Eur. Phys. J. C (2018) 78:530
https://doi.org/10.1140/epjc/s10052-018-5983-x

THE EUROPEAN PHYSICAL JOURNAL C

Regular Article - Theoretical Physics

Metric-torsion decay of non-adiabatic chiral helical magnetic fields against chiral dynamo action in bouncing cosmological models

L. C. Garcia de Andrade[a]

Departamento de Física Teórica, IF, UERJ , Rua São Francisco Xavier 524, Maracanã, Rio de Janeiro, RJ 20550, Brazil

Received: 25 April 2018 / Accepted: 2 June 2018 / Published online: 28 June 2018

Abstract Metric-torsion effects on chiral massless fermions are investigated in the realm of the adiabatic amplification of cosmological magnetic fields (CMFs) in a general relativistic framework and in the framework of Einstein–Cartan (EC) bouncing cosmologies. In GR the chiral effect is proportional to the Hubble factor and the solution of the dynamo equation leads to an adiabatic magnetic field, while in Einstein–Cartan bouncing cosmology we have non-adiabatic magnetic fields where the breaking of adiabaticity is given by a torsion term. Using a EWPT magnetic field of the order of $B_{\text{seed}} \sim 10^{24}$ G at 5 pc scale, we obtain a CMF in EC of the order of 10^{-10} G, which is still able to seed a galactic dynamo which amplifies this field up to galactic magnetic fields of four orders of magnitude, which is a mild dynamo. In the case of massive chiral fermions it is shown that torsion actually attenuated the convective dynamo term in the dynamo equation obtained from the QED of an electron–positron pair e^-e^+. Chiral effects on general relativity may lead to strong magnetic fields of the order of $\sim 10^{18}$ G at the early universe resulting from pure metric effects. Strong magnetic fields of the order of $B_{\text{metric}-\text{torsion}} \sim 10^8$ G may be obtained from very strong seed fields. At 1 Mpc scale of the present universe a galactic dynamo seed of the order of 10^{-19} G is found. It is shown in this paper that chiral dynamo effects in the expanded universe can be obtained if one takes into account the speed of the cosmic plasma.

1 Introduction

Recently, Dvornikov [1,2] in a series of papers argued that the chiral magnetic effects (CMEs) and the associated current where the electron current moves along the magnetic field is only valid when the chiral fermions are massless. This idea was also used by Sigl [3–5] in the context of neutron star astrophysics, and one concluded that the amplification of the magnetic field is replaced actually by an attenuation of the magnetic field. By making use also of chiral QED in spacetimes with torsion (referring to work by de Sabbata and Gasperini [6]) one derived from the polarization of vacuum and electron–positron massive fermion pairs that the time component of the torsion axial vector term in the $curl\, B$ equation induces the chiral term where indeed the electric current seems to be along the magnetic field. This model in electrodynamics considers a torsion axial vector appearing naturally in terms of Dirac spinors ψ and gamma matrices γ where the torsion is given by $Q^{\mu} = -3\pi\bar{\psi}\gamma_5\gamma^{\mu}\psi$. Here we adopt the cgs systems of units and the fine structure constant is $\alpha = e^2$ where e is the unit of electric charge of electron. More recently [7] we use this model in electrodynamics in the case where the torsion vector is a constant background and show that this expression, which reduces to Chern–Simons electrodynamics (CS), gives rise to torsionful chiral electrodynamics and chiral dynamos in electrodynamics. In analogy, Dolan [8] associated torsion with the spin–spin interaction of Einstein–Cartan gravity [9] in terms of spinor fields where torsion would obey the Cartan equation in differential forms language as before. Also the spin–spin contact interaction would be analogous to a weak force—the weak interactions. In this paper we show that in the two cases of massless and massive chiral fermions there are distinct physical consequences: First in the case of the chiral massive fermions given in torsionful background we show that actually there is an attenuation in the form of damping of the convective term of the chiral Faraday self-induced equation where the dynamo convective term is therefore damped by the chiral torsion [10–12] term. In the second case, where the chiral plasma [13] is composed of massless fermions, for example neutrino–anti-neutrino pairs, bouncing cosmological models driven by the quantum contribution of Dirac spinors to FRW Einstein–Cartan cosmological equations are obtained. Thus one can say, as shown by Dvornikov and Semikoz, that a chiral dynamo [14] can be obtained in the early universe with

