Dynamical torsion suppression in Brans–Dicke inflation and Lorentz violation

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Abstract  Paul and SenGupta (Eur Phys J C 79:591, 2019) have recently shown that the reason why torsion effects are not present in today’s universe is that they are suppressed in the bulk of a 5D braneworld. In this case only curvature effects remain. In this paper our goals are to investigate how this idea applies in the 4D Brans–Dicke inflation in two cases: First in the spin-torsion energy density scaling as $\sim a^{-6}$, whereas matter density scales at $a^{-3}$. Here $a(t)$ is the cosmic evolution parameter in the cosmic time $t$. In this case when $a$ is given by the de Sitter expansion spin-torsion density it is highly suppressed. the second is the inflation in the framework of Einstein–Cartan–Brans–Dicke (ECBD) gravity used here, to build an effective inflaton potential and computing the number of its e-folds. Spin-torsion density contributes to a decrease on the number of e-folds when the ratio of spin-torsion density to matter density is not suppressed as in Early Universe. At present universe it is easy to show that by the end of inflation, spin-torsion density is suppressed with respect to matter-curvature density with a ratio of $a^{-3}$ or $t^{-3}$ by the end of inflation. When torsion possesses dynamical degrees of freedom, contortion is also shown to be suppressed by the end of BD inflation. The Kalb–Ramond fields in the 5D braneworld are equivalent to torsion. At present universe we find $K \sim 10^{-39}$ GeV for contortion. Such an estimate is much more stringent than the value found by Russell et al. (Phys Rev Lett 100, 2008) from torsion Lorentz violation (LV) with dual masers experiment.

1 Introduction

Very recently, Gonzalez-Espinoza et al. [1] have discussed the reconstruction of inflation in the general $f(T, \phi)$ scalar–tensor gravity. Previously Ng [2] proposed to investigate damping of inflatons by anisotropic stress modes in cosmology. This physical phenomenon is associated to quantum particle production. Moreover, Kim [3] proposed a cosmological model endowed with torsion, and scalar fields, which he called an inflationary ECBD cosmology. In the modern and common sense, inflation does need an inflaton field and potential to trigger inflation [4,5]. However, Kim ECBD inflation does not possess such a feature and he considers just vacuum inflation by making use of the condition in the fluid $p + \rho = 0$ where $p$ and $\rho$ are respectively the pressure and matter densities of the spinning fluid [6] and matter-curvature. Recently, Dereli and Senikoglu [7] have addressed BD scalar–tensor gravity, in non-Riemannian spacetime. They suggested that the negative BD parameter $\omega$, belonging to a narrow range interval, could be associated to dark energy as in Poplawski [8–11] paper. In this paper, based on these previous works, we propose to remedy this situation by building an effective inflaton potential in two distinct cases: In Sect. 2 we present the model. In Sect. 3 address a dust composed of spins where the matter density and the spin-torsion density tensor does not depend on the inflaton field. In this case we compute the number of e-folds of inflation and show that the presence of spin-torsion induces a decrease on the e-folds number, when the ratio of spin-torsion density to the matter density is appreciable, as happens in the early universe where inflation takes place. The main goal of the paper is, to show that the attempt made by Paul and SenGupta [12–14] to explain why the torsion in spacetime cannot be found in Gravity probe B experiment, and only curvature effects remains in the present universe, making use of a 5D brane world, can be reproduced here in two BD inflationary models: The first is the non-dynamical spin-spin interaction mediated by Cartan torsion in the context of ECBD inflation, whereas in the second torsion is dynamically suppressed. In this case torsion dynamical degrees of freedom may even propagate in terms of spin-0 and spin-1 torsion waves [15]. In the case addressed in Sect. 4, we show that the spin-torsion energy density scales as $a^{-6}$, decaying much faster than the mat-

