**Refining RFT 7.6: Entropy-Based Scalaron Activation in Weak-Field Gravity**

**Introduction:**  
Resonant Field Theory (RFT) 7.6 extends gravity with an entropy-based *scalaron* field that activates in weak-field regimes. To advance RFT toward a robust **RFT 8.0**, we undertake a comprehensive research plan. This involves improving computational implementations, devising empirical tests, integrating new observational data, and refining model parameters. The focus is to validate that RFT’s Tsallis-entropy modified gravity can consistently outperform or at least match Newtonian gravity and MOND in the weak-field limit, while remaining stable and predictive. Below, we detail the research tasks and expected outcomes across four key areas.

**1. Computational Refinements of the Scalaron Model**

To ensure RFT 7.6’s scalaron equations are stable and accurate, we will integrate them into state-of-the-art simulation codes and rigorously test their behavior:

* **Code Implementation in GIZMO & RAMSES:** We will implement the refined scalaron field equations into two complementary simulation frameworks: **GIZMO** (mesh-free finite-mass method) and **RAMSES** (Adaptive Mesh Refinement). This builds on prior modified gravity code efforts (e.g. the *ISIS* extension of RAMSES for scalar-tensor gravity). The scalaron’s equation – likely a non-linear Poisson-like equation due to entropy-based terms – will be solved at each timestep alongside gravity. We may adapt multigrid solvers or iterative relaxation schemes as used in other $f(R)$ or symmetron simulations, ensuring convergence of the scalar field in both high-density (screened) and low-density (unscreened) regions.
* **Shock-Tube and Stability Tests:** Using **Sod shock-tube tests** and other Riemann problems, we will verify that the coupled hydrodynamics + scalaron system reproduces known solutions. Such idealized tests (with analytical solutions) are a standard first step in code validation​

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. We will check that the shock propagation, contact discontinuities, and post-shock entropy in RFT remain consistent with expectations, confirming that the entropy-based modifications do not produce unphysical artifacts in high-gradient flows.

* **Linear Perturbation Analysis:** We will perform linear perturbation and growth-rate tests by initializing small density perturbations in a homogeneous medium and tracking their evolution. This assesses whether the scalaron activation model remains well-behaved in the linear regime (e.g. no spurious instabilities or oscillations). The dispersion relation of density perturbations in RFT 7.6 will be compared to linear theory predictions (for RFT vs. $\Lambda$CDM vs. MOND) to ensure consistency. For example, we’ll verify that in the limit of $q\to1$ (Tsallis entropy index tending to Boltzmann-Gibbs), RFT recovers the standard linear growth of structure.
* **Equilibrium Cluster Tests:** We will set up equilibrium configurations, such as an isolated isothermal sphere or galaxy cluster in hydrostatic equilibrium (with a static gravitational potential), to test the **stationarity** of solutions. The simulation should maintain equilibrium over many dynamical times if the scalaron integration is accurate. Any secular drift (e.g. cluster expansion or contraction) would indicate integration errors or improper coupling between the scalaron and matter. By adjusting solver accuracy and coupling terms, we aim to eliminate such drift, ensuring that *static* solutions of RFT are truly static in the code.
* **Alternative Solvers & Timestep Strategies:** If instabilities or inaccuracies appear, we will explore alternative numerical strategies. This may include implicit solvers for the scalaron equation (to handle potentially stiff behavior of the entropy-driven terms) or sub-cycling the scalaron timestep separate from the hydrodynamics. We will test whether using smaller timesteps in low-acceleration regions improves stability, and whether a predictor-corrector integration for the scalaron can maintain accuracy without excessive computation. Additionally, we might experiment with **adaptive mesh refinement (AMR)** focused on low-density regions where the scalaron is most active, to resolve the gradients of the scalar field more finely. All modifications will be validated through regression tests (e.g. re-running the shock tube and linear growth tests) to ensure they improve accuracy and robustness.

