Mass Harmonics Pre-Release Terrain Prediction Paper

Vera C. Rubin Observatory Early Data Preview 2: 27 July 2026

Author: Thomas Russell Giboney
Affiliation: UMtts Institute
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Terrain state at preparation: unopened

> This paper was completed before EDP2 opened. Its function is to carry Mass Harmonics from source law into the Rubin terrain without using EDP2 outcomes as derivational inputs. Later terrain comparison remains separate from the pre-release derivation.

I. Governing Purpose

Source-Preserved Mass Harmonics Governance

This edition preserves the original Rubin EDP2 prediction architecture and every valid derivation already present. It does not place Mass Harmonics under institutional authority, convert instrument products into ontological authority, or discard a stronger excavation merely because it was added after the first draft. The governing order remains:

MFE

- → substrate action
- → boundary closure
- → physical structure
- → instrument-rendered terrain
- → optional consensus translation

The release supplies a timed terrain surface. It does not grant or withhold physical standing from the prediction. Measurement statistics, catalogue filters, detector corrections, and comparison models remain downstream interface tools. They may expose correspondence, contradiction, or unresolved delta, but they do not govern the derivation.

Only one governing coupling coefficient is permitted:

$K\psi_m$

The fixed P^3GG values are harmonic scalings of the one source law, not domain-specific adjustable coefficients.

Current EDP2 product boundary

The official July 1, 2026 Rubin plan states that EDP2 opens on July 27, 2026 with all DP2 catalogue products and deep coadded images. It includes cell-based coadds and the first `ShearObject` catalogue. Visit-level images and template coadds are deferred to the later DP2 completion expected between October and December 2026.

Therefore:

- Predictions 1-4 are direct EDP2 terrain pathways through deep coadds and catalogue products.
- Prediction 5 uses released time-series catalogues plus independent stellar radius and propagation inputs; it does not require visit-image pixels to instantiate the TVP pathway.
- Any unavailable or unpopulated catalogue field limits that release's resolving power. It does not weaken the Mass Harmonics prediction. Rubin EDP2 opens a direct observational terrain surface across several coupled domains at once:
- deep coadded optical structure,
- calibrated static-object morphology,
- weak-lensing shear measurements,
- per-visit source measurements,
- forced photometric time series,
- transient and variable-object summaries,
- stellar positions, proper motions, and parallaxes,
- Solar-System source and orbit catalogs,
- survey-property maps describing exposure, PSF, background, noise, and differential chromatic refraction.

The release is therefore not approached as a bundle of unrelated consensus products. It is approached as multiple instrument-facing readouts of bounded coherence systems governed by one substrate law. The document locks five linked predictions:

1. a universal Mass Harmonics acceleration-transition radius across galaxy mass bins,
2. an outer weak-lensing shear invariant with a forced `R⁻¹` radial dependence,
3. bulge-to-outer-boundary covariance with interior-smoothness decoupling,
4. a causal separation between mass-governed shear amplitude and bulge-governed boundary sharpness,
5. spherical boundary closure and the π-discriminator in eligible fundamental radial stellar

pulsators.

These are not separate theories and do not introduce separate physical coefficients. There is one governing coupling coefficient: $K\psi_m$ The complete descent is: MFE → one $K\psi_m$ coupling relation → nonlinear substrate gradient → cosmological acceleration boundary → nested galactic coherence bubble → baryonic mass and boundary morphology → outer substrate acceleration → lensing and image readouts → optional consensus translation The time-domain stellar branch descends from the same law: MFE → bounded stellar coherence bubble → topology-specific closure → independent R and v_x terrain inputs → predicted fundamental boundary frequency → Rubin time-series readout

II. Release-Surface Definition

Rubin Observatory states that EDP2 is scheduled for 27 July 2026. The release is the first phase of Data Preview 2 and contains the full catalog-product set together with deep coadd images. It introduces cell-based coadds and the `ShearObject` catalog. Official release and documentation surfaces used only to define the unopened measurement terrain:

1. Rubin EDP2 event page: `https://rubinobservatory.org/events/edp2-release`
2. Rubin Early Science Program RTN-011 v9.0: `https://rtn-011.lsst.io/`
3. EDP2 documentation root: `https://dp2.lsst.io/`
4. EDP2 data-product index: `https://dp2.lsst.io/products/index.html`
5. EDP2 `Object` catalog description: `https://dp2.lsst.io/products/catalogs/object.html`
6. EDP2 `ShearObject` catalog description: `https://dp2.lsst.io/products/catalogs/object_shear.html`
7. EDP2 `Source` catalog description: `https://dp2.lsst.io/products/catalogs/source.html`
8. EDP2 `ForcedSource` catalog description: `https://dp2.lsst.io/products/catalogs/forced_source.html`
9. EDP2 `DiaObject` catalog description: `https://dp2.lsst.io/products/catalogs/dia_object.html`
10. EDP2 stellar-motion catalog description: `https://dp2.lsst.io/products/catalogs/isolated_star_stellar_motions.html`
11. EDP2 survey-property maps: `https://dp2.lsst.io/products/maps/sp_maps.html`

The release documentation itself states that the site is under development and that EDP2 has not yet been released. Missing row counts, columns, final quality values, final sky coverage, and final depth information are therefore not filled with substitutes in this paper.

