Applying 6-Sigma DMAIC problem solving discipline, structure, and mindset to the Anomalies of The Universe.

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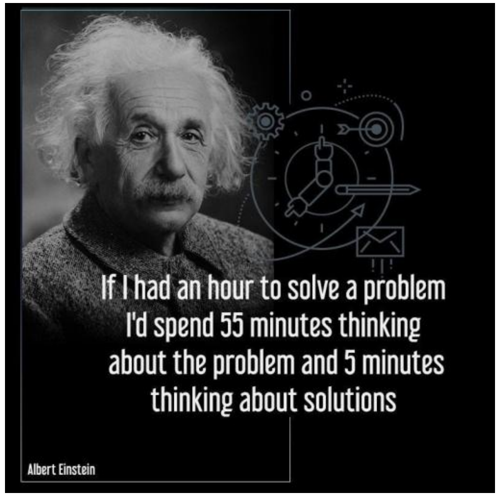
Executive Summary

This report applies the DMAICR problem-solving framework to the deepest puzzles in cosmology. The Define–Measure–Analyse phases reveal a clear pattern: every major anomaly arises at or across density thresholds, while high-density regimes remain fully consistent with General Relativity. The Improve phase introduces a novel theory, the mechanism of which naturally explains galaxy rotation curves, late-time acceleration, void lensing, neutron star behaviour, and more — without exotic particles or patchwork fields. The Control–Replicate phases catalogue falsifiers and observational tests, ensuring the theory remains strictly scientific.

This is not another patch, or a gap-filling hypothesis; it returns to first principles, and constructs a framework based on the evidence.

Keywords:

- *General Relativity*
- *Albert Einstein*
- *Edwin Hubble*
- *Anomalous Universe*
- *Unexplained phenomena*
- *Unification*
- *Quantum Gravity*
- *Standard Model of Cosmology*
- *Cosmological constant*
- *Dark Energy*
- *Dark Matter*
- *Hubble Tension*
- *Universe Expansion*
- *Acceleration*
- *Galaxy Rotation*
- *Gravitational Lensing*
- *Gravitational Waves*
- *Density-Dependence*
- *Void physics*
- *Low-density space*
- *Black holes*
- *Neutron stars*
- *MOND*
- *BAO*
- *Quantum Field Theory*
- *Expanse Tension Theory*
- *Expanse Tension Ripples*
- *Mass Resists Expansion*
- *Emergent Gravity*
- *Emergent Inertia*
- *Emergent Time*



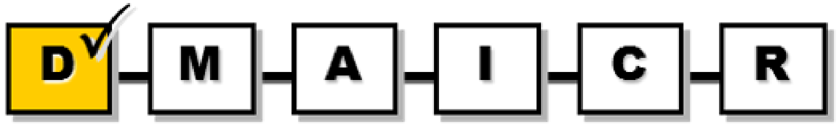
Introduction

Albert Einstein had no concept of Late-Time Acceleration within his lifetime, it was only in the late 1990s, decades after his death that the observation of very high redshift photons from extremely distant supernova indicated that universal expansion, known since Edwin Hubble's 1929 work, was accelerating.

Anomalous galaxy rotation speeds did emerge within Albert's lifetime, however, the equipment and measurement errors at the time made the result less than definitive. Albert initially added then later removed Λ (Lambda), the *cosmological constant* from his work.

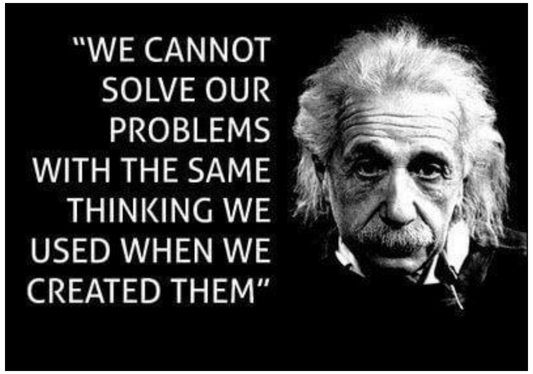
Whilst General Relativity remains our foremost standard model of cosmology, it was formulated in a different age, and under vastly different information and assumptions. So, it is time to restart at Problem Definition.

The work here started with a blank sheet of paper. Nothing is taken for granted.



Here, the author tackles the greatest current challenges of science, physics, and the Universe using a well-proven commercial problem-solving structure: DMAICR. By carefully and diligently progressing through ***Define, Measure, Analyse, Improve, Control and Replication*** of these issues, it may reframe the problem and shed new light.

Albert believed in a stable, static, eternal universe, and based his solutions on those notions, from the information he had at the time. Times have changed.



Define the Problem (Part 1)

WHAT. Central Issues – empirical anomalies

1. Gravity is not unified into Quantum Field Theory (QFT); we have not achieved underlying causal mechanism. General Relativity provides geometrical prediction of effect, not quantum cause.
2. Late-Time Acceleration (LTA) of the current era has a 70% energy deficit and relies on "Dark Energy", combined with a 26% Cold Dark Matter (CDM) component of the continuing unexplained mystery.
3. Galaxy outer region rotation speeds demonstrate a 26% matter deficit , invoking "Dark Matter" and the failure of ΛCDM to explain structure formation without additional unseen matter.
4. Gravitational lensing through the deep void is greater than that adjacent to large mass structures, such as galaxies and stars, also relying on Dark Matter to explain.
5. Across nine Hubble probes, a delta, a conflict exists which highlights a severe discrepancy in understanding the expansion rates of the universe, the delta is called the *Hubble Tension*, at 8.31% disagreement range.
6. The Equivalence Principle has been tested to exquisite precision within the current reach of human endeavour, yet its ultimate cause is unknown.
7. Unexplained physics of neutron star interiors, pulsar glitches, and black hole singularities.
8. Unresolved nature of cosmic voids, fast radio bursts, and other extreme astrophysical phenomena.
9. Baryon Acoustic Oscillation (BAO) discrepancies across redshift.
10. We have counted ~47,000 publicly available respected datasets which show observational deviation conflict to General Relativity prediction, all within, across or between the deep void of the cosmos. GR shows systematic deviation in low-density regimes.

WHEN. *Key timeline and moments*

Here are four precise time points in physics history where the cracks in the framework became visible:

- **1915–1919 (Birth of GR and first cosmological tensions):** Einstein's General Relativity explained gravity as spacetime curvature but offered no causal mechanism for why mass curves spacetime; Einstein himself introduced and later abandoned the cosmological constant to fit observations.
- **1933 (Dark Matter hypothesis):** Fritz Zwicky's analysis of the Coma Cluster revealed galaxy motions too fast for visible matter alone, marking the first proposal of "dark matter" and the beginning of reliance on invisible components.
- **1998 (Discovery of cosmic acceleration):** Type Ia supernova observations showed accelerating expansion, forcing the reintroduction of the cosmological constant as "dark energy," an unexplained component dominating ~70% of the universe.
- **2010s–present (Precision cosmology anomalies):** Increasingly precise datasets (Planck CMB, BAO, Pantheon+, JWST) exposed persistent >5σ tensions (e.g., Hubble constant) and unexpected structures (early galaxies, void anomalies), highlighting the incompatibility of GR+ΛCDM with observations.

The issues originated >100 years ago and have only exacerbated as the confidence in accuracy of observational method and equipment has cemented the anomalies.

COST. The magnitude of expenditure or commitment value

1. Our research has identified globally, ~$16 billion spent on searching for Dark Energy without a Joule discovered, and ~$9 Billion spent on searching for Dark Matter, without a gram found.
2. Whilst particle colliders are not built explicitly for searching for Gravitons and quantum gravity, several CHF Billions have been spent in this pursuit, with a further $25 – 35 billion committed to accelerate the future search.
3. Globally, ~$3 Billion spent on searching for resolution to the Hubble Tension – without success. BAO $1.5 Billion. Neutron Star glitches $2 Billion. Cosmic Void / FRBs $1 Billion.
4. Estimated ~$1.6 Billion spent/ committed to the search for Gravitational Waves, despite spacetime being a purely geometric construct, without medium, fabric, or quantum field associated (how are they supported or propagated? Whilst the author acknowledges and respects the detections, later in the report we reinterpret their nature.
5. Tens of thousands of scientists, physicist, astronomers, cosmologists, engineers globally involved in the search.

Overall Spent: $25 – 34 Billion Investment in the search

Define the Problem (Part 2)

D M A I C R

WHERE. ***What region or environment <u>does</u> the Problem exist***

- GR (ΛCDM) predictions show up in **low-density regimes**, especially in and around cosmic voids and underdense environments
- Late-Time Acceleration (LTA) arises only as **mean cosmic densities fall** since the galaxy, matter and radiation eras passed.
- Galaxy outer region rotation speed anomalies arise only as the galaxy **mean densities fall** along the radii to the outer rim.
- Gravitational lensing anomalies arise in areas of **deep low-density voids** not in high density matter regions.
- Early time Hubble probes likely underestimate Hubble constant from observations which have travelled **great distances through the great low-density void** over billions of years.
- Late-era Hubble probes likely overestimate the Hubble constant from observations which have **<u>not</u> travelled great distances across the low-density cosmic void**.
- The sharp drop in star formation efficiency observed in the outer regions of galaxies, where **baryonic density falls to very low levels**, cannot be explained by conventional gravitational collapse.
- The Equivalence Principle has been tested to exquisite precision, however, **never in the deep void of low-density space** beyond the Solar System.
- Fast Radio Burst dispersion anomalies propagate through vast **low-density voids**, inconsistent with baryon accounting.
- **As high density changes** Neutron stars behaviour becomes more erratic, glitchy, or exotic, with transitions.

WHERE <u>NOT</u>. ***What region or environment <u>doesn't</u> the Problem exist***

- We are not experiencing any dark energy or dark matter effects here on Earth, in our **stable high-density** region.
- Gravity experiments here in **stable dense space on Earth** (Cavendish torsion balances, atomic interferometers, MICROSCOPE satellite): no deviations attributable to DM/DE.
- Our moon, lunar laser ranging: sub-cm precision matches General Relativity, as a **stable dense object** has never displayed any dark effects
- The planets orbits of our solar system, Mars, Venus, Saturn, etc**, stable dense objects** have never been observed displaying any dark effect.
- Spacecraft navigation (Cassini, Juno, New Horizons, etc.): no dark components needed for trajectory predictions, which exists within the **mean density of the solar system**
- Our own sun, and the Milky Way galaxy appear to behave as GR predicts.
- Inner galactic bulges: stellar motions in **high-density cores** largely fit baryonic mass + GR.
- White dwarfs: **dense masses** and radii follow Chandrasekhar limit, no DM/DE invoked.
- Local stars near Sgr A*: orbits of the "S-stars" around the Milky Way's central **black hole** precisely match GR predictions.

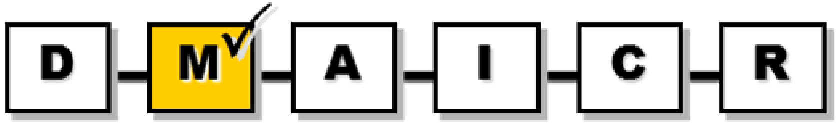
Problem Statement

- Physics today rests on a fractured foundation: General Relativity and Quantum Field Theory remain incompatible, requiring unverified constructs such as dark matter and dark energy while leaving gravity's causal mechanism undefined. At the same time, persistent high-significance anomalies—from the Hubble tension to galaxy rotation, cosmic voids, and neutron star interiors—expose systemic misalignment, underscoring the absence of a single predictive, falsifiable, and mechanistic framework uniting the quantum and the cosmic.
- Each case involves light, matter, or time propagation through **low-density** environments or a density transition, mostly **high-to-low**, but also some low-to-high (Neutron stars, Black Holes). Dark phenomena do not arise in high-density regions, or around massive objects or structure. Could this be a strong hint?

