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INTERACTIONS BETWEEN DARK MATTER AND DARK ENERGY: IMPLICATIONS FOR THE EXPANSION OF THE UNIVERSE

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Abstract: Dark matter and dark energy are two of the biggest mysteries in cosmology today. This paper reviews theories on potential interactions between these two entities and presents a new explanatory concept called the Thermal Anti-Gravitational Field (TAGF). When photons and electromagnetic radiation collide, TAGF proposes that heat energy is created and an anti-gravitational field is created. The heat formed combines with the anti-gravitational field resulting in the accelerated expansion of the universe that we perceive as dark energy. This field can also interact with gravity to produce dark matter. Dark matter in my theory is a 4-dimensional matter whose projection in the 3D world is gravity. We explore the implications of TAGF theoretically and review observational evidence from recent experiments. The cosmological constant or Lambda-CDM model currently provides the best explanation for observational data, but we discuss where TAGF could account for anomalies. We conclude by proposing future avenues of research that could further test connections between dark matter, dark energy, and the expansion of the universe.

IndexTerms **:** TAGF, dark matter, dark energy, ΛCDM, gravity, quantum superposition

1. INTRODUCTION

The accelerated expansion of the universe, first discovered in 1998, remains an outstanding puzzle in physics [1]. To explain this observation, cosmologists have posited an invisible, uniform energy pervading space called "dark energy" that counters the attractive force of gravity [2]. Meanwhile, the gravitational effects of unseen "dark matter" have been evident since the 1970s from galactic rotation curves and cosmological structure formation [3]. Dark matter and dark energy together are estimated to make up 95% of the total mass-energy content of the universe. Yet the physical nature of both phenomena is unknown. Back in the 1900s, Einstein called his renowned cosmological constant his life's biggest failure because his aim was to create a static model of the universe.

Various theories suggest that dark matter and dark energy may interact rather than being completely independent [4]. The exchange of energy or momentum could ease tensions between cosmological parameter estimates from different experiments [5]. Interactions might even account for cosmic coincidence—the seemingly conspiratorial fact that dark matter and dark energy contribute comparable fractions of the universe's current energy budget. This suggests their densities may evolve in lockstep over cosmic time [6].

We propose a new concept, the Thermal Anti-Gravitational Field (TAGF), whereby the kinetic energy released when photons collide creates a temporary distortion in space-time with anti-gravitational effects. Where the density of electromagnetic radiation is high, repeated photon collisions could generate enough heat to produce this "negative gravity." Thus, the TAGF effect concentrated in voids between galactic superclusters drives cosmic acceleration. TAGF may also react with strong gravitational fields to produce dark matter particles. Below we theoretically develop the foundations of TAGF and discuss how it could address certain unsolved problems in cosmology.

2. Research Methodology:

Independent researchers searched for scientific information related to dark matter and dark energy, and their gravitational interactions between them. The search terms used to find the correct research papers on the internet are keywords like "dark matter", "dark energy", "IDE models", "interactions between dark matter and dark energy", and "the gravitational interactions between dark matter and dark energy". The platforms that were used to get the research papers are Nature Journals, Scopus Journals, JSTOR, and Google Scholar. We did our research in primary and secondary journals. Though we got the desired results relating to our research paper, we filtered the results so that the most recently published research papers came to our eye. We did this so that our research paper is more relevant to the current times.

Few of the research papers gave us a brief review of the recent theories regarding the dark sector, which gave an idea of the new theories being created. The journals we read had analyzed other reviews and journals, it had data from telescopes like Planck

2018 about the CMB, BAO, etc. We also noted the mathematical models and what results they got in their research paper, and from that we got an idea of how to frame the mathematical evidence for our TAGF model. In our analysis, we did find some strong points that highly support the TAGF model.

3. Theoretical Basis of TAGF

When two photons collide at extreme energies, for instance, gamma rays from a supernova explosion, they release kinetic energy as heat. Standard cosmology considers colliding photons to simply scatter or annihilate into other particles [7]. But what if some of that kinetic energy went into generating an anti-gravitational field?

Photons must carry intrinsic gravitational fields, albeit extraordinarily weak ones, as evidenced by gravitational lensing. The distortion of space-time curvature around a massive object like a galaxy causes passing light rays to bend, confirming Einstein's prediction. Hence we infer photons themselves minimally "gravitate" the space-time they occupy.

Now imagine two gravitating photons collide. Their kinetic energy transforms into thermal energy, creating a localized TAGF zone. Within this brief window, standard space-time curvature is not just deformed but inverted: particles accelerate away from each other rather than accelerating together under normal gravitational attraction.

We hypothesize the photons' intrinsic gravitational fields momentarily cancel when they destructively interfere as a quantum superposition state, in this state, TAGF is everywhere in the path of the colliding photons, it's in the past, present, and future all at the same time. The kinetic energy drives them apart explosively. In the aftermath, the photons' warped wavefronts redistribute the heat from that blast across an expanding bubble of TAGF, priming further collisions.

The more collisions from energetic radiation concentrated inside this zone, the stronger the induced TAGF effect grows. However, photons crossing large voids between superclusters have far fewer collisions over cosmological distances. TAGF density should peak inside supernova remnants and the intense radiation fields of galactic cores, then dilute rapidly in sparser intergalactic space. Still, even tiny cumulative distortions across megaparsec voids combine to drive galaxies apart.

4. Interaction with Dark Matter

What becomes of TAGF in places where matter dominates over radiation density, like in galaxies? Strong gravitational fields should overwhelm the intrinsically weak anti-gravitational TAGF contribution from occasional photon collisions. However, we hypothesize that the interaction between TAGF and gravity spawns dark matter particles.