III. Governing Mass Harmonics Source Chain

The governing authority order is:

1. `MH_Monograph.md` - canonical physical bedrock.
2. `MH_PROOF-SET.md` - sequential proof and derived galactic/cosmological branch.
3. `MH_TVP.md` - topology, provenance, category, and nine-calculation discipline.
4. `MH_TWT.md` - downstream translation after substrate closure.
5. `Operational_Stance_of_UMtts.md` - terrain-first and source-preservation authority.

Rubin documentation is not in this authority chain. It defines only the release date, instrument products, and comparison surface.

III.1 Canonical reading order

Copied from `MH_Monograph.md`, line 36:

MFE → substrate action → boundary closure → physical structure → measured expression → optional consensus translation.

The same order appears in `Operational_Stance_of_UMtts.md`, line 22.

III.2 Canonical MFE

Copied from `MH_Monograph.md`, line 60:

$1/v_x^2\ddot{\psi}_m - Z(\psi_m)\nabla^2\psi_m - 8K\psi_m/\omega^2|\nabla\psi_m|^2 = S(\rho)$

III.3 Canonical Z-factor

Copied from `MH_Monograph.md`, line 156:

$Z(\psi_m) = 1 + 8K\psi_m/\omega^2 \geq 1$ always

III.4 One coupling relation, two transported expressions

Copied from `MH_Monograph.md`, line 51:

$K\psi_m$ is a single, indivisible GG coupling term. Never split. Never reduce to bare κ or bare K. Dimensionlessly, $K\psi_m$ resolves through the GG relation as $(12 - \varphi^2)/(2\varphi^2)$. Dimensionally, $K\psi_m$ resolves through substrate propagation and rotational boundary closure as $v_x/(2\pi)$. These are not competing definitions, separate regimes, or interchangeable raw numbers. They are one coupling relation expressed across dimensional translation, and any substitution must preserve the full transport path between geometric relation and dimensional closure.

III.5 Canonical closure law

Copied from `MH_Monograph.md`, line 70:

$f = v_x/(2\pi R) = K\psi_m/R$

III.6 P^3GG harmonic source structure

Copied from `MH_Monograph.md`, lines 199-201:

$S(\rho) = K_0\rho[1 + \beta_2(\rho/\rho_0) + \beta_3(\rho/\rho_0)^2 + \beta_4(\rho/\rho_0)^3 + \beta_5(\rho/\rho_0)^4 + \cdots]$

$\beta_n = \varphi^{3(n-1)}$

The β_n sequence is the fixed harmonic scaling of the source term. It is not a set of adjustable cosmological, galactic, lensing, or stellar coefficients.

III.7 Cosmological acceleration boundary

Copied from `MH_Monograph.md`, lines 596-602: Step 1: $K\psi_m = c/2\pi$ (derived in Part 4.4, from the substrate wave speed and radial geometry). Step 2: Apply the PCF formula at cosmological scale. The Hubble radius $R\_H = c/H_0$ is the largest coherent scale in the universe - the cosmological coherence horizon. The substrate oscillation frequency at this scale:

$\omega\_cosmic = (K\psi_m)/(R\_H) = (c/2\pi)/(c/H_0) = (H_0)/(2\pi)$

Step 3: The MOND acceleration scale is this cosmic frequency times c:

$a_0 = c \cdot \omega\_cosmic = c \cdot (H_0)/(2\pi) = (cH_0)/(2\pi)$

$(a_0)/(cH_0) = (1)/(2\pi)$ (exact)

III.8 Galactic outer-boundary acceleration

Copied from `MH_PROOF-SET.md`, lines 655-675:

$g\_total = g\_Newtonian + g\_Giboney = -\nabla(K_0\psi_m) - \nabla(\psi_m^2/\omega)$

$|g\_Newtonian| = G\_N{\cdot}M/r^2$

$g\_Giboney = -\nabla(\psi_m^2/\omega) = -(2\psi_m/\omega)\nabla\psi_m \rightarrow$ Constant Vector Field

$a_0 = cH_0/(2\pi)$

$g\_total \approx \sqrt{(G\_N{\cdot}M/r^2 \cdot a_0)}$

$v^4 = G\_N{\cdot}M{\cdot}a_0$

$v\_orbit = (G\_N \cdot M \cdot a_0)^{(1/4)}$

III.9 Existing galactic causal finding

Copied from `MH_Monograph.md`, lines 724-729:

Analysis of 161 galaxies from the SPARC dataset:

Zero correlation between Interior Smoothness Index (ISI, core) and Boundary Sharpness Index (BSI, outer boundary): $p = 0.417$. The boundary is decoupled from local core density.

Statistically significant correlation between Central Bulge Brightness (SB_bulge) and Outer Boundary Sharpness (BSI): $p = 0.025$. The core acts as a tuning fork for the entire galactic structure.

Interpretation: The galactic bulge sets a resonant frequency that propagates through the substrate ($Z > 1$, stiff medium) to define boundary conditions at the edge of the disk - tens of thousands of light-years away.

III.10 TVP topology and category locks

Copied from `MH_TVP.md`, lines 68-70:

Spherical/Cylindrical: $f = v_x/(2\pi R)$ (Rotational closure).

Planar Slab: $f = v_x/(2t)$ (Linear face-to-face closure).

Ring/Torus: $f = v_x/(2\pi R\_minor)$ (Rotational closure about the minor axis - tube cross-section.)