“The formulation of a problem is often more essential than its solution, which may be merely a matter of mathematical or experimental skill.”

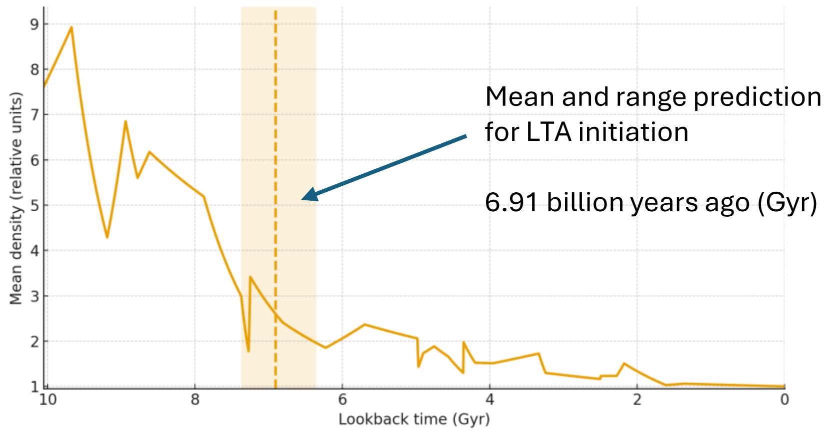
Albert Einstein. The Evolution of Physics 1938

Measure the Problem (Part 1)



1. Late-Time Acceleration (LTA) – *when did it start?*

Empirically assessing if Late-Time Acceleration initiated as mean cosmic densities fell, and if so both when in time and at what absolute density.



- **When LTA began (marker):** central estimate at $z = 0.8$ → **lookback** $t_L \approx 6.91$ **Gyr** (shaded band shows $z = 0.7$–0.9 → $t_L \approx 6.35$–7.38 Gyr).
- **Mean density at onset (absolute, from CC-only $H(z)$):**

$$\rho_c(z_t) = \frac{3H(z_t)^2}{8\pi G} \Rightarrow$$

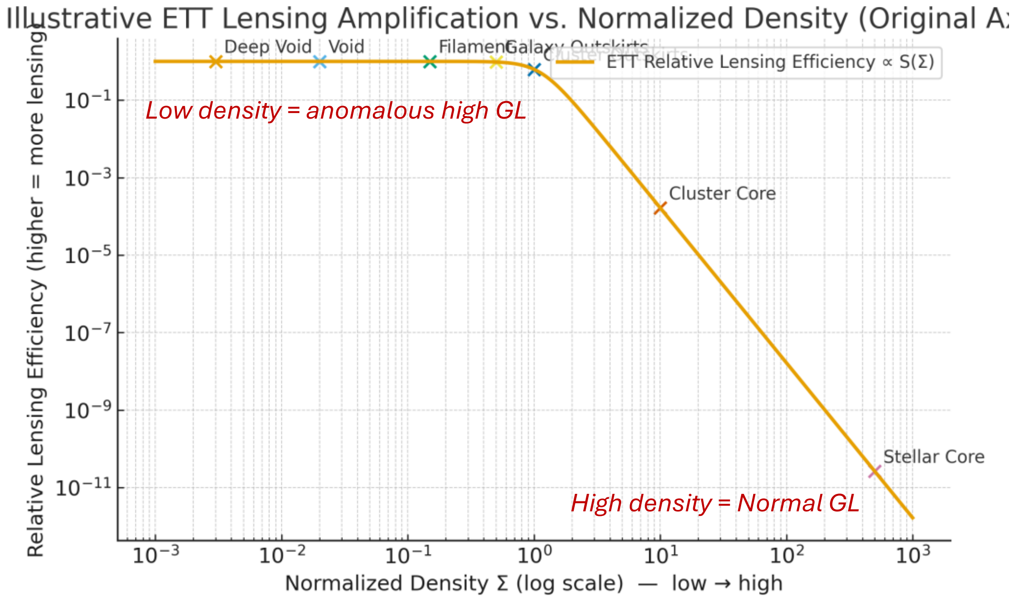
central $z = 0.8 : 2.23 \times 10^{-26}\ \mathrm{kg\ m^{-3}}$ (range for $z = 0.7$–0.9: 1.68–$2.57 \times 10^{-26}\ \mathrm{kg\ m^{-3}}$).

1. We built the curve from cosmic chronometer H(z) data.
2. Then we used $\rho(z) \propto H\left((z)^2\right.$ as a proxy for mean cosmic density (critical density).
3. The plot is essentially showing how the Hubble expansion rate squared evolves with time
4. LTA means expansion accelerates → the Hubble rate tends asymptotically toward a constant
5. So the critical density curve "flattens" after the transition, not steepens.
6. Critical density proxy: flattening is the signature of the acceleration era

Conclusion. LTA does indeed appear to trigger following a very steep **fall in cosmic density**.

2. Gravitational Lensing Anomaly – *where do photons lens / bend the most?*

To assess specifically where anomalous Gravitational Lensing (GL) occur, we plot Relative Lensing Efficiency (RLE) against normalized density.



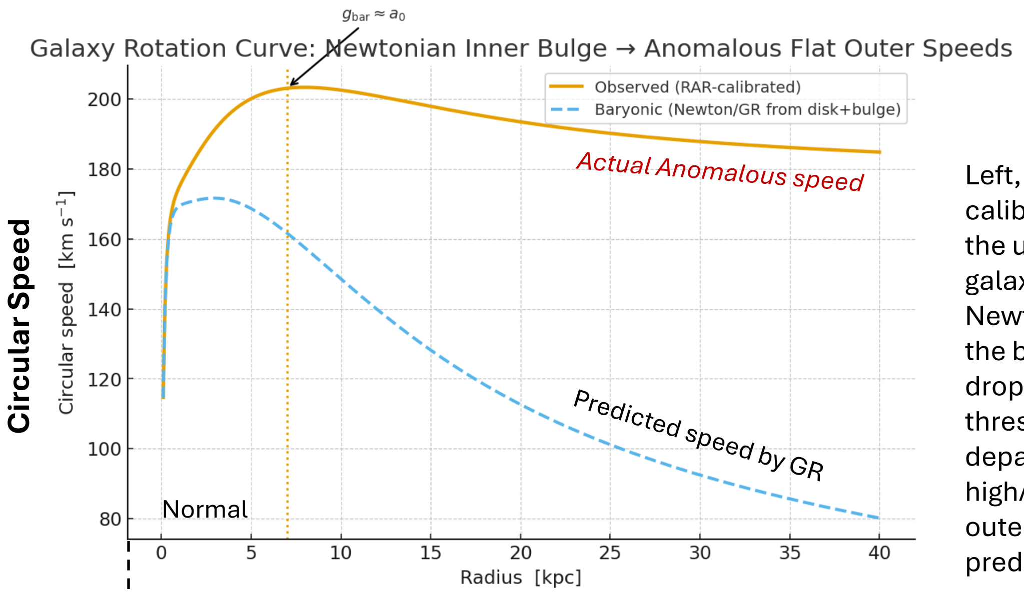
Graph description: *The graph shows the baseline General-Relativistic lensing response—e.g., convergence κ or shear amplitude $|\gamma|$—as a function of environment density (from deep underdensities/voids to cluster cores), assuming standard matter-only lensing along the line of sight.*

Key finding: *In the standard framework, gravitational lensing strength increases with* ***higher*** *density (peaking for galaxies and clusters), while voids produce weak* ***demagnification*** *($\kappa < 0$); the curve crosses through a natural, non-anomalous zero at roughly mean density (transition from demagnification to magnification), rather than showing an enhanced lensing signal at low density.*

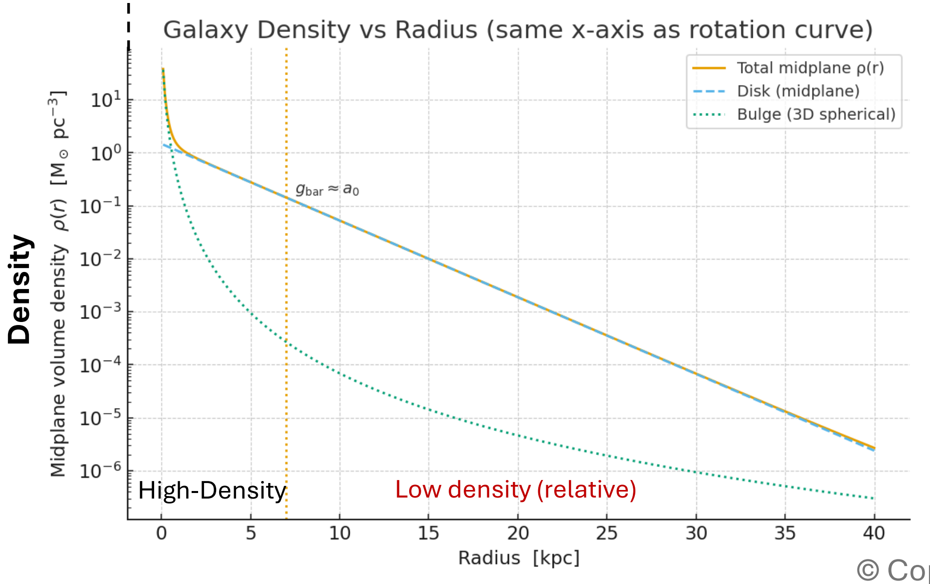
Empirically, low-density regions increase RLE, whereas in pure GR/ΛCDM they should decrease it. We repeatedly see excess lensing effects along **low-density** lines of sight

Measure the Problem (Part 2)

3. Galaxy rotation outer region speed anomaly – *where does it exist?*



Left, here is a data-calibrated visual showing the usual pattern of a galaxy: inner bulge follows Newton/GR, then—once the baryonic acceleration drops below the empirical threshold—the curve departs and stays high/flat- demonstrating outer region higher than predicted rotation speeds.



Left, the radial density profile plotted on the same x-axis (radius in kpc). It shows the midplane volume density $\rho(r)$in $M_\odot\ pc^{-3}$. A basic and possibly obvious confirmation: galaxy rotation speeds become anomalous as density falls.

