Slow decay of cosmic magnetic fields
superadiabatically on
curvature-torsion scales

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Abstract

Recently Barrow, and Tsagas [Phys Rev D 77: 107302, (2008)] have shown that slow decay of cosmological magnetic slowly decay in FRW universes on curvature scales as $B \sim a^{-1}$ in the context of general relativity (GR). This helps possible amplification of cosmic magnetic fields. In this paper starting from dynamo equations in spacetimes with torsion we obtain also slow decay of magnetic fields naturally on curvature-torsion scales of Riemann-Cartan spacetime on a de Sitter universe. In this case the constant of proportionality between the magnetic field and the curvature scale is the torsion in the present universe. Thus the B-field becomes $B \sim \frac{\eta}{H_0 T} a^{-1}$ where $T$ is torsion vector modulus, $H_0$ is the Hubble constant and $\eta$ is the diffusive scale. The torsion effect is therefore enhanced by diffusive processes in the universe. Galactic dynamo seeds of the order of $10^{-26}$ Gauss are obtained. If one still uses the constant torsion, and the scale of $10 Kpc$ the galactic dynamo seed is given by $B \sim 10^{-13}$ Gauss which is lies very well within the interval obtained for the cosmic magnetic field obtained by K. Pandey et al [ApJ (2013)] for primordial magnetic field lines using $Ly\alpha$ clouds on $1 Kpc$ scales, which is $10^{-20}$ Gauss $\leq B \leq 10^{-9}$ Gauss. In comoving cosmic plasmas endowed with torsion cosmic magnetic fields as low as $10^{-25} G$ are obtained, which are still strong enough to seed galactic dynamos.

Key-words: Torsion theories, primordial magnetic fields, galactic dynamo seeds.
1 Introduction

Earlier Barrow and Tsagas [1] have shown that in the context of GR, FRW universes magnetic field can experience superadiabatic growth with B-field of the order of $B \sim a^{-1}$ instead of $B \sim a^{-2}$ of the adiabatic growth. In their case the Maxwell equations is used instead of more general Maxwell's equations used to find galactic dynamo seeds [2]. Coupling of vector fields to spacetime geometry slows down the decay of large scale magnetic field in open universe, compared to that seen in perfectly flat models. This results in a large gain in B-field strength during the pre-galactic era that leads to astrophysically interesting B-fields. Seeds around $10^{-34}Gauss$ can sustain galactic dynamos if the FRW universe is dark-energy dominated. It is well-known that dynamo mechanism requires magnetic seeds with a collapse coherence length of $100pc$. This corresponds to a comoving (pre-collapse) scale of approximately $10Kpc$. Here we consider seed fields on curvature-torsion scales of $10Kpc$, which from dynamo equation with torsion [3], yields a cosmological magnetic field of $10^{-26}Gauss$ in contrast to the $10^{-22}Gauss$ obtained from cosmic strings [4]. If one still uses the constant torsion, and the scale of $10Kpc$ the galactic dynamo seed is given by $B \sim 10^{-10}Gauss$ which is only one order of magnitude less than the one obtained for the low limit of cosmic magnetic field obtained by K. Pandey et al [5] for primordial magnetic field lines using $Ly\alpha$ clouds on $1Kpc$ scales. To further test the model we compute the cosmic magnetic fields in comoving cosmic plasmas with torsion and obtain primordial magnetic seeds of the order of $B \sim 10^{-25}Gauss$ which though is weak is still enough to seed galactic dynamos [6].