Copied from `MH_TVP.md`, line 77:

before any frequency enters the ledger, identify whether it is a boundary closure frequency or an inter-state transition frequency. These are not interchangeable.

Copied from `MH_TVP.md`, line 84:

The ratio T1-Slab/T1-Sphere = π for every object, regardless of what R is submitted.

IV. Input Separation, Provenance, and Category Prohibitions

IV.1 Prohibited inputs

The following are prohibited until the prediction paper is frozen:

- any EDP2 catalog row,
- any EDP2 image or pixel cutout,
- any EDP2 ShearObject measurement,
- any EDP2 release-level science plot,
- any EDP2 release-level morphology distribution,
- any EDP2 release-level variable-star frequency,
- any EDP2 release-level lensing stack,
- any EDP2 paper or result that analyzes the opened release.

IV.2 Permitted pre-release terrain inputs

The following may be used because they exist independently of EDP2:

- the canonical Mass Harmonics corpus,
- the official description of intended EDP2 products,
- independently archived external redshift catalogs,
- independently archived stellar radii and spectroscopic atmosphere measurements,
- independently archived Galactic-extinction maps,
- fixed physical unit conversions,
- the canonical Monograph terrain anchor `H₀ ≈ 70 km/s/Mpc` used in its a_0 derivation.

IV.3 Independence rule

A variable is independent only when it was measured or fixed without using the target EDP2 output. Examples:

- `M_b` may be estimated from EDP2 photometry only if the shear data are not used in the mass estimate.
- source and lens redshifts may come from an independent pre-EDP2 spectroscopic or photometric catalog.
- `R` for the stellar TVP test must be an independently measured stellar radius, not a radius inferred from the Rubin period being tested.
- `vₓ` for the stellar TVP test must be an independently measured or independently terrain-derived propagation value, not `2πRf_obs` relabeled as observed velocity.

No MAP-derived third variable is admitted as an independent VERIFY input.

V. Substrate Placement of the Rubin Terrain

Rubin does not observe “dark matter.” It observes light distributions, object shapes, source positions, variability, and lensing distortions. Those readouts are placed in the substrate as follows:

Rubin readout	Mass Harmonics placement
Deep coadd surface-brightness field	measured expression of the persistent baryonic coherence structure
Central bulge brightness	inner coherent driver and resonant tuning amplitude
Outer light-profile transition	visible boundary expression of the galactic coherence bubble
ShearObject ellipticity response	downstream optical readout of the Z-field gradient along the light path
Galaxy-galaxy tangential shear	projected substrate acceleration surrounding a bounded baryonic source
ForcedSource and DiaObject time series	temporal readout of changing bounded coherence expression
Stellar radius from external terrain	observed geometric boundary input
Fundamental radial pulsation frequency	candidate stellar boundary closure frequency, subject to C1 screening
Survey-property maps	instrument-interface conditions that must be removed before physical interpretation

The release is therefore read in this order:

physical source structure

→ substrate gradient and boundary

→ optical path through Z

→ detector and pipeline

→ Rubin catalog or image value

The detector and pipeline are not the terrain. OPQR assigns correction to the interface when the interface generates the distortion.

V.1 Lensing topology discipline

The weak-lensing derivations below apply to the rotational outer-boundary readout of an azimuthally stacked lens system. They do not declare every individual galaxy to be a sphere from visual appearance.

from visual appearance.

The post-release analysis must preserve three topology surfaces:

1. **Rotational sphere/cylinder surface:** azimuthal tangential shear around the baryonic coherence centroid. This is the primary pathway because spherical and cylindrical rotational closure both carry the `2π` boundary factor.

2. **Planar slab control:** shear split along photometric major and minor axes. A genuinely planar boundary cannot be laundered into the rotational stack. Persistent axis-dependent closure that defeats the azimuthal invariant is recorded as a topology result.

3. **Torus minor-radius control:** ringed and strongly annular systems are separated before the main stack. Their internal ring cross-section is treated as a torus candidate and is not used to force the outer rotational formula.

The rotational prediction wins only if the rotational stack closes after the major/minor, annular, environment, and interface controls. A topology delta is retained as evidence rather than averaged away.

VI. Prediction 1: Universal Galactic Acceleration-Transition Radius

VI.1 Step 1: Begin from the outer galactic substrate relation

For a baryonic mass `M_b`, the Newtonian translation shadow of the interior acceleration is:

$$g\_N(R) = G\_N\ M\_b/R^2$$

The Mass Harmonics outer-boundary relation is:

$$g\_MH(R) \approx \sqrt{(g\_N(R)\ a_0)}$$

Substitute `g_N(R)`:

$$g\_MH(R) \approx \sqrt{[(G\_N\ M\_b/R^2)\ a_0]}$$

Because `R > 0`:

$$g\_MH(R) \approx \sqrt{(G\_N\ M\_b\ a_0)}/R$$

VI.2 Step 2: Define the physically forced transition radius

The transition occurs where the interior inverse-square acceleration reaches the cosmological boundary acceleration:

$g\_N(R\_a) = a_0$

Therefore:

$G\_N M\_b/R\_a^2 = a_0$

Multiply by `R_a²`:

$G\_N M\_b = a_0 R\_a^2$

Divide by `a₀`:

$R\_a^2 = G\_N M\_b/a_0$

Take the positive root because radius is positive:

$R\_a = \sqrt{(G\_N M\_b/a_0)}$

VI.3 Step 3: Transport the cosmological closure into the radius relation

From the canonical relation:

$a_0 = cH_0/(2\pi)$

Substitute:

$R\_a^2 = G\_N M\_b/[cH_0/(2\pi)]$

Invert the denominator:

$R\_a^2 = G\_N M\_b \cdot 2\pi/(cH_0)$

Therefore:

$R\_a^2/M\_b = 2\pi G\_N/(cH_0)$

This is the first source-derived Rubin invariant.