- **Acceleration threshold** (onset of mass discrepancy):
  $a_0 = (1.20 \pm 0.02_{stat} \pm 0.24_{sys}) \times 10^{-10}\,m\,s^{-2}$. Physical Review ...
- **Equivalent baryonic surface-density threshold** (widely used, radius-independent):
  $\Sigma_M \equiv a_0/(2\pi G) \simeq 137\,M_\odot\,pc^{-2} \approx 0.029\,g\,cm^{-2}$. Systems with mean surface density above this are Newtonian in their centres; below it, the discrepancy appears. Physical Review ... +1
- **Related upper disk scale** sometimes quoted:
  $a_0/G \simeq 860\,M_\odot\,pc^{-2}$ (the classic Freeman-law scale for bright disks; Σ_M is the more relevant "transition" value). astroweb.case.edu

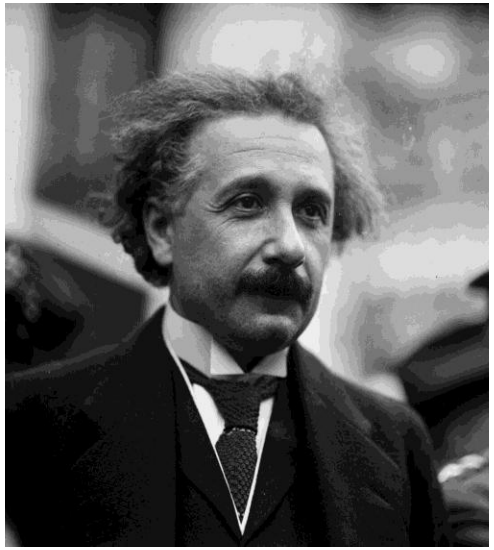
Why this is "based on all available data": the RAR/MDAR and a_0 are calibrated on 150–175 high-quality rotation-curve galaxies in **SPARC** (Spitzer Photometry & Accurate Rotation Curves) and recapitulated in later analyses. The tight relation between g_{obs} and g_{bar} fixes both the departure radius and the outer "flat" speeds across Hubble types and masses. ADS +3

In the very centre of a galaxy the stars and gas are packed tightly. Gravity there behaves exactly as Einstein's General Relativity predicts.

- As you move outward, the ***matter density falls*** away.
- At some ***critical low density***, the behaviour suddenly changes: instead of orbital speeds dropping with radius (as Newton/GR would expect), the rotation curve "flattens out" and stays high.
- This is the well-known galaxy rotation anomaly.
- In the model galaxy we just plotted, that turning point (the "inflection" where the anomaly begins) happens at roughly 7 kpc from the centre, right where the average mid-plane density has dropped to:ρ ≈ 0.14 M☉/pc^3(≈ 5×10^{-22} kg/m^3 in SI units)

That's the density threshold below which galaxies stop following the normal GR pattern and instead exhibit the anomalous flat, high-speed outer rotation.

Measurement conclusion. Three anomalous phenomena assessed, and all appear to show a relationship of unexplained behaviour to density.



"The important thing is not to stop questioning. Curiosity has its own reason for existing."

Albert Einstein. Interview in *Life Magazine*, 1955.

Analyse the Problem

Our current standard cosmological model is founded on Albert Einstein's 1915 work on General Relativity. Founded without any knowledge of expansion, which only began to emerge in 1929.

During Albert Einstein's Lifetime

- **1915 – Einstein (GR)**
  - Predicts dynamical spacetime, but Einstein assumes a static universe.
- **1917 – Einstein (Λ)**
  - Introduces the cosmological constant to freeze the universe in place.
- **1922–1924 – Alexander Friedmann (Russia)**
  - Derives expanding and contracting solutions from Einstein's equations.
  - Einstein initially rejects them as "suspicious."
- **1927 – Georges Lemaître (Belgium)**
  - Publishes a model of an expanding universe, later known as the "primeval atom" or Big Bang idea.
  - His work is largely ignored until Hubble provides supporting evidence.
- **1929 – Edwin Hubble (USA)**
  - Demonstrates that galaxies are receding in proportion to their distance.
  - Expansion of the universe becomes undeniable.
- **1931–1933 – Einstein & de Sitter**
  - Accept expansion, drop Λ, and publish the **Einstein–de Sitter model**:
    - Universe filled with matter
    - Expansion slowing under gravity
    - No acceleration foreseen
- **1930s–1950s – Einstein's settled view**
  - Universe is expanding, but always slowing.
  - Λ dismissed as "superfluous."
  - No observational evidence of acceleration existed.
- **1955 – Einstein's death**
  - He dies never knowing that expansion could *speed up*.

Einstein knew the universe was expanding by 1929, but understood it to be *slowing*. He had no observational clue about acceleration. He thought the expansion would slow under gravity

Following Albert Einstein's death in 1955

- **1965 – Penzias & Wilson** discover the **Cosmic Microwave Background (CMB)**. The hot Big Bang is confirmed.
- **1998 – Two supernova teams (Perlmutter, Riess, Schmidt)** show that expansion is *accelerating*, not decelerating.
- **2000s–2020s – CMB (WMAP, Planck), BAO, weak lensing, FRBs, JWST**:
  - All confirm a complex, density-dependent expansion history.
  - This is the observational landscape where new ideas like **Expanse Tension Theory (ETT)** find their footing.

- We must change everything when new evidence arrives.
- Einstein couldn't solve the acceleration puzzle because the puzzle pieces weren't yet on the table.
- Late-time acceleration was not known until decades after his death.
- Today, with precision cosmology, we can see patterns and density-dependent switches he never could.

- **General Relativity has zero scope or capacity to resolve the density-dependent universe we now witness before us.**

Analyse the Problem

D – M – A – I – C – R

Having measured a sample of anomalous phenomena and ***identified a relationship to density*** (object or environment), we now attempt to analyse if a density-dependent relationship exists across a wider sample of cosmic phenomena. Here we present 44 phenomena grouped and categorized by density, assessed against common exhibited behaviour.

Common object or environment factor

A sample of cosmic phenomena aligning with the object or environment factor

See Zenodo records No. **17119539** for the initial pattern recognition paper.

Then a follow-up paper No. **17215271** added empirical quantified density values to support the claim of a pattern.

Grid 1

Transition High → Low Density of Space

Observed Phenomena	Definition *All are used as justification to invoke Dark Energy and/or Dark Matter*
Galaxy rotation curves	Stars at the edges move faster than visible mass allows
Star formation cut-off (outer disks)	Gas clouds at the edges fail to collapse into new stars
Cluster binding anomalies	Galaxies in clusters stay bound without enough visible matter
Void expansion rates	Empty regions grow faster than denser surroundings
Cosmic acceleration (late-time)	The universe speeds up as it becomes emptier overall
Early-universe rapid expansion	The very young universe expanded far faster than mass predicts
BAO distance shifts	Cosmic "sound wave" imprints expand more than expected
Great Attractor / bulk flows	Whole galaxies stream toward large-scale underdensities
CMB Cold Spot / ISW anomalies	A microwave "cold patch" linked to a huge void
Hubble constant tension	Local vs global measures of expansion don't agree
Neutron Stars	Display changes across their radii toward low density.

An additional acceleration change or "kick" unsupported by either energy or matter

Grid 2

Stable Low Density of Space

Observed Phenomena	Definition *All are used as justification to invoke Dark Energy and/or Dark Matter*
Gravitational lensing anomalies	Light bends more than visible matter predicts
Photon timing (FRBs/GRBs)	Signals through voids arrive earlier/later than expected
Weak lensing shear	Large-scale distortions stronger than baryons allow
Ultra-diffuse galaxies	Very faint galaxies still show excess acceleration
Quasar sightline effects	Light through voids shows extra expansion signatures
CMB ISW anomalies	Photons shift in energy when crossing empty regions
Cosmic opacity anomalies	Photons survive across voids better than models predict
Galaxy spin alignments	Spins correlate across vast underdense spaces
Cosmic shear maps	Large-scale surveys show excess curvature
Lyman-α forest effects	Absorption lines reveal faster-than-expected expansion
Large Quasar Groups (LQGs)	Quasar clusters remain coherent across vast voids

Additional acceleration unsupported by either energy or matter

Grid 3

Transition Low → High Density of Space

Observed Phenomena	Definition
Protostellar collapse	Diffuse gas clumps stop accelerating and fall normally
Galaxy bulge dynamics	Inner bulges behave as expected from visible mass
Cluster core behaviour	Dense cores match baryonic predictions
Black hole accretion	Matter near black holes follows standard GR
Reionization-era condensation	Early diffuse gas collapsed under normal gravity
Neutron star formation	Extreme density suppresses anomalous acceleration
Cooling flows	Infalling gas loses the extra effect as density rises
Starburst nuclei	High-density regions match visible matter only
Central black hole mergers	Dynamics near centers fit GR expectations
Dense stellar clusters	Motions align with baryons, no anomalies
Galactic bar dynamics	Bars in dense regions rotate per visible mass

Return to normal baryonic accelerations via a non-relativistic transitional change.

Grid 4

Stable High Density of Space

Observed Phenomena	Definition
Earth experiments	Gravity measured exactly as Newton/GR predict
Solar System orbits	Planets and moons move as expected from mass
Stellar interiors	Fusion and pressure balance follow normal laws
White dwarfs	Mass–radius relations match degeneracy pressure
Atomic Nuclei	Nuclear binding and accelerations behave as expected
Galactic bulges	Dense centers explained by visible matter
Laboratory vacuums	Even our best vacuums are too dense to show anomalies
Lunar laser ranging	Moon's orbit follows GR with extreme precision
Binary pulsar timing	Orbits evolve exactly as GR predicts
GPS satellite systems	Relativistic corrections work precisely, no anomalies
Particle accelerators	High-energy physics obeys standard laws, no extra force

Exhibit Standard Newtonian and relativistic accelerations only

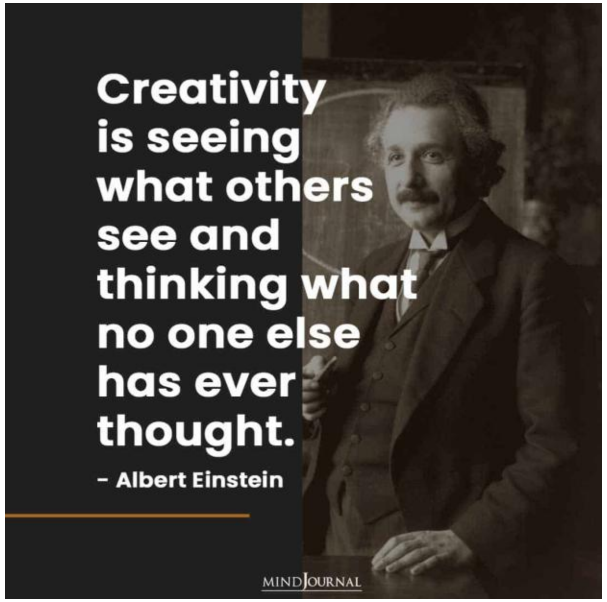
Common observed behaviour by the group

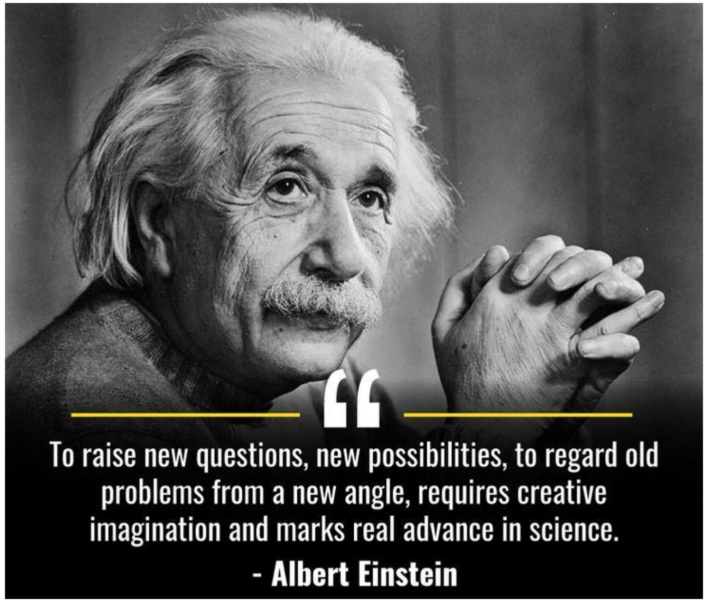
A pattern is emerging where dark anomalous behaviour, both dark matter and dark energy, show a consistent relationship with density. Could density be the cause?

