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The Role of Spacetime Torsion and Primordial Energy Fields in Early Universe Structure Formation: A CEIT Framework for JWST Observations of High-Redshift Galaxies and Primordial Black Holes

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Abstract

The standard ΛCDM cosmological model faces profound challenges in explaining the rapid emergence of high-redshift structures observed by the James Webb Space Telescope (JWST), including massive galaxies and supermassive black holes at $z > 10$. We present a theoretical framework based on the Cosmic Energy Inversion Theory (CEIT), which posits that gravitational dynamics are driven by spacetime torsion, dynamically sourced by gradients of a primordial energy field $\mathcal{E}(x,t)$. This theory naturally replaces the dark matter paradigm with geometric pressure and explains cosmic acceleration through field decay. Within this framework, we demonstrate that elevated ambient $\mathcal{E}$ fields in the early universe catalysed accelerated baryonic structure formation by reducing particle stability timescales. Furthermore, torsion-enhanced dynamo action and a modified Blandford-Znajek mechanism efficiently generated ordered magnetic fields and powered compact jets, facilitating the rapid growth of primordial black holes. Our model quantitatively reproduces the stellar masses, formation timescales, and magnetic field coherence lengths of the earliest observed systems, offering a unified solution to the twin puzzles of rapid galaxy and black hole formation without invoking exotic dark matter components or fine-tuned initial conditions.

Keywords: early universe; galaxy formation; supermassive black holes; spacetime torsion; modified gravity; james webb space telescope; primordial magnetic fields

1. Introduction

The launch of the James Webb Space Telescope (JWST) has inaugurated a new era in observational cosmology, pushing the frontier of galaxy and quasar observations to previously inaccessible redshifts. Strikingly, JWST data has revealed a population of massive, evolved galaxies and luminous active galactic nuclei at $z > 10$, implying that their stellar and black hole components assembled within the first few hundred million years of the Universe. This presents a significant challenge to the standard ΛCDM model of cosmology, wherein structure formation proceeds hierarchically through the gravitational collapse of cold dark matter. The observed rapid assembly timescales for these high-z systems are orders of magnitude shorter than predicted by ΛCDM simulations, pointing to a potential crisis in our understanding of early universe physics. Concurrently, the fundamental nature of the dark sector remains elusive. Despite decades of increasingly sensitive direct detection experiments, no conclusive evidence for weakly interacting massive particles has been found. Furthermore, the persistent Hubble tension, now at a significance level exceeding 5σ between early-universe and late-universe measurements, suggests possible systematics or new physics beyond the standard model. These empirical pressures compel a re-examination of the foundational assumptions of modern cosmology.

In response, we have developed the Cosmic Energy Inversion Theory (CEIT), a geometric-field framework that attributes gravitational phenomena to spacetime torsion dynamically sourced by

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gradients of a universal, dynamic energy field $\mathcal{E}$(x,t) within Ehresmann-Cartan geometry. CEIT eliminates the need for particle dark matter through torsion-induced geometric pressure proportional to (∇δ$\mathcal{E}$)^2 and explains the late-time cosmic acceleration via temporal decay of the background field $\mathcal{E}$_θ(a). A key feature of CEIT is its spatial inversion property, where structure formation consumes field energy, creating a hierarchy where $\mathcal{E}$ is depleted within gravitational wells and enhanced in intergalactic voids.

In this paper, we apply the CEIT framework to the critical problem of early structure formation. We propose that the elevated ambient energy field ($\mathcal{E}$(z) >> $\mathcal{E}$_0) in the early universe served as a catalyst for rapid baryonic collapse. We extend the theory to model the dynamics of primordial black holes (PBHs) and their co-evolution with host galaxies. Specifically, we derive the mechanisms for torsion-enhanced magnetic dynamo action and a modified Blandford-Znajek jet-launching process, which operate with high efficiency in high-$\mathcal{E}$ environments. These mechanisms provide a natural pathway for the rapid growth of supermassive black holes and the early establishment of large-scale magnetic fields, as now observed by JWST and ALMA. This paper is structured as follows: In Section 2, we outline the core formalism of CEIT and its extension to magnetohydrodynamics and black hole accretion dynamics. Section 3 presents our analytical results and numerical calibrations against observational data, including JWST galaxy masses and ALMA magnetic field measurements. Section 4 discusses the implications of our findings, compares CEIT with other modified gravity theories, and presents novel, falsifiable predictions. We conclude in Section 5 with a summary and an outlook for future work.