[a] e-mail: garcia@dft.if.uerj.br

this bounce [14] and this is shown in the case of EWPT. The plan of the paper is as follows: In Sect. 2 the massless chiral fermions are shown to be responsible for the driven bouncing cosmological model amplification of the magnetic fields. In the second case the chiral massive fermions of the chiral anomaly currents QED is shown to produce an attenuation of the magnetic field. In Sect. 3 the chiral dynamo equation is presented in the EC framework, and in Sect. 4 the helical magnetic fields are found. Section 5 handles the problem of the computation of CME on GR and in EC bouncing cosmologies. Section 6 presents our conclusions.

2 Chiral dynamo equation and EC bouncing universes

Here we shall consider, in principle by Hamiltonian methods, massive fermions with a difference between right-chiral and left-chiral fermions which is understandable when we address extremely high temperature conditions in the universe as in the early universe. Here we shall consider finally massless fermions at the EWPT of the early universe in a bouncing state. Let us start by considering the Dirac equation in the form

$$i\gamma^0\partial_0\psi = -i\gamma.\nabla\psi + m\psi - \frac{3\chi}{8}\bar{\psi}\gamma_n\gamma_5\psi\gamma_n\gamma_5\psi \tag{1}$$

where, as above, we see that axial torsion is present. As pointed out by de Sabbata and Sivaram the torsion contact interaction between two Dirac particles has a formal analogy with the weak interactions Lagrangian in the Einstein–Cartan static term for the field. This allows us within this formalism to considered the EW interaction in a bouncing universe. In the Hamiltonian formulation [9]

$$H = H_{\text{free}} + H_{\text{int}} \tag{2}$$

where

$$H_0 = \int \mathrm{d}V \left[\frac{1}{2}(-i\bar{\psi}\gamma.\nabla\psi + h.c.) + m\bar{\psi}\psi\right] \tag{3}$$

and

$$H_I = -\frac{3\chi}{32}\int \mathrm{d}V\bar{\psi}(Q_n)\gamma_n\gamma_5\psi. \tag{4}$$

By making use of second quantization and using different couplings to particles and anti-particles as in the case that the torsion couples with isospin, one obtains an asymmetry in the occupation number $N_+ - N_-$ in the case of baryons. Actually this case shall also be discussed in the next section where we review recent results where the chiral chemical potential is proportional to the torsion's 0-component. The vacuum expectation value of the Hamiltonian density is given by

$$\frac{1}{V} < \phi/H/\phi >= \frac{E_0}{V} - \frac{3\chi}{32}(n^+ - n^-)^2. \tag{5}$$

Here χ is the Einstein gravitational constant. At sufficiently high density, spin effects become dominant in the early universe in the Einstein–Cartan cosmology bouncing model as we shall see next. In the case of the FRW metric

$$\mathrm{d}s^2 = -(1-2\phi)\mathrm{d}t^2 + (1+2\phi)[\mathrm{d}x^2 + \mathrm{d}y^2 + \mathrm{d}z^2]. \tag{6}$$

Let us now consider the Einstein–Cartan gravity equation with the stress-energy sources given by the quantum fluctuation <> of this EMT:

$$G_{\mu\nu} = 8\pi < T_{\mu\nu} > \tag{7}$$

where now the EMT semiclassically can be obtained by the FRW equations

$$3\frac{k}{a^2} + 3\frac{\dot{a}^2}{a^2} = g^{00}\chi < T_{00} > \tag{8}$$

where k is the spatial scalar curvature of the universe, which we here consider to be flat, $k = 0$, to simplify matters, while the other FRW equations reduce to