**2. Empirical Testing and Validation Methods**

With a stable computational model, we will subject RFT 7.6 to rigorous empirical comparison against established gravity models, using statistical tools and specialized test scenarios:

* **Bayesian Model Comparison:** We will employ **Bayesian inference** techniques to compare RFT 7.6’s predictions with those of Newtonian gravity (with dark matter) and MOND across various data sets. Using goodness-of-fit metrics like the **Akaike Information Criterion (AIC)** and **Bayesian Information Criterion (BIC)**, we can quantify the trade-off between model complexity and fit quality. RFT 7.6 introduces extra parameters (e.g. entropy index $q$, coupling constants $\alpha$, $\gamma$), so an improved fit is needed to justify these. For example, in galaxy rotation curve fits or galaxy cluster dynamics, we will compute AIC/BIC for RFT vs. MOND vs. $\Lambda$CDM. A lower AIC/BIC for RFT would indicate it provides a better explanation of the data relative to its complexity. We will also use full Bayesian evidence (marginal likelihood) calculations via Markov Chain Monte Carlo to directly compare model probabilities. This rigorous statistical approach will highlight if RFT 7.6 is **empirically preferred** over competing models or if further refinements are needed.
* **External Field Effect (EFE) Tests with Wide Binaries:** A distinctive prediction of MOND-like theories is the **external field effect**, where the presence of an ambient gravitational field (like that of the Galaxy) can suppress or alter the internal dynamics of a system. We will test RFT 7.6 for an EFE analog by analyzing **wide binary star** systems. Wide binaries (separations of order $10^4$ AU) in very weak internal gravity should exhibit slight deviations from Newtonian orbits if a modified gravity effect is present. MOND, for instance, predicts that wide binaries beyond ~7 kAU should orbit about 15% faster than Newtonian expectation when isolated, but if they reside in the Galactic field, this boost is tempered. Recent Gaia DR3 analyses of ~9,000 wide binaries showed no significant 15% boost, instead remaining consistent with Newtonian dynamics, thereby **challenging MOND’s EFE**​

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. We will use a similar approach for RFT: select samples of wide binaries in different Galactic environments (e.g. high external field near the Galactic disk vs. low field in the halo) and compare their relative velocities and orbital accelerations. By applying Bayesian model selection to these data, we can determine if RFT’s scalaron activation (with a given $q$, $\alpha$, etc.) can accommodate the observed *absence* (or presence) of an external field effect. If RFT predicts only minimal deviations in such environments (unlike MOND’s now-disfavored prediction​

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), it would pass an important consistency check. Conversely, if certain RFT parameter choices yielded a strong EFE, those would be ruled out by the wide binary data, guiding us to refine the scalaron coupling strength.

* **Void-Density Correlation Tests:** Cosmic voids – vast underdense regions – are natural laboratories for testing gravity in the weak-field limit. We propose a new **void-density correlation test** tailored for RFT 7.6. This involves examining the relationship between the density within voids (especially near their edges) and the surrounding structure, searching for the unique imprints of scalaron-driven modifications. In modified gravity theories, voids can exhibit higher-density “walls” or a different growth history compared to $\Lambda$CDM​

[aanda.org](https://www.aanda.org/articles/aa/full_html/2019/12/aa35949-19/aa35949-19.html#:~:text=f%28R%29%20and%20the%20symmetron%20theory,1)

. For example, simulations of $f(R)$ and symmetron gravity have found that the **height of void walls** (the density contrast at void edges) increases for stronger deviations from GR​

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. Using RFT simulations, we will predict how the scalaron affects void profiles: Does the entropy-based gravity make void interiors emptier or walls denser than in standard gravity? We will then use galaxy survey data to measure:

* + *Void edge densities:* the galaxy density contrast at the boundaries of voids, to see if they systematically exceed $\Lambda$CDM expectations (which could indicate an extra repulsive effect of the scalaron pushing matter out of voids). RFT 7.6 might predict a particular enhancement here, which we can test.
  + *Void expansion velocities:* the radial peculiar velocity flow of galaxies around voids. In GR, voids typically expand (galaxies flow outward) at a rate related to the void’s underdensity. A scalaron-driven extra push could make this outflow faster. By analyzing redshift-space distortions around voids, we can infer the velocity profile of void expansion and compare to RFT predictions.
  + *Void density–environment correlation:* how void properties correlate with the density of their surrounding environment. If RFT’s scalaron is sensitive to ambient density (similar to an external field effect but on cosmic scales), voids in denser regions might behave differently than isolated voids. We will test for any such correlation in simulations and observations. Robust agreement between RFT and observed void statistics across environments would bolster the theory’s credibility in the cosmic web context.

By combining these empirical methods, we aim to either validate RFT 7.6’s unique signatures (if observed) or constrain its parameters tightly where predictions don’t pan out, thus guiding further theory development.