Conceptually, TAGF from a high-energy photon collision undergoes gravitational collapse, but the heat energy prevents immediate annihilation. The temporary standoff creates a type of virtual particle from the quantum vacuum. Like all quantum effects, this phenomenon lasts only fleetingly before the virtual particle winks out of existence again. But surrounding gravitational fields may "capture" some virtual particles midway through materializing, stabilizing them as real dark matter.

These dark matter particles created via TAGF must inhabit a higher dimensional "bulk" space relative to our 4-dimensional universe, in order to gravitationally attract ordinary matter across vast distances. Higher-dimensional topology can enable gravitational coupling over larger scales than the inverse square law predicts [8]. What we perceive as the "shadow" or projection of the extra-dimensional dark matter crossing our 4-dimensional subspace manifests as gravity. This neatly explains empirically observed properties like the flat rotation curves of galaxies.

5. Theoretical Advantages over a Cosmological Constant

The discovery of cosmic acceleration led many cosmologists to revive Einstein's discarded idea of a "cosmological constant" Λ permeating the vacuum of space. By interpreting dark energy as constant vacuum energy represented by Λ, the well-established Lambda Cold Dark Matter (ΛCDM) model beautifully matches all existing astrophysical observations [9].

Nevertheless, some open theoretical issues plague ΛCDM [10]. The tiny but nonzero value of Λ remains unexplained, even though quantum field theory predicts an enormous, paradoxical discrepancy 120 orders of magnitude too high. This "fine-tuning problem" suggests an unknown cancellation mechanism must be reducing the vacuum energy almost, but not completely, to zero. TAGF offers a novel alternative explanation for dark energy relying only on well-understood electromagnetic and gravitational effects, sidestepping mysterious quantum vacuum energy.

A related advantage is that TAGF provides a physical mechanism driving the accelerated expansion. Even if quantum field theory could properly calculate the value of Λ to agree with observations, a constant could only describe dark energy—not originate or actively fuel cosmic acceleration over time.

TAGF arises from known properties of radiation and gravity dynamically interacting. Photons have collided for billions of years since the first stars formed after recombination, progressively generating more TAGF. New supernova explosions continually add to existing concentrations of TAGF inside voids. This self-reinforcing, evolutionary process naturally results in accelerating expansion picking up in recent epochs as observed.

In contrast, the unchanging cosmological constant cannot explain why cosmic acceleration switched on roughly 5 billion years ago. ΛCDM just treats it as a coincidence that matter and Λ contributed similarly to total energy density around that recent epoch. TAGF offers hope of physically answering this "why now?" question.

6. Observational Evidence

At this early, speculative stage, the TAGF hypothesis lacks direct experimental confirmation. However, tantalizing anomalies in recent observations could indicate observational signatures of TAGF activity—particularly in connection with dark matter. This motivates further theoretical development plus cosmological simulations incorporating TAGF effects.

One study found that including dark matter interactions actually degrades rather than improves fits to Planck satellite cosmic microwave background (CMB) data versus ΛCDM [5]. This disfavors explanations invoking nongravitational couplings between dark matter and dark energy. Yet intriguingly, allowing dark matter to couple to neutrinos or radiation fields instead did improve consistency. This could support the notion that TAGF helps mediate transformations between dark energy and matter.
In another hint, combining Planck data with the novel gravitational-wave standard siren technique tightened error bounds on cosmological parameters for interacting dark energy models [11]. Future experiments as this methodology matures could reveal TAGF connections. Extragalactic gamma-ray data has also been interpreted as a possible signal of dark matter annihilation [12], which TAGF might naturally facilitate.
As stated unequivocally in the research methodology, we have thoroughly examined numerous research journals that account for the fundamental interactions between dark energy and dark matter. It is imperative to note that the following fields are indisputably relevant to this paper that support our idea:

6.1. Quintessence -The Leading Theory for Dark Energy

Quintessence is a dynamical, homogeneous scalar field that has negative pressure, it solves the fine-tuning and cosmic coincidence problems because it has interaction between dark energy and the matter-radiation background. [13] Typically quintessence models are beyond the standard model [26]. It interacts with matter through gravity and is more accurate than the cosmological constant with the observational data. The value of the w constant for the equation of state parameter in quintessence is given as -0.56. [13] The equation for the scalar field's pressure is: [13]

$$p=\frac{1}{2} \dot{Q}^{2}-V(Q)$$

The equation of motion with synchronous gauge for the scalar field is

$$\delta \ddot{Q}+3H\delta \dot{Q}+(c_s^2k^2+a^2V''(Q))\delta_Q=-1/2h_k \dot{Q}$$

Quintessence is a dynamical, homogeneous scalar field. When compared to TAGF there are some differences and similarities, and how some effects seem to give it a false conception that it is homogeneous. TAGF isn't like quintessence or the cosmological constant, but after the collision event, TAGF is in a state of quantum superposition of being everywhere in the path constantly in both the reacting photons/radiation/electromagnetic waves. This may give it an effect of being either a homogeneous/inhomogeneous field type of effect, but in reality, it isn't a field. Another thing to note is that these TAGF are in quantum superposition and are not quantumly entangled, so in a particular point in the path of the reacted photon after the collision effect, where TAGF inhabits, TAGF can gain some amount of energy if different photons come into contact with that particular TAGF, but this gain of energy will not be applied to all the other TAGF in the path, this could lead to the believing of the inhomogeneous effect.
Just like how quintessence has the special ability to solve the cosmic coincidence problem, the same ability is also possessed by TAGF. TAGF solves the cosmic coincidence problem as the thermal part in TAGF reduces the energy density, and gravity gives potential energy to an object therefore giving in an energy density, so the opposite of gravity, anti-gravity, should be able to reduce the energy density. Due to these two qualities, TAGF has a reduced energy density yet still has the capability to cause expansion. The quintessence usually interacts with matter mainly gravitationally. In a similar manner, TAGF does cause its repulsion effect gravitationally except for the fact that it is anti-gravity. TAGF typically won't get that chance to interact with matter because typically matter has gravity, and gravity converts TAGF into dark matter.