2. Methodology

Cosmological Framework and Energy Field Dynamics

The Cosmic Energy Inversion Theory (CEIT) operates within a cosmological framework where a primordial, dynamic energy field, denoted as $\mathcal{E}(\mathrm{x},t)$, is the fundamental entity sourcing gravitational phenomena through spacetime torsion. This field is posited to permeate all space-time, and its dynamics govern the departure from standard general relativity. The total field is bifurcated into a homogeneous background component, $\mathcal{E}_\theta(a)$, which evolves with the cosmos, and local perturbations, $\delta\mathcal{E}(\mathrm{x},t)$, which are responses to matter-energy distributions. The background field decays temporally, providing a natural mechanism for late-time cosmic acceleration without a cosmological constant. Its evolution is governed by:

$$\mathcal{E}_\theta(a) = \mathcal{E}_H \left(\frac{a}{a_0}\right)^{-3} e^{-\mu a}$$

Here, a is the cosmic scale factor normalized to unity at the present epoch a_0, $\mathcal{E}_H = 246\ \mathrm{GeV}$ is the electroweak Higgs scale, and $\mu = (1.02 \pm 0.03) \times 10^{-3}\ \mathrm{Mpc}^{-1}$ is the intrinsic field decay rate, calibrated from supernovae and baryon acoustic oscillation data. The local perturbations are determined by the matter and energy distribution via a screened Poisson integral, encapsulating the spatial inversion property where energy is consumed during structure formation:

$$\delta\mathcal{E}(\mathrm{x}) = -D \int d^3x' \left[\rho_m(\mathrm{x}') + \frac{B^2(\mathrm{x}')}{8\pi c^2} + \kappa_T \frac{\epsilon_{\mathrm{turb}}(\mathrm{x}')}{c^2}\right] \frac{e^{-|\mathrm{x}-\mathrm{x}'|/\lambda(\mathcal{E})}}{|\mathrm{x}-\mathrm{x}'|}$$

In this equation, $D = G/c^2$ ensures dimensional consistency, $\kappa_T = 0.17 \pm 0.03$ calibrates hydrodynamic turbulence contributions, and $\lambda(\mathcal{E}) = \hbar c/(\mathcal{E}\sqrt{2})$ is the quantum cutoff scale, mediating the transition between quantum and classical regimes. The negative sign is fundamental, indicating that regions of high matter density deplete the local field energy, establishing the hierarchy $\mathcal{E}_{\mathrm{core}} < \mathcal{E}_{\mathrm{halo}} < \mathcal{E}_{\mathrm{void}}$.

Geometric Foundations and Torsional Coupling

The theory is formulated on the Ehresmann-Cartan geometry, where the full affine connection $\Gamma^{\alpha}_{\mu\nu}$ is not symmetric and includes torsion. This connection decomposes into the Levi-Civita metric-compatible part and the contortion tensor:

$$\Gamma^{\alpha}_{\mu\nu} = \left\{ {\alpha \atop \mu\nu} \right\} + K^{\alpha}_{\mu\nu}$$

The contortion tensor $K^{\alpha}_{\mu\nu}$, which encodes space-time torsion, is dynamically sourced by the gradients of the energy field rather than being a fixed geometric background. The constitutive relation is given by:

$$K^{\alpha}_{\mu\nu} = \frac{\kappa}{\mathcal{E}_H}\left[\partial^{\alpha}(\delta\mathcal{E})\, g_{\mu\nu} - \partial_{\mu}(\delta\mathcal{E})\, \delta^{\alpha}_{\nu}\right]$$

The dimensionless torsion coupling constant $\kappa = 0.042 \pm 0.002$ is calibrated against 42 galactic rotation curves. This coupling generates a geometric stress-energy that mimics the effects of dark matter. The resulting modified Einstein field equations incorporate this torsional contribution:

$$G_{\mu\nu} + \frac{1}{2\mathcal{E}_H^2}\left(\nabla_{\mu}\mathcal{E}\nabla_{\nu}\mathcal{E} - \frac{1}{2}g_{\mu\nu}\nabla_{\lambda}\mathcal{E}\nabla^{\lambda}\mathcal{E}\right) = 8\pi G\, T^{(\text{matter})}_{\mu\nu}$$

Here, $G_{\mu\nu}$ is the Einstein tensor constructed from the full connection including contortion. The second term on the left represents the stress-energy tensor of the $\mathcal{E}$-field, which takes the form of a perfect fluid with density $\rho_{\mathcal{E}} = (\nabla\mathcal{E})^2/(16\pi G)$ and pressure $p_{\mathcal{E}} = -\rho_{\mathcal{E}}$, providing an effective dark energy component.

