Enchan RAR Test Report v0.1

Public-data verification of the SPARC Radial Acceleration Relation (RAR)

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Abstract

This report documents a minimal, reproducible verification of the *radial acceleration relation* (RAR) using the publicly released SPARC rotation-curve decomposition files (`Rotmod_LTG`). We compute the observed centripetal acceleration $g_{\rm obs}(r) = V_{\rm obs}(r)^2/r$ and the baryonic acceleration proxy $g_{\rm bar}(r) = \left(V_{\rm gas}^2 + \Upsilon_{\rm disk} V_{\rm disk}^2 + \Upsilon_{\rm bul} V_{\rm bul}^2\right)/r$, and fit a one-parameter empirical curve of the form $g_{\rm obs} = g_{\rm bar}/\left(1 - e^{-\sqrt{g_{\rm bar}/a_0}}\right)$. For a baseline choice $(\Upsilon_{\rm disk}, \Upsilon_{\rm bul}) = (0.50, 0.70)$ we obtain $a_0 \simeq 1.39 \times 10^{-10}\,\mathrm{m/s^2}$ and an RMS scatter of ~ 0.213 dex. A one-dimensional scan in $\Upsilon_{\rm disk}$ shows that the weak residual dependence on disk surface brightness (SBdisk) is minimized near $\Upsilon_{\rm disk} \simeq 0.60$, without materially changing the overall scatter (~ 0.212 dex). Compressing the dataset to one point per galaxy (median in $\log g$) preserves a strong RAR correlation and yields a galaxy-median scatter of ~ 0.196 dex around a refit curve.

Contents

1 Scope and deliverable

This document is intentionally narrow: it records a **single** verification task that can be rerun from public data with short Python code. The goal is to establish an externally intelligible handle for later work:

- the RAR is an empirical regularity that is easy to explain to non-specialists;
- the same regularity is a natural junction point for contrasting a geometric interpretation (direct $g_{\text{bar}} \to g_{\text{obs}}$ mapping) with a particle-dark-matter interpretation (visible matter plus a dark component shaped by formation history).

No claim of definitive model selection is made here; the report fixes numbers, definitions, and reproducible artifacts.

2 Data and definitions

Data

We use the public SPARC rotation-curve decomposition files `Rotmod_LTG` (`.dat` per galaxy), which tabulate radius r (kpc), observed velocity $V_{\rm obs}$ (km/s) with uncertainty, and component velocities $V_{\rm gas}$, $V_{\rm disk}$, and $V_{\rm bul}$, as well as disk surface brightness SBdisk (when available). After basic quality cuts ($r > 0$, $V_{\rm obs} > 0$, finite values) the dataset contains 175 galaxies and 3391 radial points. For analyses that explicitly use SBdisk, we restrict to points with SBdisk> 0, yielding 3111 points.

Accelerations

We compute

$$g_{\rm obs}(r) = \frac{V_{\rm obs}(r)^2}{r}, \tag{1}$$

$$g_{\rm bar}(r) = \frac{V_{\rm gas}(r)^2 + \Upsilon_{\rm disk} V_{\rm disk}(r)^2 + \Upsilon_{\rm bul} V_{\rm bul}(r)^2}{r}, \tag{2}$$

converting $({\rm km/s})^2/{\rm kpc}$ to ${\rm m/s}^2$. Velocity uncertainties are propagated into an approximate uncertainty for $\log_{10} g_{\rm obs}$ using $\sigma_g/g \approx 2\,\sigma_V/V$ (radius uncertainty ignored for this quick test).

One-parameter reference curve

We fit an empirical one-parameter curve used widely in the RAR literature:

$$g_{\rm obs}(g_{\rm bar}; a_0) = \frac{g_{\rm bar}}{1 - \exp\left(-\sqrt{g_{\rm bar}/a_0}\right)}. \tag{3}$$

The fit is performed in $\log_{10}$ space with a simple mean-squared residual objective weighted by the propagated $\sigma_{\log g_{\rm obs}}$.

3 Results

RAR is strongly present in public SPARC data

Figure 1 shows the point-level RAR for the SB-clean subset using the recommended setting $(\Upsilon_{\rm disk}, \Upsilon_{\rm bul}) = (0.60, 0.70)$. A one-parameter curve provides a compact summary of the trend.