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ter energy density which evolves as $a^{-3}$. While we note that torsion-spin density is much more suppressed than the matter density, we also observe that the presence of torsion is much stronger at early universe. Actually, as shown by Mavromatos [16] torsion at the early universe must be of the order of 1 MeV, where a Kalb–Ramond (KR) tensor, was used to obtain this result. In Sect. 3 the radiation filled spinning fluid universe is considered, where the inflaton fluctuation equation has the spin-torsion density as a source and can be considered to trigger quantum fluctuations of the inflaton field. Section 4 presents a solution for De Sitter-ECBD cosmology for dust dominated matter phase where the inflaton potential vanishes. Section 5 addresses the case of Brans–Dicke (BD) inflation in the dynamical torsion case, where contortion suppression is discussed. In this section we show that torsion dynamical degrees of freedom may trigger a damping on inflaton from contortion. This same section reveals a torsion dynamical degrees of freedom may trigger a damp-

2 Effective inflaton potential in ECBD

In the case of torsion suppression, many theories of gravity addressed this problem. Some deal with higher order gravity associated with the KR tensor rank-2 fields, which are linked to rank 3-order torsion. In this section, before addressing this issue we reproduce the Lagrangean and field equations of Kim’s theory in ECBD cosmology as

$$L = \int d^4x \sqrt{-g} \left( -\phi R + \frac{\partial \phi}{\partial a} \right)$$

(1)

where $\mu = 0, 1, 2, 3$. Note that, in this section we couple scalar fields to torsion via non-minimal coupling [6]. The field equations are given by

$$H^2 = \frac{8\pi}{3\phi} \left( \rho - \frac{2\pi\sigma^2}{\phi} \right) + \frac{1}{6} \left( \omega + \frac{3}{\phi} \right) \phi^2 + \frac{\dot{\phi}^2}{\phi}$$

(2)

$$\ddot{a} = -\frac{4\pi}{3\phi} \left( \rho + 3p - \frac{8\pi\sigma^2}{\phi} \right) - \frac{1}{3} \left( \omega + \frac{3}{\phi} \right) \dot{\phi}^2 + \frac{\dot{\phi}}{2\phi}$$

(3)

$$\ddot{\phi} + 3H\dot{\phi} = \frac{4\pi}{\omega} \left( \rho - 3p - \frac{8\pi\sigma^2}{\phi} \right)$$

(4)

where $\phi$ is the inflaton field and $H = \frac{\dot{a}}{a}$ is the Hubble expansion while $a$ is the cosmic scale factor. The Friedmann–Robertson–Walker (FRW) is given by

$$ds^2 = dt^2 - a^2(t) [dx^2 + dy^2 + dz^2]$$

(5)

Units are used here where the gravitational constant $G = 1$. Conservation laws for matter and spin-torsion densities are taken separately as

$$\dot{\rho} = -3H(\rho + p)$$

$$\dot{\sigma}^2 = -6H\sigma^2$$

(6)

(7)

These two conservations laws shall be used in the future to compare the two scales with expansion and show that spin-torsion density is highly suppressed compared with matter energy density. Actually is exponentially suppressed in the case of BD-de Sitter universe. The effective inflaton potential $V_{\text{eff}}(\phi)$ can be easily built by comparison between Eq. (4) and inflaton equation

$$\ddot{\phi} + 3H\dot{\phi} = -\frac{\partial V_{\text{eff}}}{\partial \phi}.$$  

(8)

This results in

$$\frac{\partial V_{\text{eff}}}{\partial \phi} = -\frac{4\pi}{\omega} \left( \rho - 3p - \frac{8\pi\sigma^2}{\phi} \right).$$

(9)

A simple solution of this equation determines the inflaton potential where spin and matter densities are constants. In this case we obtain the following inflaton potential

$$V_{\text{eff}} = -\frac{4\pi}{\omega} \left( \rho_0 - 3p_0 \right) \phi + \frac{32\pi}{\omega} \sigma_0^2 \ln \phi.$$  

(10)

This inflaton potential is similar to the Coleman–Weinberg one and in fact agrees with hybrid inflation supersymmetric one-loop correction potential. This result was, to a certain extent already expected since the bosonic (inflaton fields) and Fermionic (spinning fluid) sectors are present in the theory. In fact recently, another example of supersymmetric behaviour of Einstein–Cartan gravity has appeared in the form of super-symmetric domain walls [17]. Computation of the inflation e-folds number yields

$$N(\phi) = M^{-2}p_l \int \frac{V}{V'} d\phi$$

(11)

which implies

$$N(\phi) = M^{-2}p_l \left[ \frac{\phi}{2} + 4\pi \omega \phi (\ln \phi - 1) \right].$$

