TORSION AT LHC AND HYPERDYNAMOS
L C GARCIA DE ANDRADE
DFT-UERJ-RIO DE JANEIRO

Institute of **cosmology-Croacia**

r cosmology-Croacia.

OUTLINE:

1. EINSTEIN-CARTAN GRAVITY WITHOUT MATTER FIELDS (FÉRMIONS AND GAUGE BÓSONS) REDUCE TO GR!
2.MINIMAL COUPLING OF AXIAL TORSION TO FÉRMIONS AND NON-MINIMAL COUPLING OF TRACE TORSION TO GAUGE BÓSONS (NAM PRD 2022).
3. POSSIBLE INVESTIGATION OF CP TORSION FROM FÉRMIONS AT LHC (FUTURE WORK). BASED ON ALMEIDA ET AL PRD (2017)

outline1

Matter matters in Einstein-Cartan gravity

Georgios K. Karananas,* Mikhail Shaposhnikov,†
Andrey Shkerin,‡ Sebastian Zell †

Einstein-Cartan Portal to Dark Matter

Mikhail Shaposhnikov,[1] Andrey Shkerin,[1] Inar Timiryasov,[1] and Sebastian Zell[1]

Canadian Journal of Physics

Artic

Einstein–Cartan–Holst–Proca dynamos massive photons as dark matter and GWs

L.C. Garcia de Andrade

Departamento de Física Teórica, IF, UERJ, Rua São Francisco Xavier, 524, Institute for Cosmology and Philosophy of Nature, Rio de Janeiro, RJ, Maracanã CEP:20550, Croatia

Corresponding author: **L.C. Garcia de Andrade** (email: luizandra795@gmail.com)

Torsion at LHC and Hyperdy | talk_nepomuceno_phenoEx| | Torsion at LHC and Hyperdy | 2007.12595.pdf
https://arxiv.org/pdf/2007.12595.pdf
1 de 26 | Sumário | Ajustar à página | Exibição de página | Ler em voz alta | Adicionar anotações

HIP-2020-22/TH

Higgs inflation with the Holst and the Nieh–Yan term

Miklos Långvik,[a] Juha-Matti Ojanperä,[b] Sami Raatikainen[b] and Syksy Räsänen[b,c]

[a]Åshöjdens grundskola,
Sturegatan 6, 00510 Helsingfors, Finland

[b]University of Helsinki, Department of Physics and Helsinki Institute of Physics,
P.O. Box 64, FIN-00014 University of Helsinki, Finland

[c]Birzeit University, Department of Physics
P.O. Box 14, Birzeit, West Bank, Palestine

E-mail: miklos.langvik@protonmail.com, juha-matti.ojanpera@helsinki.fi,
sami.raatikainen@helsinki.fi, syksy.rasanen@iki.fi

astro-ph.CO] 20 Apr 2021

Torsion at LHC and Hyperdy | talk_nepomuceno_phenoEx| | Torsion at LHC and Hyperdy | 2112.10446.pdf
https://arxiv.org/pdf/2112.10446.pdf
1 de 7 Sumário Ajustar à página Exibição de página Ler em voz alta Adicionar anotações

Probing dark gauge boson via Einstein-Cartan portal

Cao H. Nam[1,*]

[1] *Phenikaa Institute for Advanced Study and Faculty of Fundamental Sciences, Phenikaa University, Yen Nghia, Ha Dong, Hanoi 12116, Vietnam*

(Dated: March 24, 2022)

Einstein-Cartan gravity which is an alternative formulation of general relativity introduces new degrees of freedom contained in the torsion field which encodes the torsion feature of spacetime. Interestingly, the torsion field couples to all fermions through its axial-vector mode with a universal coupling $\eta = 1/8$ which is possible to change under the quantum effects. We argue that Einstein-Cartan gravity provides a significant portal to probe A' dark gauge boson which resides in dark sector existing as an invisible world parallel to our own and couples to the standard model (SM) particles through only the kinetic mixing. For the (very) small kinetic mixing, searches for the A' from Drell-Yan processes are insensitive due to the suppressed production cross-section and the considerable SM backgrounds. However, through the mediation of torsion field the pp collisions produce dark-sector fermions which would significantly produce the A' due to unsuppressed dark gauge coupling. We explore the potential production modes of the A' through bremsstrahlung off dark-sector fermion and the cascade decays. Einstein-Cartan gravity suggests the torsion mass $\gtrsim \mathcal{O}(4)$ TeV for η varying

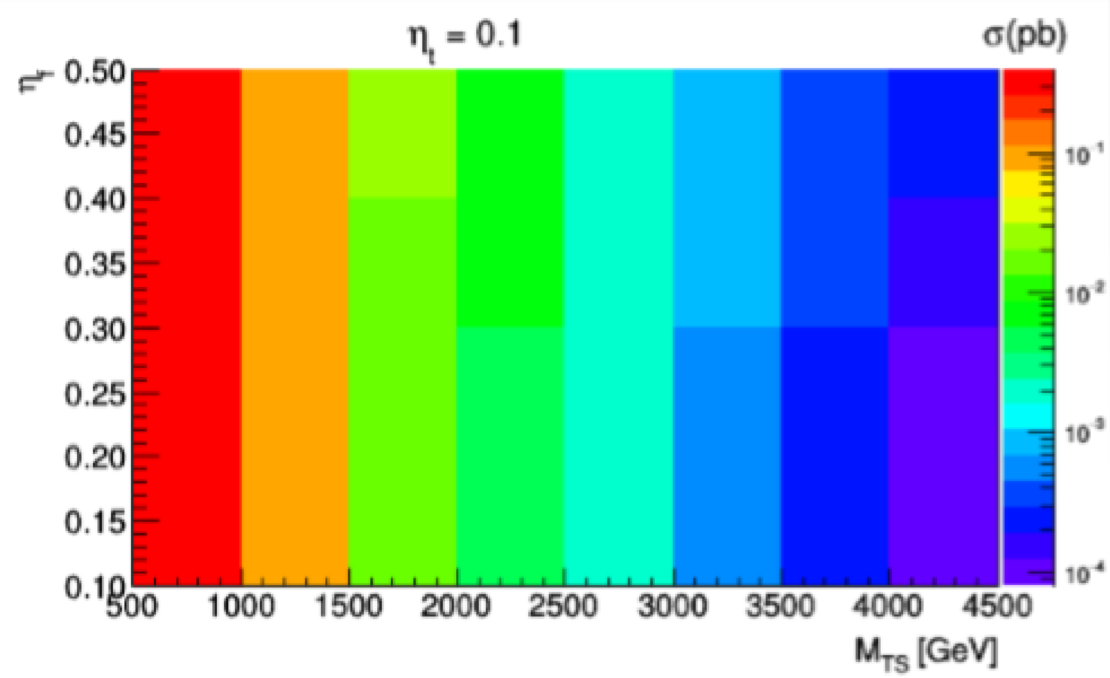
Torsion action and symmetry

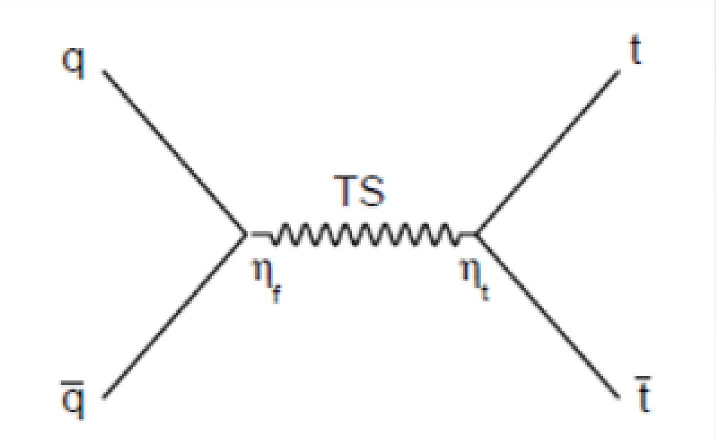
$$\mathcal{S}^{TS-matter}_{non-min} = i \int d^4x \sqrt{g}\, \bar{\psi}_{(i)} \left(\gamma^\alpha \nabla_\alpha + \imath\, \eta_i \gamma^5 \gamma^\mu S_\mu - \imath\, m_i \right) \psi_{(i)} \,,$$

