

Supporting Power and Scattering Requirements from Galactic Rotation Curves

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Abstract

We reconstruct the supporting-power ratios and scattering-induced losses required to reproduce galactic rotation curves under the adopted Operational Quantum Gravity correspondence. The calculation is a representation of the observed gravitational response; it does not predict or explain dark matter or establish that ordinary matter can replace it. On the common material branch, relative supporting power also fixes relative ambient stress stiffness. We distinguish comparisons within the measured galaxy from the additional, unmeasured contrast to a remote reference. Published rotation curves for DDO 154, NGC 2403, and NGC 7814 require inner-to-outer power deficits of 0.0632, 0.990, and 4.28 parts per million, respectively. These are inferred ratios, not direct power measurements. A selected finite response profile gives an excess circular-speed contribution that rises near the centre, is approximately flat over an intermediate range, and declines at large radius. With fixed ordinary-matter models and a prescribed outer turnover, its two fitted parameters give reduced chi-square values of 1.24, 19.69, and 0.70. The profile describes DDO 154 and NGC 7814 at the level of the adopted errors but fails to reproduce substantial structure in NGC 2403. Moving the prescribed turnover outward tenfold changes fitted speeds by less than 0.17 kilometres per second while substantially changing the inferred outer contrast. Finally, interference bounds quantify minimum equivalent amplitude changes and coherence requirements. The results specify the spatial power variations and reception changes that a microscopic scattering model would have to reproduce; the source of the excess response remains undetermined.

Keywords: Operational Quantum Gravity; galactic rotation curves; supporting power; ambient stress stiffness; collective scattering; asymptotic boundary conditions

1 Introduction

In Operational Quantum Gravity (OQG), matter reaches equilibrium through balanced exchange with its shared electromagnetic environment. Scattering by surrounding matter changes that exchange and can reduce the power available to sustain the receiving state. The resulting material adjustment changes recoverable energy, clock frequency, dimensions, and motion. The latest power-balance construction [3] establishes the linked ratios for a specified family of corresponding states and derives geodesic propagation from the material Hamiltonian. Its physical hypothesis is direct: the loss of available supporting power is the source of gravity.

A rotation curve plots orbital speed against distance from a galaxy's centre. For motion treated as approximately circular, these speeds determine the inward acceleration across the measured interval. Baryonic matter here means the ordinary gas and stars included in the adopted mass model. Comparing their calculated contribution with the observed motion identifies the excess gravitational response conventionally attributed to dark matter. The present paper expresses the total, baryonic, and excess responses as supporting-power ratios under the OQG correspondence. It does not identify the source of the excess, predict dark matter, or show that dark matter is unnecessary.

The earlier constitutive reconstruction [2] supplied this inverse map from motion to relative material response. We develop it with an explicit outer reference and a selected spatial profile whose derivative gives a rotation curve for comparison with the observations. The objective is to make the required power variation quantitative, including the scattering-induced losses that would be needed to realize it within the OQG interpretation.

An absolute comparison requires a reference beyond the measured galaxy. A larger intergalactic stiffness, and a still larger limiting stiffness in a remote region, would change the power ratio assigned to every inner point. These would be values of the same material response, if the global solution admits them. The last measured radius supplies a useful local comparison point, while the contrast beyond it remains unknown. We retain that outer contrast explicitly; a hypothetical limiting state is not treated as an observed region.

The construction has two complementary uses. First, integrating the observed motion determines the relative power variation that must be explained. Second, selecting a mathematical power profile and differentiating it tests whether that profile can reproduce the observed speeds. We perform both calculations for three published rotation curves and report the successes and failures of a deliberately simple response family. Its fitted parameters describe requirements on a future collective calculation; they are not predictions from the constituent matter. The final interference analysis expresses the same requirements as changes in received electromagnetic exchange.

2 Supporting power and ambient stiffness

We first compare the same complete material system in different equilibrium environments. The comparison standards are one fixed set of clocks, rulers, and units used throughout that comparison. Let P be its balanced supporting power and P_0 the power in a fixed reference state. Each is a positive exchange rate: incoming power equals outgoing power at an equilibrium endpoint, so the net power is zero even though the exchange itself is nonzero. Let E_{rest} and E_0 denote the complete rest energies in those states. Define f as the common ratio of corresponding transition frequencies and rest energies, and b as the ratio of corresponding material lengths. The dimensionless power ratio p then follows from the supporting-power theorem of Ref. [3]:

$$p \equiv \frac{P}{P_0} = f^2, \quad \frac{E_{\text{rest}}}{E_0} = f = \sqrt{p}. \quad (1)$$

Equation (1) says that power changes as the square of the clock-frequency factor, while complete rest energy changes as that factor itself. Thus the square root of the power ratio gives the energy ratio. The theorem compares matched equilibrium states with fixed charge and corresponding current profiles, spectra, energy-loss channels, frequency cutoffs, and correlations. These conditions preserve the dimensionless response and the radiation resistance at corresponding frequencies. Scaling the current spectrum and its frequency measure then supplies the factor f^2 in power.

Subscript 0 will denote the same fixed reference state for all quantities, including stiffness, propagation speed, gravitational coupling, permittivity, permeability, and temperature. If T and T_0 are the current and reference temperatures, the finite-temperature correspondence is $T = f T_0$. The power result is a theorem for the stated family of corresponding states. Its identification with the electromagnetic realization of gravity is the OQG hypothesis adopted here.

Write $A = A_{2,E}^{\text{tot}}$ for the full ambient stress stiffness used in Ref. [3]. It measures the response cost of a slowly varying shear pattern in the retained stress sector. Technically, it is the coefficient of the quadratic gradient term in the completed transverse, traceless response: the deformation is transverse to its spatial wave vector and has no trace, or isotropic part. This coefficient has units of energy squared and is distinct from a bulk compression modulus. Its definition retains both the reference ambient contribution and the matched material contributions. The index E labels the Euclidean response convention; cosmic epoch will be written separately as t_* . Let c be propagation speed in the fixed comparison standards, G the gravitational coupling, and $\hbar$ the reduced Planck constant. The adopted branch keeps $\hbar$ and the combination $\kappa = G/c^4$ invariant across the compared states. Its normalization, inherited from the calibrated branch in Ref. [3], is

$$A = \frac{\hbar c^5}{32\pi G}, \quad \kappa \equiv \frac{G}{c^4} = \text{constant}, \quad \frac{A}{A_0} = \frac{c}{c_0} = fb. \quad (2)$$

Equation (2) connects stiffness, propagation speed, and gravitational coupling. Paper 56 uses that normalization; it does not independently determine the absolute gravitational coupling. The common material branch is the family for which the clock factor and corresponding length factor are equal, $f = b$. Let ϵ and μ denote the electric permittivity and magnetic permeability, which describe electric and magnetic field response. On this branch, Eq. (1) makes $f b = p$, so

$$\frac{A}{A_0} = \frac{c}{c_0} = p, \quad \frac{\epsilon}{\epsilon_0} = \frac{\mu}{\mu_0} = p^{-1}, \quad \frac{G}{G_0} = p^4. \quad (3)$$

The dependencies in Eq. (3) are different but linked. Stiffness and propagation speed follow the power ratio directly. Permittivity and permeability follow its reciprocal, while the gravitational coupling follows its fourth power. Equal changes of permittivity and permeability preserve wave impedance, the electric-to-magnetic field ratio for propagation. The corresponding material capacitance and inductance each scale as $p^{-1/2}$. The full stiffness is essential: a calculated change in stiffness alone cannot replace the total coefficient. All these comparisons use the same fixed standards rather than separately rescaled local units.