$$\frac{k}{a^2} + \frac{\dot{a}^2}{a^2} + \frac{\ddot{a}}{a} = g^{11}\chi < T_{11} > \tag{9}$$

where by isotropy of this universe $< T_{11} >=< T_{22} >=< T_{33} >$. Since we are interested in the influence of a magnetic field in this universe one may introduce the magnetic field from the energy-stress tensor of the magnetic field in the form

$$E_{\mu\nu} = F_{\mu\alpha}F_\nu{}^\alpha - \frac{1}{4}F^2 g_{\mu\nu} \tag{10}$$

where

$$E_{11} = E_{22} = E_{33} = \frac{B^2}{a^2}, \tag{11}$$

which would add the magnetic field energy B^2 to the FRW cosmological equations with torsion sources in the form

$$3\frac{k}{a^2} + 3\frac{\dot{a}^2}{a^2} = g^{00}\chi < T_{00} > + \frac{3B^2}{4} \tag{12}$$

$$\frac{k}{a^2} + \frac{\dot{a}^2}{a^2} + \frac{\ddot{a}}{a} = g^{11}\chi < T_{11} > + \frac{5}{4}\frac{B^2}{4} \tag{13}$$

where $g_{\mu\nu}$ is the Riemannian metric. Now combination of these equations yields

$$\chi(g^{00}\chi < T_{00} > +3g^{11}\chi < T_{11} >) = 2B^2 + \frac{\dot{a}^2}{a^2} + \frac{\ddot{a}}{a} \tag{14}$$

and finally

$$\chi\left(m < \bar{\phi}\phi > + \frac{3\chi N^2}{8a^6}\right) = 2B^2 + \frac{\dot{a}^2}{a^2} + \frac{\ddot{a}}{a}. \tag{15}$$

Of course, the presence of axial torsion is revealed by the term

$$Q^2 = \frac{3\chi N^2}{8a^6} \tag{16}$$

where

$$Q = \bar{\psi}\gamma_n\gamma_5\psi \tag{17}$$

is the axial torsion. Here the following expression is assumed, as we have a kind of flat curvature inside the electroweak bubble:

$$\frac{\dot{a}^2}{a^2} + \frac{\ddot{a}}{a} \sim 0. \tag{18}$$

This equation yields the following solution:

$$a(t) \sim t^{\frac{-1}{4}}, \tag{19}$$

which characterizes the bouncing cosmology [14] universe, since as cosmic time t goes to infinity the radius of this local universe is shrinking. Actually then this electroweak bubble could be unstable [15]. Now let us compute the magnetic field which is given by

$$B(t) \sim Na^{-3}; \tag{20}$$

we note from this expression that the magnetic field is non-adiabatic or $B(t) \sim a^{-2}$. From Eq. (19) one obtains

$$B(t) \sim t^{\frac{3}{4}} \sim 10^{-6}\ \text{G} \tag{21}$$

in the case of EWPT where $t \sim 10^{-11}s$. This is of the order of magnitude of the galactic magnetic fields. So this bubble flat model with chiral torsion leads to the possibility of obtaining a galactic dynamo from the small scale chiral dynamos. Note from Eq. (21) that the magnetic fields undergo a slow amplification in the universe's expansion phase. Let us now examine what happens with an anomalous chiral fermionic torsion and its relation with the previously found Lorentz violation (LV) [7] results. In our case we see that for the torsion

$$Q \sim -3\sigma\frac{\dot{a}}{a} \sim Na^{-3}. \tag{22}$$

Since we have already a solution for $a(t)$ this expression yields a time dependence for the conductivity, which is

$$\sigma(t) \sim \frac{4N}{3}t^{\frac{1}{4}}, \tag{23}$$

which at EWPT yields for this chiral conductivity $\sigma(t) \sim 10^34$. Now to end this section let us finally compute the torsion Q:

$$Q \sim Na^{-3} \sim 10^3. \tag{24}$$

At the EWPT this yields $\sim 10^{-20}$ GeV $\sim 10^{-6}\text{cm}^{-1}$, which breaks more LV than in previous maser LAB results by Kostelecy et al. [16]. Note that this shows that this bubble model for the EWPT with chiral dynamos may also yield a new interesting bound for LV symmetry breaking. From a simple computation one notes that the conductivity is

$$\sigma = \sigma_0\left(\frac{t}{t_0}\right)^{\frac{1}{4}}, \tag{25}$$

similar to the expression obtained by Sigl et al., $\sigma = \sigma_0(\frac{t}{t_0})^{\frac{1}{3}}$, which is no surprise, since turbulent methods used in strong magnetic fields of stars are similar used in the early universe's chiral magnetic fields.

3 Chiral torsion damping of the magnetic fields against dynamo action

In this section, from a simple derivation of the chiral dynamo equation, we show that the damping torsion effect on the dynamo action from a metric-torsion background does not affect much the amplification of magnetic fields via dynamo since the torsion damping term acts as damping the dynamo convective chiral term in the torsion chiral chemical potential in the denominator of the ratio between the dynamo term and torsion term. Let us consider the Ohm equation:

$$\mathbf{E} = -\mathbf{v} \times \mathbf{B} + \eta{\mu_5}^{-1}\mathbf{B}; \tag{26}$$

by using this equation along with the Faraday and Ampère equations one obtains the chiral dynamo equation:

$$\nabla \times (\mathbf{v} \times \mathbf{B}) - \eta\mu_5\nabla \times \mathbf{B} = \partial_t\mathbf{B} \tag{27}$$

where momentarily we drop the metric term to stress the torsionful effects. In this chiral dynamo equation one seems momentarily not to have torsion contributions; however, when one goes to the curl B expression in the anomalous QED equations one observes that the chiral equation with explicit torsion comes from

$$\nabla \times \mathbf{B} = 4\frac{\pi}{c}\mathbf{J} + 4\frac{\alpha}{3\pi}(-g)^{\frac{1}{2}}[Q^0\mathbf{B} + \mathbf{E} \times \mathbf{Q}]. \tag{28}$$

Here one drops the spatial part of torsion as is done in the neutrino sea by de Sabbata and Sivaram. Let us now show one of the main results in the paper, namely that the dynamo term $curl(vXB)$ is well damped by metric-torsion effects. This is simply done by examining the ratio

$$\frac{\nabla \times (\mathbf{v} \times \mathbf{B})}{\eta\mu_5 Q_0 \mathbf{B}} \sim v\eta\mu_5 Q_0 L. \tag{29}$$

By physically examining this term the speed v of the particles enhances the chiral dynamo term, while the coherent length L, the torsion Q, and the conductivity may damp the chiral dynamo effect depending upon their values. In the early universe where L is short and torsion is not too strong, while velocities agree with this ratio, this seems yet to favor the chiral dynamo action, while in the laboratory where these conditions change and torsion is very small one is able to enhance yet further the dynamo action by the presence of torsion, though there the coherent lengths are very large, which is the reason one has difficulties in detecting the presence of torsion in the laboratory and rather small values are obtained: 10^{-31} GeV. Here the axial chiral torsion is given by the expression $Q^\mu = -3\bar{\psi}\gamma^\mu\gamma_5\psi$ in terms of the Dirac gamma matrices and Dirac spinors ψ. Here we already note that there is a coupling of the metric field through the term determinant of the metric g to the 0-component of the axial torsion, which in turn also represents a natural chiral current in this anomalous equation. Here $\mathbf{J}$ is the electric current. Note that from these equations one obtains a simple form of the torsion, a generalization of the charge current conservation $\mathbf{J}_{Ch} = Q_0\mathbf{B}$ for chiral current in terms of the 0-component torsion. The traditional chiral current

$$\mathbf{J}_{Ch} = \mu_{(5)}\mathbf{B} \tag{30}$$

has to be replaced into the Maxwell equation by the torsion 0-component term which mimics the chiral term.