6.2. The Equivalence Principle and its Relation With Dark Matter

Einstein's equivalence principle states that two bodies of neutral charge but different compositions will accelerate at the same speed as a 3rd body. Some applications of the equivalence principle is that it led to the discovery of gravitational waves, black holes, etc. It is used to explain quantum entanglement and the effects of dark matter. It was made by Einstein and was used extensively in General Relativity.

The torsion balance experiment is done by suspending two different elements, in this case, it is beryllium and copper, which are placed at different places and are attached to the opposite ends of the beam. They found that 25%-50% of dark matter is the reason for a body to accelerate toward the center of the Milky Way, hence hinting that dark matter interacts with matter gravitationally [14]. The two bodies accelerating toward the middle of the galaxy due to dark matter is the following distance: 6*10^(-9) cm s^(-2)[14]. Without regard to dark matter we get the following distance covered by the elements: 5.8 * 10^(-12) cm s^(-2)[14].
This research sheds light on any long-range force related to dark matter would be mediated by a lightweight or massless particle. This massless particle might be a graviton, and these gravitons help to convert TAGF into dark matter.
Galaxies are bound to have a lot of dark matter, and there is no force that separates and stops the formation of galaxies, so this implies that a long-range repulsive force, kind of like dark energy, cannot distort the structure of galaxies within, therefore this repulsive force should have energy that is less than gravity[14]. TAGF doesn't have energy that is more than that of gravity,

hence that's why TAGF mainly inhabits vacuums where there is no gravity, and TAGF can't sustain that long in galaxies because it will be converted into dark matter in the presence of gravity. At the border, TAGF is probably more powerful than gravity in many orders hence causing a rapid acceleration.

6.3. Gravitational Theories Regarding Dark Energy

According to string theory, the cosmological constant is very close to zero and it might not be zero itself, this should be inferred in such a way because if the cosmological constant's value was much bigger, then the acceleration of the universe should have started more earlier. In Robert Caldwell's model, the energy density of dark energy increases further and will lead to a Big Rip scenario of the universe in 50 billion years[15]. In Paul Steinhardt's model, the distance between our universe and a parallel universe is smaller than an atomic nucleus, and the interactions between them cause the effects of dark energy[15]. Gia Dvali's model proposes that gravitons escape to a different dimension by escaping our 3D universe[15]. In Jae-Weon Lee's model, the universe's border works in the same way as Hawking radiation for a black hole, it would be at the right amount to cause the expansion[15]. Finally, in Rocky Kolb's model, the universe is thought to be inhomogeneous, this inhomogeneity causes expansion[15].
A relation between Gia Dvali's model and TAGF is that in TAGF, dark matter is a higher dimensional form of matter whose projection is gravity, perhaps gravitons are actually just 3D but have the ability to cast the projection of higher dimensional matter, this could also mean that the gravitons have the ability to convert TAGF into a higher dimensional dark matter, which could mean that gravitons are the gateway for interdimensional travel but are confined into our 3D space. It can also be inferred that gravitons can also project gravity in higher dimensions, maybe gravity is 3D projection, and maybe extra gravity in a 3D + xD that is not visible to our 3D world can cause this binding of galaxies.
A difference between Jae-Weon Lee's model and TAGF is that in TAGF, perhaps the universe is created by a black hole's explosion, so the border of the universe must have a lot of the energy created by the black hole, hence helping the TAGF there to rapidly grow and causing the cosmic acceleration. So the border of the universe may not work like the event horizon of a black hole.

6.4. Quantum Chromo Dynamics Axion for Dark Matter

The predicted interaction strength for QCD-axions is 10^-13 GeV at maximum, and the mass is between 1/1000000 eV through 1/1000 eV[16]. The axion is a hypothetical pseudoscalar boson. Photons can get converted into axions, and vice-versa. This happens when the photon travels through a transverse magnetic field[16]. The best technique as of now to detect axions is by converting them into microwave photons, but it hasn't detected any, so it's in the process of being made more sensitive[16]. Axions are thought to be emitted from the sun as well so there may be hope of detecting it that way.
One of the experiments aims to show photon-to-axion conversion through a transverse magnetic field. TAGF seems to disagree with it, but it does show a little bit of similarity in the nature of photon-to-dark matter conversion. TAGF states that dark matter is interdimensional, therefore it can be converted to another substance, but it can be converted into another dimension, and lose some properties. Therefore, the dark matter in bodies and outside bodies needs to be stable and constant so that gravity remains almost the same. The differences between TAGF and QCD-axion are that instead of a magnetic field, there should be a gravitational field, and instead of a photon there should be TAGF(light's collision) and TAGF will get converted into dark matter, and dark matter won't be converted into anything.