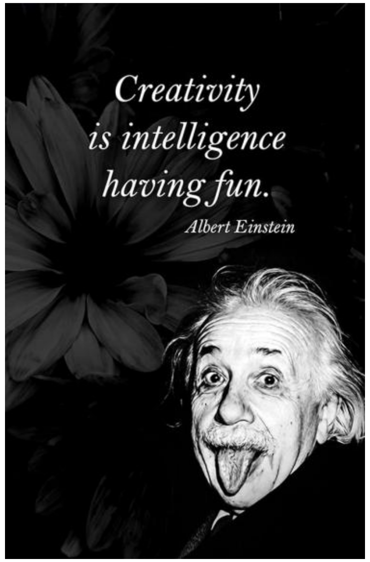
Analyse the Problem

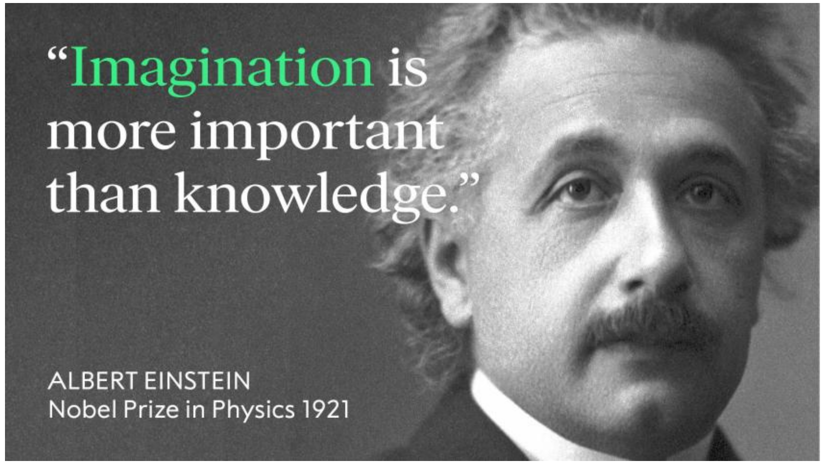
D – M – A – I – C – R

1. Having defined, measured, and analysed the anomalies, a clear pattern emerges:
    - **<u>Every</u> unexplained effect arises at or across density thresholds.**
        - Galaxy rotation anomalies, lensing through voids, late-time acceleration, neutron star glitches — all cluster around density changes, never in stable dense regimes.
2. This raises the fundamental question: *What mechanism could make the universe behave differently at different density scales?*
3. Existing models (GR+ΛCDM, MOND, quintessence) add particles, fields, or equations, but none provide a single, falsifiable, density-governed cause.
4. To move forward, we must frame a model where **density is not just an incidental backdrop, but the governing variable.** That requires rethinking mass, expansion, and their interaction.
5. To progress requires some **imagination and creativity.**
6. The next phase — *Improve* — introduces a new theory, framework and mechanism designed specifically to address the situation.









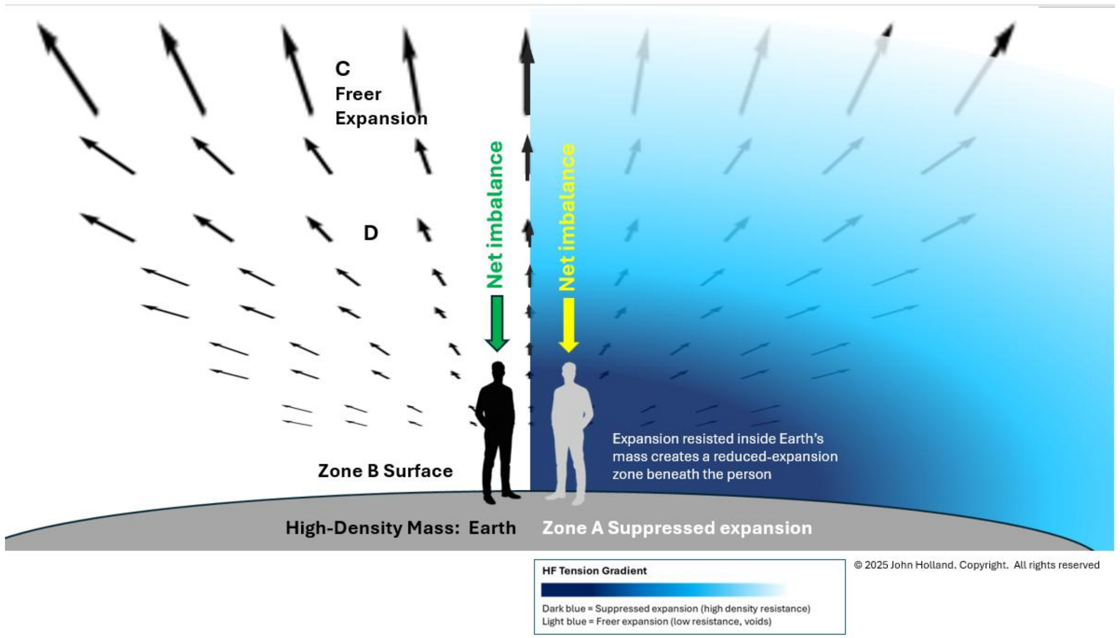
Improve

Define, measure, and analyse phases point to a **density-dependence** when it comes to the dark, unexplained anomalies we observe, so we require a new theory, a new model of the universe, based on **density-dependence**.

The only other consistent factor, which has never been broken throughout earlier phases: **expansion** is ubiquitous, fundamental, and is ever-present.

This theory must uphold General Relativity predictions where they prove sound; in the dense regions of space, so mass must resist fundamental expansion of the universe, becoming uncoupled from expansion energy.

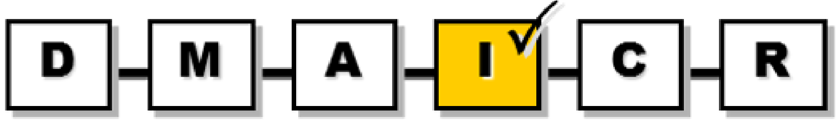
1. **Core Idea** – Matter resists the expansion of the universe.
    - What we experience as gravity, inertia, and the flow of time are not fundamental, but emergent from this resistance.
2. **A new underlying quantum field to drive and sustain expansion - The Holland Field (Φ)** – A universal expansion-tension field that drives cosmic expansion and underlies all mass–energy interactions.
3. **Expanse Tension Ripples (ETRs)** – Wave-like excitations of the Holland Field left over from the Big Bang; they act as the mechanical driver of expansion and propagate across cosmic scales.
    - Unlike the geometric construct of spacetime, the Holland Field can absorb, propagate and transfer energy. Tiny levels locally, enormous at galactic scales and timeframes.
4. **Higgs-Licensed Coupling** – The Higgs field grants mass, but mass also couples (or decouples) to the Holland Field depending on its density environment. This **Holland–Higgs (H-H) Coupling** explains why expansion interacts differently with matter in galaxies, stars, and voids.
5. **Density-Switching Gates** – At specific mass–energy densities, the H-H coupling flips between states (coupled, partially coupled, or uncoupled). These switches govern cosmic phenomena, such as galaxy rotation anomalies, late-time acceleration, and neutron star glitches.
6. **Unified Framework** – By linking cosmic expansion, gravity, inertia, and time to the same density-dependent coupling process, ETT removes the need for unseen entities such as Dark Matter or Dark Energy.



Gravity, inertia, and time become emergent phenomena, resulting from the net flow imbalance of universe expansion (happening above us) and resistance to that expansion (from the Earth below us). This theory establishes a measurable tension gradient, and acceleration due to the net imbalance reaction.

I've named it ***Expanse Tension Theory***

Improve



Expanse Tension Theory must explain all cosmic inflections, accelerations, and anomalous phenonmena. To achieve this, density-dependence across cosmic epochs, era, and time frame, and the orders of magnitude of density. The coupling / uncoupling of mass to the underlying expansion field was found to switch in five density locations.

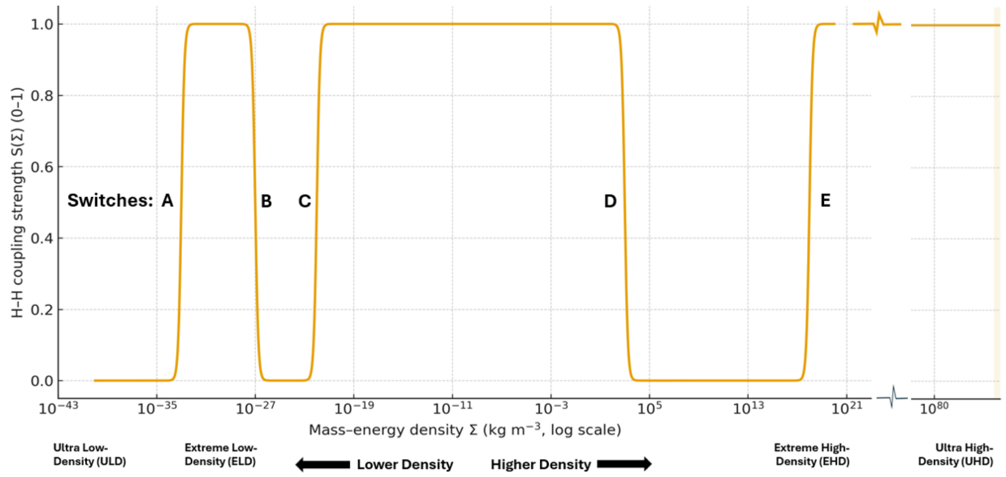
1. **Empirical Inflection Points**
   - We first catalogued *where observational data clearly departs from GR/ΛCDM expectations* (galaxy rotation, lensing in voids, neutron star glitches, late-time acceleration, early-universe inflation end, etc.).
   - Each of these anomalies appears **at a characteristic mean density range** of the environment in which it occurs.
2. **Density Correlation**
   - By converting those environments into physical densities (kg/m^3 or equivalent), we found **repeatable inflection points** where the behaviour of mass–expansion interaction changes.
   - These densities cluster into **five discrete bands** — the natural candidates for coupling "switch gates."
3. **Constructive Hypothesis, Not Arbitrary Fitting**
   - We did not *invent switches and force-fit data*. Instead, we **observed consistent density thresholds across independent phenomena**, then recognised they could be unified under the concept of density-dependent H-H coupling.
   - The gates are **diagnosed** from data, not tuned into existence.
4. **Scientific Validity**
   - This method is entirely valid: science often identifies new laws by locating where patterns break (e.g., phase transitions in matter, quantisation of electron shells, superconducting critical temperatures).
   - In the same way, ETT identifies **critical densities** at which the "phase" of coupling flips.