4 Galactic mild dynamo seeds as helical magnetic field from torsion

According to Schober et al. [15] magnetic fields produced by chiral dynamos are fully helical. This is the main motivation of presenting this section on magnetic helical fields in torsionful spacetimes. Here force-free magnetic fields are considered from chiral torsion where the chirality of torsion sign is fundamental for dynamo amplification or the chiral dynamo action. Helicity is a fundamental ingredient for turbulence [17] and for chiral dynamos [18]. Let us first consider the Beltrami chiral equation with torsion which comes from Ampère equation above:

$$\nabla \times \mathbf{B} \sim \eta Q^0 L^{-1}\mathbf{B}. \tag{31}$$

By considering the local coordinates (x, y, z, t) and the choice $(B_x, B_y, 0)$ and $B = B(z, t)$, one can derive the following expressions from this equation:

$$\partial_y B_z - \partial_z B_y = \eta Q_0 L^{-1} B_x, \tag{32}$$

$$\partial_z B_x - \partial_x B_z = \eta Q_0 L^{-1} B_y. \tag{33}$$

The last equation is

$$\partial_x B_y - \partial_y B_x = \eta Q_0 L^{-1} B_z. \tag{34}$$

Of course, this equation is trivial since B_z vanishes by choice and $B = B(z, t)$. It is also easy to see that these equations are compatible with the absence of the monopole hypothesis, or $div\mathbf{B} = 0$. These equations reduce to

$$\partial_z B_y = -\eta Q_0 L^{-1} B_x, \tag{35}$$

$$\partial_z B_x = \eta Q_0 L^{-1} B_y. \tag{36}$$

By applying the partial derivative, the del operator, in the direction of z on both sides of these equations one obtains

$$\partial_A{}^2 B_B + \eta Q_0 L^{-1} B_B = 0 \tag{37}$$

where $(A, B = 1, 2)$ and L is the coherent length. This last equation can be expressed in the form of an oscillatory motion field equation giving the helical form of the magnetic solution $B(z, t) = B_0(t)(\cos kz + \sin kz)$. This form of the solution where $B_0 = B_{\rm seed}$ yields the following expression when substituted in the chiral dynamo equation with torsion:

$$\partial_t B_0 + \eta Q_0 L^{-1} B_0 = 0, \tag{38}$$

which yields the following solution:

$$B_{\rm torsion} \sim B_W \exp[\eta Q_0 t]. \tag{39}$$

Therefore with this expression one may compute the seed field at the EWPT for example which from the above data yields

$$B_{\rm seed} \sim \eta Q_0 L^{-1} t \sim 10^{-10}\mathrm{G} \tag{40}$$

where we use a scale of $L \sim 5pc$. This is a galactic dynamo seed field. At the early universe the bubble model of Ahonen and Enqvist [15] may lead to magnetic fields of the order of $\sim 10^{20}$ G. Here, however, we use the more recently updated value of $B_w \sim 10^{24}$ in the last computation, and one notes that torsion in the EC bouncing universe induces a strong decay of the magnetic fields. If one uses the value of the early universe torsion obtained by de Cesare et al. [19] using baryonic asymmetry in a torsionful background of $Q \sim 10^{-11}$ GeV one obtains from the last expression a magnetic fields as huge as $\sim 10^{7}$ G. A stronger value than this one shall be obtained in the next section. This shows explicitly that the magnetic helical fields can induce turbulence and this actually makes the chiral magnetic seed fields quite strong, as strong as the one obtained here. Note that for making simulations as in Schober et al. [20] one would have a helical magnetic chiral field from torsion:

$$B(z,t) = 10^{-4}(t)(\cos kz + \sin kz). \tag{41}$$

We apply the pencil code. By making use of the weak force magnetic field given by Olesen [21,22] a magnetic field is found of $B_W \sim \frac{m^2}{e} = 10^{24}$ G. Olesen found this primordial magnetic field from EWPT non-Abelian gauge fields. Note that if one takes into account this W-boson magnetic field one obtains