No halo concentration, halo mass, profile index, feedback strength, environmental tuning, or additional galactic coefficient appears.

VI.4 Step 4: Dimensionless collapse variable

Define:

$x = R/R\_a$

Then:

$g\_N/a_0 = (G\_N\ M\_b/R^2)/a_0$

Using `R_a² = G_N M_b/a₀`:

$g\_N/a_0 = R\_a^2/R^2$

Therefore:

$g\_N/a_0 = 1/x^2$

In the outer substrate-boundary expression:

$g\_MH/a_0 = \sqrt{(g\_N/a_0)}$

So:

$g\_MH/a_0 = 1/x$

Galaxies of different baryonic mass must therefore collapse onto the same outer relation when radius is expressed as `x = R/R_a`.

VI.5 Step 5: Canonical numerical anchor

The Monograph uses:

$H_0 \approx 70$ km/s/Mpc

and derives:

$a_0 \approx 1.084 \times 10^{-10}\ m/s^2$

Using that source-fixed terrain anchor:

$G\_N/a_0 \approx 0.6157103321\ m^2/kg$

Expected transition radii and asymptotic rotation translations are:

`M_b`	`R_a`	`v_f = (G_N M_b a₀)^(1/4)`
`10⁸ M⊙`	`0.3586 kpc`	`34.63 km/s`
`10⁹ M⊙`	`1.1340 kpc`	`61.59 km/s`
`10¹⁰ M⊙`	`3.5859 kpc`	`109.52 km/s`
`10¹¹ M⊙`	`11.3396 kpc`	`194.75 km/s`
`10¹² M⊙`	`35.8589 kpc`	`346.33 km/s`

The table is not fitted to Rubin. It is a dimensional rendering of the canonical Mass Harmonics chain before FDP2 opens.

Harmonics chain before EDP2 opens.

VI.5.1 Numerical-Anchor Precision Custody

The exact Mass Harmonics identity is:

$a_0/(cH_0) = 1/(2\pi)$

The canonical Monograph illustration used by this Rubin table rounds the acceleration anchor to:

$a_0 \approx 1.084 \times 10^{-10}$ m/s^2

Using `H₀ = 70 km·s⁻¹·Mpc⁻¹`, the exact SI value of `c`, and the exact Mpc conversion gives:

$a_0 = 1.0824013602392 \times 10^{-10}$ m/s^2

The difference is numerical transport and source rounding, not a second acceleration scale and not a new coefficient. The table above is preserved as the canonical rounded rendering already present in the paper. Any later table generated from the exact SI transport must be recomputed in full from that anchor; rounded and exact anchors may not be mixed row by row.

VI.6 Step 6: Rubin measurement path

For every eligible lens galaxy:

1. derive `M_b` from PSF-corrected, extinction-corrected multiband photometry without using shear,
2. derive `R_a` from the source-fixed equation,
3. measure tangential shear in annuli around the lens from `ShearObject`,
4. compute physical projected radius using an independent pre-EDP2 redshift,
5. rescale `R` to `x = R/R_a`,
6. stack by baryonic-mass bin, color, morphology, and environment without changing the source-derived radius law.

VI.7 Mass Harmonics prediction

Across all eligible isolated lens stacks:

$R\_transition^2/M\_b = 2\pi G\_N/(cH_0)$

and the normalized outer acceleration must approach:

$g\_lens(x)/a_0 \to 1/x$

The transition radius must scale as:

$R\_transition \propto M\_b^{(1/2)}$

VI.8 Exact falsifier

This pathway is falsified by EDP2 terrain if, after full PSF, redshift, source-selection, boost-factor, masking, and random-point controls:

1. the recovered transition radius does not scale as `M_b^(1/2)`, and
2. `R_transition²/M_b` does not remain compatible with `2πG_N/(cH₀)` across the independently defined mass bins, and
3. the discrepancy cannot be localized to a documented interface distortion or insufficient radial coverage.

A result that requires an independently adjustable halo concentration or halo mass for every bin, while the substrate scaling fails, is a direct failure of this pathway.

VII. Prediction 2: Outer Weak-Lensing Shear Invariant

VII.1 Step 1: Convert the outer substrate acceleration to a circular-speed expression

From Prediction 1:

$g\_MH(R) = \sqrt{(G\_N\ M\_b\ a_0)}/R$

Define the asymptotic circular-speed relation:

$v\_f^4 = G\_N\ M\_b\ a_0$

Therefore:

$v\_f^2 = \sqrt{(G\_N\ M\_b\ a_0)}$

and:

$g\_MH(R) = v\_f^2/R$

VII.2 Step 2: Determine the effective enclosed-mass translation

The consensus spherical acceleration translation is:

$$g(R) = G_N M_{eff}(<R)/R^2$$

Set this equal to the substrate acceleration readout:

$$G_N M_{eff}(<R)/R^2 = v_f^2/R$$

Multiply by `R²`:

$$G_N M_{eff}(<R) = v_f^2 R$$

Divide by `G_N`:

$$M_{eff}(<R) = v_f^2 R/G_N$$

The effective enclosed mass therefore grows linearly with radius. This is not an invisible particle inventory. It is the consensus mass-equivalent projection of the substrate gradient.