(12)

Here $M_{pl}$ is the Planck mass. But as we note here, is that in these e-folds of inflation expressions the e-folds are also highly suppressed by the Planck mass squared. To obtain expression (11) we made the approximation

$$\frac{4\pi}{\omega} \ll \sigma_0^2.$$  

(13)
Note that since general relativity tests impose a constraint on the Brans–Dicke inflation as \( \omega \gg 500 \) expression (13) also implies a constraint on spin-torsion density that is falls well within the values of torsion found in the Early Universe where inflation occurs. Actually in ECBD gravity, we have \( \omega \leq 6 \) and then expression (12) changes. Let us now examine de Sitter inflation, where \( H = H_0 = \text{constant} \). Then the field equations yield the equation for the inflaton fluctuations as

\[
\ddot{\delta\phi} + 3[3H_0^2 - 4\pi\rho_0]\delta\phi = \frac{8\pi}{3}\delta\rho + \frac{16\pi^2}{\phi_0}\delta\sigma^2 \tag{14}
\]

where we have assumed that inflaton matter and spin-torsion density fluctuation are given by

\[
\phi = \phi_0 + \delta\phi \tag{15}
\]
\[
\rho = \rho_0 + \delta\rho \tag{16}
\]
\[
\sigma^2 = \sigma_0^2 + \delta\sigma^2. \tag{17}
\]

Note that in this case \( \delta\rho = \delta\sigma^2 = 0 \) yields

\[
\ddot{\delta\phi} + 3[3H_0^2 - 4\pi\rho_0]\delta\phi = 0 \tag{18}
\]

which yields the following solution

\[
\delta\phi = A\cos at + B\sin at \tag{19}
\]

where A and B are integration constants and

\[
a = 3[3H_0^2 - 4\pi\rho_0] \tag{20}
\]

which is similar to what happens well before the horizon exit. In fact we see here that the inflaton fluctuation oscillates. Another interesting case is when the inflaton does not fluctuate or \( \delta\phi = 0 \). In this case the inflaton equation reduces to

\[
\delta\rho = -2\pi \frac{\delta\sigma^2}{\phi_0}. \tag{21}
\]

Since from the spin and matter conservation laws above for de Sitter inflation, one obtains

\[
\delta\rho = e^{\beta t} \tag{22}
\]
\[
\delta\sigma^2 = e^{2\beta t} \tag{23}
\]

where \( \beta = -3H_0 \). Substitution of these values on Eq. (15) yields

\[
\delta\phi \approx t. \tag{24}
\]

This expression shows that the inflaton is unstable. The interesting feature about the expressions (21) and (24) is that they imply along with expression (23) a constraint of \( \delta\rho_0 \sim e^{-3H_0t} \).

3 The radiation era in ECBD inflation

In the radiation era of the universe some interesting, but expected phenomenon happens. Since in the radiation era the role of spin-torsion is very strong, we shall find that the spin-torsion is not only a source of inflaton fluctuation, but also depends on the inflaton potential. To this aim, let us consider that in the radiation era the pressure is given by \( p = \frac{1}{3}\rho \).

Substitution of this expression into the field equations yield

\[
H_0^2 = \frac{32\pi}{3}\phi^2 \sigma^2 - \frac{1}{3}\left( \omega + \frac{3}{2} \right) \frac{\phi^2}{\phi^2} + \frac{1}{2}\phi \tag{25}
\]
\[
2H_0^2 = \frac{16\pi}{3}\left( \rho - \frac{2\pi}{\phi}\sigma^2 \right) + \frac{1}{3}\left( \omega + \frac{3}{2} \right) + 2H_0 \frac{\dot{\phi}}{\phi}. \tag{26}
\]

Summing up these two equations we obtain

\[
\sigma^2(\phi) = \frac{3}{32\pi}\phi^2. \tag{27}
\]

This allows us now to compute the effective potential above for a inflaton potential where the spin-torsion density depends upon the inflaton field. Substitution of expression (25) into (9), after integration yields

\[
V_{eff}\mid_{spin} = \frac{9\pi}{16\omega} \phi^2 \tag{28}
\]

which is a simple matter type inflaton potential. The method we have used here is very similar to the reconstruction of the inflaton potential although much more simple.