$$B_{\text{seed}} \sim B_W \exp[L^{-1}\eta Q_0 t]; \tag{42}$$

since we have the term $L^{-1}\eta Q_0 t << 1$ for t_{EWPT} above and the early universe torsion above, one may use the following approximation:

$$B_{\text{seed}} \approx B_W[1 + \eta Q_0 t], \tag{43}$$

which implies that

$$B_{ch-tors} \approx B_W L^{-1}\eta Q_0 t, \tag{44}$$

$$B_{ch-tors} \approx B_W \eta Q_0 t \approx 10^4 \text{G}, \tag{45}$$

which is certainly still a strong torsion chiral contribution to the magnetic field in the early universe.

5 GR galactic dynamo seeds and non-adiabatic amplification in EC bouncing universes

In this section we shall consider the Faraday self-induction equation, sometimes called the dynamo equation, in the form

$$\nabla \times (a^2\mathbf{E}) = -\partial_t(a^2\mathbf{B}) \tag{46}$$

where the torsion has been dropped since we first examine the CME in Riemannian GR. This equation is expanded to provide the following equation:

$$-\nabla \times (\mathbf{E}) = \partial_t(\mathbf{B}) + \frac{2\dot{a}}{a}\mathbf{B}. \tag{47}$$

Note that from the RHS of this equation we have the metric-chiral effect in the form of the last term. Since here we are just interested in the chiral metric effect we need only consider the equation

$$\partial_t(\mathbf{B}) + \frac{2\dot{a}}{a}\mathbf{B} = 0. \tag{48}$$

A simple solution of this equation leads to

$$\mathbf{B} = (\mathbf{B})_{\text{seed}} a^{-2}, \tag{49}$$

which characterizes an adiabatic solution for the cosmological magnetic field in GR. For the above case of a bouncing solution, for $t_{EWPT} \sim 10^{-12}s$, one obtains

$$B = B_{\text{seed}} t^{\frac{1}{2}} \sim 10^{18}\text{G}, \tag{50}$$

where we have used a seed field of $\sim 10^{24}$ G. Now let us compare this result with the one we obtain when torsion is introduced. Let us start by introducing the dynamo equation in terms of the axial torsion expressed by the metric scale factor $g_{ij} = \delta_{ij} a^2(t)$:

$$\partial_t(\mathbf{B}) = -\frac{2\dot{a}}{a} - \alpha\eta Q_0 \nabla \times \mathbf{B}. \tag{51}$$

A solution of this dynamo equation yields

$$B = B_{\text{seed}} a^{-2}[1 - \alpha\eta^2(Q_0)^2]; \tag{52}$$

with the appropriate data one obtains

$$B = 10^{24}\alpha\eta^2(Q_0)^2 t^{\frac{3}{2}} \tag{53}$$

where $B_{\text{seed}} \sim 10^{24}$ G has been used at the EWPT. Thus one obtains finally $B_{\text{torsion}/EWPT} \sim 10^{30}$ G, which agrees with our previous statement that chiral dynamo non-adiabatic amplification is possible at the early universe. Actually a growth rate amplification of a magnetic field of $\approx 10^6$ is possible characterizing a mild dynamo mechanism, since the dynamo growth rates are in general around $\sim 10^8$. At scales of 1 Mpc this would result in a magnetic field of 10^{-19} G, which is able to seed a galactic dynamo to amplify the magnetic fields up to the order of microgauss. This last magnetic field is in accordance with chiral dynamo results obtained from Schober et al. [20], since their result is $< B^2 > \sim 6x10^{-38}$, which is the same result as we obtain here if squared. Actually their result, obtained from chiral dynamos, takes into account the convective term in the dynamo amplification $\gamma = kv - k^2 t$. Here the plasma speed v is not taken into account, but the chiral dynamo may be obtained as in this section by taking into account the expansion of the universe not only in GR but also in EC bouncing cosmology. Note that if one dimensionally substitutes the expression k^2 by ${Q_0}^2$ in the last expression in the text one obtains the torsion expression for the magnetic fields. Unfortunately the magnetic fields adiabatically decay with the FRW metric factor a^{-2} and more from the factor a^{-3} in the case of torsion; this shows that clearly the expansion of the universe contributes does not contribute to chiral dynamos and, moreover, the presence of torsion accelerates the decaying of magnetic fields. It is interesting to note that in Ref. [15] numerical calculations were taken into account using the bounds $B \geq 10^{-18}$, which is in agreement with values of the magnetic fields obtained in this section by considering expansion.