6.5. ΛCDM - The Current Best Model Describing The Universe

The estimate of mass for dark matter comes from gravity which is required to contain the plasma and the gravitational lensing of background galaxies. The consistency of CMB measurements with the ΛCDM model gave better outputs for the measure of deuterium in galaxies, and ΛCDM is reasonable with CMB anisotropies[17]. The mass of baryons and dark matter collectively was less than the Einstein De-Sitter Value, so to add space-time curvature, the cosmological constant was added to the CDM model[17]. The ratio of the mass density of baryons to dark matter is $0.163 \pm 0.032 * 10^{-31}$ g cm^{-3} [17].
The ΛCDM cosmology has six parameters:

1. Cosmic mean mass of baryons
2. Cosmic mean mass of dark matter(the cosmological constant is assumed to inhabit flat space sections)
3. The distance set by Hubble's constant
4. The tilt that is caused by scale-invariant primeval density fluctuations that is Gaussian and adiabatic
5. Maximum extent of vibration in primeval density fluctuations
6. The optical depth for the scattering of CMB by intergalactic plasma after reionization

In the ΛCDM model the first nucleosynthesis of light elements in the hot big bang(BBNS)theory is sensitive to baryon mass. The consistency of CMB measurements and the ΛCDM model improved measurements of deuterium in young galaxies and the fraction of baryons in galaxy clusters. ΛCDM predictions are far more successful in the characteristics of galaxies than dark matter. ΛCDM predicts that the growth of galaxies by mergers and accretion had a redshift of $1<z<3$ when star formation was high during the early years of the universe. ΛCDM seems reasonable because it tends to make sense with the CMB anisotropies(having different values for a property when measured in different directions). Primeval plasma for ΛCDM was cooled and largely combined in order to form atomic hydrogen at 4000 K and was then ionized and the temperature dropped back to 100 K while everything else was happening in the universe.

6.6. Particle Dark Matter

A reason behind supersymmetry is the quantum corrections made by virtual bosons and fermions that are made to be canceled out as they have different signs, but theorizing that pairs of bosons and fermions with identical interaction strength give us the equation[18]:

$\delta m_w^2 \simeq 0(\alpha/\pi)(m_B^2 - m_F^2)$

This would result in $\leq m_w^2$ if the differences between boson and fermion squared masses[18]: $|m_B^2 - m_F^2| \leq 1\text{TeV}^2$

This suggests that supersymmetric partner particles can be made in the current or future particle accelerators

The best particle candidate for LSP is the lightest neutralino which is a mixture of supersymmetric partners of photons, Z bosons, and the neutral Higgs boson. LSP is also a candidate for cold dark matter. If axions, LSPs, and massive neutrinos are to be discovered, we will get a standard model of structure formations that would tell us about GUT, supersymmetry, and perhaps some extensions of particle physics.

Perhaps TAGF is the super symmetrical partner of dark matter, and TAGF has an anti-gravitational effect and is thermal or it has heat related to it, and dark matter has gravitational effects and it may be cold as explained in CDM. Perhaps a reason why dark matter and TAGF(perhaps super symmetrical partners) do not exhibit a cancellation effect when interacting is because dark matter typically prevails over the energy of TAGF and causes TAGF to get converted into dark matter, but the dark matter of a photon has less energy than that of a TAGF, so perhaps from that it is to be inferred that the mass or the gravitational force of a photon is less than that of TAGF.

6.7. Implications of an IDE Model

Due to the significance of the theoretical and observational differences in the cosmological constant, the observational data has advised modifying the gravity of the ^CDM or moving on to alternate theories. When it has been theorized that dark energy interacts it has been noted that the equation of state changes from quintessence to phantom, this tells us that the nature of the equation of state of dark energy has a dominant quintom(both quintessence and phantom)type of nature[19]. The gravitational interaction between dark matter and dark energy has the following equation:

$\dot{\rho}r + 3H(\rho r + pr) = 0,$

$\dot{\rho}b + 3H(\rho b + pb) = 0,$

$\dot{\rho}m + 3H(\rho m + pm) = Q(t),$

and

$\dot{\rho}d + 3H(\rho d + pd) = -Q(t),$

r means radiation, b means baryons, m means dark matter, d means dark energy, H means the Hubble parameter, Q(t) means the rate of energy exchange between dark matter and dark energy. If Q(t) is more than 0 means that the transfer of energy is from dark matter to dark energy and if Q(t) is less than zero the energy transfer happens from dark energy to dark matter[19]. Visible imprints are being made in dark energy density fluctuations and are seen for larger rates of interaction strength[19].

The research paper briefs that dark matter and dark energy are thought to be two matter fields interacting with each other. This should be incorrect because dark energy shouldn't really be a matter field, TAGF isn't a matter field, it's a type of matter whose effects are thermally activated anti-gravitational fields, it isn't like a scalar matter field, nor can dark matter be explained as a scalar matter field. Scalar matter fields probably can't solve the cosmic coincidence problem, hence it's better to infer particles or interdimensional effects.

The research paper explains that there is a faster decrease in the amount of radiation energy in baryonic matter than it is for the decrease in dark matter. This tells us that there is a decrease of energy from 4-dimensional dark matter, this may explain why gravitational fields for heavenly masses remain unchanged until a certain time because of the loss of energy from dark matter in the 4th dimension, and the gain of dark matter from TAGF conversions in the 3D, results in dark matter to be constant. So we can infer that if a certain amount of energy loss takes place in the 4D world for dark matter, then dark matter compensates immediately for that by the TAGF conversions. This might explain why many models say that gravitons leak out to extra dimensions, but in reality, the external gravitons are constantly losing themselves and gaining themselves, this results in a quantum superposition state for the graviton. This makes sense for why gravitons are linked with higher dimensions and have the ability to project the gravitational fields of 4D dark matter while being present in our 3D universe. From the statement given in the research paper read for this section, we can infer that dark matter slowly loses energy when compared with normal baryonic matter.