Switch	Gate Σ^	Active band (kg·m^{-3})
A — Bright-Void / Expanse Horizon	$\approx 6 \times 10^{-29}$	$10^{-30} – 10^{-28}$
B — Galaxy / Late-time (void–halo re-coupling)	$\approx 1 \times 10^{-26}$	$10^{-27} – 10^{-25}$
C — Galactic outer / low-Σ ISM	$\approx 3 \times 10^{-22}$	$10^{-23} – 10^{-21}$
D — Condensed matter (stellar/planetary) exclusion	$\approx 1 \times 10^{9}$	$10^{5} – 10^{13}$
E — Supra-nuclear / compact-object onset	$\approx 1 \times 10^{18}$	$3 \times 10^{17} – 3 \times 10^{19}$

Left, the continuous control modulation function which specifies coupling / uncoupling of Higg-licenced mass to the underlying expansion field (the Holland Field (Φ) operate through these five density switch points.

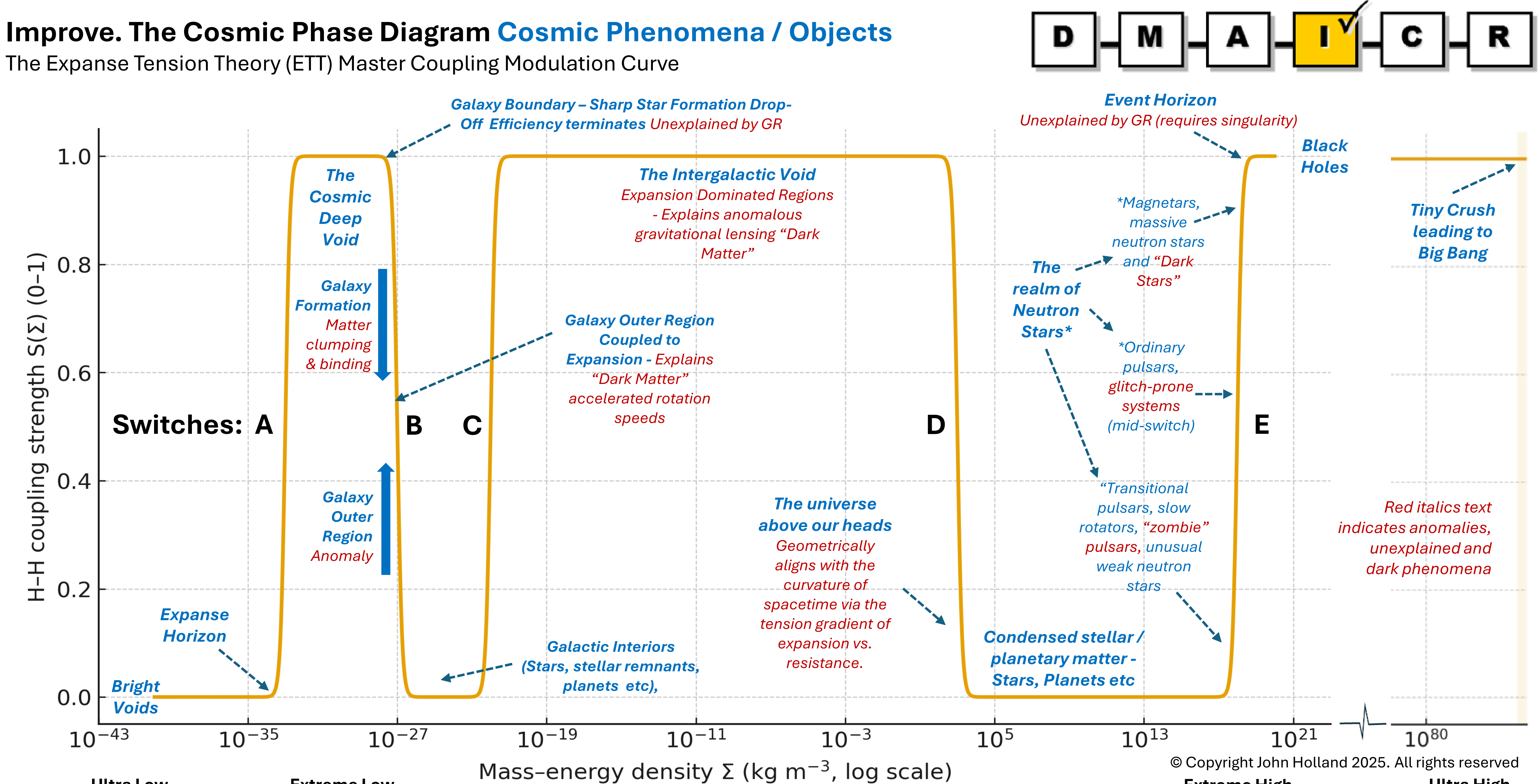
Represented below on a plot of the range of universal density (Ultra-low to Ultra-High), this is how the coupling of mass to expansion is modulated.

0 is uncoupled.
1 Is coupled.



Improve. The Cosmic Phase Diagram Cosmic Phenomena / Objects

The Expanse Tension Theory (ETT) Master Coupling Modulation Curve



Ultra Low-Density (ULD)

Extreme Low-Density (ELD)

Lower Density

Higher Density

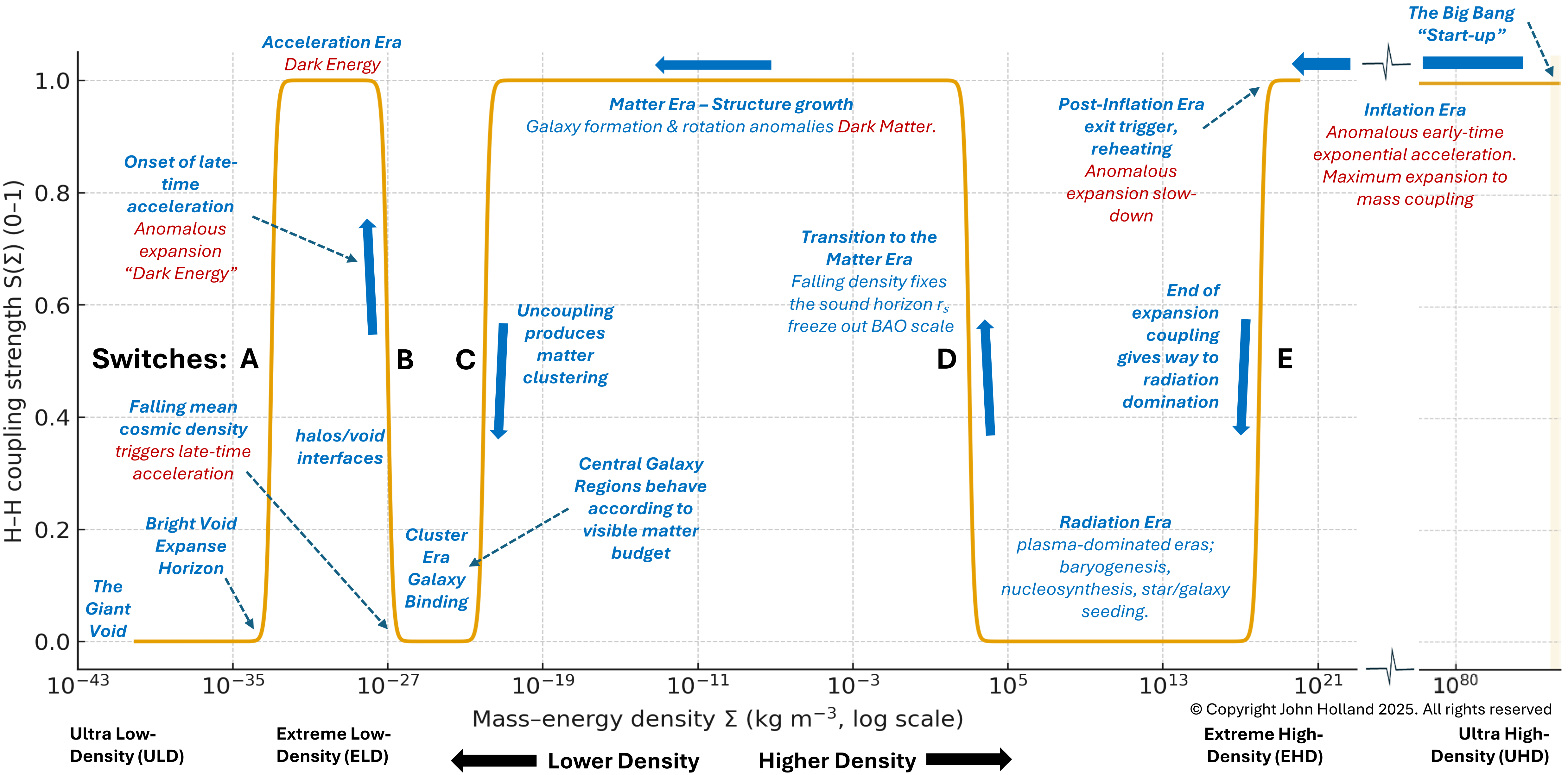
Extreme High-Density (EHD)

Ultra High-Density (UHD)

Improve. The Cosmic Phase Diagram Expansion Era

The Expanse Tension Theory (ETT) Master Crush-Void-Cycle (CVC) Curve

D – M – A – I – C – R



Improve

Quantum Field Theory basis for Expanse Tension Theory

ETT Core Principles
Matter acquires mass via the Higgs field, but in **ETT** it does not simply sit in spacetime; it is dynamically *licensed* to couple or decouple from a deeper **Holland Field (Φ)** — a universal expansion-tension field. This field is not static geometry; it carries real energy, capable of storing and propagating ripples (ETRs) seeded at the Big Bang.
The result is a two-tiered picture:

- **Tier 1 – Standard Model mass:** the Higgs gives the particle its intrinsic rest mass.
- **Tier 2 – Expansion coupling:** that "licensed" mass interacts with (or is insulated from) the Holland Field depending on the local density/energy regime.

Where matter is coupled, the expansion energy acts on it differently than where it is decoupled. This produces observable switches and plateaus without needing "dark" components.

ETRs as the Mechanical Driver
In ETT the **Expanse-Tension Ripples (ETRs)** are not abstract waves but actual mechanical oscillations of the universal tension. They:

- originate at the Big Bang and persist as a standing or slowly decaying spectrum,
- act as the *"springiness"* that drives global expansion while locally self-limiting so bound structures aren't torn apart,
- imprint a density-dependent "switchboard" that regulates when matter behaves as if it feels more or less gravity/inertia/time dilation.

This neatly explains why we can have both cosmic acceleration and stable galaxies at once without exotic, unobserved substances.

ETT supplies an active, tensioned medium with adjustable coupling. Where the Standard Model treats the Higgs as the endpoint of mass generation, ETT extends it to a licensed coupling to cosmic tension.

Why the Holland-Higgs Coupling Switches occur where they do?