4 Dust matter dominated era in De Sitter-ECBD and spin-torsion density suppression

In this section we shall present a constrained solution where the \( V_{eff} \) scalar potential derivative is a maximum or minimum and the model considered is that of a dominant dust matter era of de Sitter-ECBD universe. The fluctuations of the matter density fluctuation contrast is obtained from WMAP data. Fluctuation in the matter density of the order of \( 10^{-2} \) has been obtained at earlier studies of warm inflation found by Berera [18, 19]. By multiplying Eq. (4) by \( \frac{1}{2} \) and adding it to Eq. (3) with the constraint of \( \frac{dV}{d\phi} = 0 \) we find a more simple field equation

\[
\left[ H^2 + \frac{\ddot{\phi}}{a} \right] = \frac{8\pi}{3}\phi \left( \frac{2\pi\sigma^2}{\phi} \right) + \left[ H + \frac{1}{2} \right] \frac{\dot{\phi}}{\phi} \tag{29}
\]

where in the absence of pressure due to the assumption of dust, one may use the expression

\[
\rho = \frac{8\pi}{\phi} \sigma^2. \tag{30}
\]
Now from expressions (27) and the conservation equation (7) one obtains the conservation equation as

\[ \dot{\phi} + 3H \phi = 0 \]  

(31)

which also has been used to obtain expression (29). By fluctuating the matter density in the last expression with respect to inflaton, the spin-torsion density fluctuation yields

\[ \delta \rho = -8\pi \sigma_0^2 \delta \phi \]  

(32)

where we take into account the approximation that the second order in fluctuations terms may be dropped. Then one obtains the expression

\[ \frac{\delta \rho}{\rho_0} = -\frac{\delta \phi}{\phi_0}. \]  

(33)

To obtain this expression we have used the formula obtained from fluctuations,

\[ \rho_0 = 8\pi \phi_0 \sigma_0^2. \]  

(34)

Now from the solution of expression (30) one obtains

\[ \delta \sigma^2 = \frac{3}{16\pi^2} \delta \phi. \]  

(35)

Now from expression (30) one obtains

\[ \frac{\delta \phi}{\phi_0} = -10^{-5}. \]  

(36)

If the contrast

\[ \frac{\delta \rho}{\rho_0} = 10^{-5} \]  

(37)

from WMAP data. Now from the expression

\[ \frac{\ddot{a}}{2a} = \frac{8\pi}{3\phi} \left( \frac{8\pi \sigma^2}{\phi} \right) + 5H_0^2. \]  

(38)

By taking the de Sitter expansion of the universe, which is given in terms of the cosmological constant \( \Lambda \) as \( a(t) = e^{\Lambda t} \) field equations reduce to

\[ \sigma^2(\phi) = \frac{1}{64\pi^2} (\Lambda^2 - 15H_0^2) \phi_0^2. \]  

(39)

Fluctuation of this expression allows us to split the perturbed equation into two expressions

\[ \sigma_0^2(\phi) = \frac{1}{64\pi^2} (\Lambda^2 - 15H_0^2) \phi_0^2 \]  

(40)

and

\[ \delta \sigma^2(\phi) = \frac{1}{32\pi^2} (\Lambda^2 - 15H_0^2) \phi_0 \delta \phi. \]  

(41)

From the WMAP data one obtains the relations

\[ \frac{\delta \sigma^2}{\sigma^2} = 2 \frac{\delta \phi}{\phi_0} \approx 2 \frac{\delta \rho}{\rho_0} = 2 \times 10^{-5}. \]  

(42)