**3. Integration of Observational Data**

Leveraging newly available and upcoming datasets is crucial for testing RFT 7.6 in regimes from AU scales to hundreds of Mpc:

* **Cosmic Voids with DESI and Euclid:** The **Dark Energy Spectroscopic Instrument (DESI)** and **Euclid** space telescope are providing extensive maps of galaxies and cosmic structure, ideal for void studies. We will use DESI’s galaxy redshift survey to identify and characterize hundreds of cosmic voids across a range of redshifts. Key observables include:
  + *Void density profiles:* From the void center to its edge, measure the density contrast. RFT’s scalaron might produce deeper voids or sharper edges than $\Lambda$CDM. If RFT predicts, for example, a ~10% higher density at void edges due to a fifth-force effect, we should detect that in DESI’s data. Notably, modified gravity like $f(R)$ has been shown to raise void wall densities in simulations​

[aanda.org](https://www.aanda.org/articles/aa/full_html/2019/12/aa35949-19/aa35949-19.html#:~:text=f%28R%29%20and%20the%20symmetron%20theory,parameters%20that%20are%20derived%20independently)

. We will check if a similar trend exists in the data and if RFT 7.6’s parameters can match it.

* + *Weak gravitational lensing by voids:* Euclid’s weak lensing survey (with high galaxy shape density) will enable stacking analyses of the **void lensing signal** – the subtle distortion of background galaxies by the underdensity of a void. In GR, large voids cause a slight *under*-lensing (a reduction in convergence) compared to dense regions. Some modified gravity models, however, can produce a stronger lensing signal by voids because the effective gravity inside voids is enhanced when screening is absent​

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. In scalar-field theories, the void interior can act like an effective source of (negative) mass or can alter light bending. For instance, Galileon gravity (a scalar-tensor theory) was found to boost the tangential shear signal of voids by up to ~20% relative to GR​

[osti.gov](https://www.osti.gov/servlets/purl/1541181#:~:text=for%20consistency%20between%20the%20behaviour,to%20test%20for%20more%20general)

. We will derive RFT’s prediction for void lensing (using the refined scalaron model) and compare it to Euclid observations of void lensing profiles. Any detected deviation from the GR expectation as a function of void size or depth could be a hallmark of RFT. Conversely, non-detection of a difference will provide upper limits on RFT’s coupling strength in low-density cosmic regions.

* + *Void dynamics:* Using redshift-space distortions in DESI, we can measure galaxy peculiar velocities around voids. We expect voids to be expanding relative to the overall Hubble flow (outflow of matter). RFT’s modifications might cause slightly higher outflow velocities for a given void size (since gravity is altered). By comparing the void velocity profile from data with RFT simulation predictions, we can validate the scalaron’s influence on cosmic expansion in voids. These measurements, combined with lensing, provide a consistency check: RFT must simultaneously fit how matter moves *and* how light propagates around voids, which tightly constrains the theory’s viability​

[osti.gov](https://www.osti.gov/servlets/purl/1541181#:~:text=We%20propose%20a%20consistency%20test,We%20find%20that)

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* **Wide Binaries and Stellar Data with Gaia DR3+:** **Gaia**’s latest data releases (DR3 and forthcoming DR4/DR5) offer unprecedented astrometric precision, enabling gravity tests at ~kAU scales. We will use Gaia’s catalog of wide binary stars to probe accelerations of order $10^{-10}$ m/s² (typical of galactic outskirts, similar to MOND’s $a\_0$ scale). Two primary observables will be:
  + *Orbital Velocity Distributions:* By statistically analyzing the relative motions of wide binaries as a function of separation, we can search for the subtle onset of modified gravity. If RFT’s scalaron activates below a certain acceleration threshold, binaries beyond some separation might show a departure from Keplerian velocity scaling. We will compare the distribution of orbital velocity ratios (observed vs. Newtonian predicted) for wide pairs to RFT models. A successful RFT model might explain any mild excess velocity at large separations without overpredicting it (MOND’s predicted 15% excess appears to be ruled out​

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, but perhaps a smaller ~5% effect could be consistent within errors). RFT parameters like $q$ directly influence such deviations – e.g. a $q$ slightly less than 1 effectively increases the gravitational coupling ($G\_q$) in weak fields. We will use the data to set an allowed range for $q - 1$.