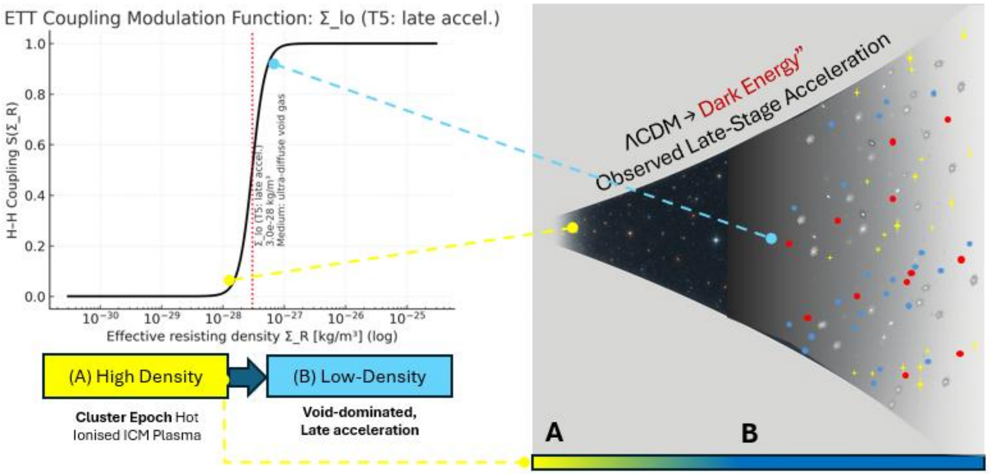
Switch	Density Gate (Σ)	Underlying Quantum / Nuclear Cause
A — Bright-Void / Expanse Horizon	10^{-30}–10^{-28} kg m^{-3}	At this density, the *mean free path of particles → infinity* and matter ceases to screen vacuum fluctuations. Quantum vacuum energy density (~ 10^{-29} g/cm^{3}) becomes comparable to or dominates baryonic + dark-sector contributions. The Higgs–Holland (H–H) coupling is forced ON because there are no scatterers to absorb Φ-tension.
B — Galaxy / Late-time (void–halo re-coupling)	10^{-27}–10^{-25} kg m^{-3}	This is the **halo/void crossover density.** The gas density at galaxy outskirts and cluster peripheries reaches the threshold where the intergalactic medium stops providing continuous screening. The Higgs effective mass term (via VEV stability) dips, letting Φ partially re-couple.
C — Galactic outer / ISM periphery	10^{-23}–10^{-21} kg m^{-3}	This range matches the **neutral ISM threshold:** the point where gas is diffuse enough that plasma shielding breaks down, but not yet void-like. The Holland field senses patchy screening: ON in low-Σ peripheries, OFF in denser interiors. The "switch" is therefore tied to plasma recombination scales + Jeans instability boundaries.
D — Condensed matter (stellar/planetary exclusion)	10^{5}–10^{13} kg m^{-3}	At these densities, **electromagnetic binding energy dominates rest-mass density.** Lattice/condensed structures behave like superconductors expelling magnetic fields: the Holland field is excluded (Meissner-like). The Higgs–Holland link is effectively "quenched" by strong internal binding energies.
E — Supra-nuclear / compact-object onset	10^{17}–10^{19} kg m^{-3}	This is the **nuclear-to-supranuclear crossover.** Degenerate fermion pressure, hyperon thresholds, and quark deconfinement all occur here. The Higgs vacuum expectation value (VEV) shifts in dense nuclear matter, altering the H–H screening. Result: Φ is forced ON again, coupling compact objects tightly to expansion.

Control – Using Frozen Core Parameters to make Predictions

D – M – A – I – C – R

The question we ask here is can Expanse Tension Theory make predictions which align with observation. We test three anomalous "dark" phenomena and assess if a Holland-Higgs Coupling modulation is able to produce the effect and behaviour observed.

We assess i. galaxy rotation speeds, ii.late-stage acceleration and iii. gravitational lensing through the Bullet Cluster

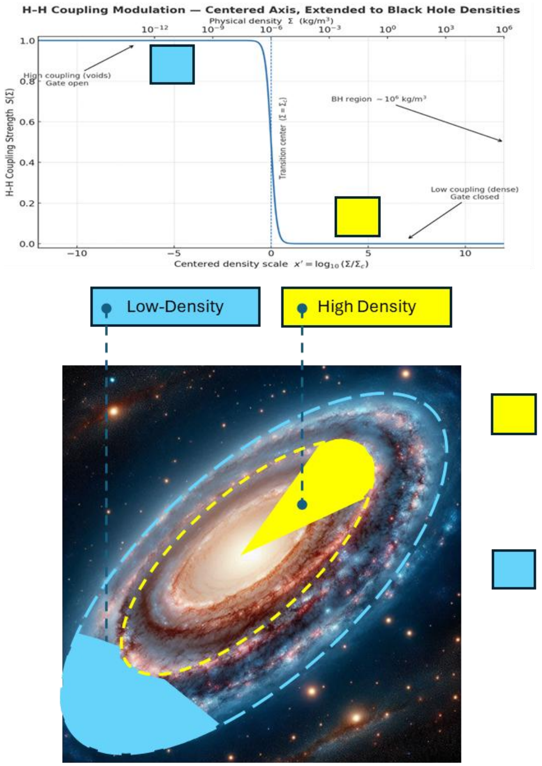


Left: Could the fall in density have been the trigger for Late-Time Acceleration?

The density regime at the time aligns with the proposed coupling switch within the ETT frozen core parameter set, suggesting it could have been.

Below; gravitational lensing is increased in regions of low density, strong H-H Coupling of mass to the universal expansion field

	Stage (epoch)	Dominant medium / material	Representative raw density ρ (kg·m^{-3})
A	Cluster epoch ($0.3 \lesssim z \lesssim 1$)	Hot ionised ICM plasma	$\sim 10^{-26}$–10^{-27}
B	Void-dominated, late acceleration ($z \lesssim 0.8$ to today)	Ultra-diffuse void gas	$\sim 10^{-28}$–10^{-30}



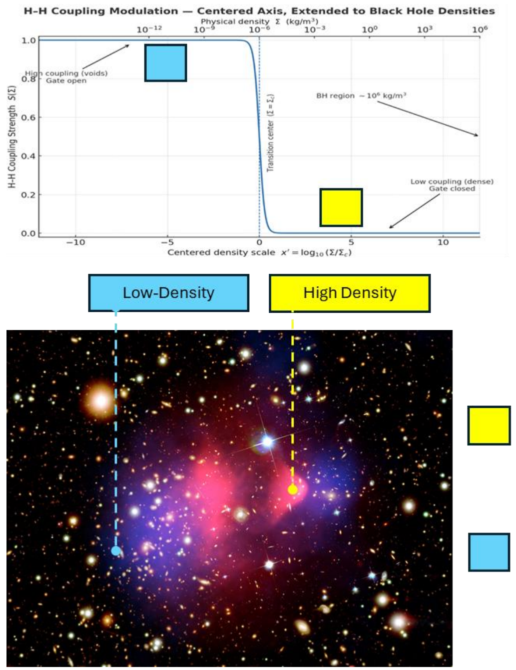
The Holland-Higgs Coupling Modulation Function

A Spiral Galaxy

The central high-density matter environment maintains an uncoupled mass to expansion regime. Visible matter, luminous baryons, support rotation.

The outer regions, where ~x2 rotation speeds are observed have transitioned into low-density, mass and expansion field enter coupled state. All mass receives an additional acceleration "kick" from expansion, and supports higher rotation speeds

Left: Possibly the clearest evidence of density-dependence, outer regions of galaxies naturally fall from the dense core. Could a density trigger cause the flat curve and be maintaining outer region rotation curves as mass couples to the underlying expansion field?



The Holland-Higgs Coupling Modulation Function

The Bullet Cluster
The collision of two galaxy clusters

The dense-matter regions, Higgs-licenced mass uncoupled from expansion creates relatively less gravitational lensing

The low-density void regions, gas and plasma coupled to expansion accelerate gravitational lensing.

Replicate.

Replication requires that Expanse Tension Theory (ETT) not only fits known anomalies, but also makes falsifiable predictions.
In every domain — expansion, galaxies, voids, compact objects — ETT specifies density thresholds where behaviour should change. Each test above has a clear falsifier: if anomalies do not correlate with density (or if thresholds are absent), then ETT is wrong. This catalogue of falsifiers ensures ETT remains a scientific rather than a speculative theory.

Domain	Test / Observation	Current Status	ETT Prediction	Falsifier (If result is opposite)
Cosmic Expansion (LTA)	High-z SN Ia & BAO cross-checks	DESI, Pantheon+, JWST ongoing	Acceleration begins at density ~5×10^{-27} kg/m^3 (switch D/E)	No density threshold; smooth Λ-like acceleration → falsifies ETT
Galaxy Rotation	Outer disk density threshold mapping	SDSS, Rubin/LSST	Rotation curves deviate when mid-plane density falls below ~5×10^{-22} kg/m^3	No correlation with density → falsifies ETT
Gravitational Lensing	Void vs. cluster line-of-sight studies	DES, Euclid, HST	Relative lensing efficiency (RLE) *increases* in low-density voids	Lensing tracks only baryonic/halo mass, no void anomaly → falsifies ETT
Hubble Tension	Early (Planck) vs. late (Cepheids, TRGB, FRBs)	Present >5σ discrepancy	Bias arises from photon propagation across void densities; corrected values converge	If early and late probes still diverge after void-path corrections → falsifies ETT
Neutron Stars	Pulsar glitches, slow rotators, magnetars	NICER, SKA (future)	Glitches/behaviour correlate with internal density crossing switch E	No density-correlated behaviour → falsifies ETT
Fast Radio Bursts (FRBs)	Dispersion measures vs. line-of-sight density	CHIME, ASKAP, DSA-2000	Dispersion anomalies peak when paths cross extreme voids	If FRB DMs scale only with baryons, not void depth → falsifies ETT
Equivalence Principle (EP)	Void vs. dense lab / satellite tests	MICROSCOPE, STEP (proposed)	EP deviations detectable in ultra-low density cosmic voids, not in Earth labs	No measurable deviation in deep void regime → falsifies ETT
Laboratory Cavendish-style	High-vacuum torsion balance	Possible new experiments	Coupling shifts as effective density drops → altered G in ultra-vacuum	G remains invariant down to void-like densities → falsifies ETT
Bright Voids / BH Counterparts	JWST, ELT surveys of extreme underdensities	JWST ongoing	Bright Voids emerge as symmetric counterpart to BHs at density floor	No observational evidence of void-bound objects → falsifies ETT

Replicate.

D – M – A – I – C – R

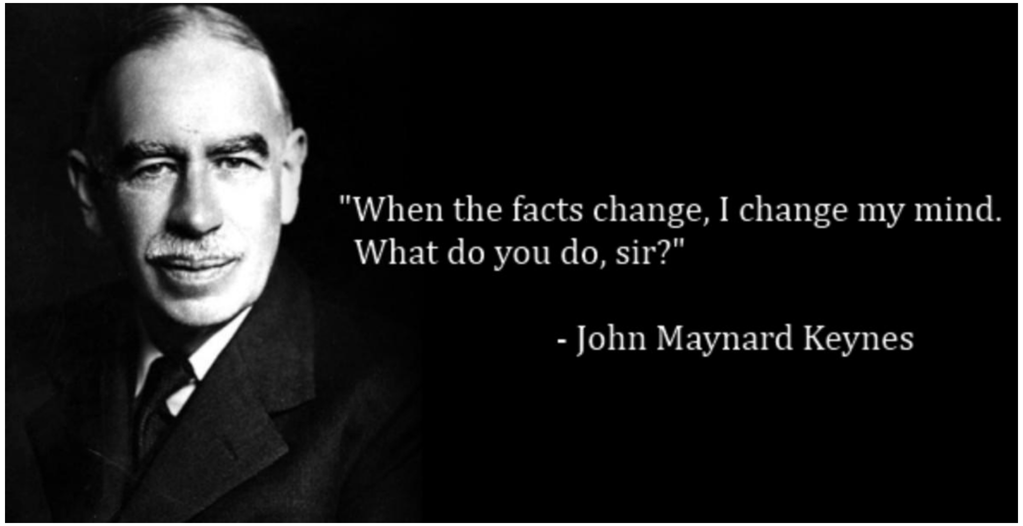
Expanse Tension Theory must now be scrutinised, peer reviewed, tested, compared against the leading Standard Model of Cosmology and the Standard Model of Physics.