6 Conclusions and discussions

An important conclusion drawn from this paper is that here, different from previous papers on chiral dynamos, the torsion chemical potential, torsion and chiral conductivity are time dependent and not constants as before. In the case of massless chiral fermions, i.e., neutrino–anti-neutrinos, bouncing cosmology is in order on a Ricci-flat spacetime bubble of electroweak type as in the paper of Enqvist and Olesen [15], where torsion-driven dynamo amplification is used. A similar result without torsion was obtained by Dvornikov and Semikoz [13] in the case of chiral dynamos on a hot plasma of neutrino–anti-neutrinos also from Hamiltonian methods. As in the case of magnetars where Sigl et al. have obtained a damping as well on the magnetic fields, showing that the strong magnetic fields of magnetars cannot be explained by chiral dynamos from virtual pairs of electrons and positrons, we show that a torsion chiral current in this case damps the magnetic field of the universe in much the same way as is done in stars. In the massless chiral anomaly fermions the FRW cosmological equations are used in this bubble solution in Ricci-flat spacetime to show that the evolution of this isotropic expansion endowed with magnetic fields may produce a bouncing cosmological solution with electroweak bubbles as considered by Enqvist and Olesen. Future prospects in this field point to using this Chern–Simons QED of electron–positron pairs on a spacetime with torsion to investigate the metric-torsion effects in the laboratory. Gregori et al. have [21,22] obtained rescaled dynamo amplification of magnetic fields in the laboratory. The study of magnetic helicity chiral fields with torsion shows that with the appropriate sign choice of torsion strong magnetic fields are obtained in accordance with strong magnetic fields previously obtained in chiral battery model and bubbles in EWPT mechanisms. Of course, the investigation of magnetic turbulent fields in the background of torsionful geometries and its influence on chiral dynamos is a topic of interest to be pursued in the near future. Certainly, if in this case torsion depends upon time, one certainly shall have to use simulation methods to investigate these chiral dynamos [23]. We must conclude here that even a chiral dynamo is able to amplify existing non-abelian W currents primordial magnetic fields of three orders of magnitude from torsion and still very strong fields are obtained in the early universe from chiral dynamos—a result similar to work of Dvornikov and Semikoz [13]. In that paper an extra term in the chiral current has been found of the type $\mathbf{J} \sim (V_0 + \mu_5)\mathbf{B}$, which is the electroweak extra potential $V_0 \sim Q_0$ in our analogy. Of course, in some sections also torsion can replace the chiral chemical potential itself. Generation of magnetic fields in a bouncing universe without considering torsion has been found by Salim et al. [24], but in this paper several different features are considered; here our universe bounce decouples with torsion inside the bubble which is Ricci flat. When we consider the inflating magnetic fields, actually we obtain deflating magnetic fields since the magnetic fields decays with expanding scales as $a(t) \approx t^{\frac{-1}{4}}$, which shows that the magnetic field grows. However, note that when one uses the cosmic time of EWPT this contraction of the bouncing universe actually imposes a deflation in inflating magnetic fields [24], which is really not possible here due to chiral magnetic effects at the EWPT bouncing phase of the universe. In the latest eras of the universe, Barrow et al. [25] have shown that a galactic dynamo can seed the amplification of the magnetic fields obtained from superadiabatic (non-adiabatic) amplification using the GR dynamo equations where non-conventional quantum theory or extradimensional theory is needed. In the present paper we have shown that, also in the EC bouncing cosmology, we have non-adiabatic amplification due the presence of chiral fermionic torsion galactic dynamo seeds of the order of 10^{-19}G from metric-torsion effects at 1 Mpc scales of the present universe. This is to be compared with the present radius of the universe, approximately 4 Mpc.

