool set up by the rod at its center.

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