The energy relation also determines reversible work. Label two equilibrium positions by 1 and 2, with power ratios p_1 and p_2 . Let $W_{1 \rightarrow 2}$ be the external work required for reversible adiabatic displacement between them in a static environment, and F_{rest} the force associated with the position-dependent rest energy. The gradient ∇ measures how a quantity changes with position in the comparison coordinates. Equation (1) gives

$$W_{1 \rightarrow 2} = E_0 (\sqrt{p_2} - \sqrt{p_1}), \quad F_{\text{rest}} = -E_0 \nabla \sqrt{p}. \quad (4)$$

Equation (4) compares the stored energies at the two positions. The force points toward lower stored energy and therefore toward lower supporting power. The moving-body dynamics are supplied by the material Hamiltonian in Ref. [3]. At a stationary endpoint, the lower balanced exchange is compatible with constant stored energy. During displacement, applied work and transient exchange account for the change. The deficit is a difference between equilibria, rather than a continuous drain of a star's rest energy or an orbital drag power.

The independent clock and ruler factors must be retained outside the common branch. In the exact Schwarzschild construction of Ref. [3], $p = f^2$ still holds while $A/A_0 = fb$; these expressions need not be

equal. The galactic reconstruction uses a weak, quasistatic common response, meaning a small spatial variation that changes slowly on the timescale of the local comparison. The equality applies to the retained weak-field order. Exponentiating its integral preserves positive ratios without establishing higher-order dynamics. Within these conditions, one relative power change fixes the corresponding energy and material-response changes.

3 One power field from the galaxy to infinity

We next connect a measured local power comparison to a possible remote reference. At position x and a chosen cosmic epoch t_* , let $P_\infty(t_*)$ and $A_\infty(t_*)$ denote the limiting supporting balance and stiffness, if the global solution admits such a limit. Define p_∞ as the local-to-limiting power ratio and τ as its logarithmic contrast:

$$p_\infty(x; t_*) \equiv \frac{P(x; t_*)}{P_\infty(t_*)}, \quad \tau(x; t_*) \equiv -\ln p_\infty(x; t_*). \quad (5)$$

The symbol $\ln$ denotes the natural logarithm. Its inverse is the exponential, so $p_\infty = \exp(-\tau)$. These are two representations of the same comparison. A positive τ means less local support than at the reference; the fractional shortfall is $1 - \exp(-\tau)$ and is approximately τ only when the contrast is small. Within the common branch, $A/A_\infty = p_\infty$. A stiffer reference therefore has a larger supporting balance in the same standards. The limiting reference may lie beyond the observable domain in a proposed global model. The visible horizon itself supplies no material boundary condition, and no power or stiffness value beyond it is assumed to have been measured.

Let r be distance from the galaxy's centre and r_m its last measured radius. Define $q(r; r_m) = P(r)/P(r_m)$ as the local power comparison and $\tau_m = -\ln[P(r_m)/P_\infty]$ as the unmeasured outer contrast. Comparing the inner position with the last measured point, then comparing that point with infinity, multiplies the two power ratios. In logarithmic form the same successive comparisons add:

$$p_\infty(r) = e^{-\tau_m} q(r; r_m), \quad \tau(r) = \tau_m - \ln q(r; r_m). \quad (6)$$

This identity holds independently of the weak-field approximation used to infer q . It also permits successive comparisons between a galaxy, its group, an intergalactic environment, and a global reference. Their power ratios multiply and their logarithmic contrasts add. A change of comparison point therefore preserves the underlying field.

To connect this comparison to motion, let Φ be gravitational potential energy per unit reference mass and $g = -\nabla\Phi$ the acceleration field. In a weak static coordinate description calibrated by speed c_0 , the rest-energy change in Eq. (4) gives $\ln(P/P_0) \approx 2\Phi/c_0^2$, up to the chosen reference constant. This is the leading-order relation between fractional supporting-power variation and gravitational potential. Taking its spatial gradient gives

$$g \approx -\frac{c_0^2}{2} \nabla \ln(P/P_0) = \frac{c_0^2}{2} \nabla \tau. \quad (7)$$

Equation (7) directs acceleration toward lower supporting power. The derivative of the logarithmic ratio is the fractional power gradient, $\nabla P / P$, and is unchanged by a fixed normalization. A larger outer reference changes the inferred depth of the power field; its local slope determines acceleration. If a different epoch state changes the equilibrium response itself, its spatial profile must be calculated in that state. Adding only a constant outer contrast τ_m leaves the existing rotation curve unchanged.

For an axisymmetric disk, take r in the disk plane and let v_c be circular speed. Circular motion requires inward acceleration of magnitude v_c^2 / r , which explains the squared speed in the following relation. Define $s_p(r)$, with units of inverse length, as the outward fractional power gradient:

$$s_p(r) \equiv \frac{d}{dr} \ln(P / P_0) = -\frac{d\tau}{dr}, \quad v_c^2(r) \approx \frac{c_0^2}{2} r s_p(r). \quad (8)$$

Positive s_p means that supporting power increases outward and the associated acceleration points inward. A stronger inward acceleration at a fixed radius requires a larger gradient. In the OQG interpretation this is a larger spatial change in the scattering-induced reduction of supporting exchange. The required quantity is the net response, including interference; the local number of scatterers alone does not determine its sign or strength.

If one weak static radial coordinate description extends to a finite asymptotic reference, the local gradients can be accumulated outward. In the integrals below, s is the running radius and ds / s is a fractional radial interval. Equation (8) then gives

$$\tau(r) \approx \frac{2}{c_0^2} \int_r^\infty v_c^2(s) \frac{ds}{s}, \quad \tau_m \approx \frac{2}{c_0^2} \int_{r_m}^\infty v_c^2(s) \frac{ds}{s}. \quad (9)$$

In Eq. (9), $v_c^2(s) = s d\Phi / ds$ denotes the radial force function, including where no orbiting tracers have been measured. The integral adds its contribution from the selected radius to infinity. A nonzero flat curve continued forever makes this accumulation diverge. A finite limiting ratio therefore requires an outer change of profile or a different cosmological matching prescription. Section 5 supplies a smooth finite continuation as a model choice.

On larger scales the environment is generally nonspherical and time dependent. Within a conservative weak static region, label two positions 1 and 2. Their power comparison is $\ln[P(2) / P(1)] = -\left(2 / c_0^2\right) \int_1^2 \mathbf{g} \cdot d\boldsymbol{\ell}$, where $d\boldsymbol{\ell}$ is a directed path element. The integral accumulates the component of acceleration along the path; it is path-independent only for a conservative field. Galaxy-centred rotation data constrain internal acceleration after the centre's acceleration is removed, rather than the entire external field or its tidal variation. Applying the map across cosmological regions requires matched clocks, rulers, epochs, and response fields. The ratio composition in Eq. (6) remains exact even when a single Newtonian integral to infinity is inapplicable. Thus inner rotation measurements determine local variation, while the level relative to infinity requires additional outer information.

4 Power contrasts reconstructed from observed motion

We now work backward from measured motion to the required relative supporting power. Let $v_{\text{obs}}(r)$ denote the circular speed inferred from the observations under the adopted kinematic model. The subscript obs labels that observational reconstruction. Define ℓ_{obs} as its accumulated logarithmic contrast between r and r_m , q_{obs} as the corresponding power ratio, and D_{obs} as the fractional power deficit. Squared speeds are accumulated over fractional radial intervals and the exponential converts the resulting contrast to a positive ratio:

$$\ell_{\text{obs}}(r; r_m) = \frac{2}{c_0^2} \int_r^{r_m} v_{\text{obs}}^2(s) \frac{ds}{s}, \quad q_{\text{obs}} = e^{-\ell_{\text{obs}}}. \quad (10)$$

$$D_{\text{obs}} = 1 - q_{\text{obs}}, \quad \frac{P(r)}{P(r_m)} \simeq q_{\text{obs}}, \quad \tau(r) \simeq \tau_m + l_{\text{obs}}(r; r_m). \quad (11)$$

Equation (11) obtains the fractional shortfall by subtracting the ratio from one. Positive squared speed makes supporting power lower inward. Setting $q_{\text{obs}}(r_m) = 1$ establishes the local comparison, while $P(r_m)/P_\infty = \exp(-\tau_m)$ remains unspecified. The full deficit relative to infinity is $1 - \exp[-\tau_m - \ell_{\text{obs}}]$. The stiffness ratio on the common branch uses the same reference convention. These quantities are inferred through the adopted correspondence, not direct measurements of received power.

