Torsion Modified Plasma Screening in Astrophysics

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Abstract

The torsion modified Maxwell-Proca equations when applied to describe a plasma is shown to lead to a correction to the Debye screening length.

For hot new born neutron stars the torsion correction is shown to be significant. This effect may provide an indirect evidence for Torsion.

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In recent papers[1, 2], the Maxwell equations in the back ground of an Einstein-Cartan spacetime were shown to take the form

$$\nabla.\vec{E} = 4\pi\rho - \frac{3\lambda}{k}\left(\partial_0 Q^0 + \nabla.\vec{Q}\right)\phi \tag{1}$$

$$\frac{\partial\rho}{\partial t} + \nabla.\vec{J} = -\frac{3\lambda}{4\pi k}\left(\frac{\partial^2 Q^0}{\partial t^2}\right)\phi \tag{2}$$

Here Q is the torsion vector, which is the background spin density of σ given by the Einstein-Cartan theory as

$$Q = \frac{4\pi G\sigma}{c^2} \tag{3}$$

In the gauge $\nabla.\vec{Q} = 0$, the first of above equations is equiva lent to the Proca-Equation, ie,

$$\nabla.\vec{E} = 4\pi\rho - {m_\gamma}^2\ \phi \tag{4}$$

where ${m_\gamma}^2$ is given in this case by:

$${m_\gamma}^2 = \frac{3\lambda}{k}\left(\frac{\partial Q_0}{\partial t}\right) \tag{5}$$

In the Work[3], which involved the torsion-photon coupling of the form $\cong \lambda R(\rho) A_\mu\ A^\mu$, it was shown

$${m_\gamma}^2 \cong \lambda\ Q^2 \tag{6}$$

being constraint by[4] $\lambda < 10^{-24}$.
We now apply the above equations to Debye sreening in a plasma. We write eq.(1) in the form:

$$\nabla^2\phi = 4\pi n_e e - {m_\gamma}^2\phi \tag{7}$$

Where n_e is the electron number density, e is the electron charge in a hot charged plasma at temperature T, is given by the Boltzmann distribution :

$$n_e \cong n_{e_0} exp(-e\phi/k_B\ T) \tag{8}$$

Where k_B is the Boltzmann constant, ϕ is the average potential in the vicinity of an ion, so that the typical electron has an electros static energy $\cong e\phi$

As is usual in the discussions of plasma screening we can approximate from eq. (8) as

$$n_e \cong n_{e_0} \left(1 - e\phi/k_B T\right) \tag{9}$$

Eq. (7) then has the form

$$\begin{aligned} \nabla^2 \phi &= 4\pi n_{e_0} e \; exp\left(-e\phi/k_B T\right) - m_\gamma{}^2 \phi &(10)\\ \nabla^2 \phi &\cong 4\pi n_{e_0} exp\left(1 - e\phi/k_B T\right) - m_\gamma{}^2 \phi &(11) \end{aligned}$$

with $m_\gamma{}^2 \cong \lambda Q^2$ (in the static case considered here)
As shown in refs. [4, 5], the contraint λ is $\cong 10^{-24}$.
The solution of eq.(1) can in general be written as

$$\phi \cong \frac{e}{r}\left(1 - exp\left(-\lambda_D^{\prime -1} \gamma\right)\right) \tag{12}$$

Where the modified Debye lenght is given as

$$\lambda_D^{\prime} \cong \left(\frac{k_B T}{4\pi n_{e_0} e^2} + \frac{\hbar^2}{\lambda Q^2 c^2}\right)^{1/2} \tag{13}$$

or for a varying torsion background

$$\lambda_D^{\prime} \cong \left(\frac{k_B T}{4\pi n_{e_0} e^2} + \frac{\hbar^2 k}{3\lambda\left(\frac{\partial Q_0}{\partial t}\right) c^2}\right)^{1/2} \tag{14}$$

In the limit of zero torsion, eqs. (13) and (14) give the usual Debye screening in plasmas.

Since the effects of the torsion scale with the spin density. We would expect this to be significant in neutron stars with a high number density such as $n_0 \cong 10^{40} cm^{-3}$.

We can estimate the temperature at which the torsion screening term becomes comparable to the usual Debye term.

Since $Q \cong \dfrac{4\pi G \; n_0 \hbar}{c^2}$ we get the corresponding temperature T_0 at which the two terms are comparable as

$$T_0 \cong \frac{c^4 \ e^2 \beta}{4\pi G^2 \ \lambda \ n_0 k_B} \tag{15}$$

For $n_0 \cong 10^{40} cm^{-3}$ this gives $T_0 \cong 10^{12} k$.

This shows that for sufficiently hot new born neutron stars[5] (X ray emiting neutron star sources typically have T_0 of a few million degrees), the torsion modified electrodynamic terms. Here we assume $\lambda \cong 1$ i.e. strong torsion neutron spin coupling. Instead of eq.(3) we could also use for Q the expression

$$Q = -\nabla \ln(1 + \lambda A^2) \tag{16}$$

This would modify the equation (4) as :

$$\nabla^2 \phi = 4\pi\rho - (\nabla\phi)^2 \lambda \rightarrow \phi \cong \frac{A}{r} + B \ln(a - r)$$

(A and B constants). We would still get the screening solution but with an extra logarithimic term which does not contribute to the screening. The consequences of this for the stability of the system would be investigated in another work[6]. We also like to mention that this is not the first time massive photons have been assumed to "surround" a neutron star. In 1969 Feinberg[7] have assumed that all dispersion in the Crab pulsar results from massive photons which allowed him to put a limit of $m_\gamma < 10^{-44} g$ on the photon mass. Finally it is interesting to note that although direct effects F. Torsion in neutron star like the contribution to eccentricity[8] are too small to be measurable, indirect effects of Torsion in neutron star like the one proposed here and cumulative effects like the ones proposed by Zhang[9, 10] and his group can be useful as an indirect evidence for Torsion Gravity.

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