$$\mathcal{S}^{TS-kin}_{tor} = \int d^4x \left\{ -\frac{1}{4} S_{\mu\nu} S^{\mu\nu} + \frac{1}{2} M^2_{TS}\, S_\mu S^\mu \right\}$$

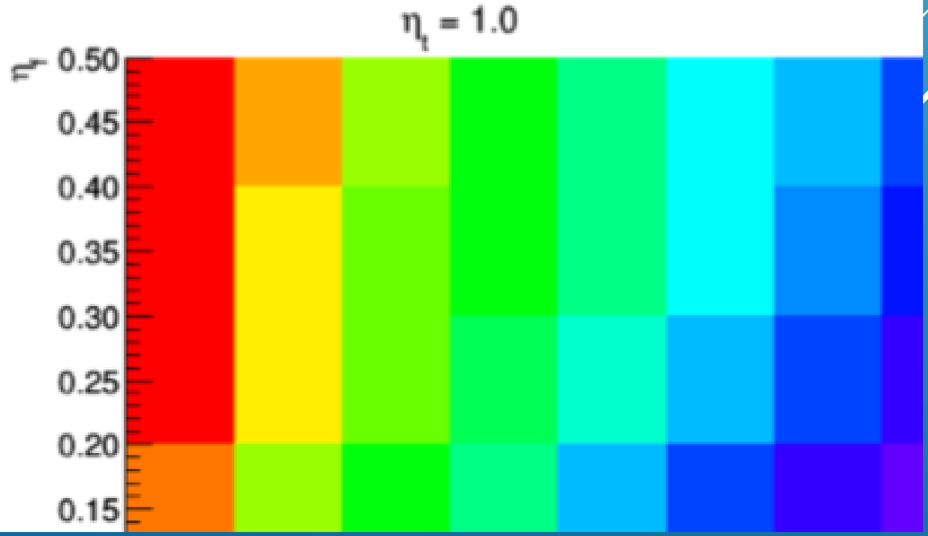
Extra transformations related to torsion

Torsion Production at LHC 13 TeV $(pp \longrightarrow TS \longrightarrow t\bar{t}X)$





For $\eta_t < \eta_f$, the increase of the torsion production is compensated by the decrease of $Br(TS \longrightarrow t\bar{t})$.



and the H parity violation term action term,

$$S_H = \frac{1}{\bar{\gamma}} \int dx^4 (-g)^{\frac{1}{2}} \left(M_P{}^2 + \chi_\gamma h^2\right) \varepsilon^{ijkl} R_{ijkl} \quad (4)$$

Here, h is the Higgs field, and (i, j, k = 0, 1, 2, 3) and T_{jkl} is the Cartan torsion tensor,

$$T^k{}_{ij} = \Gamma^k{}_{ij} - \Gamma^k{}_{ji} \quad (5)$$

us define the non-minimal coupling of the Maxwell photon field A^i to the ECH what we call ECMH action, given by

$$S_{CMH} = \frac{1}{\bar{\gamma}} \int d^4x(-g)^{\frac{1}{2}} \left(M_P{}^2 + \chi_{pt}A^2\right) \varepsilon^{ijkl} R_{ijkl} - \frac{1}{4} \int d^4x(-g)^{\frac{1}{2}} F^2 \quad (6)$$

where $F^2 = F_{ij}F^{ij}$ and $A^2 = A_iA^i$. Note that in this action χ_{pt} photon-torsion (PT) coupling replaces χ_γ, and inflaton squared h^2 is replaced by the EM potential squared, A^2, as compared with the inflaton Higgs ECH action (2). The idea here was to couple the Holst parity violation term with the pure Maxwellian action and a non-minimal coupling of photon potential squared, where the photon field squared couples with BI parameter $\bar{\gamma}$. When the BI parameter goes to infinity, the last action reduces to the Maxwell ordinary action. With this expression at hand, we are able in the next section to obtain interesting results on magnetogenesis and chiral dynamos related to the BI parameters. Last, we compute the strength of the parity violation in the inflationary stage of the early universe. To be able to make this computation, we make use of the early universe torsion estimated by

F^2 (6)
action
flaton
A^2, as
e idea
th the
f pho-
d cou-
oes to
ary ac-
e next
is and
com-
ionary
nputa-
ted by

Bossigham et al. [6] as $T^0 \sim 1$ MeV. This leads to the result

$$M_P{}^2 H_{ECH} = 10^{-24}\,\mathrm{GeV}^4 \tag{7}$$

where M_P is the Planck mass $M^2{}_P \sim 10^{-18}\,\mathrm{GeV}^2$. This shows that this parity violation Holst term at inflationary epochs is tremendously important. At present epochs of the universe, torsion component $T^0 \sim 10^{-31}$GeV as obtained by Kostelecky et al. [21], with

$$M_P{}^2 H_{ECH} = 10^{-62}\,\mathrm{GeV}^4 \tag{8}$$

In the next section, we compute the chiral dynamo equation in parity violation ECMH formulation and find large-scale magnetic fields enhanced by chiral and London currents and decay upon the Holst torsion current obtained by variation of the ECMH action in terms of both torsion axial and torsion trace vectors.

3. Chiral dynamos from parity violation and spiral torsion trace waves

The spiral torsion has been investigated previously by Hehl [22] in the context of Riemann–Cartan space–time. More recently, Alexander et al. [18] have shown that it is possible to obtain parity-odd terms in EC gravity action with respect to cosmological constants by making use of spiral stair-case torsion. In this paper, we built torsion currents from the ECMH action, written in this section in the form [7].

$$S_{ECMH} = \frac{1}{\kappa}\int dx^4(-g)^{\frac{1}{2}}\left[-\mathring{R} + \frac{1}{2\beta}\varepsilon_{ijkl}\mathring{R}^{ijkl}\left(1+\lambda A^2\right) - \frac{1}{4}F^2 + J_i A^i\right] \tag{9}$$

where κ is the Einstein's gravitational constant and λ is

Let us now solve the variational obtained equations with regard to the trace and axial torsion vectors as

$$\delta S_{ECMH}/\delta S_j = 0 \tag{13}$$

and

$$\delta S_{ECMH/\delta T_j} = 0 \tag{14}$$

Since torsion components are non-propagating and EC like spin–spin contact interaction, from these equations we obtain a system of algebraic equations,

$$T^i = \frac{1}{4\beta}S^i \tag{15}$$

and

$$S^i = \frac{3\kappa\theta J^i}{2\left(1+\lambda A^2\right)} \tag{16}$$

Substitution of (16) into (15) yields

$$T^i = \frac{3}{8}\frac{\kappa\theta J^i}{\beta\left(1+\lambda A^2\right)} \tag{17}$$