Acknowledgements I would like to thank Maxim Dvornikov for helpful discussions on the subject of this paper. Financial support from state university of Rio de Janeiro (UERJ) department of theoretical physics is grateful acknowledged.

Funded by SCOAP[3].

References

1. M. Dvornikov, Phys Rev D **90**(4), 041702 (2014). arXiv:1409.1463 [hep-ph]
2. M. Dvornikov, V. Semikoz, JCAP **1405**, 002 (2014)
3. G. Sigl, Natacha Leite, Chiral Magnetic effect in protonneutron stars and Magnetic field spectral evolution, arXiv: 1507.04983v2 [Astro-ph.HE] (2015)
4. G. Sigl, Phys Rev D **66**, 123002 (2002)
5. P. Pavlovic, N. Leite, G Sigl, Chiral Magnetohydrodynamics Turbulence, arXiv: 1612.07382v2 [astro-ph.CO] (2017)
6. V. de Sabbata, M. Gasperini, Phys Rev Lett **23**, 211 (1981)
7. L.C. Garcia de Andrade, Chiral dynamos and magnetogenesis from torsionful Chern–Simons electrodynamics. Eur Phys J C **78**, 254 (2018)
8. B.P. Dolan, Class Quantum Gravity **27**, 095010 (2010)
9. V. de Sabbata, C. Sivaram, *Spin and Torsion in Gravitation* (World Scientific, Singapore, 1995)
10. L.C. Garcia de Andrade, Phys Lett B **468**, 28 (2011)
11. L. Garcia de Andrade, Lorentz violation bounds from torsion trace and radio galactic dynamos. Phys Rev D (Brief Reports) 84, 127504 (2011)
12. L. Garcia de Andrade, JCAP **08**, 23 (2014)
13. M. Dvornikov, V. Semikoz, Chiral Magnetic Effect in the presence of electroweak interaction as a quasiclassical phenomena. A Brandenburg, ApJ Letters. arXiv: 1702.06426v2 [hep-ph] (2017)
14. M. Novello, S.P. Bergliaffa, Bouncing Cosmologies. Phys Reports **463**, 127 (2008)
15. J. Ahonem, K. Enqvist, Phys Rev D **57**, 664 (1998)
16. A. Kostelecky, Phys Rev D **69**, 105009 (2004)
17. D. Biskamp, *Magnetrohydrodynamic Turbulence*. Cambridge University Press, Cambridge Monograph on Plasma Physics (2003)
18. A. Vilenkin, Phys Rev D **22**, 3080 (1980)
19. M. de Cesare, N. Mavromatos, S. Sarkar, Eur Phys J C **75**(10), 514 (2015)
20. J. Schober, I. Rogachevsky, O. Ruchaysky, A. Boyarsky, J. Froelich, N. Kleeorin, A. Brandenburg, Laminar and turbulent dynamos in chiral MHD-II: Simulations, Los Alamos arXiv: 1711.09733v1 [phys-flu-dyn]
21. M. Wadud, B. King, R. Bingham, G. Gregori et al., Phys Lett B **777**, 388 (2018)
22. P. Tzeferacos, A. Rigby, A.F.A. Bott et al., Laboratory evidence of dynamo amplification of magnetic fields in a turbulent plasma. Nat. commun. **9**, 591 (2018)
23. A. Boyarsky, J. Froelich, O. Ruchaysky, Phys Rev Lett **109**, 111602 (2012)
24. J.M. Salim, N. Souza, S.E.P. Bergliaffa, T. Prokopec, Creation of cosmological magnetic fields in a bouncing cosmology, arXiv:astro-ph/0612281 (2006)
25. J.D. Barrow, C. Tsagas, K. Yamamoto, Do intergalactic fields imply an open universe? arXiv: 1210.1183v2 [gr-qc] (2012)