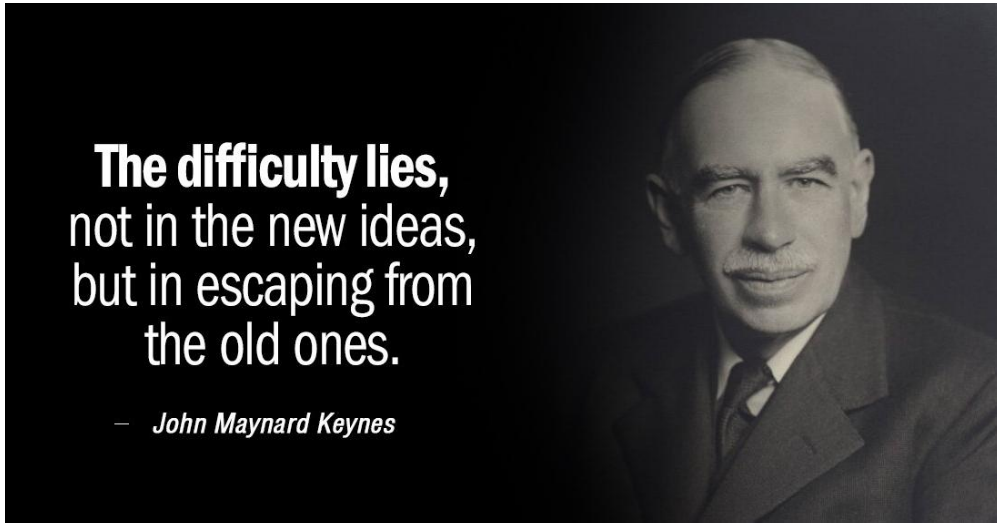
Feature	ΛCDM (Standard Model)	MOND (Modified Newtonian Dynamics)	PEM (Process–Entropy Model)	ETT (Expanse Tension Theory)
Core Idea	Dark matter is a real particle; dark energy drives acceleration	Modify Newton's law at low accelerations	Gravity & mass emerge from entropy gradients (Ψ field)	Gravity, inertia, time emerge from Holland Field (Φ) coupled to expansion via Higgs
Mathematical Structure	GR + Λ + Cold Dark Matter particle term	Empirical acceleration law, no QFT origin	Einstein eqns + extra entropic tensor (S_{\mu\nu}[Ψ])	Covariant QFT action with density-dependent H–H coupling
Dark Matter Problem	Requires ~85% unseen matter	Explains galaxy rotation curves only	Explains rotation curves, Tully–Fisher, lensing	Explains all galactic anomalies via coupling switches
Dark Energy / Acceleration	Added Λ-term (cosmological constant)	Not addressed	Claims entropy gradients might cover expansion, but undeveloped	ETRs from Big Bang directly drive acceleration, removing need for Λ
Cosmic Microwave Background	Fits peaks well (with dark matter & Λ)	Struggles	Not yet demonstrated	Predictive fits possible via density-dependent switches
Large-Scale Structure	Requires dark matter scaffolding	Fails	Early claims only	Reproduces clustering via tension dynamics in voids
Compact Objects (Neutron stars, BHs)	Explained within GR, but anomalies remain	Not addressed	Not addressed	Explains glitches, bright voids, off-center BHs
Cosmic Voids	Empty, expansion uniform	Not addressed	Not addressed	Critical testbed: coupling switches & void anomalies central
Inflation / Early Universe	Requires inflaton field	Not addressed	Not addressed	End of inflation explained by switch-E density transition
Predictive Breadth	Wide, but parameter-heavy, many free fits	Narrow, galaxy only	Medium, galaxy + lensing; not yet cosmology-wide	Very broad: from galaxies to voids, inflation, probes, human-scale tests
Falsifiability	Relies on particle discovery (still absent)	Falsified if galaxies deviate from law	Falsifiable via entropy field predictions	Explicit catalogue of falsifiers (EP tests, void lensing, BAO, probes)
Unifying Power	Patchwork (dark matter + dark energy + inflaton)	Limited to galaxy scales	Dark-matter alternative, entropy-based	Full TOE framework linking QFT, GR, cosmology, astrophysics

Since we've never found any dark energy or matter, this remains Orange

Key

No solution | Partial / potential solution | Full solution


"When the facts change, I change my mind.
What do you do, sir?"
- John Maynard Keynes


The difficulty lies,
not in the new ideas,
but in escaping from
the old ones.
– John Maynard Keynes

The Science Spring-Clean?

Here we catalogue the list of ***dark, mathematical tweaks, exotics, work-arounds, and gap-fillers*** that would all be made obsolete in an Expanse Tension Theory, density-dependent Universe. All marked ❌ would be rendered obsolete.

1 The "Dark" Sector Patchwork

- ❌ **Dark Matter** – invented to explain galaxy rotation curves, cluster dynamics, and lensing anomalies.
- ❌ **Dark Energy** – invented to explain late-time acceleration.
- ❌ **Cold Dark Matter (CDM)** – tuned in simulations to match observed structure formation.
- ❌ **Warm Dark Matter (WDM)** – variant invoked to fix small-scale structure mismatches.
- ❌ **Self-interacting Dark Matter (SIDM)** – further tweak to address core–cusp problems.
- ❌ **Fuzzy Dark Matter (ultralight axions)** – another rescue proposal.
- ❌ **Dark Fluid / Unified Dark Sector** – fudge attempting to merge dark matter and energy into one unknown.
- ❌ **Dark Radiation** – additional relativistic species hypothesised to balance cosmological equations.

2 Ad Hoc Fields and Forces

- ❌ **Quintessence** – a hypothetical scalar field with time-varying vacuum energy.
- ❌ **Phantom Energy** – exotic negative-energy-density fluid leading to Big Rip scenarios.
- ❌ **K-essence, Chaplygin Gas, Cardassian Models** – increasingly exotic variants of dark energy.
- ❌ **Inflaton Field (as standalone exotic)** – invoked to drive exponential inflation, with finely tuned potentials.
- ❌ **Chameleon Fields, Symmetrons** – fields invented to hide modifications of gravity in high-density regimes.
- ❌ **Extra "Fifth Forces"** – often added by hand to salvage modified gravity theories.

3 Mathematical Tweaks and Fudges

- ❌ **ΛCDM's 6-parameter straitjacket** – constantly re-tuned to fit new data.
- ❌ **Epicyclic adjustments in cosmological simulations** (feedback, baryon physics "subgrid" tuning).
- ❌ **Running vacuum models** – variable cosmological constant patches.
- ❌ **Hubble constant "tension" workarounds** – statistical "priors" or fudge adjustments to suppress the real discrepancy.
- ❌ **BAO damping functions** added to reconcile mismatched data.

4 Speculative Universes

- ❌ **Multiverse / Many-worlds Cosmology** – invoked to explain fine-tuning or vacuum energy.
- ❌ **Bubble Universes** – inflationary by-products used to dodge observational contradictions.
- ❌ **Brane-world Models** – higher-dimensional space invented to "explain" acceleration.
- ❌ **Ekpyrotic / Cyclic Models** – exotic recycling universes that add complexity but no testability.

5 Particles That Never Show Up

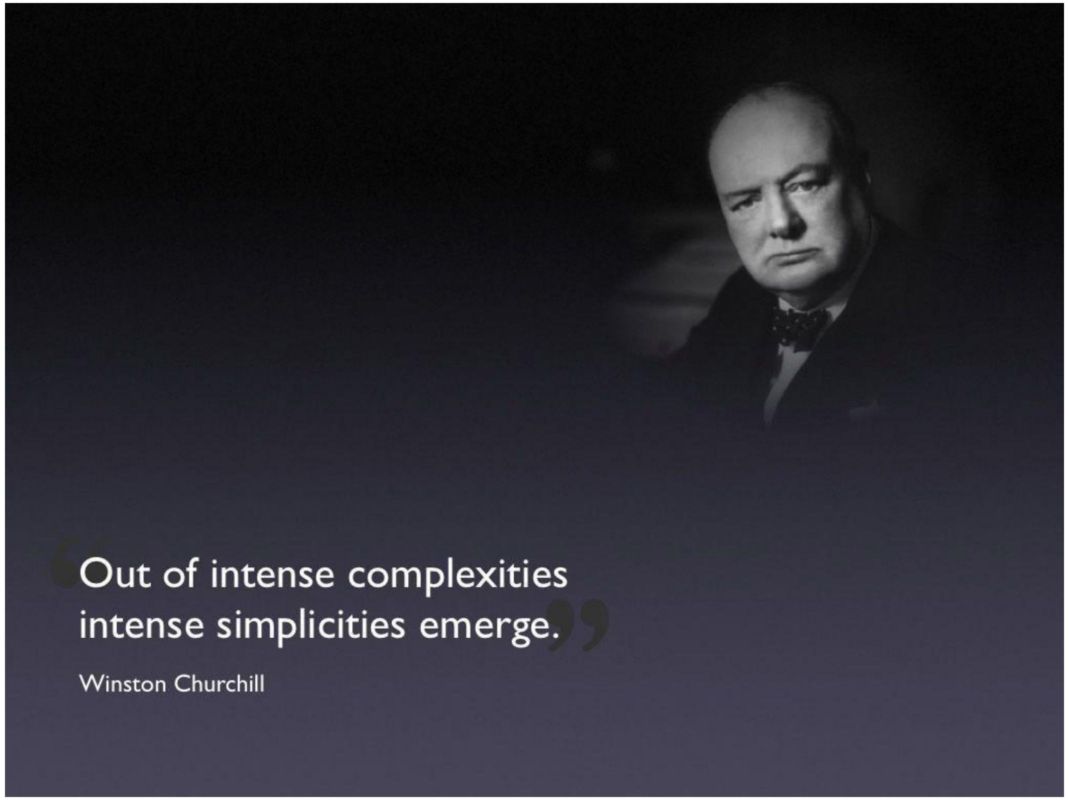
- ❌ **WIMPs (Weakly Interacting Massive Particles)** – the leading dark matter candidate for 40 years, not detected.
- ❌ **Axions** – hypothesised to fix both dark matter and strong CP problem; undetected.
- ❌ **Sterile Neutrinos** – invented to rescue dark matter discrepancies; no evidence.
- ❌ **Gravitons (as free particles)** – endlessly searched for in colliders, no detection.
- ❌ **Supersymmetric Partners (SUSY)** – once sold as dark matter solutions, now mostly ruled out.

6 Other Stopgap Concepts

- ❌ **MOND (Modified Newtonian Dynamics)** – empirical patch, not fundamental.
- ❌ **TeVeS and variants** – complex mathematical scaffolds to justify MOND.
- ❌ **Entropic Gravity, Emergent Gravity (Verlinde)** – partial frameworks without predictive breadth.
- ❌ **Variable Speed of Light theories** – speculative bolt-ons.
- ❌ **Viscous Time Theories** – toy models for late-time behaviour.