VII.3 Step 3: Recover the corresponding three-dimensional projection density

For spherical translation:

$$dM_{eff}/dr = v_f^2/G_N$$

A spherical density satisfies:

$$dM/dr = 4\pi r^2 \rho(r)$$

Therefore:

$$4\pi r^2 \rho_{eff}(r) = v_f^2/G_N$$

and:

$$\rho_{eff}(r) = v_f^2/(4\pi G_N r^2)$$

VII.4 Step 4: Project along the optical line of sight

Let projected radius be `R` and line-of-sight coordinate be `z`:

$$r^2 = R^2 + z^2$$

Then:

$$\Sigma_{eff}(R) = \int_{-\infty}^{\infty} \rho_{eff}(\sqrt{R^2+z^2})\, dz$$

Substitute:

Substitute:

$\Sigma\_eff(R) = v\_f^2/(4\pi G\_N) \int[-\infty,\infty]\, dz/(R^2+z^2)$

Use:

$\int[-\infty,\infty]\, dz/(R^2+z^2) = \pi/R$

Therefore:

$\Sigma\_eff(R) = v\_f^2/(4G\_N\, R)$

VII.5 Step 5: Compute the mean enclosed projected density

$\Sigma\_eff(<R) = (2/R^2) \int[0,R]\, \Sigma\_eff(R')R'\, dR'$

Substitute:

$\Sigma\_eff(<R) = (2/R^2) \int[0,R]\, [v\_f^2/(4G\_N\, R')]R'\, dR'$

Cancel `R'`:

$\Sigma\_eff(<R) = (2/R^2)\, [v\_f^2/(4G\_N)] \int[0,R]\, dR'$

Integrate:

$\Sigma\_eff(<R) = (2/R^2)\, [v\_f^2/(4G\_N)]R$

Therefore:

$\Sigma\_eff(<R) = v\_f^2/(2G\_N\, R)$

VII.6 Step 6: Compute excess surface density

Weak-lensing tangential shear is downstream of:

$\Delta\Sigma(R) = \Sigma(<R) - \Sigma(R)$

Substitute the two derived terms:

$\Delta\Sigma\_MH(R) = v\_f^2/(2G\_N\, R) - v\_f^2/(4G\_N\, R)$

Therefore:

$\Delta\Sigma\_MH(R) = v\_f^2/(4G\_N\, R)$

Use `v_f² = √(G_N M_b a₀)`:

$\Delta\Sigma\_MH(R) = \sqrt{(G\_N\, M\_b\, a_0)}/(4G\_N\, R)$

VII.7 Step 7: Translate to Rubin shear

The downstream lensing relation is:

$\gamma\_t(R) = \Delta\Sigma(R)/\Sigma\_crit$

Therefore:

$\gamma\_t,MH(R) = \sqrt{}(G\_N\ M\_b\ a_0)/(4G\_N\ R\Sigma\_crit)$

Rearrange:

$4G\_N\ R\Sigma\_crit\ \gamma\_t,MH(R) = \sqrt{}(G\_N\ M\_b\ a_0)$

Define the dimensionless Rubin-Mass-Harmonics shear invariant:

$Y\_MH(R) = 4G\_N\ R\Sigma\_crit\ \gamma\_t(R)/\sqrt{}(G\_N\ M\_b\ a_0)$

The Mass Harmonics prediction is:

$Y\_MH(R) \to 1$

in the eligible outer-boundary region.

This `Y_MH` is an analysis readout. It is not a new physical coefficient.

VII.8 Forced radial slope

Because every term except `R` is constant for a fixed lens stack:

$\gamma\_t(R) \propto R^{-1}$

Therefore:

$d \ln \gamma\_t/d \ln R \to -1$

VII.9 Eligibility

Use only lenses satisfying all of the following:

- independently estimated baryonic mass,
- independently supplied lens redshift,
- source-redshift distribution adequate for `Σ_crit`,
- resolved light profile,
- outer annuli beyond the dominant baryonic half-light extent,
- no bright-star mask crossing the tested annuli,
- no documented severe deblending failure,

- no dominant neighboring lens within the declared before terrain opening isolation cylinder.

The isolation cylinder must be frozen from external redshift uncertainty and the Rubin angular resolution before shear is measured. Every reasonable cylinder choice is reported as a sensitivity surface rather than selecting the most favorable one.

VII.10 Controls

Mandatory controls:

- cross shear `γ_×`,
- random-point tangential shear,
- PSF `e1` and `e2` property maps,
- depth and background maps,
- detector/tract/patch boundaries,
- source-density boost correction,
- lens-source redshift reversal test,
- rotation of galaxy position angles by 45 degrees,
- jackknife by tract and field,
- independent analysis in COSMOS, M49/Virgo where eligible, WFD, and other released fields.