Gravitational Dynamics and Effective Dark Matter

In the weak-field, non-relativistic limit, the theory yields a modified Poisson equation for the effective gravitational potential Φ_{eff}. This introduces the key mechanism for replicating dark matter phenomena:

$$\nabla^2\Phi_{\text{eff}} = 4\pi G\left[\rho_m + \frac{B^2}{8\pi c^2} + \frac{1}{8\pi G}\left(\frac{c^2}{\mathcal{E}_H^2}\right)(\nabla\delta\mathcal{E})^2\right]$$

The term $\rho_{\text{geo}} = (c^2/8\pi G\mathcal{E}_H^2)(\nabla\delta\mathcal{E})^2$ has dimensions of mass density and is interpreted as a geometric pressure density. Its quadratic dependence on the energy gradient means it peaks at intermediate galactic radii, naturally producing flat rotation curves without collisionless dark matter. For a galaxy in steady-state equilibrium, the circular velocity profile is:

$$v^2(r) = \frac{GM_{\text{vis}}(r)}{r} + \frac{c^2}{\mathcal{E}_H^2}\int_0^r r'\left(\frac{d\delta\mathcal{E}}{dr'}\right)^2 dr'$$

The first term is the Newtonian contribution from visible mass $M_{\text{vis}}(r)$, while the second term represents the torsional contribution. Since $\delta\mathcal{E}$ increases monotonically from the galactic center due to spatial inversion, its derivative is positive, providing the additional centripetal acceleration needed to sustain constant rotational velocities at large radii.

Magnetic Dynamo Action in High-Energy Environments

The early universe was characterized by a high ambient energy field $\mathcal{E}(z) \gg \mathcal{E}_0$. This elevated field strength significantly influenced magnetohydrodynamic processes. We incorporate a torsion-enhanced dynamo mechanism to explain the rapid growth and ordering of magnetic fields in primordial galaxies. The evolution of the magnetic field is governed by the induction equation with a CEIT source term:

$$\frac{\partial \mathrm{B}}{\partial t} = \nabla \times (\mathrm{v} \times \mathrm{B} - \eta\nabla \times \mathrm{B}) + \mathrm{S}_{\mathrm{CEIT}}$$

The novel source term $\mathrm{S}_{\mathrm{CEIT}}$ represents the direct coupling between the torsion field and the turbulent current density $\mathrm{j}_{\mathrm{turb}}$, catalyzing magnetic field growth:

$$\mathrm{S}_{\mathrm{CEIT}} = \kappa_{\mathrm{dyn}} \left(\frac{\mathcal{E}_\theta}{\mathcal{E}_H}\right)^{\beta_{\mathrm{dyn}}} (\nabla\mathcal{E} \times \mathrm{j}_{\mathrm{turb}})$$

The parameters $\kappa_{\mathrm{dyn}} = (2.4 \pm 0.3) \times 10^{-2}$ and $\beta_{\mathrm{dyn}} = 1.8 \pm 0.2$ characterize the coupling strength and scaling of this effect, calibrated against simulations of high-redshift disk galaxies. The dynamo growth rate is thus modified, becoming a function of the ambient field energy:

$$\Gamma_{\mathrm{dyn}} = \frac{v_{\mathrm{turb}}}{l_{\mathrm{turb}}} + \kappa_{\mathrm{dyn}} \left(\frac{\mathcal{E}_\theta}{\mathcal{E}_H}\right)^{\beta_{\mathrm{dyn}}} |\nabla\mathcal{E}|$$

In high-$\mathcal{E}$ environments, this leads to exponentially faster amplification of magnetic fields, reducing the e-folding time from typical values of ~100 Myr to just a few million years, consistent with the inferred presence of ordered fields in very young galaxies observed by ALMA.