Note that this last expression allows us to build the dynamo equation from the three current vectors,

$$J_H{}^i = \frac{8}{3}\frac{\beta\left(1+\lambda A^2\right)}{\kappa\theta}T^i \tag{18}$$

The three-vector total current J is

$$J_{ECMH} = J_{Ohm} + J_L + J_H + J_{Chiral} \tag{19}$$

where κ is the Einstein's gravitational constant and λ is the massive photon-torsion coupling [14]. Moreover, the tilde over the scalars and tensors corresponds to Riemann–Cartan curvatures, which may be expressed in terms of the Riemann correspondent quantities and torsion vectors as

$$\varepsilon_{ijkl}\tilde{R}^{ijkl} = -\nabla_i S^i - \frac{2}{3}T^i S_i + \frac{1}{2}\varepsilon_{ijkl}q^{pij}q_p{}^{kl} \tag{10}$$

where torsion q is taken to be zero to simplify calculations. The Ricci–Cartan scalars in terms of trace vector S and axial vector T is

$$\tilde{R} = R - 2\nabla_i T^i - \frac{2}{3}T^i T_i + \frac{1}{24}S_i S^i. \tag{11}$$

In this section, we assume that the Riemannian–Ricci scalar R vanishes approximately since the metric is taken as a very small perturbation and almost Minkowskian or Riemann flat. With these expressions, one may write down the Holst action as

$$S_{ECMH} = \frac{1}{\kappa}\int dx^4(-g)^{\frac{1}{2}}\left[-\frac{1}{3\beta}T^i S_i\left(1+\lambda A^2\right) + \frac{2}{3}T_i T^i - \frac{1}{24}S_i S^i - \frac{1}{2}F^2 + J_i A^i + \frac{1}{2}S_i J^i\right] \tag{12}$$

$$J_{ECMH} = J_{Ohm} + J_L + J_H + J_{Chiral} \tag{19}$$

which are, respectively, as the Ohm current,

$$J_{Ohm} = \sigma\left(\boldsymbol{E} + \mathbf{v}\times\boldsymbol{B}\right) \tag{20}$$

where σ is the electric conductivity and the London current,

$$J_L = \lambda\boldsymbol{A} \tag{21}$$

the Holst current,

$$J_H = \frac{8}{3}\frac{\beta\left(1+\lambda A^2\right)}{\kappa\theta}\boldsymbol{T} \tag{22}$$

and the chiral magnetic current,

$$J_{Ch} = \mu_5\boldsymbol{B} \tag{23}$$

These four currents help us deduce the chiral dynamo equation with the Holst source as

$$J_{ECMH} = \sigma\left(\boldsymbol{E} + \mathbf{v}\times\boldsymbol{B}\right) + \frac{8}{3}\frac{\beta\left(1+\lambda A^2\right)}{\kappa\theta}\boldsymbol{T} + \lambda\boldsymbol{A} + \mu_5\boldsymbol{B} \tag{24}$$

Taking the curl of this previous current, one obtains

$$\nabla \times \boldsymbol{J}_{\mathrm{ECMH}} = \lambda \boldsymbol{B} + \sigma \nabla \times [(\boldsymbol{E} + \boldsymbol{v} \times \boldsymbol{B})] + k\eta\mu_5 \boldsymbol{B} + \frac{8}{3}\frac{\beta\left(1+\lambda\Lambda^2\right)}{\kappa\theta}\chi \boldsymbol{T} \tag{25}$$

where we have used the helical magnetic fields assumption,

$$\nabla \times \boldsymbol{B} = k\boldsymbol{B} \tag{26}$$

and the spiral-like torsion as

$$\nabla \times \boldsymbol{T} = \chi \boldsymbol{T} \tag{27}$$

where the magnetic helical field may be expressed as

$$\boldsymbol{B} = B_0 [\mathbf{x} \ \cos(kz) + \mathbf{y} \ \sin(kz)]\, e^{\gamma t} \tag{28}$$

and the spiral torsion or helical torsion is

$$\boldsymbol{T} = T_0 [\mathbf{x} \ \cos(kz) + \mathbf{y} \ \sin(kz)]\, e^{\gamma t} \tag{29}$$

where the magnetic helical field may be expressed as

$$B = B_0 \left[\mathbf{x} \ \cos(kz) + \mathbf{y} \ \sin(kz) \right] e^{\gamma t} \tag{28}$$

and the spiral torsion or helical torsion is

$$T = T_0 \left[\mathbf{x} \ \cos(kz) + \mathbf{y} \ \sin(kz) \right] e^{\gamma t} \tag{29}$$

Note that if the expression $J_{\mathrm{ECMH}} = grad\Psi$ the $rotJ_{\mathrm{ECMH}}$ vanishes, and expression (25) reads

$$[\lambda\eta + \nabla.\mathbf{v} + k\eta\mu_5] B - \partial_t B = \frac{8}{3} \frac{\beta\left(1 + \lambda A^2\right)}{\kappa\theta} \chi T \tag{30}$$

In this expression, we have used the Faraday induction equation. This expression is exactly the dynamo equation with the convective dynamo term of $div\mathbf{v}$, which is negative, if the conductivity is too low as in the early universe, then it is negative, since the magnetic field lines should follow the flow lines [3] and must converge instead of expand. If we want to solve this expression for chiral dynamos, we shall assume the following ansatz $B_0(t) \sim e^{\gamma t}$. Therefore, the dynamo equation reduces to a dependence between the torsion vector and magnetic fields,

$$B = \frac{\frac{8}{3} \frac{\beta\left(1+\lambda A^2\right)}{\kappa\theta} \chi}{[\lambda\eta + \nabla.\mathbf{v} + k\eta\mu_5 - \gamma]} T \tag{31}$$

It is shown in this paper that the magnetic field dynamo amplification possesses a contribution from the square of the ratio between the photon mass and torsion, which is given by the photon-torsion coupling $\lambda \sim 10^{-24}$ as computed by de Sabbata, Garcia de Andrade, and Sivaram [23]. This can be simply shown by defining the proportionality between B and T (31) as a constant β_0. Inverting this relation, one obtains an expression for the amplification factor when this dynamo regeneration wins the competition with the other components,

tional wave astronomy observatory data [24]. Gravitational waves (GWs) are actually very important to decide whether a modified gravity theory may be as good as general relativity or can be dismissed. As pointed out by Coda, the improvements of sensitivity allow one to perform GWs astronomy with frequencies-dependent response functions of the interferometer for GWs from several extended theories of gravity. These LIGO-like experiments may help us to find a definitive theory of gravity. Let us now show that from ECH action, it is possible to build a torsion trace spiral wave when one allows an axion scalar field dependence of torsion as its gradient. Trace torsion waves were previously investigated by Lucat and Prokopec [25], who argued that torsion waves are of trace torsion nature, and no torsion skew-symmetry can produce any kind of torsion wave. Here, this is questioned since, as we reviewed in section 2, both types of torsion are linked by one expression. Recall that from expression above, we obtained

$$\partial_t T^t = \frac{1}{4\beta} \partial_t S^t \tag{34}$$

Assuming that the torsion trace vector S is given in terms of the axion scalar field as $S_t = \partial_t \phi$ where ϕ is axion-torsion potential. Thus, one obtains

$$\partial_t T^t = \frac{1}{4\beta} \Box \phi \tag{35}$$

This expression shows that a scalar torsion trace wave in ECH gravity would in principle imply another spin-0 skew-torsion wave would exist if a torsion trace scalar wave exists, since if one defines a scalar function Θ, the gradient of which produces a skew-torsion wave. It seems that the Lucat–Prokopec argument is not valid for ECH gravity. However, note that eq. (33) maybe inverted and expressed as

$$\Box \phi = 4\beta \partial_t T^t \tag{36}$$

expression for the amplification factor when this dynamo regeneration wins the competition with the other components, which are the results of resistivity and the compressibility of the plasma flow. This can be obtained as

$$\gamma = \frac{8}{3}\frac{\beta\left(1+\lambda A^2\right)\chi}{\kappa\theta\beta_0} \tag{32}$$

