TORSION, MASSIVE ELECTRODYNAMICS AND PRIMORDIAL MAGNETIC FIELDS IN THE EARLY UNIVERSE

(Letter to the Editor)

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Abstract. A recent model of torsion-modified electrodynamics which breaks the electromagnetic conformal invariance is shown to lead to the generation of magnetic fields in the Early Universe.

The problem of the origin of interstellar and intergalactic magnetic fields has remained a long standing puzzle. Magnetic fields in the early universe have been dealt with and a maximum primeval magnetic field at the Planck epoch of

$$B_{\max} \approx \frac{c^4}{Ge} \approx 10^{-58}\,\text{Gauss} \tag{1}$$

was obtained (Sivaram and de Sabbata, 1991). However, it was also noted (de Sabbata and Sivaram, 1988) that inflationary expansion subsequent to the Planck epoch at around the GUTs era, would have considerably diluted such magnetic fields to values

$$B_0 \approx B_{\max} \exp(-2H_{\text{inc}}t) \approx B_{\max} 10^{-100} \tag{2}$$

which are unimaginably smaller than known values of interstellar magnetic fields $\sim 10^{-6}$ Gauss.

There have been several mechanisms which have been suggested to generate magnetic fields in the post-inflation epoch.

For instance Harrison (1970) uses primordial vorticities to produce differential rotation of negatively charged relativistic and positively charged, non-relativistic components of the cosmic plasma thus providing the dynamo mechanism for generating a primordial magnetic field that is linearly proportional to w.

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A recent interesting possibility for generating a cosmic magnetic field has been suggested by Turner and Widrow (1988) who generate a large scale magnetic field. They break the conformal invariance through gravitational coupling of the photon by adding terms such as RA^2 and RF^2 (R is the Ricci scalar ($A^2 = A_\mu A^\mu$ for the 4-potential) and F^2 is a quadratic combination of the field strengths $F_{\mu\nu}$) to the usual Maxwell Lagrangian. In recent work (Garcia de Andrade, 1990; Garcia de Andrade and Sivaram, 1992), torsion coupling to the electromagnetic field was used to break the conformal invariance, i.e. through terms of the type $\sim R(\Gamma)A^2$, Γ being constructed from the non-symmetric connection. Again in a recent work, it was shown that starting from the usual Maxwell action:

$$\delta \int (\frac{1}{4} F_{\mu\nu}F^{\mu\nu} + j + \mu A_\mu)\sqrt{-g}\, \mathrm{d}^4x, \tag{3}$$

if for $F_{\mu\nu}$ we write:

$$F_{\mu\nu} = A_{\mu|\nu} - A_{\nu|\mu} = A_{\mu,\nu} - A_{\nu,\mu} - 2Q^\alpha_{\mu\nu}A_\alpha. \tag{4}$$

(Here '|' stands for covariant derivative w.r.t the Γs and denotes ordinary partial differentiation. Equation (4) has the additional minimal coupling between torsion and the 4-potential, the torsion tensor being $Q^\alpha_{\mu\nu} = |\Gamma^\alpha_{[\mu\nu]})$.

We get the modified electromagnetic field equation:

$$F^{\mu\nu}_{;\nu} + Q^\alpha_{\mu\nu}F^{\alpha\nu} = j^\mu. \tag{5}$$

This modified torsion covariant equation corresponds to London's equation which holds in a superconductor, i.e. we can write (5) in the form:

$$\nabla^2\overline{B} + \lambda^2 Q^2 \overline{B} = \overline{J}. \tag{6}$$

Now in a superconductor, the photon can be interpreted as having an effective rest mass, i.e. the London equation (Equation (6)) implies a finite range or penetration depth μ for the field and thus an effective rest mass for the photon (phase invariance being now broken) of:

$$\mu^{-2} \approx m_\gamma^2 \approx \lambda^2 Q^2, \tag{7}$$

λ the photon-torsion coupling being constrained by other arguments (Sivaram and Garcia de Andrade, 1992) to be $\lambda < 10^{-24}$. The photon mass arising in this model (where conformal invariance is broken by the torsion-photon coupling) was shown to be:

$$m_\gamma^2 \approx \frac{(8\alpha G)^{1/2}\, \hbar^2\, m_e^3 c^2 \lambda}{e^5}, \tag{8}$$

with a corresponding critical field arising from the London current given by Equations (5) and (6) given as:

$$B_{\text{crit}} \approx \frac{m_\gamma^2 c^3}{\lambda e \hbar} \approx (8\alpha G)^{1/2} \frac{\hbar m_e^3 c^5}{e^6} \tag{9}$$

Coincidentally this happens to have the same value as Harrison's seed field (Harrison, 1970). In our picture this would be the large scale value of the magnetic field.

By flux conservation, i.e.

$$B_{\text{crit}} R_H^2 \approx B_G R_G^2, \tag{10}$$

where R_H is the Hubble radius, R_G is a typical galaxy size $\approx 10^2$ kpc, B_G is the galactic magnetic field of:

$$B_G \approx 10^{-5} \text{ Gauss} \tag{11}$$

which agrees with the observed value, showing that proton-torsion coupling in the early universe breaking the conformal invariance and leading to modified London type equations (Equations (4)–(6)), is capable of generating the observed galactic magnetic fields.

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