For a flat rotation curve with constant speed v_f over a finite interval, the squared speed can be taken outside the integral. The remaining fractional-radius integral is a logarithm, giving

$$q_{\text{obs}}(r; r_m) = \left(\frac{r}{r_m} \right)^{2v_f^2/c_0^2}, \quad l_{\text{obs}} = \frac{2v_f^2}{c_0^2} \ln \frac{r_m}{r}. \quad (12)$$

A radial decade means a tenfold increase in radius. A speed of 200 km/s across one decade gives a power deficit of 2.05 parts per million (ppm), where one ppm is 10^{-6} of the specified reference. A large excess over the baryonic acceleration can therefore correspond to a small fractional power contrast. Flat speed requires a fractional power gradient proportional to inverse radius over that interval; Eq. (12) states the resulting ratio without assigning its physical source.

The baryonic comparison uses the measured distributions of ordinary gas and stars. Let Φ_{bar} be their model potential and $v_{\text{bar}}^2 = r d\Phi_{\text{bar}}/dr$ their signed radial force contribution. Despite the squared-speed notation, this contribution may be negative where the modeled force points outward. We use the Spitzer Photometry and Accurate Rotation Curves database (SPARC) [6]. Its components V_g , V_d , and V_b encode the gravitational contributions of gas, stellar disk, and bulge; they are not three independently observed orbital speeds. The stellar components are tabulated for unit mass-to-light ratio. Multiplying their signed squared contributions by the adopted disk and bulge ratios Y_d and Y_b rescales them to the chosen stellar masses. These ratios refer to 3.6-micrometre luminosity and are expressed in solar mass per solar luminosity in that band:

$$v_{\text{bar}}^2 = V_g |V_g| + Y_d V_d |V_d| + Y_b V_b |V_b|, \quad Y_d = 0.5, \quad Y_b = 0.7. \quad (13)$$

The product of each component with its absolute value preserves the sign of its radial force. The gas term already includes SPARC's factor of 1.33 for helium. Applying the same fractional-radius integration as in Eq. (10) gives the baryonic logarithmic contrast ℓ_{bar} and power ratio $q_{\text{bar}} = \exp(-\ell_{\text{bar}})$. The excess, labelled X , is the part of the required contrast remaining after this adopted comparison. Its logarithmic contrast ℓ_X , ratio q_X , and deficit D_X are

$$l_X \equiv l_{\text{obs}} - l_{\text{bar}}, \quad q_X \equiv \frac{q_{\text{obs}}}{q_{\text{bar}}} = e^{-l_X}, \quad D_X \equiv 1 - q_X. \quad (14)$$

To obtain ℓ_X , the integrand is $2(v_{\text{obs}}^2 - v_{\text{bar}}^2)/c_0^2$ with measure ds/s . Subtracting logarithmic contrasts is equivalent to dividing power ratios. Fractional deficits do not simply add, because the excess ratio is referred to the baryonic comparison. Multiplying its deficit by q_{bar} converts it to the common outer reference:

$$D_{\text{obs}} = D_{\text{bar}} + q_{\text{bar}} D_X, \quad D_{\text{bar}} \equiv 1 - q_{\text{bar}}. \quad (15)$$

This decomposition yields total, baryonic, and excess relative-power profiles over the measured interval. It compares one observed response with a specified baryonic reconstruction, without adding a second physical field or allocating emitted luminosity among galaxy components. A negative local discrepancy changes the slope of the cumulative excess and is retained. If the cumulative excess itself is negative, $q_X > 1$ means enhancement relative to the adopted baseline. The excess is a reconstruction target; its definition makes no claim about the existence, composition, or replacement of dark matter.

5 A finite forward model of the collective response

We next test whether a simple, finite spatial profile can represent the required excess. Let $s_X(r)$ be the modeled excess logarithmic power gradient, with units of inverse length. It describes the gradient left after the adopted baryonic comparison. Let $V_s > 0$ be a speed scale controlling its strength, $r_c > 0$ an inner response radius controlling where the rise levels off, and $R_t > r_c$ an outer turnover radius controlling where the flat contribution begins to decline. Define the dimensionless strength $\alpha = 2V_s^2/c_0^2$ and prescribe

$$s_X(r) = \alpha \frac{r}{r^2 + r_c^2} \frac{R_t}{\sqrt{r^2 + R_t^2}}. \quad (16)$$

The first radial factor grows from zero at the centre and becomes proportional to $1/r$ beyond r_c . The second factor changes the large-radius gradient to $1/r^2$, making its total contrast to infinity finite. This is a specified mathematical profile whose parameters are fitted to the data. Its form is selected to test these radial behaviours, rather than derived from individual-dipole intensity or nuclear spectra. Its success would establish a useful representation of the required response, not its microscopic origin.

Proposition 1. The excess profile in Eq. (16) has a finite nonnegative logarithmic contrast to infinity. Its circular-speed contribution rises linearly near the centre and decreases in proportion to the inverse square root of radius at sufficiently large distance. When the inner and outer response radii are well separated, the excess contribution is approximately constant between them. These statements concern the excess contribution alone; the total curve also includes the separately supplied baryonic term.

To evaluate the accumulated excess, introduce the positive auxiliary length $d = \sqrt{R_t^2 - r_c^2}$. The inverse hyperbolic sine is a compact logarithmic function, $\text{arsinh } z = \ln(z + \sqrt{1 + z^2})$, with dimensionless argument z . Direct integration of the gradient from the chosen radius outward gives the excess logarithmic contrast τ_X :

$$\tau_X(r) \equiv \int_r^\infty s_X(s) ds = \alpha \frac{R_t}{d} \text{arsinh} \frac{d}{\sqrt{r^2 + r_c^2}}. \quad (17)$$

Differentiating Eq. (17) recovers $-d\tau_X/dr = s_X$, so its slope is exactly the prescribed gradient. Its value is finite at the centre and approaches zero at infinity. Let v_X denote the circular-speed contribution associated with this modeled excess, and v_{model} the total model speed. Equation (8) gives

$$v_X^2(r) = V_s^2 \frac{r^2}{r^2 + r_c^2} \frac{R_t}{\sqrt{r^2 + R_t^2}}, \quad v_{\text{model}}^2 = v_{\text{bar}}^2 + v_X^2. \quad (18)$$

Squared-speed contributions add because the corresponding radial accelerations add at the same radius. The total expression is used where $v_{\text{model}}^2 \geq 0$, as required for a real circular speed. Near the centre, $r \ll r_c$ gives $v_X \approx V_s r/r_c$, a linear rise. Between well-separated scales, $r_c \ll r \ll R_t$ gives $v_X \approx V_s$, an approximately flat contribution. Far outside the turnover, $r \gg R_t$ gives $v_X^2 \approx V_s^2 R_t/r$ and $\tau_X \approx \alpha R_t/r$. The resulting speed decreases as the inverse square root of radius, conventionally called a Keplerian decline. These limits prove Proposition 1 and show how the excess can have a flat intermediate region without an infinite accumulated contrast.

A further check translates the excess acceleration into a familiar mass representation. Define $M_X(r) = r v_X^2 / G_0$, where G_0 is the gravitational coupling in the reference state. This is the mass that a spherical distribution would need to enclose to produce the same excess acceleration in the Einstein-equivalent weak-field description. It does not identify the source's composition or establish that the actual galaxy is spherical. The profile gives

$$M_X(r) = \frac{V_s^2 R_t}{G_0} \frac{r^3}{(r^2 + r_c^2) \sqrt{r^2 + R_t^2}}, \quad M_X(\infty) = \frac{V_s^2 R_t}{G_0}. \quad (19)$$

Its logarithmic derivative is $3/r - 2r/(r^2 + r_c^2) - r/(r^2 + R_t^2) > 0$ for positive radius. Thus this equivalent enclosed mass increases outward to a finite limit, and the corresponding spherical density is nonnegative. These are consistency checks on the selected profile. The additional acceleration remains present in the macroscopic description, with its physical source left open.