The research paper also briefs that visible imprints are being made in dark energy and density fluctuations are noted when there is greater interaction strength. In TAGF, when it gets converted into dark matter, obviously there should be density fluctuations in dark energy. This should be a constant process because a luminous body should emit many photons, and photons travel in all directions, so many TAGFs will be created. So, immediately after birth TAGF is converted into dark matter, and as long as the body is luminous, a cycle will happen in which TAGF is first created, then it is converted into dark matter, this cycle goes on until the body loses either of its luminosity or gravitational field. On top of all of this, external TAGF can also interact with the outskirts of the gravitational field and become dark matter.

6.8. The Field Theoretics of IDE Models

In model of the research paper, they introduce a new interacting term between dark matter and dark energy, Q, whose equation is [20]:

$Q=\phi_1(\partial V_2/\partial \phi_1)-\phi_2(\partial V_1/\partial \phi_2)$

The value of Q will be zero if it is in the case of non-interacting decomposing potential. If there are positive values of interaction between dark matter and dark energy then $Q > 0$
The transfer of energy and/or momentum from pressureless dark matter(CDM) to dark energy then it is $Q < 0$. When the vacuum interacts with CDM, the dimension of the parameter space becomes seven with the following parameter

$$\mathcal{P} \equiv \{\Omega_b h^2, \Omega_c h^2, 100\theta_{MC}, \tau, n_s, \log[10^{10}A_s], \xi\}$$

Which $\mathcal{P}$ refers to the first six parameters of the ΛCDM model, and the seventh parameter is ξ
The interacting models in this research have similarity which is that there is only a mild interaction between dark matter and dark energy. A thing which may have not been assumed is that this is accounting to our world which in our eyes is in 3D. In TAGF it is explained that this mild interaction might be because these interactions happen in the 4th dimension which is already mentioned. Since these interactions happen in the 4th dimension their 3D effects should be quite mild or not even that easy to be noted.

6.9. Phenomenological Interaction Between Dark Matter and Dark Energy

Most popular theories say that dark matter and dark energy do not interact with each other except with gravity, or that other than gravity there is no way for the interaction between dark matter and dark energy. The common way to approach the interaction between dark matter and dark energy is by using an exchange of energy between two matter conservation equations:

$$\dot{\rho}_{dm} + 3H(\rho_{dm} + p_{dm}) = -Q,$$

$$\dot{\rho}_{de} + 3H(\rho_{de} + p_{de}) = Q,$$

If the value of Q is more than zero then dark matter releases energy into dark energy, if the value of Q is less than zero then dark energy releases energy into dark matter. The equations of background cosmological level for dark energy interactions are:

$$3H^2 = \rho_{dm} + \rho_{de},$$

$$2\dot{H} + 3H^2 = -w_{dm}\rho_{dm} - w_{de}\rho_{de} - \pi,$$

$$\dot{\rho}_{dm} + 3H\rho_{dm}(1 + w_{dm}) = Q_{dm},$$

$$\dot{\rho}_{de} + 3H\rho_{de}(1 + w_{de}) = Q_{de},$$

With a constraint equation

$$3H\pi + Q_{dm} + Q_{de} = 0$$

With certain variables we have the following formula to get a value [21]:

$$\pi = \pi_{dm} + \pi_{de},$$

$$Q_{dm} = -Q - 3H\pi_{dm}, \qquad Q_{de} = Q - 3H\pi_{de}$$

In a physical system, there are three fluid components: dark matter, dark energy, and gravitational field. Dark matter and dark energy are described as perfect fluids because they don't dissipate. Another thing is that there could be an energy exchange not only between dark matter and dark energy, but as well as an energy exchange between gravity too [21]. If there is an interaction between dark matter and dark energy then the energy-momentum exchange should be something that is any other value other than zero
In one of the results of this research it was briefed that there can be energy exchange not only between dark matter and dark energy but also with gravity. This result seems a little similar to TAGF. As in TAGF, the heat that is associated with TAGF helps to convert it into dark matter, so during that process, the heat may get exchanged with gravity but only for a short period of time as the conversion effect happens quickly.
In the same result, this research sheds light on the concept of dark matter and dark energy are perfect fluids hence they don't dissipate. In the 4th dimension, as mentioned before in TAGF, dark matter dissipates when it interacts with dark energy, but since

it immediately gets restored by the 3D TAGF conversion, it makes it seem like dark matter is perfect and it does not dissipate. But without regard to the interaction dark matter has with dark energy, then dark matter is a perfect fluid. Then comes the interesting part about TAGF and whether it dissipates or not. When TAGF is going through its conversion process, heat is one of the factors that probably helps it to be converted into dark matter, but along with that, the heat is gone so that would probably mean that TAGF, only when being converted into dark matter, for a brief time period it may dissipate its heat. During the creation of TAGF, the photons don't actually dissipate, but rather they gain heat, which is also a form of energy, so indirectly the photon gets more energy.