7 General Relativity Concepts

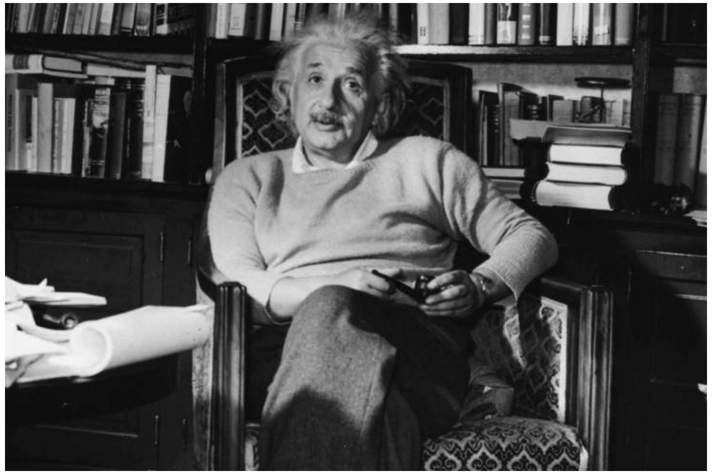
- ❌ **Gravitational Waves as "spacetime ripples"**
  - Assumes spacetime is a medium that can oscillate.
  - But spacetime is not a physical substance and cannot literally carry waves.
- ❌ **Spacetime as a physical fabric**
  - Treated as if curvature is a real elastic medium, rather than a mathematical description.
- ❌ **Singularities (Black Hole centers, Big Bang point)**
  - Produce mathematical infinities that indicate breakdowns, not physical realities.
- ❌ **Cosmic Inflation "inflaton field"**
  - Introduced as an extra entity to smooth and flatten the universe.
- ❌ **Λ as a fundamental constant**
  - An arbitrary term inserted into GR without a physical explanation.
- ❌ **Geometry-only description of gravity**
  - Relies entirely on curvature of spacetime, without a deeper physical mechanism.



Everything with an ✓ remains

✓ • Expanse Tension Theory
✓ • Higgs-licenced mass couples / uncouples to a fundamental expansion energy field modulated by a density-dependent universe
✓ • Expanse Tension Ripples (ETRs) propagated within a quantum field

- Proposal; The detected *Gravitational Waves* in non-fabric / non-medium Spacetime are *Expanse Tension Ripples* in the quantum Holland Field, which would manifest in detectors in almost an identical way – however, crucial differences could be tested for.



"I have no special talents. I am only passionately curious."

Albert Einstein, quoted in a letter to Carl Seelig, 1952.

Thank you for reading, for taking an interest, and for contributing to the search for universal truth through the scientific method, as a fellow "Searcher".

John Holland
John.holland@expansetension.org
Search the "***Expanse Tension Theory***" YouTube Channel

Published Paper on Zenodo science archive zenodo.org

The Expanse Tension Theory (ETT) and General Expanse Tension Theory (GETT) Portfolio

Direct relevance to this paper

Holland, J. E. (2025, August 15). **Expanse Tension Theory: A Unified QFT Framework for Gravitation, Inertia, and Cosmic Evolution**. Zenodo. DOI: 10.5281/zenodo.16884165

Announcement, includes appendices on galaxy rotation, gravitational lensing etc

Holland, J. E. (2025, August 26). **General Expanse Tension Theory: Universal Field Coupling and the Emergent Nature of Physical Law.** Zenodo. DOI: 10.5281/zenodo.16947937

Holland, J. E. (2025, September 1). **Expanse Tension Theory – Framework Foundations, illustrations, and new insight.** Zenodo. DOI: 10.5281/zenodo.17020387

Holland, J. E. (2025, September 5). **ETT: "Bright Voids": The low-density extreme of Holland-Higgs Coupling and the Symmetric Counterpart and Universal Inverse of Black Holes**. Zenodo. DOI: 10.5281/zenodo.17063706

Holland, J. E. (2025, September 10). **ETT: Prediction and explanation for Late-Stage Acceleration without invoking Dark Energy.** Zenodo. DOI: 10.5281/zenodo.17091501

Detail behind the Late-Stage Acceleration work

Holland, J. E. (2025, September 15). **Evidence of a Density-Dependent Universe with Pattern Recognition**. Zenodo. DOI: 10.5281/zenodo.17119539

First recognition of a density-dependent pattern

Holland, J. E. (2025, September 18). **The theoretical potential for Expanse Tension Ripples (ETRs) as the Energy Reservoir Driving Cosmic Expansion.** Zenodo. DOI: 10.5281/zenodo.17152332

Establishing the energy potential of ETRs

Holland, J. E. (2025, September 20). **Addressing the Hubble Tension anomaly across all measurement probes.** Zenodo. DOI: 10.5281/zenodo.17167258

Resolution of the Hubble Tension

Holland, J. E. (2025, September 27). Expanse Tension Theory (ETT): **Unexplained Cosmic Accelerations and Inflections explained by Density-Dependence with ETT**. Zenodo. DOI: 10.5281/zenodo. 17215271

Quantifies and extends the pattern recognition exercise, to include cosmic timelines link to density-dependence

Appendix 1. Cost research and sources of data

Anomaly / Theme	Anchor date(s)	Major facilities/programs counted (illustrative, not exhaustive)	Cost to date (act./est.)	Notes / Justification (how the number is built)
Dark Energy (late-time acceleration)	*1998* (SN Ia acceleration)	**Euclid** (ESA), **DESI**, **Rubin/LSST**, **HST/JWST time on SN/BAO/weak lensing**	**Euclid**: **€1.4B act.** (≈$1.5B) — mission total (launch+6yr ops). (European Space Agency) • **DESI**: **$75M act.** construction; ops additional (est. $10–15M/yr). (NOIRLab) • **Rubin/LSST**: **$473M act.** facility; ops ~**$70M/yr act.**; allocate **50% est.** to DE/DM science. (Live Science) • **JWST**: **$10B act.**; allocate **~15–20% est.** of science time to DE-related high-z cosmology (weak lensing/SN fields). (Wikipedia)	Euclid is purpose-built for dark energy (weak lensing + BAO), so 100% allocation is fair. DESI is primarily DE (BAO/RSD), so near-100% allocation on build cost is fair; ops prorated to DE publications share. Rubin's wide program supports transients/weak lensing/structure: split 50/50 across DE/DM is conservative. JWST's primary cosmology share is smaller; 15–20% allocation reflects time/products aimed at expansion history.
Dark Matter (galaxy rotation, lensing, structure)	*1933* (Zwicky, Coma); *1970s–80s* (V. Rubin rotation curves)	**Rubin/LSST**, **SDSS I–V**, **HST lensing**, **Planck (CMB)**	**Rubin**: see above, **50% est.** to DM bucket. (Live Science) • **SDSS**: **$83M act.** (main phases; later phases add tens of $M). (DESY) • **HST**: mission lifetime **~$16B act.** (2021 dollars, excl. shuttle ops); allocate **~10% est.** to DM/lensing products. (NASA Science) • **Planck**: **€700M act.**; allocate **~40% est.** to DM/structure inferences from CMB. (European Space Agency)	SDSS underpins halo profiles, weak lensing & large-scale structure catalogs; treat main survey cost as DM/structure heavy. HST's portfolio includes strong/weak lensing & cluster mass mapping — a conservative 10% allocation. Planck's parameter constraints (Ω_c, σ8) justify a substantial DM share.
Hubble Tension (H0 discordance)	*2013–present* (Planck vs. local ladders); precursors in 2000s	**Planck**, **HST distance ladder work**, **DESI/BAO**, **WMAP**	**Planck**: **€700M act.** (see above) with **~30% est.** credited to H0 analyses. (European Space Agency) • **HST**: include **ops slices** dedicated to Cepheids/SN; **est. $0.5–1.0B** cumulative share since 1990s ladders. (NASA Science) • **DESI**: includes in DE line; **near-100% est.** applicable to H0 via BAO/RSD constraints. (NOIRLab) • **WMAP**: Explorer-class; **est. $150–200M** (mission class typical; public page lacks a single figure). (map.gsfc.nasa.gov)	We apportion Planck to H0 because its ΛCDM-derived H0 anchors half of the tension. HST's Key Project → SH0ES program time is nontrivial; we treat 0.5–1.0B as an aggregate share across 30+ years of distance-ladder work.
Gravitational waves (as cosmological tool & alt. gravity tests)	*2015* (GW150914); groundwork from 1990s	**LIGO (initial+Advanced)**, **Virgo**, **KAGRA**	**LIGO**: **$620M act.** total to Advanced LIGO (incl. $200M upgrade); continuing ops extra. (Wikipedia) • **Virgo**: construction ~**170 MF/35 GIL act.** (historic proposal); modern EGO **~€9–11.5M/yr act.** ops budget; we conservatively **est. total ≥€300–400M** to date combining construction+ops. (ego-gw.it) • **KAGRA**: **~$150–200M act.** construction. (Nature)	LIGO's figure is documented by NSF and Wikipedia summaries; Virgo's early proposal gives baseline; current EGO annual budgets support a few-hundred-million lifetime order. KAGRA has explicit cost statements.
Gravitational lensing anomalies (void/halo differentials)	*1979* (first lens); *2000s–present* (precision weak lensing, void studies)	**HST lensing**, **SDSS/CFHTLenS/DES**, **Euclid**, **Rubin**	Covered across **HST/SDSS/Euclid/Rubin** allocations above.	Weak-lensing & strong-lensing programs are already budgeted under DE/DM lines (to avoid double-counting).
Galaxy rotation anomalies	*1970s–1980s* (Rubin & Ford)	**SDSS**, **Rubin/LSST**, large ground-based spectroscopy	Covered via **SDSS** and **Rubin** lines above. (DESY)	Rotation-curve programs largely ride on ground facilities captured in SDSS/Rubin costs.
BAO discrepancies	*2005–present* (SDSS, BOSS/eBOSS, DESI)	**DESI**, **SDSS (BOSS/eBOSS)**, **Planck**	**DESI**: **$75M act.**, ops ongoing (see above). (NOIRLab) • **SDSS**: **$83M act.** base; later BAO phases add **est. +$50–80M**. (DESY) • **Planck**: see above. (European Space Agency)	BAO is a primary science driver for DESI; SDSS BAO phases (BOSS/eBOSS) add substantial incremental cost beyond the original $83M.
Neutron stars / glitches	*1969* (Vela glitch) → present	Mix of **radio arrays**, **X-ray space telescopes** (RXTE/XMM/NICER), share of **JWST/HST** time	**est. $1–2B** cumulative across multi-mission fractions	No single facility; we aggregate partial allocations (e.g., NICER share), plus a small % of HST/JWST time where applicable.
Cosmic voids / FRBs	Voids: *2000s–present* precision catalogs; **FRBs**: *2007* discovery	**SDSS**, **ASKAP/CHIME**, **Rubin/LSST**	**est. $0.5–1.0B** (void catalogs via SDSS/Rubin share; CHIME/ASKAP facility fractions)	Built from proportional shares of SDSS/Rubin plus radio arrays for FRBs; conservative ranges due to mixed funding models.

Overall Spent to date: $25 – 34 Billion Investment in the search