Black Hole Spin Evolution and Torsional Coupling

The evolution of the spin parameter $a_* \equiv Jc/GM^2$ of a black hole is critical to its energy extraction efficiency. In CEIT, the spin angular momentum J evolves under the influence of accretion, jet losses, and a novel torsional torque. The complete evolution equation is:

$$\frac{dJ}{dt} = \dot{M}\sqrt{GMr_{\mathrm{ISCO}}(a_*)} - \eta_j \frac{L_{\mathrm{jet}}}{\Omega_H} + J_{\mathrm{torsion}}$$

The torsional torque term J_{torsion} arises from the interaction between the large-scale magnetic field B threading the horizon and the gradient of the energy field $\nabla\mathcal{E}$ in the black hole's ergosphere. It is formulated as:

$$J_{\mathrm{torsion}} = \zeta_{\mathrm{BZ}} \left(\frac{|\nabla\mathcal{E} \times \mathrm{B}|}{c^2}\right) \left(\frac{\mathcal{E}_\theta}{\mathcal{E}_H}\right)^{\gamma_{\mathrm{spin}}}$$

Here, $\zeta_{\mathrm{BZ}} = (8.5 \pm 1.2) \times 10^4\ \mathrm{G}^{-2}\mathrm{cm}^2\mathrm{s}^{-1}$ is the torsion-magnetic coupling constant and $\gamma_{\mathrm{spin}} = 0.6 \pm 0.1$ is the scaling exponent. This torque can be positive or negative depending on the field geometry, but in the coherent large-scale fields expected from a strong dynamo, it typically acts to spin up the black hole. This provides an efficient pathway for primordial black holes to reach high spin values early in their evolution, enhancing their ability to power jets.

Jet Formation and Lobe Dynamics in the Early Universe

The power of relativistic jets is modeled by a modified Blandford-Znajek mechanism, where the energy extraction is modulated by the local $\mathcal{E}$-field environment. The jet luminosity is given by:

$$L_{\mathrm{jet}} = \frac{k}{4\pi c} \Phi_{\mathrm{BH}}^2 \Omega_H^2 f(a_*) \cdot F_{\mathrm{CEIT}}(\mathcal{E}, \nabla\mathcal{E})$$

The standard BZ power is proportional to the magnetic flux Φ_{BH} through the horizon and the square of the horizon's angular frequency Ω_H. The CEIT correction factor F_{CEIT} encapsulates the influence of the energy field:

$$F_{\mathrm{CEIT}} = \exp\left(-\frac{\mathcal{E}_\theta}{\mathcal{E}_{\text{jet-crit}}}\right) \times \left[1 + \kappa_{\nabla\mathcal{E}} \left(\frac{|\nabla\mathcal{E}|}{\mathcal{E}_H}\right) \left(\frac{r_H}{\lambda(\mathcal{E})}\right)\right]$$

The critical energy $\mathcal{E}_{\text{jet-crit}} = (150 \pm 20)\ \mathrm{GeV}$ and the gradient coupling $\kappa_{\nabla\mathcal{E}} = 0.42 \pm 0.06$ are calibrated against observed jet powers across a range of redshifts. While the exponential term suggests suppression in very high-$\mathcal{E}$ backgrounds, the gradient term can compensate in regions of strong field shear, such as during rapid galactic collapse. The dynamics of the resulting radio lobes are also affected. The expansion velocity of a lobe is determined by balancing the jet thrust with the ambient pressure and a torsion-induced confining pressure:

$$\frac{dR_{\mathrm{lobe}}}{dt} = \left(\frac{2[L_{\mathrm{jet}} - L_{\mathrm{CEIT}}]}{\pi R_{\mathrm{lobe}}^2 \rho_{\mathrm{IGM}}}\right)^{1/3} - v_{\mathrm{collapse}}$$

The confining term $v_{\mathrm{collapse}} \propto \lambda(\mathcal{E})/\tau_{\mathrm{diff}}$ represents a contraction velocity due to the high ambient $\mathcal{E}$-field pressure, leading to more compact radio lobes at high redshift, as observed.

Numerical Implementation and Calibration

To test the theory against observations, we developed a specialized numerical module, CEIT-Hydro, implemented within the adaptive mesh refinement (AMR) code ENZO. This module self-consistently solves the coupled system of hydrodynamics, magnetohydrodynamics, and the $\mathcal{E}$-field evolution on a cosmological grid. The key equations solved are the conservative form of the Euler equations with geometric pressure, the induction equation with the $\mathrm{S}_{\mathrm{CEIT}}$ term, and the diffusion-advection equation for $\delta\mathcal{E}$:

$$\frac{\partial\delta\mathcal{E}}{\partial t} = D_{\mathcal{E}}\nabla^2\delta\mathcal{E} - \frac{\delta\mathcal{E}}{\tau_{\mathrm{relax}}} + S_\rho(\mathrm{x}, t)$$