Note from this expression that the torsion contribution is present in the dynamo amplification factor through the pres-

$$\Box\phi = 4\beta\partial_i T^i \tag{36}$$

where $\Box = \partial_i\partial^i$ is the wave D Alembertian operator in Minkowski M^4 spacetime. Now, one may read this equation as a torsion trace scalar spin-0 wave sourced by the divergence of the skew symmetric torsion vector. If one gauges this skew torsion as $\partial_i T^i = 0$, one would end up with the scar torsion wave equation in the vacuum. To close the paper, let us now address the question of how the ECH transforms under the action of the axionic torsion trace assumption. This can be

Can. J. Phys. **00:** 1–6 (2022) | dx.doi.org/10.1139/cjp-2021-0406

substituted at once in the ECH action above, which yields

$$S_{\mathrm{ECH}} = \frac{1}{\kappa}\int \mathrm{d}x^4(-g)^{\frac{1}{2}}\left[-\frac{1}{3\beta}T_i^i + \frac{2}{3}T_iT^i - \frac{1}{24}S_iS^i + \frac{1}{8}S_iJ^i\right) \tag{37}$$

Hence, the ECH action with a torsion scalar field reads

$$S_{\mathrm{ECH}} = \frac{1}{\kappa}\int \mathrm{d}x^4(-g)^{\frac{1}{2}} \times\left(-\frac{1}{3\beta}T^i\partial_i\phi + \frac{2}{3}T_iT^i - \frac{1}{24}\partial_i\phi\partial^i\phi + \frac{1}{8}\partial_i\phi J^i\right) \tag{38}$$

Now, let us examine how the other equation for torsion becomes ϕ. This yields

$$\partial_i S^i = \frac{\kappa\theta}{2}\partial_i J^i \tag{39}$$

Hence, the J^i divergence is the source of torsion trace scalar

which shows that Θ plays the role of a torsion trace potential. The current is locally conserved in Minkowski–Cartan space–time. It is also important to note that the non-dynamical torsion present in the original EC gravity may now accommodate a dynamical torsion in its extensions like ECH gravity. It is interesting to note that Bombacigno et al [26] have shown that the inverse of Immirzi parameter β satisfies the equation $\Box\delta\beta = 0$, which they claim is a genuine torsion effect able to be detected. In our case, the Immirzi parameter acts as a torsion wave source. This is a consequence of the local current conservation.

4. Conclusions

This paper was motivated for previous publications where a very particular type of the non-chiral dynamo with parity-violating electrodynamics in Riemann–Cartan space–time was

CANADIAN J PHYS 2023.

Einstein-Cartan-Holst-Proca dynamos, massive photons as dark mater and GWs

L C Garcia de Andrade

Departamento de Física Teórica, IF, UERJ, Rua São Francisco Xavier, 524, Institute for Cosmology and Philosophy of Nature, Rio de Janeiro, RJ, Maracanã CEP:20550, Croatia

Corresponding author: L.C. Garcia de Andrade (email: luizandra795@gmail.com)

Abstract

In this paper, we extend Shaposhnikov et al.'s parity violating the Einstein–Cartan–Holst action by adding to Holst term H, a Proca photon–torsion coupling as computed by De Sabbata, Garcia de Andrade, and Sivaram. The strength of Holst term is obtained, in the case of early universe torsion as, T ~ 1 MeV.

Holst TERM IS GIVEN BY THE PARITY VIOLATING TORSION TERM WHICH IS THE PRODUCT OF RIEMANN-CARTAN CURVATURE TENSOR AND THE TOTALLY SKEW-SYMMETRIC LEVI-CIVITA OBJECT.

SSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSS

PRIMORDIAL MAGNETIC FIELD AND DYNAMO FROM TORSION PARITY VIOLATION PLB 2012. GARCIA DE ANDRADE,

Physics Letters B 711 (2012) 143–146

Contents lists available at SciVerse ScienceDirect

Physics Letters B

www.elsevier.com/locate/physletb

Primordial magnetic fields and dynamos from parity violated torsion

L.C. Garcia de Andrade

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

A R T I C L E I N F O

Article history:
Received 13 December 2011
Received in revised form 26 March 2012
Accepted 26 March 2012
Available online 28 March 2012
Editor: M. Trodden

Keywords:
Parity violation
Torsion theories
Lorentz violation
Dynamos
Gravitation

A B S T R A C T

It is well known that torsion induced magnetic fields may seed galactic dynamos, but the price one pays for that is the conformal and gauge invariance breaks and a tiny photon mass. More recently I have shown [L.C. Garcia de Andrade, Phys. Lett. B 468 (2011) 28] that magnetic fields decay in a gauge invariant non-minimal coupling theory of torsion is slow down, which would allow for dynamo action to take place. In this Letter, by adding a parity violation term of the type $R_{\mu\nu\rho\sigma}\epsilon^{\mu\nu\rho\sigma}$ to the non-coupling term, a magnetic dynamo equation is obtained. From dynamo equation it is shown that torsion terms only appear in the dynamo equation when diffusion in the cosmic plasma is present. Torsion breaks the homogeneity of the magnetic field in the universe. Since Zeldovich anti-dynamo theorem assumes that the spacetime should be totally flat, torsion is responsible for violation of anti-dynamo theorem in 2D spatial dimensions. Contrary to previous results torsion induced primordial magnetic fields cannot seed galactic dynamos since from torsion and diffusion coefficient the decaying time of the magnetic field is $10^6 yrs$, which is much shorter than the galaxy age.

© 2012 Published by Elsevier B.V. Open access under the Elsevier OA license.

FROM THE PLB AND CAN J PHYS IT WOULD BE POSSIBLE TO PLACE LIMITS ON TORSION FROM LHC CP EXPERIMENTS?