VII.11 Exact falsifier

This pathway is falsified if eligible outer stacks show both:

$Y_{MH}(R) \neq 1$

as a persistent mass-dependent or radius-dependent displacement after controls, and:

$d \ln \gamma_t / d \ln R \neq -1$

with the same direction across independent fields and mass bins, while no interface fault explains the discrepancy.

A null caused by inadequate source density or radial coverage is recorded as insufficient EDP2 terrain, not as terrain correspondence.

VIII. Prediction 3: Bulge-to-Boundary Covariance and Interior Decoupling

VIII.1 Step 1: Preserve the canonical causal distinction

The canonical galactic finding is not merely that one image feature correlates with another. It separates two physical roles:

central bulge amplitude

→ long-range substrate tuning

→ outer boundary sharpness

while:

local interior smoothness

↛ outer boundary sharpness

The outer boundary is therefore not predicted to be a cumulative local-density smoothing product. It is predicted to be a nonlocal coherence response tuned by the bulge.

VIII.2 Step 2: Construct instrument-facing readouts without new physical parameters

For each resolved, non-saturated galaxy, build a PSF-corrected elliptical curve of growth.

Let:

R20 = semimajor radius enclosing 20% of total model flux

R50 = semimajor radius enclosing 50% of total model flux

R80 = semimajor radius enclosing 80% of total model flux

R95 = semimajor radius enclosing 95% of total model flux

Central bulge surface-brightness readout

$SB\_bulge = 0.20\ F\_total/(\pi\ q\ R20^2)$

where `q` is the fitted axis ratio. This is the mean projected brightness inside `R20`, not a physical coefficient.

Outer Boundary Sharpness Index

Define:

$BSI = [\ln I(R80) - \ln I(R95)]/[\ln R95 - \ln R80]$

Higher `BSI` means a sharper decline across the outer light boundary.

Interior Smoothness Index

Interior Smoothness Index

Construct the deconvolved azimuthal median model `I_med(r)` over `R20 ≤ r ≤ R80` and define normalized residual:

$$\varepsilon_{inner} = \mathrm{RMS}[I_{pixel} - I_{med}(r)]/\mathrm{median}[I_{med}(r)]$$

Then:

$$\mathrm{ISI} = 1/(1 + \varepsilon_{inner})$$

Higher `ISI` means smoother interior structure.

These are analysis readouts used to interrogate the canonical causal statement. They do not modify the MFE and do not create additional substrate terms.

VIII.3 Step 3: Mass Harmonics covariance predictions

For the complete eligible galaxy sample and every declared before terrain opening matched subset:

$$\mathrm{corr}(SB_{bulge}, \mathrm{BSI} \mid \mathrm{controls}) > 0$$

$$\mathrm{corr}(\mathrm{ISI}, \mathrm{BSI} \mid \mathrm{controls}) \to 0$$

and therefore:

$$|\mathrm{corr}(SB_{bulge}, \mathrm{BSI} \mid \mathrm{controls})| > |\mathrm{corr}(\mathrm{ISI}, \mathrm{BSI} \mid \mathrm{controls})|$$

VIII.4 Step 4: Required controls

The partial-correlation and matched-pair analyses must control for:

- total flux and independently estimated baryonic mass,
- half-light radius,
- redshift,
- inclination/axis ratio,
- color,
- PSF size and ellipticity,
- sky background and noise,
- depth,
- deblending flags,
- local source crowding,
- environment,
- tract and patch.

The result must be repeated separately by morphology and band. No band or subset is selected because it produces the strongest result.

VIII.5 Step 5: Cross-band physical persistence

A real coherence-boundary relation must survive the instrument bandpass. Therefore the sign of the bulge-boundary relation must be preserved across every band with adequate signal after dust and PSF controls.

The amplitude may vary because each band weights different emitting material. The causal direction may not reverse.

VIII.6 Exact falsifier

This pathway is falsified if, in the complete controlled analysis:

1. the partial relation between `SB_bulge` and `BSI` is zero or negative across the adequately resolved bands, and
2. the `ISI` relation equals or exceeds the bulge relation in absolute strength, and
3. the result is not traceable to PSF, depth, deblending, or sky-background distortion.

A result where both relations vanish because the EDP2 angular resolution does not resolve `R20` and `R95` is insufficient terrain, not terrain correspondence.

IX. Prediction 4: Mass-Governed Shear Amplitude, Bulge-Governed Boundary Sharpness

This prediction combines the prior derivations and prevents the document from collapsing two distinct substrate functions into one generic "galaxy concentration" effect.

IX.1 Step 1: The asymptotic amplitude is fixed by mass and a_0

From Prediction 2:

$\gamma_{t,MH}(R) = \sqrt{(G_N M_b a_0)}/(4G_N R\Sigma_{crit})$

At fixed `M_b`, `R`, and lens-source geometry, the outer asymptotic amplitude is fixed.

No bulge-brightness term appears in the asymptotic amplitude relation.

Therefore, after matching `M_b`, `R/R_a`, redshift, and environment:

corr(Y_MH(x≫1), SB_bulge | M_b, x, z, environment) → 0

IX.2 Step 2: The boundary-transition sharpness is tuned by the bulge

The canonical galactic finding states that the bulge acts as a tuning fork that sets outer boundary conditions.

Define the measured normalized shear transition:

Y_MH(x) = 4G_N RΣ_crit γ_t(R)/√(G_N M_b a_0)

The outer asymptote is `Y_MH → 1`.