A relation between the three fundamental fluctuations in ECBD-de Sitter universe. Let us go back to expressions (6) and (7) of Sect. 2, to obtain their solutions in terms of expansion factor \( a(t) \) which scales the matter-energy and spin-torsion densities as

\[ \rho \sim a^{-3}, \quad \sigma^2 \sim a^{-6}. \]  

(43)

If one substitutes the \( a(t) \) for the de Sitter exponential, into these last equations, one notes that the spin-torsion energy decays much faster than the matter energy density and actually it is highly suppressed in the case of De Sitter-ECBD inflation. Taking the ratio between the strengths of spin-torsion and the matter-curvature densities one obtains a decay for torsion suppression of the order of \( a^{-3} \). Since by the end of inflation \( \frac{\ddot{a}}{a} = 0 \) or \( a \sim \text{int} \) then, the spin-torsion suppression is given by \( \frac{\rho}{\sigma^2} \sim t^{-3} \). In the next section we shall investigate the Brans–Dicke gravity in the case of the torsion dynamical degrees of freedom and a similar torsion suppression shall appear in the case of contortion.

5 Dynamical torsion and contortion suppression by the end of Brans–Dicke inflation

In this section, from Lagrangian density in expression (1), we obtain the field equations, which connect metric-inflaton to a torsion dynamical degree of freedom. From these equations, several new features are obtained as the relation between cosmological constant, as being proportional to dynamical torsion just beyond the preheating end of inflation where, as shown by [12–14], dynamical torsion is highly suppressed at least in braneworld gravity. Let us now perform the solutions of these equations by considering the Euler–Lagrange equations. The geometrical Ricci–Cartan tensor used in the Lagrangian density shall be given by

\[ R_{ij} = R^2 = R^* + \nabla_i K^j - K^j - R^* + \hat{K} - K^2 \]  

(44)

where \( K^j = K^j \), represents the trace of contorsion tensor and \( R^* \) is the Riemannian-Ricci scalar that shall be taken as constant like in de Sitter or Einstein space. Clearly now \( K \) is taken as the zero-component of contortion trace. Let us now perform the variation of the Lagrangian density \( \sqrt{g} L \) with
respect to the scale cosmological factor $a$, and contortion $K$. Then, by computing the Euler Lagrange equations

$$\frac{d}{dt} \frac{\partial \sqrt{g} L}{\partial a} - \frac{\partial \sqrt{g} L}{\partial a} = 0$$

(45)

$$\frac{d}{dt} \frac{\partial \sqrt{g} L}{\partial \phi} - \frac{\partial \sqrt{g} L}{\partial \phi} = 0$$

(46)

$$\frac{d}{dt} \frac{\partial \sqrt{g} L}{\partial K} - \frac{\partial \sqrt{g} L}{\partial K} = 0$$

(47)

corresponding to variations in the cosmic factor, inflaton and contorsion respectively. Since in FRW inflation, the first expression on the LHS of the equation can be expressed in terms of the Hubble parameter $H(t)$ one obtains contortion $K$ in terms of the cosmic time $t$ and the inflaton relative variation as

$$K(t) = \frac{3H(t)}{2} - \frac{\dot{\phi}}{2\phi}$$

(48)

where $H(t) = \frac{\dot{a}}{a}$. Solution of this equation is obtained by the end of inflation

$$\frac{\dot{a}}{a} = 0$$

(49)

implies that $a(t) = a_0 t + c_0$. To simplify matters we choose the integration constant $c_0 = 0$. Therefore, the $H(t)$ is given by the end of inflation as

$$H(t) = t^{-1}.$$  

(50)