For comparison with the observed interval, subtract the modeled contrast at the last measured radius from the modeled contrast at the selected inner radius. This places the model on the same local reference as the data. Define the resulting excess logarithmic contrast and power ratio by

$$l_{X,\text{model}}(r; r_m) = \tau_X(r) - \tau_X(r_m), \quad q_{X,\text{model}} = e^{-l_{X,\text{model}}}. \quad (20)$$

The full ratio to infinity also needs the baryonic outer potential and the environmental continuation. In a weak approximately radial decomposition, write $\tau = \tau_{\text{bar}} + \tau_X + \tau_{\text{env}}$. Here τ_{bar} is the baryonic logarithmic contrast to the same limiting reference, and τ_{env} is the remaining environmental contribution, including any broader epoch-dependent reference. These are additive contributions to the logarithm of one power field. Their values at r_m contribute to τ_m ; their spatial variations also enter acceleration. The fits below neglect differential external effects within the measured disk. They leave the environmental level and total ratio to infinity undetermined.

The outer turnover has a separate role from the inner shape. At radii small compared with R_t , including $r_c \ll R_t$, Eq. (17) and the speed contribution reduce to

$$\tau_X(r) \simeq \alpha \ln \frac{2R_t}{\sqrt{r^2 + r_c^2}}, \quad v_X^2(r) \simeq V_s^2 \frac{r^2}{r^2 + r_c^2}. \quad (21)$$

Let $\lambda > 0$ multiply the outer turnover radius while the inner parameters are held fixed. In this regime, increasing R_t by that factor increases τ_X by approximately $\alpha \ln \lambda$ but changes the inner speed very little. An extended shallow gradient can therefore add integrated depth without appreciably altering the measured inner slope. The chosen family supplies two outputs: a locally testable rotation curve and a conditional outer continuation with finite integrated contrast. Local rotation data alone need not determine that continuation.

6 Data and numerical method

We use the public SPARC files [6] for the three systems in the earlier reconstruction [2]. Their underlying kinematic studies include Refs. [1, 4, 5]. Table 1 lists the sampling and geometry held fixed in the calculation. Distance is the adopted separation between observer and galaxy. Inclination is the angle between the disk normal and the line of sight, so 90 degrees describes an edge-on disk. A kiloparsec (kpc) is one thousand parsecs and a megaparsec (Mpc) is one million parsecs; one parsec is approximately 3.26 light-years. Every tabulated point is retained, with the mass-to-light ratios in Eq. (13). The examples span different baryonic structures and are not a population-level statistical sample.

Table 1. SPARC sampling and adopted geometry.

Galaxy	Points	Distance (Mpc)	Inclination	Radius (kpc)
DDO 154	12	4.04	64°	0.49–5.92
NGC 2403	73	3.16	63°	0.16–20.87
NGC 7814	18	14.4	90°	0.63–19.53

For numerical comparisons, $c_0 = 299\,792.458$ km/s is the speed in the fixed local calibration used for the galaxy reconstruction. It is not an independent measurement of c in an unobserved asymptotic state. Exact composition through Eq. (6) carries that local reconstruction to a specified outer reference. Using Eq. (9) over a global domain would additionally require its stated chart and weak-field conditions.

The numerical reconstruction follows three steps. We square the measured speeds, join adjacent values by straight segments on a logarithmic-radius axis, and add their contributions from each selected radius to the last measured point. Equation (10) then converts that sum to a relative power. Let $x_i = \ln(r_i/r_*)$, where r_* is an arbitrary fixed reference length and i labels a measured radius; write $v_i = v_{\text{obs}}(r_i)$. The index j labels each velocity input contributing to the sum. Trapezoidal weights W_{ij} specify how much of each input enters the integral beginning at sample i . The logarithmic contrast ℓ_i and its sensitivity matrix J , called the Jacobian, are

$$l_i = \frac{2}{c_0^2} \sum_j W_{ij} v_j^2, \quad J_{ij} = \frac{\partial l_i}{\partial v_j} = \frac{4 W_{ij} v_j}{c_0^2}. \quad (22)$$

Each J_{ij} measures how the reconstructed contrast at radius i changes when measured speed v_j changes. Let $\sigma_{v,j}$ be the quoted one-standard-deviation error of that speed. Treating these errors as independent gives the first-order covariance matrix Σ_ℓ , which describes both individual uncertainties and shared uncertainty between reconstructed points. The individual deficit uncertainty is $\sigma_{D,i}$:

$$\Sigma_l = J \text{diag}(\sigma_{v,j}^2) J^T, \quad \sigma_{D,i} = e^{-l_i} \sqrt{(\Sigma_l)_{ii}}. \quad (23)$$

In Eq. (23), $\text{diag}(\sigma_{v,j}^2)$ places the individual velocity variances on a matrix diagonal and puts zero elsewhere. The superscript T transposes a matrix, exchanging rows and columns. Diagonal entry $(\Sigma_\ell)_{ii}$ is the variance of one logarithmic contrast; off-diagonal entries describe how errors at different reconstructed radii move together. Shared uncertainty arises because the outward integrals reuse some of the same measured speeds. Multiplication by $\exp(-\ell_i)$ converts the logarithmic uncertainty into the deficit uncertainty.

The same logarithmic covariance applies to the excess when the baryonic model is held fixed. The full covariance matrices are retained. Quoted errors and shaded bands are one propagated standard deviation under this independent-velocity-error approximation. They exclude uncertainty in distance, inclination, stellar mass-to-light ratio, the baryonic model, and any unreported covariance of the velocity measurements. SPARC's quoted velocity errors include noncircular motions and kinematic asymmetries but exclude systematic inclination errors [6]. The error bands and fit statistics are conditional on these assumptions.

For the forward test, fix $R_t = 10 r_m$ and adjust V_s and r_c . At each observed radius, subtract the measured speed from the model speed, divide by the quoted velocity error, square the result, and sum over the points. Minimizing this error-weighted sum defines the fit:

$$\chi^2(V_s, r_c) = \sum_i \left[\frac{v_{\text{model}}(r_i; V_s, r_c, R_t) - v_i}{\sigma_{v,i}} \right]^2. \quad (24)$$

For N data points and two adjusted parameters, the nominal number of degrees of freedom is $N - 2$. The reduced statistic is $\chi^2/(N - 2)$. A value near one indicates residuals roughly the size of the adopted errors; a much larger value signals a poor fit under those assumptions. We optimize the logarithms of the positive parameters with bounds $10^{-3} < V_s < 10^4$ km/s and 10^{-5} kpc $< r_c < 0.99 R_t$, using six starting points. None of

the solutions lies near a bound, and the starting points converge to the same objective values. A second fit with $R_t = 100 r_m$ tests the outer continuation. These turnover radii are prescribed examples, not inferred galaxy or environmental sizes. No additional scatter is adjusted to make the residuals acceptable.

Small deficits are evaluated with the stable function $- \exp m 1(-\ell)$, where $\exp m 1(x) = \exp(x) - 1$, to avoid subtracting nearly equal floating-point numbers. Independent quadrature to infinity checks Eq. (17), and numerical differentiation checks its force. Further checks cover the equivalent mass's positivity, monotonicity, and finite limit; the constant-speed integral; endpoint normalization; component decomposition; covariance construction; and recovery of interval-average squared speeds. This procedure gives a reproducible reconstruction and a consistently weighted profile comparison. The numerical checks verify the implementation; the residuals test the selected profile against the observations.