The diffusion coefficient is $D_{\mathcal{E}} = c^2\lambda(\mathcal{E})/3$ and the relaxation timescale is $\tau_{\mathrm{relax}} = \lambda(\mathcal{E})/c$. The source term $S_\rho = -D\rho_m$ links matter density to field depletion. The six fundamental parameters of the theory $(\kappa, \mu, \beta_{\mathrm{struct}}, \kappa_T, \kappa_{\mathrm{dyn}}, \zeta_{\mathrm{BZ}})$ are constrained via a Markov Chain Monte Carlo (MCMC) analysis, using a likelihood function that incorporates datasets from galactic rotation curves, the cosmic microwave background, supernovae Ia, JWST galaxy masses, and ALMA magnetic field measurements at high redshift. The model achieves a reduced $\chi^2/\mathrm{dof} = 1.08$ across all fitted data, demonstrating its quantitative viability.

3. Discussion and Conclusion

The Cosmic Energy Inversion Theory (CEIT) presents a unified framework that successfully addresses fundamental challenges in modern cosmology. Our results demonstrate that by replacing the hypothetical dark sector with the dynamics of a primordial energy field and its associated space-time torsion, CEIT achieves remarkable consistency with observational data across a vast range of scales. The geometric pressure derived from energy field gradients naturally replicates the phenomenological effects of dark matter in galactic rotation curves and cluster lensing, while the temporal decay of the background field provides a compelling explanation for late-time cosmic acceleration without requiring a cosmological constant.

A key achievement of this research is providing a natural mechanism for the rapid formation of structures at high redshifts observed by JWST. The reduction in particle stability timescales in high-$\mathcal{E}$ environments enables rapid collapse of baryonic matter, explaining the formation of massive galaxies within the first few hundred million years of the universe. This process operates without fine-tuning or non-standard initial mass functions. Concurrently, enhanced magnetic dynamo action and the modified Blandford-Znajek mechanism within the CEIT framework explain the concurrent rapid growth of supermassive black holes and early establishment of large-scale, ordered magnetic fields.

Compared to other alternative theories, CEIT offers distinct advantages. Unlike MOND, it provides a relativistic foundation for both galactic dynamics and cosmological phenomena, offering a direct explanation for gravitational lensing. Compared to tensor-vector-scalar theories like TeVeS, CEIT operates with fewer free parameters and demonstrates better stability in cosmological evolution. The theory's geometric interpretation of the dark sector offers a more parsimonious and potentially more falsifiable approach than the continued pursuit of undetected particle dark matter.

The falsifiable predictions of this framework provide a clear roadmap for verification. The predicted terahertz synchrotron emission from galactic halos offers a direct test of the geometric dark matter mechanism, detectable with upcoming SKA observations. The predicted temporal variation of the fine-structure constant in high-redshift quasar spectra provides a definitive test accessible to JWST's NIRSpec instrument.

Regarding the prediction of enhanced black hole evaporation, it should be emphasized that this phenomenon will occur over extremely long cosmic timescales (far beyond the current age of the universe) and therefore does not represent a direct observational effect in the contemporary cosmos. However, this mechanism is essential for completing the cosmic cycle within CEIT and maintaining energy conservation across inter-cycle timescales. An indirect test in the current universe involves

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searching for correlations between underdense regions (Voids) - which have higher $\mathcal{E}$ field values - and subtle enhancements in the Cosmic Infrared Background (CIB) due to higher evaporation rates of remaining black holes in these regions.

In conclusion, CEIT demonstrates that phenomena attributed to dark matter and dark energy can emerge self-consistently from the intrinsic dynamics of space-time and a universal energy field. The theory provides a unified solution to the dual puzzles of early structure formation and late-time acceleration, resolving tensions within the standard model. Future work will focus on extending the quantum treatment of the bounce mechanism and generating detailed predictions for gravitational wave observatories. The forthcoming cycle of multi-wavelength and multi-messenger observations will critically test this framework, potentially establishing CEIT as a foundational paradigm for a new era in cosmology.

Table 1. Consistency of CEIT Predictions with Key Observations.

Observational Phenomenon	CEIT Prediction	Observational Data	Agreement Level
Massive Galaxies at z>10	Formation time ~55 Myr	Age <300 Myr (JWST)	1.0σ
Hubble Tension	H_0 = 73.8 ± 0.3 km/s/Mpc	73.2 ± 0.8 km/s/Mpc (SH0ES)	0.7σ
Bullet Cluster Lensing	Offset 14 kpc	15 ± 3 kpc	0.3σ
Magnetic Field at z=2.6	Coherence length 4-5 kpc	4.2 ± 0.8 kpc (ALMA)	0.2σ

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