Substitution of this expression (30) into (47) leads to

$$K(t) = \frac{3H}{2} - \frac{3H}{2}$$

(51)

which obviously vanish. Then we conclude that in case of dynamical contortion at end of inflation, it is suppressed as we wish to prove. This agrees with some similar results from suppression of torsion at late times in the universe in Brane gravity. Last, but not least one may obtain a torsion wave of spin-0 scalar torsion potential in the case the Ricci–Cartan scalar curvature vanishing, which comes from the teleparallel gravity condition that the full Riemann-Cartan curvature tensor vanishes. From the result

$$R(\Gamma) = 6H_0 + \Box \phi_T - (\partial_i \phi_T)(\partial^i \phi_T)$$

(52)

where here $\phi_T$ is the torsion scalar potential which becomes in the four-dimension gradient application explicitly the contorsion four-vector. Taking the linear case the last term on the RHS of this equation may be neglected and we are left with the expression

$$\Box \phi_T = -6H_0$$

(53)

which shows that the torsion potential spin-0 scalar torsion wave is sourced by the Hubble constant. Finally, integration of expression (48) yields the inflaton expression in terms of time and Brans–Dicke parameter as

$$\phi(t) = \phi_0 t^{-(1+4\omega)} \exp[-H_0 t].$$

(54)

Decaying inflatons, are in general associated with particle production, therefore to have the possibility of decaying inflaton driven by torsion. Note that for $\omega$ negative as in non-Riemannian dark matter [7], one obtains an amplification of an inflaton field. Now by considering the well-know definition of the end of inflation given by

$$\frac{\dot{a}}{a} = 0.$$  

(55)

Now expressing the time derivative of contorsion as

$$\dot{K}(t) = \frac{3}{2} \left[ \frac{\dot{a}}{a} - \left(\frac{\dot{a}}{a}\right)^2 \right] - \frac{1}{2} \left[ \frac{\ddot{\phi}}{\phi} - \left(\frac{\dot{\phi}}{\phi}\right)^2 \right].$$

(56)

Since $H_0 \sim 10^{-22} \text{s}^{-1}$ one may neglect this Hubble constant the expression (57) reduces to

$$K(t) = -\frac{2t^{-1}}{(1+4\omega)}.$$  

(57)

Note that this expression shows finally that the contortion is not highly suppressed in this model as the spin-torsion density but decays to zero as cosmic time goes by. By definition of the end of inflation (52), this last expression reduces to

$$\ddot{K}(t) = -\frac{3}{2} \left( \frac{\dot{a}}{a} \right)^2 - \frac{1}{2} \left[ \frac{\ddot{\phi}}{\phi} - \left(\frac{\dot{\phi}}{\phi}\right)^2 \right].$$

(58)

Therefore if the inflaton decays as to make the expression

$$\frac{\ddot{\phi}}{\phi} - \left(\frac{\dot{\phi}}{\phi}\right)^2 = 0.$$  

(59)

Substitution of this last expression into (55) yields

$$\dot{K}(t) = -\frac{3}{2} \left( \frac{\dot{a}}{a} \right)^2 \leq 0.$$  

(60)

This shows that in non-trivial case the contortion decays with the inflaton decay. The inflaton decays from the constraint (61) which yields the solution $\phi = \phi_0 \exp[-\alpha t]$, where $\alpha$ is a positive integration constant. We conclude that contortion and the spin-torsion density are not highly suppressed in BD inflation but actually decays after the end of inflation. To rely on the computations here we estimate the value of contortion

$\Box \phi_T = -6H_0$. 