2 Slow decay of cosmic magnetic fields with torsion

It is important to say here that since torsion effects on magnetic fields are enhanced by diffusion according to previous obtained dynamo equation [3]

$$\partial_tB - \nabla \times [v \times B] - \eta (\Delta + div \mathbf{T}) \mathbf{B} = 0$$

we call the attention that the galactic magnetic fields are more vulnerable to dissipation in the absence of a regenerated dynamo. Dissipation of magnetic
field is also associated with the presence of magnetic monopoles [7]. It can be noticed from equation (ref1) the fourth term on the left where divergence of torsion is placed vanishes in highly conducting phases of the universe where dissipation $\eta$ may be neglected. Let us now investigate based on the dynamo equation above, the issue of the decay of magnetic field on curvature-torsion scales. One shall prove that for a FRW universe

$$ds^2 = dt^2 - a^2 dx^2$$

(2)

torsion scales do not change the character of the superadiabatic amplification of the magnetic field but only adds a proportionality factor linear on torsion and diffusion coefficient. By making use of the partial differential operator

$$\partial_t = \frac{\partial a}{\partial t} \frac{\partial}{\partial a}$$

(3)

and substitution on dynamo equation yields

$$H_0 \partial_a B = \eta \left[ \frac{1}{a^3} + \frac{T}{a^2} \right] B$$

(4)

where use has been made of the Hubble parameter $H_0 = \frac{\dot{a}}{a}$ in this equation. Now the new dynamo equation is simply solved to yield

$$B \sim \frac{\eta}{H_0} Ta^{-1}$$

(5)

which shows that for constant torsion the superadiabatically expansion of the universe has a slower decay of the magnetic field which is enhanced by torsion scales. Since $\eta \sim 10^{26}cm^2s^{-1}$ and $a \sim 10Kpc$, $H_0 \sim 5.5 \pm 0.5 cm.sec^{-1} pc^{-1}$ and $T \sim 10^{-17} cm^{-1}$ for torsion [8]. Substitution of these values into expression yields $B_{\text{torsion}} \sim 10^{-13} Gauss$ which fits very well within the limits of the interval obtained for the cosmic magnetic field obtained by K. Pandey et al [ApJ (2013)] for primordial magnetic field lines using Ly$\alpha$ clouds on 1Kpc scales, which is $10^{-20} Gauss \leq B \leq 10^{-9} Gauss$. Besides this torsion scale bound obtained for the cosmic magnetic field is strong enough to seed galactic dynamos. Actually it is also another interval obtained by Barrow and Tsagas recently [8] using FRW GR metric.
3 Magnetic fields in comoving plasmas with torsion

In this section we shall show that the comoving cosmic plasmas ($v \sim 0$) with torsion induces a seed primordial field which although is very weak is strong enough to seed galactic dynamos. Let us now consider the dynamo equation using the following ansatz for the cosmic magnetic field $B \sim e^{\gamma t}$. Substitution of this ansatz in the dynamo equation in torsion scales above one obtains

$$\gamma = -\eta[L^{-2} + TL^{-1}]$$

(6)

according to the above data and new data $L \sim 10^{28} cm$ for the radius of the universe, yields

$$|\gamma_{\text{torsion}}| \sim 10^{-19} s^{-1}$$

(7)

Thus the B-field is given by

$$B \sim B_{\text{seed}}\gamma_{\text{torsion}}\Delta t$$

(8)

which yields $B_{\text{torsion}} \sim 10^{-21} Gauss$ for a seed field of $10^{-20} Gauss$ such as in the lower bound obtained in (7). Thus this value is still a well within limits able to seed galactic dynamos. For scale of $10Kpc$ one obtains $\gamma \sim 10^{-13} s^{-1}$ which yields $B_{\text{torsion}} \sim 10^{-25} Gauss$ which is still a strong value to seed galactic dynamos.

4 Conclusions

Therefore one may conclude that though five orders of magnitude lower than the lower bound obtained astronomically this is still a value able to seed galactic dynamos. We also know than the values of the amplification factor $\gamma_{\text{torsion}}$ is very weak compared to the values for fast dynamos, as $\gamma \sim 10^{8} s^{-1}$ which leads us to conclude that the dynamos associated with torsion are very slow. We hope to left more clear in this Brief Report the role of torsion modes in the galactic dynamo seeds.
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