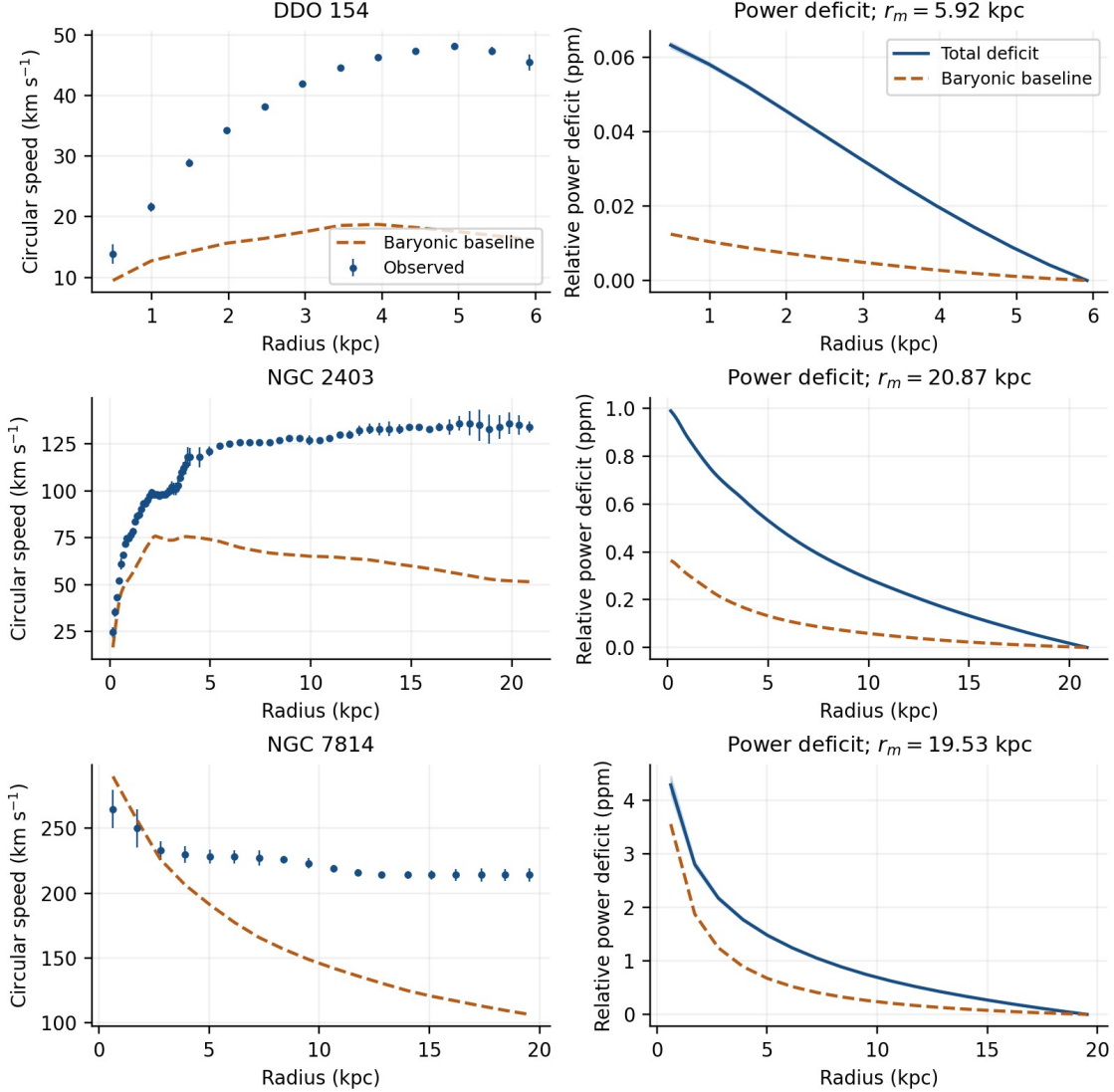


Figure 1. Observed circular speeds and reconstructed power contrasts. Left: SPARC velocities with quoted one-standard-deviation errors and the fixed baryonic baseline. Right: total and baryonic deficits relative to the last measured radius, in ppm. Shading shows one propagated standard deviation from velocity errors only. The zero deficit at r_m fixes a local comparison and leaves the outer contrast τ_m undetermined. Rows have different vertical scales. The power profiles are transformations of the observations under the adopted OQG correspondence.

7 Reconstructed contrasts and forward results

The results have three features: the required fractional power contrasts are small, their excess over the baryonic comparison depends on that baseline, and the selected profile fits two of the three galaxies at the level of the adopted errors. Table 2 reports the inner-to-outer contrasts. The total values depend on observed velocities, while the excesses also depend on the fixed ordinary-matter model. The last column is $\eta_x = 1 - \sqrt{q_x}$, the smallest equivalent coherent amplitude reduction derived in Section 8.

Table 2. Power deficits and equivalent excess amplitude reductions in ppm, evaluated at the innermost listed radius relative to the outermost listed radius in Table 1. Errors are one propagated standard deviation from velocity errors, with the baryonic model and geometry held fixed.

Galaxy	Total deficit	Baryonic deficit	Excess deficit	Excess amplitude
DDO 154	0.06320 ± 0.00072	0.01242	0.05077 ± 0.00072	0.02539 ± 0.00036
NGC 2403	0.9896 ± 0.0062	0.3639	0.6256 ± 0.0062	0.3128 ± 0.0031
NGC 7814	4.283 ± 0.158	3.551	0.732 ± 0.158	0.366 ± 0.079

The component integrals add exactly in l_{bar} . For DDO 154, gas supplies 70.33% of that contrast and the disk 29.67%. For NGC 2403 the shares are 15.70% and 84.30%. For NGC 7814 they are 0.17% gas, 9.88% disk, and 89.95% bulge. These are contributions to an integrated potential contrast, rather than total mass fractions or elemental abundances. The excess shares of the observed logarithmic contrasts are 80.34%, 63.23%, and 17.09%, respectively.

NGC 7814 has negative local squared-speed discrepancies at 0.63 and 1.72 kpc. Its cumulative excess remains positive at every interior sampled radius because the integral also includes the larger outward contributions. Figure 2 retains this structure. An everywhere attractive excess profile cannot reproduce each negative local residual exactly; the statistical fit must be judged with that restriction visible.

The forward fits in Table 3 use one response form for all three galaxies, with $R_t = 10 r_m$. The fitted quantities describe its amplitude and radial scale. They have not been predicted from the galaxy’s nuclear composition.

Table 3. Conditional forward fits with fixed baryonic models and a prescribed outer turnover. RMS is the root-mean-square velocity residual, obtained by averaging squared speed differences and taking the square root. The reduced fit statistic uses $N - 2$ nominal degrees of freedom.

Galaxy	V_s (km/s)	r_c (kpc)	R_t (kpc)	$\chi^2 / (N - 2)$	RMS (km/s)
DDO 154	50.41	2.561	59.2	1.24	1.07
NGC 2403	116.13	3.145	208.7	19.69	6.93
NGC 7814	188.96	5.557	195.3	0.70	7.44

DDO 154 and NGC 7814 have residual levels comparable to their tabulated errors under the fixed assumptions. NGC 2403 has structured residuals much larger than those errors. The same two-parameter profile therefore does not adequately describe all three galaxies. Its failure in the well-resolved spiral

identifies radial structure that must be retained in a more detailed collective calculation, or addressed through independently supported revisions to the adopted inputs. A good fit in the other two systems does not establish the microscopic origin of their response.

The fitted excess logarithmic contrasts over the measured intervals are 0.05112, 0.57027, and 1.02295 ppm. They need not equal the direct reconstructions in Table 2: the fit minimizes velocity residuals, while the reconstructed integral weights squared speed over logarithmic radius. In particular, NGC 7814's inner velocity uncertainties and locally negative discrepancy allow a low velocity-space statistic with a different cumulative contrast. The figures and reproduction tables retain both representations.