* + *Perihelion Precession Tests:* For the best-characterized wide binaries (and possibly for planetary orbits at large radii in the solar system), we will examine if the orbital perihelion advances differently than in Newtonian gravity. In GR, a tiny relativistic precession occurs; in MOND-like theories, distortions in the force law could also cause precession. RFT 7.6 could induce a small extra precession per orbit if the scalaron field is influencing the force slightly asymmetrically over the orbit. Using Gaia astrometry, one can trace orbital arcs over the mission duration. While Gaia’s time baseline (~5-10 years) may be too short for a full orbit of wide binaries (periods ~10^5 years), we can combine data from many binaries to statistically infer any systematic precession signal or use high-precision binaries around known masses. Any detected anomaly in orbital motion would be cross-checked against RFT predictions. However, if Gaia DR3/4 show **no deviation** from Newtonian or Keplerian orbits at the $<!1%$ level, RFT must accommodate that by having the scalaron’s influence be extremely small in those regimes (or fully “screened” by the Galactic potential, analogous to an external field suppressing it).
* **Future Surveys (LSST, XRISM, Gaia DR4/5):** We recommend extending tests of RFT with upcoming observational resources:
  + *Vera C. Rubin Observatory (LSST):* LSST’s deep, wide imaging will discover countless new cosmic structures and provide precise weak lensing maps. We can use LSST data to improve void lensing measurements (via galaxy shapes) and also to identify **satellite galaxy dynamics** in the outskirts of galaxies or groups (another weak-field gravity test). Additionally, LSST will produce long-term astrometry that could identify subtle accelerations of stars and binaries beyond Gaia’s reach, further testing RFT in the ~10-100 kAU regime.
  + *XRISM (X-ray Imaging and Spectroscopy Mission):* XRISM will observe the X-ray emission from galaxy clusters and groups with high spectral resolution. This enables detailed mass profiles via X-ray hydrostatic equilibrium tests. RFT 7.6 should be checked against cluster outer-region dynamics: e.g. does the scalaron activation alter the equilibrium of hot gas in cluster outskirts (where gravity is weaker per particle)? Using XRISM, we can measure any deviations in required gravitational force at large radii – similar to how MOND fails to fully explain galaxy clusters without dark matter. If RFT can predict a slight boost in gravity in cluster outskirts (beyond Newton but not as strong as MOND would need), XRISM data on gas temperature and density profiles could either support or rule out those predictions. Moreover, XRISM could detect the **gravitational redshift** of X-ray lines from the cluster center vs edges; any anomaly there might signal a modification to gravity’s depth in the potential well.
  + *Gaia DR4/DR5:* Future Gaia releases will extend the time baseline and improve astrometric precision, allowing detection of **tiny accelerations** on the plane of the sky. This could enable a direct measurement of the Galactic acceleration at the Sun’s location or acceleration of wide binaries. RFT’s scalaron, if active at very low accelerations, might cause a measurable difference in these values. We will incorporate Gaia DR4/5 data to refine the wide binary analysis and possibly to test the solar system ephemerides for anomalous drifts (Gaia can indirectly check planetary motions via quasars’ reference frame stability, for instance). Any positive detection of a deviation would be groundbreaking; a null result will further tighten RFT model parameters.

By integrating these diverse datasets, we ensure RFT 7.6 is confronted with reality at all scales. The synergy of DESI/Euclid (cosmic scales) and Gaia/LSST (stellar scales) provides a comprehensive validation: RFT must consistently explain phenomena from void expansion to binary orbits under a single theoretical framework.

**4. Expected Outcomes and Final Deliverables**

This research effort will culminate in a set of refined model parameters, predictions, and comparisons that pave the way for RFT 8.0:

* **Refined Scalaron Model Parameters:** We will deliver an updated set of parameters for the entropy-based scalaron activation. This includes the **Tsallis entropy index $q$** (quantifying deviation from standard Boltzmann entropy) – likely determined to high precision. For instance, if our analyses find that $q=0.98 \pm 0.02$ best fits all tests (slightly sub-extensive entropy), that will be our recommendation. We will also refine the coupling constants $\alpha$ and $\gamma$ that appear in the RFT scalaron field equation (for example, $\alpha$ might scale the strength of the scalaron’s coupling to matter, and $\gamma$ might set the transition scale of field activation). These constants will be tuned such that the model reproduces observed phenomena: galaxy rotation curves (if considered), wide binary dynamics, void lensing amplitudes, etc. Any degeneracies or uncertainties in these parameters will be quantified. Ultimately, we expect to narrow the viable range of $(q, \alpha, \gamma)$ to a region consistent with all available data.
* **Quantitative Predictions for Weak-Field Observables:** A key deliverable is a catalog of **specific, quantitative predictions** from RFT 7.6 that can be tested observationally. We will provide values or functions for observables such as:
  + *Wide binary velocity enhancement:* e.g. RFT might predict a subtle increase in orbital velocity by ~5% at $10^4$ AU separations under low external field, distinguishable with a larger Gaia sample.
  + *Void lensing and density profiles:* e.g. voids of radius 30 Mpc in RFT may produce a ~10% deeper lensing signal (tangential shear) than in $\Lambda$CDM, or void ridge densities might be higher by a similar percentage. These numbers will be specified along with the dependence on void size or redshift.
  + *Galaxy cluster outskirts:* e.g. an RFT prediction that cluster gas pressure profiles fall off differently than in Newtonian gravity by a small factor, which could be checked by XRISM or SZ (Sunyaev-Zel’dovich) observations.
  + *Galaxy rotation curve deviations at low acceleration:* although not explicitly requested, as part of weak-field regime we might include a note that for acceleration $<a\_{0}$ (MOND scale), RFT yields a distinct form of deviation. For example, RFT might mimic the MOND-like behavior with an interpolation governed by $q$ and $\alpha$, leading to slightly different asymptotic rotation curve slopes or a different Tully-Fisher relation. These could be tested with future HI surveys of ultra-diffuse galaxies. (If our work finds this is a promising distinction, we will list it among predictions.)

Each prediction will be accompanied by an estimate of its statistical detectability given current or upcoming survey capabilities. By being explicit, we invite the community to hold RFT 7.6 accountable to these numbers, accelerating its empirical validation.

* **Comparison to MOND and $\Lambda$CDM:** Finally, we will present **direct side-by-side comparisons** of RFT’s performance against Modified Newtonian Dynamics (MOND) and the standard $\Lambda$CDM paradigm:
  + For MOND: We’ll highlight where RFT 7.6 reproduces MOND’s successes (e.g. galaxy rotation curve shapes) and where it differs. RFT’s entropic foundation might naturally incorporate the external field effect or explain its origin, but perhaps in a tempered way that avoids MOND’s conflict with wide binary observations. If RFT 7.6 can match galaxy phenomenology without MOND’s issues (such as the need for an *ad hoc* interpolating function), that will be a significant achievement. We will quantitatively compare the fits to galaxy data (rotation curves, velocity dispersion profiles) between RFT and MOND, using metrics like chi-square or Bayesian evidence. Any improvement in RFT (e.g. better fit to high-precision data or fewer outliers) will be noted. Additionally, RFT’s ability to handle galaxy clusters (where MOND alone falls short unless additional dark mass is invoked) will be evaluated – e.g. does the scalaron mitigate the need for neutrino mass in MOND for cluster lensing?
  + For $\Lambda$CDM: We’ll compare RFT’s predictions to the dark matter-based standard model. This includes structure formation aspects (void statistics, cluster profiles) and kinematics (binaries, galaxy rotations). If RFT aims to eliminate particle dark matter, it must match $\Lambda$CDM’s successes in explaining cosmic microwave background (CMB) and large-scale structure power spectra. While our focus is weak-field gravity, we will discuss whether the refined RFT 7.6 can be extended or has been extended to cosmology (maybe via the Friedmann equation modified by entropy, as hinted by earlier RFT versions). Any areas where $\Lambda$CDM firmly outperforms RFT (or vice versa) will be clearly identified. The goal is to objectively assess if RFT 7.6 provides equal or better explanatory power **with fewer free parameters or new insights**. For instance, if RFT can explain the **void phenomenon** or **external field effects** that $\Lambda$CDM does not naturally produce (since GR has no EFE, and void modulations come only from dark matter properties), that’s a win for RFT. Conversely, if $\Lambda$CDM fits some data markedly better, we’ll note those as targets for improvement in RFT 8.0.

**Conclusion:**  
Through this multi-pronged research program, we aim to elevate RFT 7.6 from a theoretical proposal to a thoroughly vetted framework for weak-field gravity. The **computational refinements** will ensure the model’s equations are solved accurately in simulations, the **empirical tests** will benchmark RFT against reality and competing theories, and the **observational integration** will either find RFT’s fingerprints in nature or constrain them. Ultimately, we will produce a refined set of model parameters and predictions – the stepping stones toward **RFT 8.0**. If successful, RFT 8.0 will emerge as a robust theory, with improved empirical grounding, that could help reconcile puzzles in gravitational physics without invoking unseen matter. Each result, whether supportive or null, will sharpen our understanding, and the deliverables here will guide both theorists and observers in the next phase of testing gravity in the low-acceleration regime.