MOND and Gauge CPT: Similarities, Differences, and Connection

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Abstract

The weak field Gauge CPT force law is presented and compared with the MOND low acceleration equation. The origin of the same $\frac{1}{r}$ dependence is presented as a property of the Gauge CPT Lagrangian. The origin of the different $(I_\nu)^{\frac{1}{2}}$ source term of gauge CPT as a property of the Lagrangian is also presented. The connection between MOND and Gauge CPT is discussed by determining the Gauge CPT force strength constant from the characteristic MOND acceleration, a_M, - or vice versa. Gauge CPT has no problems with the Bullet Cluster, is derived from an experimentally verified symmetry, and has cheap, verifiable experimental predictions.

We begin by acknowledging the brilliant insights of Prof. Milgrom which lead to MOND. However, we view MOND as necessity conditions (almost!) required for the flat rotation curves and slope of the Tully-Fisher law found in spiral galaxies, rather than a modification of Newtonian gravity. Gauging the CPT symmetry results in a similar point source weak field force law explaining the flat rotation curves and Tully-Fisher slope:

$$a_X = k\frac{(I_\nu)^{\frac{1}{2}}}{r},$$

where a_X is the acceleration of a test mass, I_ν is the neutrino emission luminosity of the point source, r is the distance between the source and test mass, and k is the force strength constant associated with Gauge CPT. A basic introduction to Gauge CPT and the resulting weak field force law can be found in the papers [1,2].

Similarities

The first thing in common is that the force laws are independent of the test mass. In Gauge CPT this comes from how the $x_{\mu ab}$ terms couple to matter -

the same as the coupling of the general relativity (GR) metric spin connection term, $\omega_{\mu ab}$, to matter: $D_\mu\psi = \partial_\mu\psi + \left(\frac{1}{2}\omega_{\mu ab} + \beta x_{\mu ab}\right)\sigma^{ab}\psi$, where β is the coupling constant associated with Gauge CPT, $\sigma^{ab} = \frac{1}{4}\left[\gamma^a, \gamma^b\right]$, and $x_{\mu ab}$ are complex extensions of $\omega_{\mu ab}$ required by Gauge CPT.

The second thing in common is the r^{-1} dependence. However, in Gauge CPT this arises from the expected r^{-2} behavior of the Gauge CPT force [1,2] combined with the r^{-2} distribution of (massless) neutrinos emitted by the point source - a simple Gauss' Law problem.

Differences

The obvious difference is the source term. In gauge CPT, it is argued that fermion chirality is the source (see, e.g., [3]). Briefly, this is due to the vector, $x_{\mu I}$, and pseudovector, x_{u5}, components required in the entire Gauge CPT field, X_μ, minimally coupled to the Dirac field, $D_\mu\psi = \partial_\mu\psi + \left(\frac{1}{2}\omega_{\mu ab}\sigma^{ab} + \beta X_\mu\right)\psi$, where $X_\mu = x_{\mu I}I + x_{\mu 5}\gamma^5 + x_{\mu ab}\sigma^{ab}$. The source terms of the redefined fields $x_{\mu\pm} = x_{\mu I} \pm x_{\mu 5}$ are precisely the chirality of fermions. Because the net fermion chirality in bulk matter vanishes, we normally don't see Gauge CPT effects. However, neutrinos - the second most common particle in the universe - have fixed chirality. *This is the reason why Gauge CPT has no problems with the Bullet Cluster. There is little to no production of neutrinos in the lagging gaseous medium between the two clusters.* The reason for the square root of the luminosity appearing comes from properties of the Gauge CPT Lagrangian [1,2]. However, it is interesting to note that if galactic mass is used as a proxy for the galactic neutrino luminosity, then one would expect the MOND $M^{\frac{1}{2}}$ to be equivalent to the Gauge CPT $(I_\nu)^{\frac{1}{2}}$ because of the relativistic equivalence of mass and energy.

The other difference is that Gauge CPT effects are always present if the source terms do not vanish, there is no transition region. For example, Gauge CPT predicts an acceleration of $\approx 1.0 \times 10^{-5}\frac{m}{s^2}$ at 10 meters from the core of a 200MW reactor due to the antineutrino flux [2]. This is a testable difference between MOND and Gauge CPT because the predicted acceleration is well above the onset of the MOND regime.

Connection

The connection between MOND and Gauge CPT is reflected by exploiting the outstanding success of MOND in predicting galactic rotation curves to determine k from a_M - or vice versa (as pointed out by a referee of one of my papers currently under review). Explicitly, the connection is recognized as the distance where the Gauge CPT force equals the Newtonian gravitational force. In other words, this is the onset of the MOND regime for the object (M, I_ν) under consideration:

$$a_X = k\frac{(I_\nu)^{\frac{1}{2}}}{r} = G_N\frac{M}{r^2} = a_M.$$

Obviously, as r increases from this point, the Gauge CPT effects dominate over the gravitational effects - the deep MOND regime is reached.