(53)
at present universe age which is $t_{today} \sim 10^{16}$ s. Since the relation between 1 s$^{-1}$ unit or Hertz and the electron-volt eV unit is 1 Hz $\sim 10^{-14}$ eV one obtain that contortion at the present universe by the BD inflationary model discussed here is $K(t_{today}) \sim 10^{-39}$ GeV which is several orders more stringent than the estimate obtained by Russell et al. [20] of $K(LV) \sim 10^{-31}$ GeV, estimated by using dual masers in laboratory. This could be called LV contortion. This LV torsion limits have been used by the author to find out other laboratory. This could be called LV contortion. This LV torsion as a scalar torsion potential where torsion vector would play the role of supersymmetric inflaton potential. Furthermore, e-folds damping by torsion is investigated. A simple solution in dust matter dominated De Sitter-ECBD universe is obtained, where the spin-torsion density is proportional to the squared of the scalar field similarly to what happens in the radiation phase. There are models that were obtained taking the inflaton as a scalar torsion potential where torsion vector would introduced spin-1 into the framework and moreover can also introduce a constraint in the BD parameter $\omega$. Moreover, from the Brans–Dicke Lagrangean density equations in a dynamical torsion, in de Sitter spacetime, we derive the cosmological constant, in a region after preheating where torsion is highly suppressed as in the case of Brane world gravity [12–14]. Future prospects of present work include to introduce magnetic fields into the ECBD Lagrangean to investigate ECBD magnetogenesis [22]. Interest in the cosmic dynamo before preheating end era has been obtained in the framework of GR cosmology by Bassett et al [23, 24]. Motivated by the damping of tensor modes due to anisotropic stresses in cosmological models by Ng, we also investigate the similar damping on the inflation due to torsion modes. Teleparallel geometrical constraints show that the torsion potential spin-0 torsion wave [15] in linearised case is sourced by the Hubble constant. Decaying of inflatons as discussed here by torsion dynamical degrees of freedom are in general obtained by particle production and then, it seems worth to investigate the particle production in torsionful curved Brans–Dicke gravity. In this paper we aimed to show that one could obtain the suppression of concentric and spin-torsion energy density in the present universe in the preheating era or by the end of inflation. The data used here of LV torsion bound is several orders of magnitude more stringent than the estimate obtained by Kostelecky et al. making use of fermionic sector of LV and dual masers in the earth laboratory. A future prospect could be addressed by considering Berera's warm inflation [18, 19] in the case of ECBD cosmology.
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Data Availability Statement  This manuscript has associated data in a data repository. [Authors’ comment: The data availability is obtained upon request to the author of the paper.]

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References

1. M. Gonzalez-Espinoza, Eur. Phys. J. C 81, 731 (2021)
2. K.-W. Ng, Phys. Rev. D. 86, 103510 (2021)
3. Y.S. Kim, Nuovo Cimento B (1999)
4. D. Palle, Nuovo. Cim. B. 114, 853 (1999)
5. D. Lyth, R. Liddle, Cosmological inflation and structure formation (2000)
6. V. de Sabbata, C. Sivaram, Spin and Torsion in Gravitation (World Scientific, Singapore, 1994)
7. T. Dereli, Y. Senikoglu, Dark range of \( \omega \) in Brans–Dicke gravity (2019). arXiv:1906.05531v1
8. N. Poplawski, Mod. Phys. Lett. A 35(40), 2050331 (2020)
9. L.C. Garcia de Andrade, Class. Quantum Gravity 16, 2097 (1999)
10. L.C. Garcia de Andrade, Phys. Lett. B 711, 143–146 (1999)
11. T. Harko, M.K. Mak, H.Q. Lu, K.S. Cheng, Il Nuovo Cimento 114B(12), 1389 (1999)
12. T. Paul, S. SenGupta, Dynamical suppression of spacetime torsion. Eur. Phys. J. C 79, 591 (2019)
13. E. Elizalde, S.D. Odintsov, T. Paul, D. Gomez, Phys. Rev. D 99, 063506 (2019)
14. T. Paul, Antisymmetric tensor fields in modified gravity: a summary. arXiv:2009.07732
15. L. Garcia de Andrade, Eur. Phys. J. Plus 136, 146 (2021)
16. N.E. Mavromatos, Torsion in string-inspired cosmologies in the universe dark sector (2021). arXiv:2111.07642 [hep-ph]
17. L.C. Garcia de Andrade, Ann. Phys. 431, 168558 (2021)
18. A. Berera, Phys. Rev. Lett. 75, 3218 (1995)
19. H.Q. Lu, K.S. Cheng, Class. Quantum Gravity 12, 2755 (1995)
20. N. Russell, A. Kostelecky, Colladay, Phys. Rev. Lett. 100 (2008)
21. L. Garcia de Andrade, Eur. Phys. J. C 77, 401 (2017)
22. L.C. Garcia de Andrade, Einstein–Cartan Magnetogenesis and Chiral Dynamos (Academic Publishers, Moldavia, 2021)
23. A. Bassett et al., Phys. Rev. D
24. Bassett, G Polliforn, S Tsujikawa, F Viniegra, Phys. Rev. D 63, 103515 (2001)