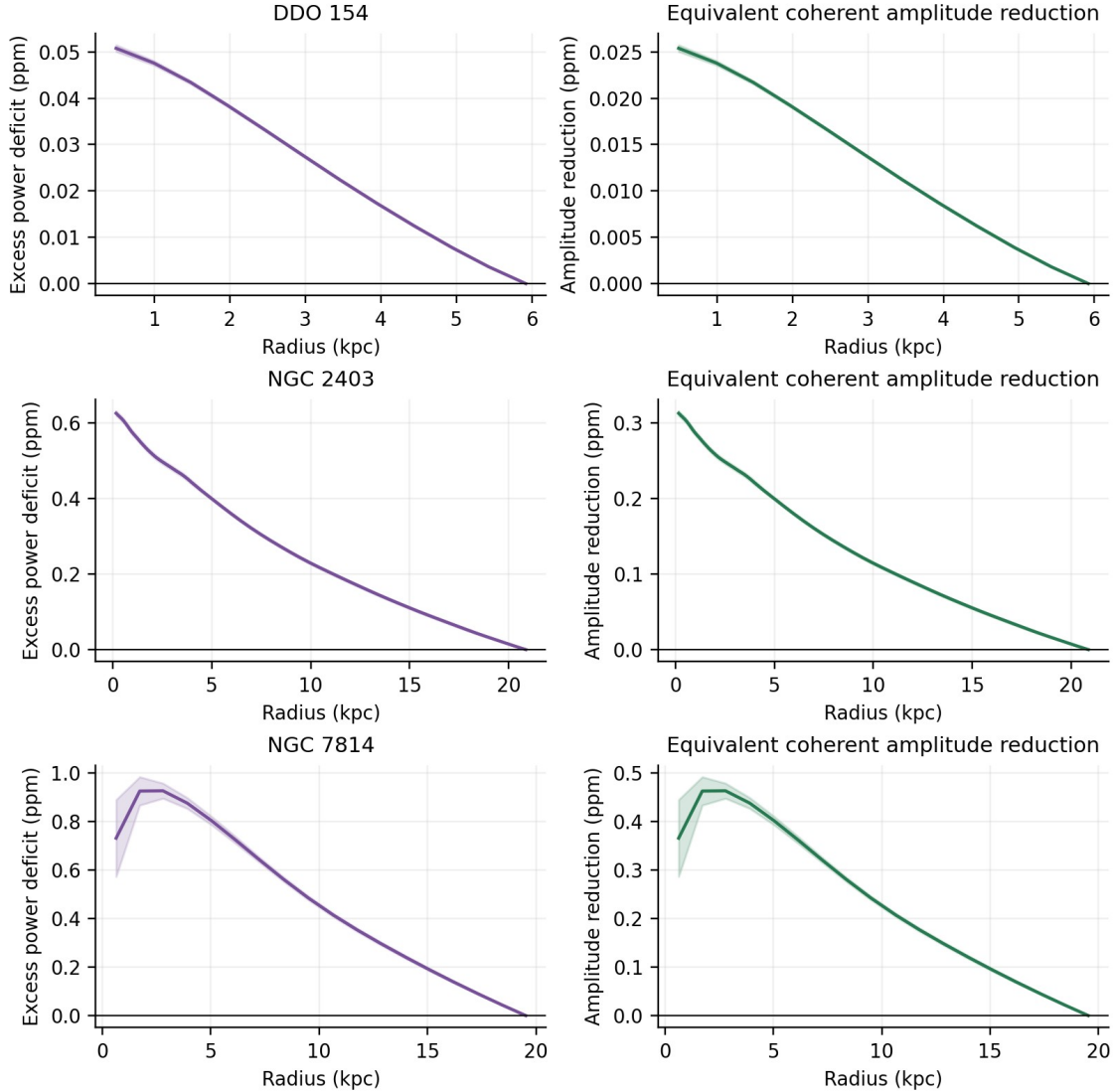


Figure 2. Reconstructed excess power deficits and equivalent coherent amplitude reductions relative to the same baryonic comparison, with all local ratios normalized at the last measured radius. The amplitude $\eta_X = 1 - \sqrt{q_X}$ is a deterministic transformation of the power ratio. Shading gives one propagated standard deviation from the adopted velocity errors. The minimum-amplitude interpretation requires the fixed reception norm in Section 8. The local normalization leaves the asymptotic stiffness unspecified.

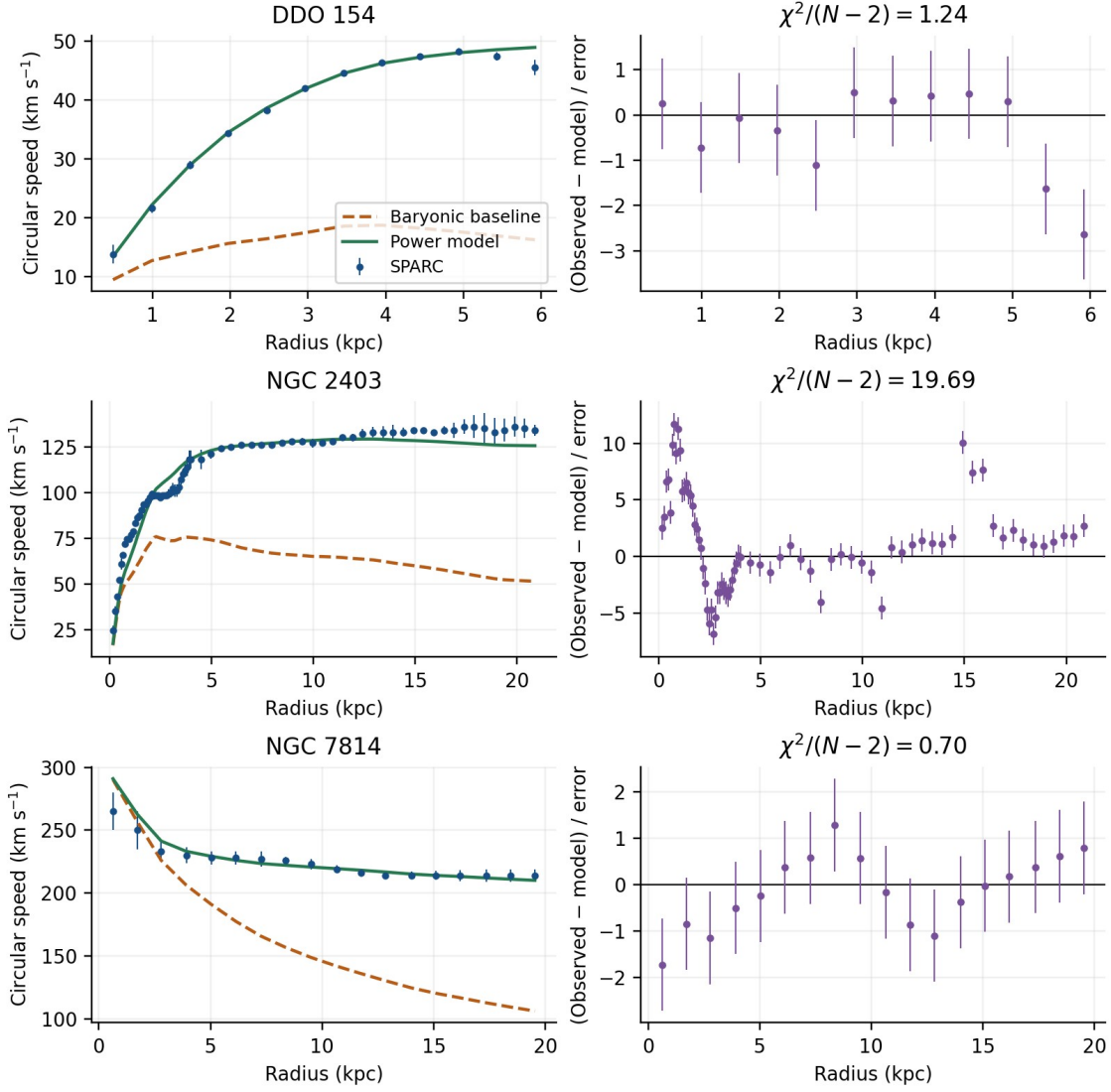


Figure 3. Forward rotation curves from the finite excess power-gradient model with $R_t = 10r_m$. Left: measured speeds with quoted one-standard-deviation errors, the fixed baryonic curve, and the two-parameter model. Right: residuals divided by the quoted velocity error, with unit error bars. NGC 2403 fails the simple profile under those errors; no added scatter parameter absorbs the mismatch.

The outer comparison changes much more than the measured speeds when the prescribed turnover is moved outward. Table 4 gives the model's excess contribution $\tau_x(r_m)$ to the logarithmic deficit from the last measured radius to infinity. It does not include the baryonic or remaining environmental contributions and is not the total τ_m .