PHYS LETTERS B 2012

2 Spin-1 dark massive photons torsion transmutation into axions and CS electrodynamics

Here we propose that in similar way as the determination of pp decay into torsion given by the cross section [11] given by

$$\sigma(pp \to TS) \tag{1}$$

where this indicates the decay of four-fermions into torsion (TS), one can by transitivity see that there is a decay rate between the dark photons and TS. This can be done easily, by the result of Agrawal et al as the decay rate between axions and dark photons as

$$\Gamma(a \to \gamma\gamma) \approx \frac{\beta^2}{64\pi}\frac{m^3{}_a}{f^2{}_a} \tag{2}$$

where this allows us to conjecture that the Duncan et al paper on torsion transmutation into the axion be in the form of a similar decay rate of the axion into dark photons as

$$\Gamma(TS \to a) \tag{3}$$

which by the universal mathematical property of transitivity lead us to suggest the following decay rate

$$\Gamma(TS \to \gamma\gamma) \tag{4}$$

which is the main idea behind this section. Thoughout the paper, we do not compute the last two decays. But we point it out that cross sections were computed recently by Nam, for on-shell torsion fields and dark gauge bosons probes via Einstein-Cartan portal [12] given by $\sigma \approx \frac{1}{4}\sigma(pp \to TS \to l^+, l^-)$ where TS represents torsion coming from the action $\mathcal{L}_T = -\frac{1}{4}S_{ij}S^{ij} + \frac{1}{2}m^2{}_T S_{ij}S^{ij}$ where S_{ij} is the curl of axial-torsion pseudo-vector S_i, whereas m_T represents the torsion mass [10]. The minimal coupling to torsion is also used in Nam paper. In this section we shall investigate the the kinematics of this decay, and less phenomenology, which can be postponed to a future publication. By taking the action of the Chern-Simons torsionful electrodynamics with minimal coupling as

$$S_{DM} = \int d^4x[\frac{1}{2}\partial_i\phi\partial^i\phi - V(\phi) - \frac{1}{4}F^2 + \frac{1}{2}m^2{}_\gamma A^2 - \frac{\beta\phi}{4f_a}F\tilde{F}] \tag{5}$$

$$e^{i\Gamma_{eff}[A,T]} = \int [d\psi][d\bar{\psi}]e^{[i\int dx\mathcal{L}_{QED}(A,T,\psi,\bar{\psi})]}det\mathcal{O} \tag{9}$$

Here the operator under the determinant det inside the sign of integral is

$$\mathcal{O}_{xy} = (i\gamma D_x - M)\delta_{xy} \tag{10}$$

where γ is are Dirac matrices, and the operator D is given by

$$D_k = \partial_k - ieA_k - igT_k \tag{11}$$

where the axial torsion is then introduced in the effective action. Effective action of dark photon expression can be expanded as

$$e^{i\Gamma_{eff}[A,T]} = \int [d\psi][d\bar{\psi}]e^{[-i\int dxT^2A^2]}e^{[i\int dx\mathcal{L}_{QED}(A,\psi,\bar{\psi})]}det\mathcal{O} \tag{12}$$

$$F\tilde{F} = F\tilde{F} + 2\tilde{F}TA \quad (13)$$

which is the invariant that again represents the coupling between axial torsion and the dark massive photon in DM, and substituting it into the dark photon action above one obtains

$$S_{DM} = \int d^4x[\frac{1}{2}\dot{\phi}^2 + \frac{1}{4}(S_0)^2\phi^0 + S^0\dot{\phi}\phi - V(\phi) - \frac{1}{4}F^2 + \frac{1}{2}m^2{}_\gamma A^2 - \frac{\beta\phi}{4f_a}[F\tilde{F} + \tilde{F}^{0c}S_0A_c + E.B + S_0\mathrm{A.B}]] \quad (14)$$

$$\partial_t \frac{\partial \mathcal{L}}{\partial \dot{X}} - \frac{\partial \mathcal{L}}{\partial X} = 0 \tag{15}$$

since $X = (A, \phi)$. The application of the EL equation to the variable A magnetic field four-potential in torsionful spacetime yields

$$\partial_i [F^{ik}(1 - \frac{\beta\phi}{4f_a})] = J^k + \frac{1}{2} m_\gamma A^k \tag{16}$$

where J is the Ohm current given by

$$\mathbf{J}_{Ohm} = \sigma[\mathbf{E} + \mathbf{v} \times \mathbf{B}] \tag{17}$$

the second current in expression (17) is the London like current for the dark massive photon in DM. By taking the equations of Maxwell-Cartan-Proca electrodynamics yields the equations

$$\partial_0 [F^{0j} + 2S^0 A^j](1 - \frac{\beta\phi}{4f_a}) = J^j + \frac{1}{2} {m_\gamma}^2 A^j \tag{18}$$

This equation is the Ampere like equations and the Coulomb like equations comes from the other equation

$$\partial_i [(1 - \frac{\beta\phi}{4f_a})(E^i + 2S^0 A^0)] = \rho_\gamma + \frac{1}{2} {m_\gamma}^2 A^0 \tag{19}$$

This is the Coulomb like equation and the first term on the right-hand-side of this equation is the dark photon mass density. The equation is explicity shown to be

$$(1 - \frac{\beta\phi}{4f_a}) \nabla . \mathbf{E} = \rho_\gamma + \frac{1}{2} {m_\gamma}^2 A^0 \tag{20}$$

The Ampere s like law is given by

$$\partial_t [(1 - \frac{\beta\phi}{4f_a})\mathbf{E} - \frac{\beta\dot{\phi}}{4f_a}\mathbf{E} + ({m_\gamma}^2 + \frac{\beta\phi}{4f_a})\mathbf{A} = \mathbf{J}_{Ohm} \tag{21}$$

$$[(1 - \frac{\beta\phi}{4f_a})]\partial^2{}_t\mathbf{B} - (\frac{\beta\dot{\phi}}{4f_a} + \sigma)\partial_t\mathbf{B} + [(m_\gamma{}^2 + \frac{\beta\dot{\phi}}{4f_a}S^0 - 2(1 - \frac{\beta\dot{\phi}}{4f_a}S^0)]\lambda\mathbf{B} = 0 \quad (26)$$

Note that in the absence of torsion one obtains an oscillating magnetic field as in Agrawal et al. Now one observes that, to solve this equation in CS electrodynamics, one must have the homogeneous axion $\phi(t)$, t being the cosmic time, we need the dynamical equation for the axion which again by the EL equation is

$$\ddot{\phi} + \frac{1}{2}S^0\dot{\phi} + \partial_\phi V(\phi) + S_0\mathcal{H} = 0 \quad (27)$$

where we have neglected the chirality term, and kept the helicity density $\mathcal{H} = \mathcal{A}.\mathcal{B}$. Assuming that the axion potential is given by

$$V = m^2{}_a f^2{}_a(1 - cos(\frac{\phi}{f_a})) \quad (28)$$

Then, the partial derivative of this potential is

$$\partial_\phi V = m^2{}_a f_a sin(\frac{\phi}{f_a}) \quad (29)$$

which approximated becomes

$$\partial_\phi V \approx m^2{}_a\phi \quad (30)$$

Thus substitution of this approximated potential in the axion dynamical equation (27) one obtains the following expression

$$\ddot{\phi} + \frac{1}{2}S^0\dot{\phi} + m_a{}^2\phi + S_0\mathcal{H} = 0 \quad (31)$$

To help to solve this equation and to determine the evolution of the magnetic field in DM, since both the axial torsion and helicity are both, very weak, one may drop the last term on the left-hand side of the last equation. Therefore the equation reduces to

$$\delta^2 + \frac{1}{2}S^0\delta + m_a{}^2 = 0 \quad (32)$$

where we have taken the ansatz $\phi = \phi_0 e^{\delta t}$ and substitution into expression (32). Now by solving the characteristic algebraic equation one obtains

$$\delta_- = \frac{2m^2{}_a}{S_0} \quad (33)$$

$$[(1-\frac{\beta\phi}{4f_a})]\partial^2{}_t\mathbf{B}-(\frac{\beta\dot{\phi}}{4f_a}+\sigma)\partial_t\mathbf{B}+[(m_\gamma{}^2+\frac{\beta\dot{\phi}}{4f_a}S^0-2(1-\frac{\beta\dot{\phi}}{4f_a}S^0)]\lambda\mathbf{B}=0 \quad (26)$$