References

[1] K. Koltko, Gauge CPT experimental predictions, Proceedings of the International Conference: Cosmology on Small Scales 2022, "Dark Energy and the Local Hubble Expansion Problem," Prague, September 21-24, 2022.
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[3] K. Koltko, Gauge CPT as a possible alternative to the dark matter hypothesis, arXiv: 1308.6341 [physics.gen-ph], [astro-ph.GA] 2013.

Gauge CPT as a Natural Extension of General Relativity

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In this paper, we outline the gauge theory of CPT transformations, in particular, the part of the new gauge field, X_μ, which is an extension of the metric spin connection, $\omega_{\mu ab}$. Even though it may seem absurd to entertain the notion of gauging a discrete symmetry because there are no continuous parameters, that's not true. The important thing is that there is more than *one* element in the symmetry group. The arbitrary choices of *where* (on the continuous spacetime manifold) one wants to apply the local CPT symmetry allows for the gauging procedure. The required mathematics is well defined [arXiv: 1308.6341, 1703.10904v3]. The actual physics is comprised of four parts: motivation, fundamental local CPT transformations, choice of Lagrangian, and experimental/observational predictions. An introduction to gauge CPT can be found in "The Baryonic Tully-Fisher Law and the Gauge Theory of CPT Transformations", Proceedings of the International Conference "Cosmology on Small Scales 2020, Prague". Experimental predictions appear in "Gauge CPT Experimental Predictions", Proceedings of the International Conference "Cosmology on Small Scales 2022, Prague".

Motivation

There are two components of the motivation - quantum gravity and astrophysical issues. Briefly, we argue that gauging the CPT symmetry is necessary for any approach to quantum gravity for two reasons. First, PT (together) is a proper Lorentz transformation just like the Lorentz rotations (boosts and spatial rotations) used to obtain the metric spin connection formulation of general relativity (GR). Therefore, it would seem logical to include local CPT (C is required in order to have a universal symmetry just like the Lorentz rotations) with local Lorentz rotations to complete the gauging of the entire group of proper Lorentz transformations. Second, the CPT symmetry is born from the successful *union* of special relativity with quantum theory - a "bridge" between the two theories. Because GR can be obtained by gauging the global Lorentz symmetries, shouldn't CPT be brought along for the ride, too? Perhaps the new physical dynamical degrees of freedom unveiled by gauge CPT can be used to resolve at least some of the renormalization problems encountered when trying to make GR a quantum field theory? This is analogous to expanding the early nonrenormalizable weak interaction theories by the renormalizable $SU(2) \otimes U(1)$ electroweak theory.

We now examine the astrophysical motivations for gauge CPT. The starting point is the flat rotation curves of spiral galaxies and the excessive gravitational lensing produced by galaxies and galactic groups. That particles (matter and photons) are not moving the way they should be *are the observational facts.* Dark matter and modified gravity theories *are not.* Even though dark matter sounds too much like the 19th century aether, it is certainly worth examining. However, the absence of its detection and the well-known theoretical issues such as the core-cusp problem should add to the motivation to examine the logical alternative of modified gravity theories.

Because accelerations are caused by forces, and all known forces can be obtained by gauging select global symmetries, we search for a candidate symmetry to be gauged. That CPT is an experimentally verified symmetry is sufficient reason to attempt gauging it and examine the consequences. Also, because CPT is a universal symmetry, there is the intuition of obtaining the required mass independent accelerations of galactic rotation curves. String theories have the problem that there is no evidence of supersymmetry or extra dimensions. There really isn't any other choice but CPT if we are going to follow the paradigm of gauging symmetries.

Another possible route to explain the flat rotation curves is to invoke modified gravity theories based on geometric concepts, however, there are problems with this approach. The Lovelock theorems impose constraints on using $g_{\mu\nu}$ and its derivatives. Nonmetricity theories, $f(Q)$, have the physical problem that matter doesn't obey the conformal symmetry. Torsion theories, $f(T)$, have the physical problem that light doesn't couple to torsion. Again, there aren't many choices left except possibly some small, higher power curvature additions to the Einstein-Hilbert action - the $f(R)$ theories. Also, could the cosmological constant, Λ, really be an averaged, weak field approximation for a missing Lagrangian density? We need to look deeper for a geometric path.

The second most common particle in the universe - the neutrino - provides a clue to such a path. The most familiar way to handle fermions in curved spacetime requires the use of vierbein and spin connections. Vierbein are the key to making the CPT symmetry local and well defined in curved spacetime. Indeed, it is not even clear how to make a global CPT transformation in curved spacetime [video recording of the author's presentation at CSS 2020, Prague]. Once the local CPT transformations are derived for vierbein and Dirac spinors, it immediately follows that the metric spin connection formulation of GR can't compensate for the induced changes in the curved spacetime Dirac action. Hence, a new gauge field, X_μ, is *required* to construct an expanded Lagrangian which is well behaved under local CPT transformations. The introduction, structure, and transformation of X_μ are not ad-hoc, and the resulting X_μ is of the form $X_\mu = x_{\mu I} I + x_{\mu 5}\gamma^5 + x_{\mu ab}\sigma^{ab}$, where $x_{\mu ab}$ is a complex extension of $\omega_{\mu ab}$.