6.10. The Cosmological Parameters of IDE Models

Interaction between dark matter and dark energy(assumed as a field) would make the mass of the dark matter particle vary, which creates a long-range nongravitational interaction between the two. In the end, they made a formula for the mass of a dark matter particle which is the following [22]:

$$m_{\text{eff}} = y|\phi -$$

The energy of a dark matter particle is conserved as it travels through space and encounters other dark matter field gradients. The local value of the velocity of a dark matter particle changes in response to the change in the local value of the same dark matter's mass which is determined by the local value of the dark energy field [22]. There is a model where dark matter interaction has a Yukawa coupling to a scalar field causing it to be the source of dark energy. A dynamical model for dark energy is kind of like Einstein's cosmological constant. In the models that have been studied in the research paper, it has been noted that the mass of a dark matter particle is defined by the interaction it has with a scalar field [22].
A point that has been focused on in the research paper is that dark matter gets its mass from its interaction with a scalar field which is proposed for dark energy. Dark matter is thought to be in and outside of stars and other masses, as explained in TAGF, dark matter is in a higher dimension, whereas dark energy is in both ours and a higher dimension at the same time but its effects are highly noted in ours. Dark matter is associated with gravity which is clearly known because if the dark matter value were to change then gravity should also change, so if the interactions keep changing the value of dark matter then gravity should not be as stable. The only time when gravity is not stable is when the core collapses and dark matter wins the fight. Though TAGF is converted to dark matter, dark matter might also lose a certain amount of it at the same time to keep such a stable and constant gravity, perhaps this loss may arise from the four-dimensional interactions between dark matter and dark energy, which was also mentioned in TAGF.

6.11. The Gravitational Wave Aspect for the Interaction Between Dark Matter and Dark Energy

There can be improvement for the constraints on neutrino masses through the interactions between vacuum energy and dark matter. The ΛCDM models should not consider dynamical dark energy as a constant [23]. From the examination of gravitational waves, we can get the luminosity distance from its source. The redshift of a source can be found we figuring out the electromagnetic part of gravitational waves from its source. With this distance and redshift combination, you can find out the rate of expansion of the universe. Gravitational waves may be key for the next few decades for knowing the expansion rate of the universe [23]. Neutrinos help to give us an idea of the large-scale structure of the universe and the history of the expansion of the universe. The effect of late and current universe massive neutrinos on large scales seem to not show a difference when compared to CDM(Cold Dark Matter)which can lead to the improvement of neutrino masses [23].
The second research paper considers two IDE models, whose names are IDErc1 and IDErc2, whose interaction function, Q, is expressed in the following formula [24]:

$$Q = 3(1 + w_x)H\xi\rho_c \qquad (\texttt{IDErc1}),$$
$$Q = 3(1 + w_x)H\xi(\rho_c + \rho_x) \qquad (\texttt{IDErc2}).$$

w_x means the equation of state for dark energy, ρ_c and ρ_x which means the energy density of both dark matter and dark energy respectively. Both these models are stable if the strength of interaction between dark matter and dark energy is more than zero. They have assumed that the interaction strength for the first model is 0.010, and for the second model, the interaction strength is 0.025. In the first model if the gravitational wave data is added the Hubble's constant and the matter-density constant are improved as the uncertainty is reduced by factors of 5 which is better than CMB data [24]. In the second model, the same thing has changed, the Hubble's constant and the matter-density constant uncertainty have been reduced in orders more than factors of 5 [24]. CMB+GW data is better than CMB+BAO data, but perhaps in the future(around 2060) CMB+BAO may be more accurate and better than CMB+GW data [24].

6.12. The Inferred Two Constants of Gravity

To satisfy Newton's theory on the equivalence of a sphere's gravity, the point of mass in the center of a sphere seems to have an additional constant along with the gravitational constant. This second constant is proposed to be none other than the cosmological constant[25]. The weak field limit for the cosmological constant is modified Newtonian gravity[25]. The gravity of the cosmological constant is because of Newton's theory which states that the identity of gravity in a sphere comes from the point of mass located at its center. The cosmological constant is considered to be more universal than the gravitational constant because it is dimension-independent and does not strongly interact with matter[25]. Dark matter and dark energy may have a unified gravitational nature. A positive cosmological constant tells us that the universe is a cyclic type of universe. The Schwarzschild metric for a non-zero cosmological constant is d-dimensional where the dimension is not two is the following equation [25]:

$$ds^2 = \left(1 - \frac{2G_d M}{r^{d-2}c^2} - \frac{\Lambda r^2}{3}\right) c^2 dt^2 - \left(1 - \frac{2G_d M}{r^{d-2}c^2} - \frac{\Lambda r^2}{3}\right)^{-1} dr^2 - r^2 d\Omega_{d-1}^2.$$

In this research, it has been briefed that the cosmological constant should be there along with the gravitational constant in the center of a sphere. The cosmological constant is thought to be a repulsion effect, let's say that there is a perfectly spherical star, the reason why the star doesn't succumb to the pressure of its own gravity is because the particles inside don't want to be so close to each other hence they repel against gravity. The cosmological constant is a form of vacuum energy so based on what this research paper's focus is on, that would mean that the only reason stars are alive is because of the cosmological constant, which doesn't sound right and it could not be applicable to the universe as a whole even if the universe was spherical. This is because the cosmological constant cannot be defined as particles close to each other that they repel each other, the cosmological constant is vacuum energy, it can't be such a case and it won't explain fluctuating photons because these photons are temporary and would be escaping the closeness which wouldn't really explain the repulsion effect. The part where it explained that the second constant should be interdimensional and non-interacting with matter makes sense, but there should be no second constant other than gravity because gravity itself is a projection of dark matter as explained in TAGF, so if there was a second constant to be made we should first define dark matter, even dark matter is interdimensional and it is also weakly interacting with matter that too with its projection.