Table 4. Modeled excess logarithmic contrast beyond the last measured radius, $\tau_X(r_m)$, for two prescribed outer continuations. These entries exclude baryonic and other environmental contributions and are not the total outer contrast τ_m . Both fits readjust V_s and r_c ; the last column gives the largest fitted-speed change at measured radii. A logarithmic contrast is approximately a fractional deficit only when small.

Galaxy	$\tau_X(r_m)$ ppm at $10 r_m$	$\tau_X(r_m)$ ppm at $100 r_m$	Maximum speed change (km/s)
DDO 154	0.1648	0.2935	0.035
NGC 2403	0.8965	1.5837	0.168
NGC 7814	2.3521	4.1620	0.121

These are conditional model continuations, not measurements outside the observed interval. They make the reference issue quantitative: nearly unchanged inner rotation curves can accompany different ratios to a stiffer remote environment. For NGC 2403 the outer excess changes by about 0.687 ppm, even though the largest fitted-speed change is only 0.168 km/s. Both versions retain the inner fit failure. Figure 4 displays their asymptotic and local contrasts side by side.

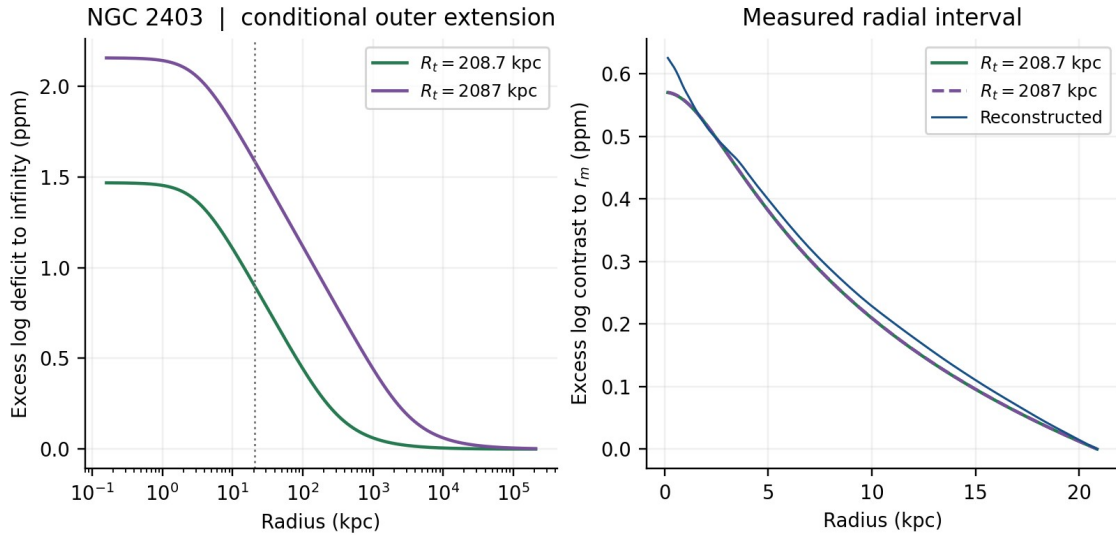


Figure 4. Two outer continuations of the supporting-power response for NGC 2403. Left: modeled excess logarithmic contrast to infinity; the vertical dotted line marks the last measured radius. Right: the corresponding local contrasts and the reconstructed excess. These are alternative profiles of one field, with prescribed extensions beyond the data. Both have finite outer limits and nearly unchanged local contrasts, while their excess levels relative to infinity differ.

8 Connecting the power profile to scattering

The reconstructed ratios specify what a scattering calculation would have to produce. We now express that requirement in terms of received exchange and interference. A material mode is a retained pattern of fluctuating charge and current. Let ν be angular frequency in radians per second, $R(\nu)$ the dissipative resistance matrix for these mode coordinates, and $S_Q(\nu)$ their two-sided symmetrized charge spectral matrix. The latter describes the frequency content and correlations of charge fluctuations, with the operator ordering averaged symmetrically. Its subscript Q labels charge; it is separate from the scalar power ratio Q introduced below. The resistance specifies the outward power associated with the current patterns. With Tr denoting the trace, or the sum of diagonal mode contributions after matrix multiplication, the balanced outward power in Ref. [3] is

$$P = \int_{-\infty}^{\infty} \frac{d\nu}{2\pi} \nu^2 \text{Tr}[R(\nu)S_Q(\nu)] = P_{\text{in}}. \quad (25)$$

Equation (25) sums exchange power across the retained modes and frequencies. The squared-frequency factor converts charge fluctuations into current fluctuations. Negative frequencies are part of the two-sided spectral convention, not negative power. At equilibrium, the result equals the incoming power P_{in} . Nuclear excitation spectra and transition currents determine the material response; the shared retarded field and its correlations determine the coupled state. Retarded means that a response follows its source causally. Radiation reaction and compensating fluctuations must enter that same calculation, consistently with storage and recoverable force. The ambient or epoch environment supplies boundary statistics and the matched material state.

Interference can reduce received power even though the added amplitude has a positive intensity of its own. To quantify this, compare amplitudes in one fixed positive reception norm: a measure of amplitude size weighted by the receiver's response and the spectral channels being counted. The amplitudes below already include those weights, so their ordinary squared norm measures relative received power and their ordinary inner product uses the same weighting. Let u be a reference amplitude normalized by $\langle \|u\|^2 \rangle = 1$, and s an added amplitude. Angle brackets denote the corresponding statistical and channel average. Define its relative intensity $\beta^2 = \langle \|s\|^2 \rangle$ and the complex correlation $C = \langle u^\dagger s \rangle$, where the dagger means conjugate transpose. The total power ratio is

$$Q = \langle \|u + s\|^2 \rangle = 1 + \beta^2 + 2 \text{Re} C, \quad |C| \leq \beta. \quad (26)$$

In Eq. (26), the three terms are reference power, added-amplitude intensity, and interference. The operation Re selects the real part of the complex correlation; its sign determines whether interference adds to or subtracts from received power. The bound $|C| \leq \beta$ limits that correlation for a unit reference amplitude. A deficit $D = 1 - Q > 0$ requires negative interference large enough to outweigh the positive added intensity. An uncorrelated addition has $C = 0$ and cannot produce such a deficit in this representation. The reverse triangle inequality then gives a minimum amplitude change for any specified power ratio:

$$\beta \geq |1 - \sqrt{Q}|. \quad (27)$$

Equation (27) states that the amplitude change cannot be smaller than the difference between the square roots of the compared powers. For $0 < Q < 1$, the minimum is reached when the added amplitude is fully correlated with the reference and opposite in phase, so it cancels part of that reference in every retained channel. Write $s = -\eta u$, with $\eta = 1 - \sqrt{Q}$. The remaining amplitude is $1 - \eta$, and squaring it gives the power ratio:

$$Q = (1 - \eta)^2, \quad D = 2\eta - \eta^2, \quad \beta_{\min} = \eta \approx \frac{D}{2}. \quad (28)$$

The label min denotes the smallest possible value of β in this norm. For a small deficit, $D \ll 1$, the minimum coherent amplitude reduction is approximately half the fractional power deficit. Treating D itself as an added-amplitude magnitude would miss the direct-scattered interference contribution.

For the numerical comparison, take $Q = q_x$. The baryonic reconstruction supplies the reference comparison and the observed reconstruction supplies the total comparison, with both normalized at the same outer radius. Their quotient is represented in the same receiver-weighted norm. The resulting amplitude is the smallest equivalent change capable of producing that ratio; the baryonic baseline has not been constructed as a microscopic receiver state. At the inner endpoints used in Table 2, the minimum coherent intensities η_x^2 are 6.44×10^{-16} for DDO 154, 9.79×10^{-14} for NGC 2403, and 1.34×10^{-13} for NGC 7814, each relative to its corresponding reference power. These are requirements for a microscopic model to reproduce, rather than observed luminosities or predicted nuclear cross sections. If $q_x > 1$, the minimum is instead the constructive amplitude magnitude $\sqrt{q_x} - 1$.