Note that in the absence of torsion one obtains an oscillating magnetic field as in Agrawal et al. Now one observes that, to solve this equation in CS electrodynamics, one must have the homogeneous axion $\phi(t)$, t being the cosmic time, we need the dynamical equation for the axion which again by the EL equation is

$$\ddot{\phi}+\frac{1}{2}S^0\dot{\phi}+\partial_\phi V(\phi)+S_0\mathcal{H}=0 \quad (27)$$

where we have neglected the chirality term, and kept the helicity density $\mathcal{H}=\mathcal{A}.\mathcal{B}$. Assuming that the axion potential is given by

$$V=m^2{}_af^2{}_a(1-cos(\frac{\phi}{f_a})) \quad (28)$$

Then, the partial derivative of this potential is

$$\partial_\phi V=m^2{}_af_a sin(\frac{\phi}{f_a}) \quad (29)$$

which approximated becomes

$$\partial_\phi V\approx m^2{}_a\phi \quad (30)$$

Thus substitution of this approximated potential in the axion dynamical equation (27) one obtains the following expression

$$\ddot{\phi}+\frac{1}{2}S^0\dot{\phi}+m_a{}^2\phi+S_0\mathcal{H}=0 \quad (31)$$

To help to solve this equation and to determine the evolution of the magnetic field in DM, since both the axial torsion and helicity are both, very weak, one may drop the last term on the left-hand side of the last equation. Therefore the equation reduces to

$$\delta^2+\frac{1}{2}S^0\delta+m_a{}^2=0 \quad (32)$$

where we have taken the ansatz $\phi=\phi_0e^{\delta t}$ and substitution into expression (32). Now by solving the characteristic algebraic equation one obtains

$$\delta_-=\frac{2m^2{}_a}{S_0} \quad (33)$$

$$\phi(t) = \phi_0 exp[(\frac{2m^2{}_a}{S_0})t] \quad (34)$$

The axion driven by torsion depends also on the torsion chirality or to the sign of S_0. Then for the negative left-hand torsion chirality implies that the axion cosmic scale decays in time, on the other hand when it is positive the axion cosmic scale is amplified. Let us now substitute this axion expression into the magnetic wave equation to obtain the magnetogenesis due to dark massive photon. Before that let us compute the time derivative of the axion as

$$\dot{\phi} = \frac{2m^2{}_a}{S_0}\phi \quad (35)$$

This expression derived once more with respect to cosmic time, leads to

$$\ddot{\phi} - \omega^2\phi = 0 \quad (36)$$

where $\omega = \frac{m^2}{S_0}$ which yields

$$\phi = \phi_0 sinh[(\frac{m^2{}_a}{S_0})t] \quad (37)$$

This solution is quite important since it shows that the axial torsion contributes to the damping of the axion. This can be better understood if we consider the approximation with this last expression with very small time t as happens in the early universe where, for example at inflation $t \sim 10^{-35}s$ and at QCD scale $t \sim 10^{-5}s$. This assumes then that $t <<< 1$ which yields

$$\phi = \phi_0[(\frac{m^2{}_a}{S_0})t] \quad (38)$$

$$[(1-\frac{\beta\phi}{4f_a})]\partial^2{}_t\mathbf{B}-(\frac{\beta\dot{\phi}}{4f_a}+\sigma)\partial_t\mathbf{B}+[(m_\gamma{}^2+\frac{\beta\dot{\phi}}{4f_a}S^0-2(1-\frac{\beta\dot{\phi}}{4f_a}S^0)]\lambda\mathbf{B}=0 \quad (39)$$

By taking the ansatz for the magnetic field as $B = B_{seed}exp[\gamma t]$ into expression (39) yields

$$\gamma^2-(\frac{\beta\phi_0 m^2{}_a}{4f_a S_0}+\sigma)\gamma+[(m_\gamma{}^2+\frac{\beta\phi_0 m^2{}_a}{4f_a}-2)]\lambda=0 \quad (40)$$

To obtain this equation we assume that the early universe era comic time $t <<< 1$, which reduce the factor of γ^2 to 1. Furthermore we have taken the Agrawal et al approach that in the conformal time metric one could taken the initial axion value $\phi_0 = f_a$. These simplification lead to the formula for the algebraic equation to

$$\gamma^2-(\frac{\beta\phi_0 m^2{}_a}{4f_a S_0}+\sigma)\gamma=0 \quad (41)$$

where in precedent section we consider that the magnetic helicity is null, and only non-helical primordial magnetic fields are considered. Therefore solving the characteristic algebraic equation we get the degenerated solution

$$\gamma_{a/tor}=[\sigma+\frac{\beta m^2{}_a}{S_0}] \quad (42)$$

with torsion contribution. Note that, if the axial torsion is positive or right-chiral here, we have a dynamo amplification, while in the other choice we have a left-chiral torsion which implies the decay of primordial magnetic field. By taking the torion of the QCD GeV order of $1MeV$ we obtain

$$\gamma_{a/tors(QCD)}\approx 10^{-6-1} \quad (43)$$

where in the TeV scale of the LHC and very early universe we obtain

$$\gamma_{a/tors(TeV)}\approx 10^{-7-1} \quad (44)$$

Hypermagnetic dynamos via Einstein-Cartan portal?

May 22, 2023

By L.C. Garcia de Andrade[1]

Abstract

In this paper we generalised the Enqvist-Olesen electroweak decay method of a ferromagnetic-like structure formation in GUT to iclude torsion potential in non-minimal coupling lagrangian. The possibility of obtaining hypermagnetic fields computed from the cooper pairs and from W-gauge bosons in the Einstein-Cartan portal, are shown to be given by $B_W \sim m^2{}_W e^{-\tau}$. Here, τ represents the chiral torsion potential. If torsion potential is right handed, or positive, it drives a dynamo amplification which reaches 10^8. This estimate is the well-known dynamo amplification, which is able to seed galactic dynamo. Of course, when the torsion potential of the torsion trace vector vanishes the torsionless Enqvist-Olesen result is recovered. Since torsion trace vector is in general linked to gauge bosons as axial torsion is associated to fermions, it seems that the present study could be applied to the recent Cao H. Nam s idea of using Einstein-Cartan portal to produce dark gauge bosons mediated by torsion and dileptons, to include primordial magnetic fields.