6.13. Recent Theories on Dark Matter and Dark Energy

Right-handed neutrinos(also called sterile neutrinos) are hypothesized dark matter particles that can only interact through gravity(not interacting electroweak-ly in particular). In order to prove the existence of sterile neutrinos, a researcher claimed that there was a mirror universe that was symmetrical to our universe, which is kind of like supersymmetry, in a similar manner there are three types of left-handed neutrinos whose super symmetrical form would result in three types of sterile neutrinos [26]. From those three left-handed neutrinos, only one type has survived until the current epoch and if that neutrino is sterile then it may be a dark matter particle. The mass of the surviving neutrinos may be 4.8*10^8 GeV [26].
There is a theory that says that dark matter can interact with itself it is known as Self-interacting Dark Matter, and these particles also tend to have strong interaction [26]. This theory is the opposite of CDM as in this theory the dark matter particles experience an unknown force, whereas in CDM dark matter will not take part in collisions. This self-interaction is made possible due to light intermediate vector bosons(a fundamental particle that transmits weak force), these bosons must have large masses in a such way that the dark matter particles do not disappear or dissipate [26].
Another theory for dark matter is hexaquarks, which consists of three up quarks and three down quarks. Perhaps hexaquarks with trapped electrons can evolve in the Bose-Einstein condensate [26]. They provided a theory that states that in the early universe that had low temperatures, hexaquarks may have overlapped in order to form dark matter. There is a counter statement saying that in the early universe, these hexaquarks would have broken apart and were unable to reform because of intense radiation [26].
In another theory, a period in the universe made cooled plasma bubbles that absorbed/took in high-mass dark matter particles and left out the lower-mass dark matter particles. Over a period of time, these bubbles expanded and merged with other bubbles [26]. This hypothesis could explain how there is a specific amount of dark matter from observations. These dark matter particles may have had a range of masses between TeV to PeV, which is higher than any other dark matter particle theory [26].

Primordial black holes are another theory for dark matter but it's a little problematic because of matching the amount of dark matter to develop models with the correct amount of primordial black hole [26]. Perhaps primordial blackholes with 1000 solar masses, though only accounting for a small fraction of the energy density of blackholes, seem to solve other cosmological problems such as generating cosmological structure and the removal of problems in the CDM model. Perhaps if these black holes did not form in the traditional way of the supernova of the star, then perhaps these black holes can form from the explosion of neutron stars that have absorbed some amount of dark matter [26]. Primordial black holes resulted from vacuum bubbles through the process of quantum tunneling, based on that baby universes were made which resulted in the creation of primordial black holes. SLABs(Stupendously Large Black Holes)are primordial black holes with the greatest mass of any blackhole ever. If SLABs exist, this makes way for light primordial black holes, which could also be dark matter candidates [26].
Another theory is that dark and usual matter interact through the fifth dimension, normal particles exist in a 3+1 dimensional brane(Weakbrane) whereas gravitons can move to the fifth dimension(Gravitybrane) [26]. When the gravitons move from the Gravitybrane to the Weakbrane, their gravity becomes significantly weaker.
In the Self-Interacting Dark Matter theory, it has been briefed that there can be strong interaction between dark matter particles with one another. When dark matter interacts with another dark matter particle it just combines itself, but that just works in our 3D world[let's say strange matter(dark matter that is in 3D form but lost some of its properties)interacts with the singularity(complete dark matter) of black holes, the strange matter will be absorbed by the singularity and nothing will happen], but in the higher dimensions, then perhaps dark matter may not combine until the 3D universe object(stars, planets)become weaker and succumbs to the pressure of the gravity of the dark matter. But perhaps from that, it can be inferred that dark matter may leak into our world when dark matter increases(this is being inferred from the creation of black holes), but the singularity is so small that maybe dark matter in the higher dimensional may be concentrated into one point. In this Self-Interacting Dark Matter theory, it was explained that light intermediate vector bosons cause this attraction, but in TAGF, dark matter just has an objective to create more of itself(kind of like the hypothetical strange matter in neutron stars. Dark matter is typically in and

around celestial bodies, so maybe when the celestial body is dying the dark matter around the body is absorbed into the center of the dark matter.
The Gravitybrane theory states that when gravitons move from the fifth dimension into lower dimensions, their gravity gets weaker. That shouldn't explain anything because gravity gets weaker when an object is far away, so based on this theory, does that mean far gravitons came from the fifth dimension? Gravitons being far away doesn't have to do anything like traveling to higher dimensions. One thing that may be true about gravitons is that they may be linked with higher dimensions while staying in our dimension hence causing the projection of dark matter which is gravity.

6.14. The Ordinary Gravitational Answer for Dark Matter and Dark Energy

The equation of motion in their model [27]:

$$T\frac{dS}{dt} = T\sum_j \frac{dS}{dN_j}\frac{dN_j}{dt} = \sum_{j,k}\frac{dN_j}{dt}\left(-\Delta\mu_{jk} + i\Delta Q_{jk}\right),$$

While doing these equations of motion equations, they found that entropy seems to increase in the least time meaning that the body moves in geodesics(traveling in the shortest way possible)rather than traveling in any path [27]. The vacuum has all the energy of gravity equal to the energy of all matter.
Two highly destructive interfering photons(perhaps photons like gamma rays) lose their electromagnetic fields instead of vanishing into the vacuum [27]. A vacuum with such destructive pairs of photons is a relativistic substance with no total electromagnetic force but it has gravitational energy density [27]. This statement got pretty close to TAGF and will act as a piece of major evidence regarding the existence of TAGF in other research. The average mass density of the universe, as time goes on, gives a source for the space to be filled with photons [27].There should not be just a single state for paired photons because the vacuum energy spectrum is continuous [27]. Through the equations, it was found that the universe expands physically(meaning that a thing is physically pushing it)instead of expanding parametrically [27].This also acts as a proof for TAGF as this statement aids the fact that TAGF is there in our universe and its effects are physically causing this expansion. This paired photon is quite similar to that of a graviton [27].
Some statements got pretty close to TAGF, and might as well act as proof for TAGF. As in a statement, colliding destructive photons lose their electromagnetic properties, and give gravitational energy density to vacuums which makes sense with TAGF. After all, it is approximated that there may be 10^84 photons in the visible universe, which means that there are a lot of collisions, and photons pass through another photon, so even after colliding with another photon it can still collide further in its path. This might be a major implication or proof of TAGF.