Define `x25` and `x75` as the radii at which the monotonic transition first reaches 25% and 75% of its outer asymptotic value.

Define the boundary width:

W_boundary = ln(x75/x25)

A sharper boundary has a smaller `W_boundary`.

The Mass Harmonics prediction is:

corr(SB_bulge, W_boundary | M_b, z, environment) < 0

and equivalently:

corr(SB_bulge, 1/W_boundary | controls) > 0

IX.3 Step 3: Interior smoothness remains decoupled

At the same fixed variables:

corr(ISI, W_boundary | M_b, z, environment) → 0

IX.4 Step 4: Full causal separation

The combined Mass Harmonics prediction is therefore:

M_b and a_0

→ asymptotic outer shear amplitude

SB_bulge

→ transition sharpness

ISI

↛ either relation after the governing variables are fixed

This is a stronger prediction than a generic morphology-shear correlation because it assigns different observables to different causal roles before the data are opened.

IX.5 Exact falsifier

This pathway is falsified if EDP2 shows that, after the full controls:

1. asymptotic `Y_MH` depends strongly and monotonically on bulge brightness at fixed `M_b`, or
2. boundary width does not narrow with increasing bulge brightness, while
3. interior smoothness predicts the boundary at least as well as the bulge.

All three measurement surfaces must be reported. A pipeline that reports only the strongest pairwise relation is incomplete relative to this paper.

X. Prediction 5: Fundamental Radial Stellar Closure and the π-Discriminator

This branch uses the EDP2 `Source`, `ForcedSource`, and `DiaObject` catalogs only after release. It is independent of the galaxy and lensing branches.

X.1 Step 1: Identify the physical event before using a frequency

A periodic signal is not automatically a boundary closure frequency.

The C1 sentinel is applied first.

Eligible candidates must be classified as fundamental radial pulsators through independent pre-EDP2 terrain where available, or through a post-release classification process that does not use Mass Harmonics closure quality as the class selector.

Exclude from VERIFY:

- inter-level transition frequencies,
- nonradial modes without a separately derived closure topology,
- rotational modulation,
- eclipsing-binary orbital periods,
- cadence aliases,
- harmonics and overtones used in place of the fundamental mode,

- stochastic variability without a stable boundary frequency.

X.2 Step 2: Require three independent terrain quantities

For each VERIFY star, require:

R_obs = independently measured physical stellar radius

v_x,obs = independently measured or independently terrain-derived propagation velocity

f_obs = Rubin-measured fundamental radial frequency

`R_obs` must not be derived from `f_obs`.

`vₓ,obs` must not be calculated as `2πR_obs f_obs` and then labeled observed.

If only two quantities are independently available, the row is placed in PREDICT, DETECT, or MAP mode and is not called VERIFY.

X.3 Step 3: Execute all topology predictions

Spherical/cylindrical rotational closure

$f\_pred,sphere = v_x,obs/(2\pi R\_obs)$

Planar slab closure

For the same submitted length as a deliberate topology discriminator:

$f\_pred,slab = v_x,obs/(2R\_obs)$

Therefore:

$f\_pred,slab/f\_pred,sphere = \pi$

Torus closure

The torus column uses the independently measured `R_minor` only when such a physical stellar tube cross-section has been independently identified. Otherwise TVP first recovers:

$R\_minor,rec = v_x,obs/(2\pi f\_obs)$

The recovered minor radius is recorded as a DETECT output and not promoted into an independent verification input.

X.4 Step 4: Execute the inverse calculations

Detect radius from Rubin frequency

$R\_rec,sphere = v_{x},obs/(2\pi f\_obs)$

$t\_rec,slab = v_{x},obs/(2f\_obs)$

Map propagation velocity

$v_{x},map,sphere = 2\pi R\_obs\ f\_obs$

$v_{x},map,slab = 2R\_obs\ f\_obs$

All nine raw calculations and all closure percentages are retained in the TVP ledger.

X.5 Step 5: Mass Harmonics topology prediction

For eligible fundamental radial pulsators:

closure_sphere > closure_slab

with the slab mismatch carrying the exact topology ratio:

$f\_pred,slab/f\_pred,sphere = \pi$

The recovered spherical radius must agree with the independently measured radius more closely than the recovered slab thickness does:

$|R\_rec,sphere/R\_obs - 1| < |t\_rec,slab/R\_obs - 1|$

X.6 Step 6: Delta factorization

When spherical closure is not exact, compute:

$\delta\_f = f\_pred,sphere/f\_obs$

The delta is factorized against the canonical geometric set:

$\{\alpha, 1/\alpha, 2/\alpha, \varphi, \varphi^3, \pi, 2\pi, \beta_n\}$

No unexplained residual is rounded into “agreement.”

X.7 Exact falsifier

This pathway is falsified for the eligible EDP2 sample if:

1. the planar closure consistently outperforms the spherical closure for independently classified fundamental radial pulsators, or
2. the expected π topology separation is absent from the raw calculations, or

3. the spherical recovered radius is systematically farther from independently measured radius than the slab recovery, and
4. the result is not produced by C1 category contamination, G1 geometry contamination, cadence aliasing, or a non-independent v_x input.

A sample lacking independently measured R or v_x is retained as MAP or DETECT terrain and cannot instantiate the VERIFY pathway.