2 Light gauge bosons in Einstein-Cartan gravity and hypermagnetic fields from spin-torsion density and W boson mass

In this section we present a review of the De Sabbata and Sivaram results on W boson mass generation of the magnetic fields in primordial universe in terms of axial torsion and fermions and the spin-torsion density in the Einstein-Cartan portal. Let us focus first on the work of Enqvist and Olesen, on the computation of averaged value of the $< F^2{}_{ij} >$ which is given by $\sqrt{F^2{}_{ij}}$. **Their idea is connected to the present paper in the sense that although here we consider abelian fields, they make use of non-abelian gauge theories to investigate the role of ferromagnetic-like vacuum with non-vanishing magnetic field, also existing at finite temperature and moreover, they use this idea to generating primordial magnetic fields from the formation of ferromagnetic-like vacuum in grand unified field theories (GUT) scales**. These magnetic fields would be comoving with the primordial plasma. On dimensional grounds this theory yields the expression

$$\sqrt{< F^2{}_{ij} >} \sim m^2{}_W \sim 100 GeV^2 = 10^{24} Gauss \tag{1}$$

In the present paper we shall show that this expression is generalised by the product of it by an exponential of the torsion potential on a a torsion trace generated torsion potential, where the primordial magnetic fields so obtained, reduces to the Enqvist-Olesen (EO) result in the case of vanishing torsion trace potential. This is why seems to be important to provide the readers with these reviews here. To obtain this result they made use of a non-Abelian gauge boson hypermagnetic field of the electroweak theory $SU(2)XU(1)_Y$, which is broken down to $U(1)_{em}$, we obtain

$$F_{ij} = 2\partial_{[i}V_{j]} + [V_i, V_j] \tag{2}$$

where [,] is the non-Abelian commutator of the Yang-Mills field like gravity. Here we notice that V_i (i,j=0,1,2,3) is the gradient of a scalar or pseudo-scalar field we note that this expression reduces to the one used by EO

$$F_{ij} = [V_i, V_j] \tag{3}$$

In their case, from this expression they found the solution

$$V_i = \frac{2}{\phi}\sqrt{\frac{sin\theta}{g}}\partial_i\phi \tag{4}$$

Since this solution can be recast in the form of a gradient of the logarythm of the Higgs scalar field ϕ,**the EW vector boson V could be expressed as a gradient of a potential function of the Higgs fields. Similar to what happens in the torsion potential case.** Then, keep only non-Abelian term is justified. However, in this paper we addopt the viewpoint of Kleinert, where the gauge bosons are free and so we may neglect non-linearities. Therefore, the hyper-EM fields are given by the field 2-tensor

$$F_{ij} = 2\partial_{[i}V_{j]} \tag{5}$$

without the non-abelian terms. **In this case we see that the vector gauge boson V cannot be a gradient of a scalar otherwise the hyperelectromagnetic field would vanish by symmetry.** Before we proceed to consider the Kleinert gauge light bosons equations with the Higgs field, it is worth mentioning that, in de Sabbata and Sivaram [15], they have considered the coupling with four-fermion interactions and axial torsion. From the use of the Cooper-pair condensate the phase transitions in the early universe (Vachaspati refs) would be followed by a primordial magnetic field, as the universe cools below phase transition temperatures, where spin-torsion interaction could be effective. Question of symmetry breaking and mass generation, today s called Higgs mechanism, brings in the analogy with superconductors type II (Kleinert book). In this case phase transition is broken, which means that the we no longer have invariance under the term $e^{\hat{\imath}\phi}$ in the superconducting ground state which makes the photon acquires a mass. Nowadays it is very usual to call a dark photon, a spin-1 gauge boson related to axion mass [**?**]. The symmetry is clearly restored above a critical value of the magnetic field. This critical value, which restores symmetry is [**?**]

$$B_c = \frac{m^2}{2eh} \tag{6}$$

where h is the Planck constant, e the electric charge and 2e is the charge carried by the Cooper pair, whereas m is the induced mass. Here we assume the relativistic units to be valid (c=h=1). De Sabbata and Sivaram argue that for a typical superconductor, with penetration depth of few microns, the magnetic field would be of the order of very few Gauss and this would correspond to an effective mass of $\sim 10^{-3} GeV$. Since torsion induces a magnetic field, when the invariance under $SL(2,C)$ or $exp[\frac{1}{4}\theta_{ab}\gamma^a\gamma^b]$ is broken, and equations (6) one obtains the equation

$$B_{EC} = \frac{8\pi}{3}(2\alpha)^{\frac{1}{2}}\sigma \tag{7}$$

where σ is the spin-torsion density contact fermionic interaction of Einstein-Cartan (EC) gravity [**?**]. By equating these last two expressions, De Sabbata and Sivaram found the mass generated in the Meissner-Higgs mechanism as where σ is the spin-torsion density contact fermionic interaction of Einstein-Cartan (EC) gravity [?]. By equating these last two expressions, De Sabbata and Sivaram found the mass generated in the Meissner-Higgs mechanism as

$$m^2 = \frac{8\pi}{c}(2e\alpha)^{\frac{1}{2}}\sigma \tag{8}$$

and as the weak interaction is already included in the general covariant Dirac equation, it was possible to compute the induced mass of the weak intermediate boson. Though here we use $G = 1$, the weak interaction coupling could be G_F, or Fermi constant. When estimating the spin-torsion density, volume would be the beta decay length cubed. Therefore from the above data used above in terms of spin-torsion density one obtains

$${m_W}^2 = 8\pi(2e\alpha G_F)^{\frac{1}{2}}(\frac{1}{G_F})^{\frac{3}{2}}\frac{4\pi}{3} \tag{9}$$

where $c = G = h = 1$. Then, at electroweak unification the mass generated by spin-torsion density is $m_W \approx 70GeV$, which is in agreement with the observed value for the mass of boson $W^{\pm}$. Now that we saw, from De Sabbata and Sivaram work, that the W boson mass can be determined from the spinor four-fermion spin-torsion density, we are able to go back, and in the next section

3 Gauge free bosons and helical hypermagnetic dynamos in Einstein-Cartan Portal

In this section we present new results concerning the production of hypermagnetic dynamos as given by solutions of unitary gauge electroweak EM equations of dynamos sourced by Higgs and W gauge light boson masses. The importance of torsion to supergravity as torsion gravitino and other aspects of new physics seems to justify such an endeavour. In this section we find solutions of the equations obtained from the Kleinert action

$$\mathcal{A}_{EW} = \int d^4x\sqrt{-g}e^{-3\tau}[\frac{1}{2}\nabla_i\phi\nabla^i\phi - \frac{m^2}{2}\phi^2 e^{-2\tau} - \frac{\lambda}{4}\phi^4 - \frac{1}{4}F^2 + m^2{}_W e^{-2\tau}V_iV^i] \tag{10}$$

where (i,j,k=0,1,2,3) and τ is the trace torsion potential which generates trace torsion through the expression

$$S_{ij}{}^k = \frac{1}{2}[\delta_i{}^k\partial_j\tau - \delta_j{}^k\partial_i\tau] \tag{11}$$

which yields the following trace of this tensor by contraction

$$S_i = -\frac{3}{2}[\partial_i\tau] \tag{12}$$

This confirms τ, as a trace torsion potential. If we use the idea of torsion transmutation to axion one may say that this scalar torsion potential could be associated to the axion cosmic scale $a(t)$. The term F^2 contains the EW EM tensor which now is given as a abelian field as

$$F_{ij} = \partial_{[i}V_{k]} \tag{13}$$

where V has replaced the electromagnetic vector four spacetime potential A, and since we are considering the assumption that for free gauge bosons, the where V has replaced the electromagnetic vector four spacetime potential A, and since we are considering the assumption that for free gauge bosons, the non-abelian commutator can be neglected. Assuming the covariant derivative minimally coupled where V has replaced the electromagnetic vector four spacetime potential A, and since we are considering the assumption that for free gauge bosons, the non-abelian commutator can be neglected. Assuming that covariant derivative is coupled with EM potential as

$$D = \partial - ieV \tag{14}$$

Performing the substitution into the Kleinert action yields

$$\mathcal{A}_{EW} = \int d^4x\sqrt{-g}e^{-3\tau}[\frac{1}{2}D_i\phi D^i\phi - \frac{m^2}{2}\phi^2 e^{-2\tau} - \frac{\lambda}{4}\phi^4 - \frac{1}{4}F^2 + m^2{}_W e^{-2\tau}V_iV^i] \tag{15}$$