Partial coherence means that the added and reference amplitudes have less than perfect normalized correlation. For $\beta > 0$, define the coherence magnitude $\gamma = |C|/\beta$, with $0 \leq \gamma \leq 1$, and let θ be the phase of C , describing their relative oscillatory alignment. The real interference term depends on both that correlation strength and its phase:

$$Q = 1 + \beta^2 + 2\gamma\beta \cos \theta, \quad D \leq 2\gamma\beta - \beta^2 \leq \gamma^2. \quad (29)$$

Equation (29) shows that a given positive deficit requires $\gamma \geq \sqrt{D}$ in this representation. Even the most favourable phase cannot compensate for insufficient correlation. The norm bound is a necessary requirement, not proof that a passive configuration reaches its equality case. Passivity means that the responding arrangement supplies no independent gain; its response equations, energy balance, and available channels impose additional conditions.

The reception norm also determines which amplitude is being compared. In the supporting-power theorem, the matched radiation resistance permits current or response-weighted exchange amplitudes to be expressed in a common reference norm. Their squared-norm ratio is p . Raw local electric and magnetic field amplitudes at corresponding coordinates instead scale as f/b , while the integration area scales as b^2 . On the common branch those raw field amplitudes are unchanged by the mapping, yet integrated supporting power scales as b^2 . The equivalent amplitude reduction in Eq. (28) therefore concerns received power in the stated norm and cannot be read as a universal reduction of local electric or magnetic field strength.

The resonant-dipole calculation in Ref. [3] demonstrates an explicit negative interference contribution and a 0.07546395% reduction of receiver absorption at its specified parameters. That fixed-receiver example establishes a sign mechanism. Its far-field absorbed-power deficit begins at inverse-square order, while its force integrates to an inverse-distance interaction potential. Neither result independently determines the stationary nuclear supporting-power profile of a galaxy. A collective calculation must make that connection

with the same response used for storage and force. Counting independent scattering intensities, or treating S_X as an ordinary opacity, would omit that requirement. This section supplies necessary equivalent-amplitude and coherence conditions; it does not identify the physical source of the reconstructed excess.

9 Physical interpretation and further constraints

The construction separates what rotation data determine from what additional physical information must supply. Equation (6) embeds a galaxy's measured contrast in its larger environment, and the full stiffness on the common branch follows the same power ratio. A stiffer intergalactic region or a still stiffer limiting state can add to the outer contrast. Their values require environmental observations or a global response solution. The three rotation curves constrain the radial changes within their measured domains.

The excess over the adopted baryonic comparison remains the gravitational discrepancy conventionally attributed to dark matter. Expressing it as a supporting-power requirement does not establish an ordinary-matter mechanism for it, identify dark matter as a scatterer, or exclude dark matter. The reconstruction can be used as a quantitative target without choosing among those unresolved physical possibilities.

Galaxy composition enters the calculation at two different levels. Observed gas, disk, and bulge distributions determine the adopted baryonic baseline. A microscopic source calculation would additionally require nuclear species, excitation spectra, current form factors describing their spatial structure, and correlations in Eq. (25). A gas-dominated dynamical component alone does not specify a different nuclear coupling. Independent material and environmental inputs would have to determine V_s , r_c , and R_t , or a more detailed profile, before the rotation curve became a prediction of that source calculation. Here the observations set the reconstructed requirements and constrain the selected profile's fitted parameters.

Uncertainty in the baseline directly affects the excess. A larger stellar mass-to-light ratio assigns more mass, and therefore more calculated gravitational pull, to the same observed light. With geometry fixed, increasing the adopted bulge ratio for NGC 7814 by 10% raises its baryonic logarithmic contrast by about 0.319 ppm, approximately 44% of the reconstructed excess. A uniform distance rescaling leaves the observed fractional-radius integral unchanged at corresponding angular samples, but changes the baryonic squared-speed contributions and physical length scales. If i denotes disk inclination, deprojected squared speeds vary approximately as $1/\sin^2 i$. A larger sample analysis must propagate these effects and their shared uncertainties before interpreting the conditional bands as a complete error budget.

Other observations can constrain parts of the response that inner rotation curves leave open. Escape speed v_{esc} is the minimum speed needed to reach infinity with zero remaining speed in a static isolated system. With potential zero at infinity, the weak-field relation is $v_{\text{esc}}^2 = -2\Phi$, giving $\tau \approx v_{\text{esc}}^2/c_0^2$ in the same reference coordinates. Escape measurements therefore constrain integrated depth. Clock comparisons constrain the energy factor through $P_2/P_1 = (f_2/f_1)^2$, where labels 1 and 2 refer to the compared states, provided motion and signal-propagation effects are included consistently. Gravitational lensing, the deflection and focusing of light, tests the fuller propagation response. External dynamics constrain the surrounding field and its tides. Each probe adds a distinct requirement beyond the rotation-curve reconstruction.

The present profile comparison has a specific outcome. The two-parameter inner family describes DDO 154 and NGC 7814 at the level of their conditional velocity errors and fails NGC 2403. Moving the prescribed outer turnover changes the integrated outer contrast substantially while leaving fitted inner speeds nearly unchanged. These results identify both the radial structure a fuller calculation must reproduce and the boundary information it must supply. They do not establish a dark-matter model or a mechanism that replaces dark matter.

10 Conclusions

Galactic rotation curves can be represented as requirements on relative supporting power under the adopted OQG correspondence. On the common material branch, stiffness follows the power ratio, complete rest energy follows its square root, and permittivity and permeability follow its reciprocal. The three SPARC examples require inner-to-outer power deficits from 0.0632 to 4.28 ppm and excess deficits from 0.0508 to 0.732 ppm relative to the fixed baryonic comparison. These are reconstructed ratios over the measured intervals, rather than directly measured exchange powers.

Keeping the outer reference explicit connects the local reconstruction to a possible intergalactic and epoch environment. Successive power ratios multiply, while their logarithmic contrasts add. The outer state remains a boundary condition of the same field. A finite limiting contrast requires an outer departure from indefinitely flat rotation or a global cosmological treatment beyond the local static approximation.

The selected finite profile describes DDO 154 and NGC 7814 at the level of the adopted velocity errors but fails to reproduce the radial structure of NGC 2403. Increasing its prescribed outer turnover tenfold changes fitted speeds by less than 0.17 km/s while substantially changing the inferred outer contrast. Thus local rotation measurements can constrain the gradient closely without determining the full depth relative to a remote reference.

The interference analysis translates the reconstructed ratios into minimum equivalent amplitude changes and necessary coherence conditions in a specified reception norm. Together, these calculations state the power ratios, spatial gradients, and scattering-induced losses that would be required to reproduce the observed rotation curves within the adopted interpretation. They do not predict or explain dark matter, determine the microscopic source of the excess, or demonstrate that ordinary matter supplies it. The contribution of this paper is a quantitative statement of the response that remains to be explained.

Data and calculation availability

The numerical results and figures are supported by the existing calculation archive OQG_Paper_56_Reproducibility_V0_2.zip. It contains the three unmodified SPARC mass-model files, source tables, original downloaded archive, SHA-256 checksums, reconstruction and forward-model scripts, radial profile tables, logarithmic covariance matrices, fit results, numerical checks, and figure files. It also contains the version 0.2 manuscript source and document-generation script. Requests for the calculation archive and the research manuscripts in Refs. [2, 3] may be directed to the correspondence address above. Public SPARC data were retrieved on 12 October 2026 and remain available through Ref. [6]. The numerical calculations can be regenerated offline. No new observational data were generated. The outer profiles are conditional model continuations, with their assumptions recorded separately from the observational reconstruction.

Declarations

This work presents a conditional reconstruction from published galaxy data and a mathematical equivalent-amplitude analysis. The underlying OQG corresponding-state assumptions are those of Ref. [3]. ChatGPT assisted with source retrieval, calculations, figure generation, and manuscript preparation. The author is responsible for reviewing the calculations and final manuscript.

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