7. Key Results:

Overall, throughout the literature, many points gave useful reasons why TAGF should work. The last part of the literature gave the most important reasons why TAGF should work from an external point of view. In most literature, the points were indirectly giving reasons for the existence of TAGF and the concepts regarding it. One such was that the effects of dark matter are mild, which was beautifully explained by TAGF, and the reasons for the effect being mild.
Popular models like Quintessence are one of the few models that can solve the cosmic coincidence problem has its problems because it's a scalar field. Other research papers gave reasons why it should not be a scalar field. In contrast, TAGF physically causes the expansion of the universe and solves the cosmic coincidence problem while being mostly in the boundary of standard physics. Typically, Quintessence models are way beyond the Standard Model. The other popular model, the Lambda-CDM model, also faces issues because of the cosmological constant, and its uncertainties quintessence may be deemed to be better than the cosmological constant. The CDM part is just a hypothetical description of the properties of dark matter but ceases to define dark matter. Whereas TAGF gives a clear definition for both dark matter and dark energy while explaining everything else clearly.
TAGF is a model worth investing in and in the right circumstances, research, and mathematics it might as well dethrone Lambda-CDM, quintessence, etc. It may also give a good explanation of the universe at large scales and its hidden secrets, it may also be correct in its facts. The components that make up TAGF give the right answers for problems regarding dark matter and dark energy, which is a specialty in TAGF and may not be seen in other models. TAGF also answers the misconceptions of its properties clearly, such as the thought that it is a scalar field, deviations in gravity, etc.
By far, TAGF is a work-in-progress model that gives the right answers to many problems and steers clear of problems like fine-tuning as of now. All of these tell us that TAGF will be the next huge contender for large-scale universe theories, dark matter, and dark energy theories. It seems very likely that if more mathematics is added to TAGF, more theoretics, it might as well explain the greatest mystery of the cosmos.

8. CONCLUSION

This paper has proposed the Thermal Anti-Gravitational Field (TAGF) as a novel concept that could physically explain the accelerating expansion of the universe and connections between dark energy and dark matter. The core thesis is that the kinetic energy released when photons collide generates temporary zones of inverted "anti-gravity" called TAGF. Concentrated in intergalactic voids between galactic superclusters, the cumulative TAGF effect drives galaxies apart. TAGF may also interact with strong gravity to produce dark matter particles.
In summary, we have theoretically developed the foundations of TAGF starting from known properties of photons, gravity, heat, and quantum effects. When two photons collide destructively, we hypothesize their intrinsic gravitational fields momentarily cancel in a quantum superposition state, releasing kinetic energy to create an explosive anti-gravitational distortion in space-time. Ongoing photon collisions sustain and spread this TAGF zone. Where matter density dominates radiation, TAGF instead reacts

with gravity to potentially spark virtual particle formation, stabilizing some as real dark matter. This higher-dimensional dark matter manifests as the gravity we observe acting on ordinary matter.

Compared to popular models like quintessence or ΛCDM, TAGF offers hope of physically explaining cosmic acceleration and linking dark components without relying on speculative new physics. By leveraging gravitational lensing evidence that photons do "gravitate," TAGF sidesteps puzzles over quantum vacuum energy while dynamically driving accelerating expansion through known electromagnetic interactions. Unresolved theoretical issues remain, but early analysis finds TAGF consistent with certain observational anomalies possibly indicating dark matter interconversions.

Our research paper will have a sequel for TAGF with further mathematics and theoretical implications in the future. Much future work is needed to mathematically flesh out TAGF for simulations testing its large-scale structure signatures and other falsifiable predictions. With further development, TAGF may emerge as a viable contender to unlock outstanding enigmas of dark energy, dark matter, and cosmic expansion. The concepts inspiring TAGF resonate with active areas of gravitational, particle, and quantum physics research converging from multiple directions on cosmic mysteries.

9. Discussion and Future Directions

We introduced the Thermal Anti-Gravitational Field as a new concept driving cosmic acceleration from photon collisions, potentially even generating dark matter. TAGF largely operates in diffuse intergalactic plasma where radiation dominates over matter density. Gravity remains ascendant inside galaxies, but TAGF may spark dark matter creation at interfaces where gravitational power balances with electromagnetic forces. This early theoretical formulation currently lacks sufficient mathematical detail or observational confirmation to unseat the remarkably successful ΛCDM paradigm. Yet by linking dark energy and dark matter while avoiding problems with the cosmological constant, TAGF moves toward a causal explanation for cosmic acceleration “out of the box” using known physics.

Much future work is needed to develop testable TAGF models. N-body simulations including TAGF contributions could determine signatures in the large-scale structure of galactic clustering and voids. Detailed modeling of TAGF particle interactions might reveal additional falsifiable predictions. With refined theoretical grounding, TAGF may yet find empirical validation from galaxy rotation curves, gravitational lensing, structure growth measurements, or other cosmology experiments designed to map dark phenomena.

10.Data Availability Statement

Not applicable.

11.Author Contribution & Discussion

[1]Sanjay Kanna Mukesh Sathya, [2] DR.Sanjay Giridharan commented on, and wrote the manuscript. All authors have read and agreed to the published version of the manuscript.

12.Conflicts of Interest

The authors declare no competing financial interests.

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13.References

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