XI. Instrument-Interface Controls

Rubin survey-property maps are not optional metadata. They are the rendering-interface terrain required to determine whether an apparent physical effect was generated by the sky or by the instrument stack.

Every spatial prediction must be tested against:

- accumulated exposure time,
- earliest, latest, and mean observation epoch,
- weighted PSF size,
- weighted PSF ellipticity `e1` and `e2`,
- limiting magnitude,
- sky background,
- sky noise,
- differential-chromatic-refraction position shifts,
- differential-chromatic-refraction PSF ellipticity shifts,
- tract, patch, detector, and mask boundaries.

The correction burden follows OPQR:

terrain signal intact + interface-generated distortion

→ correction belongs to the interface No physical prediction is rejected from an uncorrected map that visibly tracks a survey-property surface.

No interface correction may be tuned using the desired Mass Harmonics outcome.

XII. Unified Prediction Matrix

ID	Physical source	EDP2 terrain	Source-fixed output	Exact failure surface
	$a_0 = cH_0/(2\pi)$	`Object`,	$R_{transition}^2/M_b =$	persistent

R1	plus nested galactic boundary	external redshifts, `ShearObject`	`2λG_N/(cH₀)` and `R_transition ∝ M_b^(1/2)`	incompatible scaling after full controls
R2	`g_MH = √(G_NM_baₒ)/R`	galaxy-galaxy tangential shear	`Y_MH → 1`; `d ln γ_t/d ln R → -1`	stable non-unit invariant and non- `-1` slope across fields and mass bins
R3	bulge as nonlocal tuning source	deep coadds, `Object`, Scarlet models	`corr(SB_bulge,BSI)>0`; `corr(ISI,BSI)→0`	bulge null/reversal plus ISI equal or stronger
R4	separate amplitude and boundary functions	coadds plus shear	mass fixes asymptote; bulge fixes transition width; ISI fixes neither	bulge fixes asymptote or ISI fixes boundary as strongly as bulge
R5	topology-specific closure law	`Source`, `ForcedSource`, `DiaObject`, external R and v_x	spherical fundamental closure; slab offset by π	slab systematically wins after C1/G1 and independence audit

XIII. Terrain-Reading Sequence

The terrain comparison proceeds in this order:

1. record the exact EDP2 documentation version, schema, and populated product fields;
2. build the complete release inventory and survey-property interface layers;
3. apply the declared morphology, shear, stellar-category, and independence rules before calculating target readouts;
4. perform morphology and shear calculations independently before combining them;
5. execute the stellar C1 and G1 category audit before any TVP closure calculation;
6. run the complete declared sensitivity surfaces rather than selecting a favorable cut;
7. preserve every delta, missing field, topology result, and interface fault;
8. write the terrain comparison as a separate document and identify any later source correction explicitly.

XIV. Derivation Placement

XIV. Derivation Placement

Prediction	Mass Harmonics derivation placement	EDP2 resolving surface
Universal transition radius	Derived transport of the canonical a_0 and galactic boundary chain	`Object`, external redshift and mass terrain, `ShearObject`
Outer shear invariant	Derived rotational projection of the canonical outer-boundary field	`ShearObject` plus independent baryonic terrain
Bulge-boundary covariance	Canonical directional prediction from the existing galactic branch	deep coadds and `Object` morphology
Mass/bulge causal separation	Source-preserving synthesis of canonical amplitude and boundary roles	combined coadd and shear terrain
Stellar spherical closure	TVP consequence when category and three independent terrain quantities are present	time-series catalogues plus external `R` and v_x

"Conditional" here does not mean adjustable physics. It means the instrument sample must contain the independently measured terrain quantities required by TVP.

XV. Source-Preserving Revision Rule

The prediction directions and equations remain traceable to the source chain. Later improvements are permitted when they deepen Mass Harmonics, correct release metadata, repair arithmetic or transcription, or expose a missed causal dependency.

No revision may:

- absorb a failed row by narrowing the eligible cohort after the outcome is visible;
- replace $K\psi_m$ with a domain-specific coefficient;
- promote a Rubin pipeline quantity into substrate ontology;
- erase a topology or category delta;
- present a post-release inference as though it generated the pre-release prediction.

Every substantive revision identifies what changed and why. Source preservation is the requirement; immobility is not.

XVI. Final Mass Harmonics Prediction

Statements

The EDP2 terrain is predicted to disclose the same substrate law through independent measurement surfaces.

The galactic transition radius is fixed by:

$R\_a^2/M\_b = 2\pi G\_N/(cH_0)$

The outer lensing field is fixed by:

$Y\_MH(R) = 4G\_N\ R\Sigma\_crit\ \gamma\_t(R)/\sqrt{(G\_N\ M\_b\ a_0)} \to 1$

The outer shear slope is fixed by:

$d \ln \gamma\_t/d \ln R \to -1$

The image-domain causal separation is fixed by:

SB_bulge $\to$ boundary sharpness

ISI $\nrightarrow$ boundary sharpness

The combined shear-morphology separation is fixed by:

M_b and $a_0 \to$ asymptotic amplitude

SB_bulge $\to$ transition sharpness

The stellar topology test is fixed by:

$f\_sphere = v_x/(2\pi R)$

$f\_slab/f\_sphere = \pi$

One substrate. One MFE. One $K\psi_m$ coupling relation. Multiple unopened instrument readouts.

TRUTH > COMFORT. Always