By taking the Euler-Lagrange equation

$$\partial_t \frac{\partial \mathcal{L}}{\partial \dot{V}} - \frac{\partial \mathcal{L}}{\partial V} = 0 \tag{16}$$

One obtains the Maxwell-like equation for the free W bosons electrodynamics as

$$\partial_i F^{ij} = [e^2 + {m_W}^2 e^{-\tau}]V^j - ie\partial^j\phi \tag{17}$$

Expressing these equations in terms of vectorial fields notation, we may infer that for $j = 0$

$$\partial_i F^{i0} = [e^2 + m_W{}^2 e^{-\tau}]V^0 - ie\partial^0\phi \tag{18}$$

Then, by noticing that for $i = a$, $F^{a0} = E^a$ is the electric field and

$$\nabla.\mathbf{E} = [e^2 + m^2{}_W e^{-\tau}]V^0(t) - ie\dot{\phi} \tag{19}$$

The Ampere-like equation is obtained with $j = a$ as

$$\partial_t\mathbf{E} - \nabla\times\mathbf{B} = (e^2 + m^2{}_W e^{-\tau}]\mathbf{V} \tag{20}$$

Note that from this last equation, the exponential of trace torsion potential damps the effect on the massive gauge boson mass. When torsion potential is positive there is really a damping whereas the negative torsion potential, enhances the effect of boson mass in the electromagnetic fields. So it seems a chiral torsion like effect [18] appears. The remaining EW hiper-EM equations of Faraday and the absence of magnetic monopoles are contained in the Bianchi equations

$$\partial_{[i}F_{jk]} = 0 \tag{21}$$

From expression (21) and helical magnetic fields condition

$$\nabla\times\mathbf{B} = \lambda_0\mathbf{B} \tag{22}$$

one obtains the magnetic wave equation for the W-boson hypermagnetic field B as

$$\partial^2{}_t B + [\lambda_0 + e^2 + m^2{}_W e^{-\tau}]B = 0 \tag{23}$$

Where we have used that

$$B_W = \nabla\times\mathbf{V} \tag{24}$$

Now let us solve the magnetic wave equation which yields

By considering the cosmic time $t_{inflation} = 10^{-36}s$ as very small, the last expression can be written approximated as

$$B \approx B_{seed} sin[(\lambda_0 + e^2 + m^2{}_W(1+\tau))t] \quad (26)$$

Therefore, by taking only torsion contributions yields

$$B = B_{seed}[m^2{}_W(1+\tau)t] \quad (27)$$

which in the first approximation of the boson mass, coincides with the EO result above. In the second approximation it yields

$$B = B_{seed}[m^2{}_W \tau t] \quad (28)$$

Note that in Berera [?] the GUT hypermagnetic field $B_{seed} = 10^{42}G$ and since $1G \sim 10^{-20}GeV^2$ and $t_{GUT} \sim 10^{-36}s$ one obtains

$$B = 10^{-5}Gauss \quad (29)$$

Therefore, by taking only torsion contributions yields

$$B = B_{seed}[m^2{}_W(1+\tau)t] \tag{27}$$

which in the first approximation of the boson mass, coincides with the EO result above. In the second approximation it yields

$$B = B_{seed}[m^2{}_W\tau t] \tag{28}$$

Note that in Berera [?] the GUT hypermagnetic field $B_{seed} = 10^{42}G$ and since $1G \sim 10^{-20}GeV^2$ and $t_{GUT} \sim 10^{-36}s$ one obtains

$$B = 10^{-5}Gauss \tag{29}$$

Therefore, by taking only torsion contributions yields

$$B = B_{seed}[m^2{}_W(1+\tau)t] \tag{27}$$

which in the first approximation of the boson mass, coincides with the EO result above. In the second approximation it yields

$$B = B_{seed}[m^2{}_W \tau t] \tag{28}$$

Note that in Berera [?] the GUT hypermagnetic field $B_{seed} = 10^{42}G$ and since $1G \sim 10^{-20}GeV^2$ and $t_{GUT} \sim 10^{-36}s$ one obtains

$$B = 10^{-5}Gauss \tag{29}$$

From this equation and Kleinert action one obtains

$$e^{-3\tau}[\frac{3}{2}\dot{\phi}^2 + \frac{3}{4}\phi^4 + 6ie\dot{\phi}V^0 + \frac{3}{4}F^2] + 5e^{-5\tau}[\frac{1}{2}m^2{}_{Higgs}\phi^2 - m^2{}_W(V^{02} - V^{a2})] = 0 \tag{31}$$

since the exponential in front of the brackets are algebraically independent, simple linear algebra shows that for this whole expression to vanish the terms inside the brackets have to vanish and we are led to two field equations for constraining Higgs and W bosons as

$$\frac{3}{2}\dot{\phi}^2 + \frac{3}{4}\phi^4 + 6ie\dot{\phi}V^0 + \frac{3}{4}F^2 = 0 \tag{32}$$

$$\frac{1}{2}m^2{}_{Higgs}\phi^2 - m^2{}_W(V^{02} - V^{a2} = 0 \tag{33}$$

By assuming that $V^a << V^0$ in the last equation one obtains

$$\frac{1}{2}m^2{}_{Higgs}\phi^2 = m^2{}_W V^{02} \tag{34}$$

showing expliicitly that, there is a relation between the Higgs and W light gauge boson mass. The expression (32) yields

$$\frac{3}{2}\dot{\phi}^2 + \frac{3}{4}\phi^4 + 6ie\dot{\phi}V^0 - \frac{3}{4}B^2 = 0 \tag{35}$$

So the the hypermagnetic field may be expressed as

$$\frac{m^4{}_W}{16m^2{}_{Higgs}}e^{-\tau} = \dot{\phi} \tag{39}$$

From the magnetic wave equation one obtains

$$B_W = m^2{}_W e^{-\tau} \tag{40}$$

note that from a negative value of torsion this equation represents a dynamo effect generated from the torsion scalar. Now there is an important relation between the cooper pairs here too. This can be obtained by considering the dynamical equation for ϕ

$$-2(\dot{\phi})^(2) + 2ieV_(0)\phi = \frac{3}{2}{B_W}^2 \tag{41}$$

Now to determine the relation for B_W in terms of critical Cooper pair of section 2, we simply reexpress equation (40) in terms of $B_c = \frac{m^2}{2e}$ as

$$B_w = 2eB_c e^{-\tau} \tag{42}$$

A very interesting consequence of this formula, appears when the torsion trace potential is very weak. In this case this expression shows that torsion contribution is given by

$$B_{Wtors} \sim B_c\tau \tag{43}$$

Therefore, this equation can be expressed dimensionally in terms of the torsion as

$$B_W = B_c S.t \tag{44}$$

where t is the cosmic time. This last expression is exactly analogous to the expression of Sivaram and de Sabbata for the relation between primordial magnetic fields and spin-torsion density of Einstein-Cartan gravity and then to Einstein-Cartan Portal. Before closing this section it is interesting to point it out that the

CONCLUSIONS: GAUGE BOSONS IN EINSTEIN-CARTAN PORTAL (NAM PRD 2022)

2,USE OF EC PORTAL TO DERIVE HYPERDYNAMOS IN W GAUGE BOSONS LINK TO SCALAR TORSION POTENTIAL WHICH GENERALISED THE OLESEN FERROMAGNETIC NON ABELIAN MODEL TO TORSIONFUL CASE AND TO TEST IN LHC.