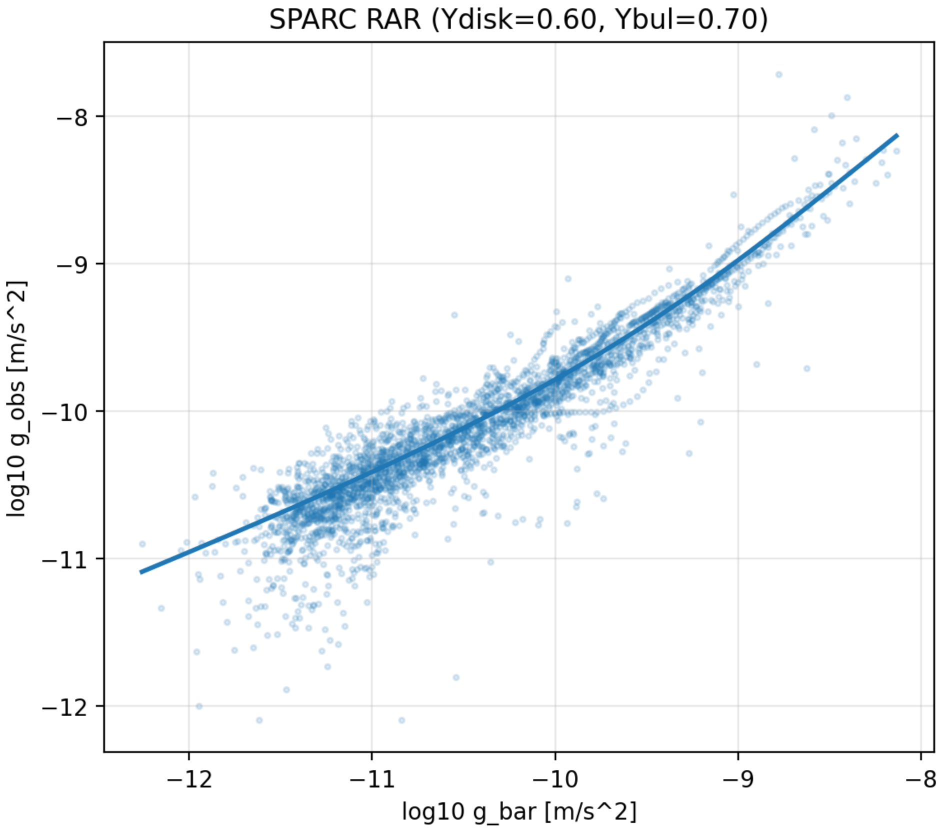

Figure 1: SPARC RAR from `Rotmod_LTG` (points) with a one-parameter reference curve.

Baseline vs recommended mass-to-light ratio

Table 1 summarizes the baseline and recommended settings. The overall scatter is stable, while the residual–SBdisk dependence (evaluated on galaxy medians) is reduced to near zero around $\Upsilon_{\rm disk} \simeq 0.60$. Figure 2 visualizes the binned mean residual versus SBdisk for the two settings.

Setting	$(\Upsilon_{\rm disk}, \Upsilon_{\rm bul})$	$a_0\,[\mathrm{m/s^2}]$	RMS (dex)	$\rho_{\rm SB}$ (gal medians)
Baseline	(0.50, 0.70)	1.39×10^{-10}	0.213	+0.074
Recommended	(0.60, 0.70)	1.12×10^{-10}	0.212	−0.008

Table 1: RAR fit summary (SB-clean subset; 175 galaxies, 3111 points). $\rho_{\rm SB}$ is Spearman ρ between galaxy-median residual and galaxy-median SBdisk.

Upsilon scan: SB-dependence is minimized near $\Upsilon_{\rm disk} \simeq 0.60$

Figure 3 shows how the galaxy-median residual–SBdisk correlation changes with $\Upsilon_{\rm disk}$ (keeping $\Upsilon_{\rm bul} = 0.70$ fixed), and Figure 4 shows the corresponding scatter. The scan indicates that a small shift in $\Upsilon_{\rm disk}$ can remove the residual SB trend without degrading the overall scatter.

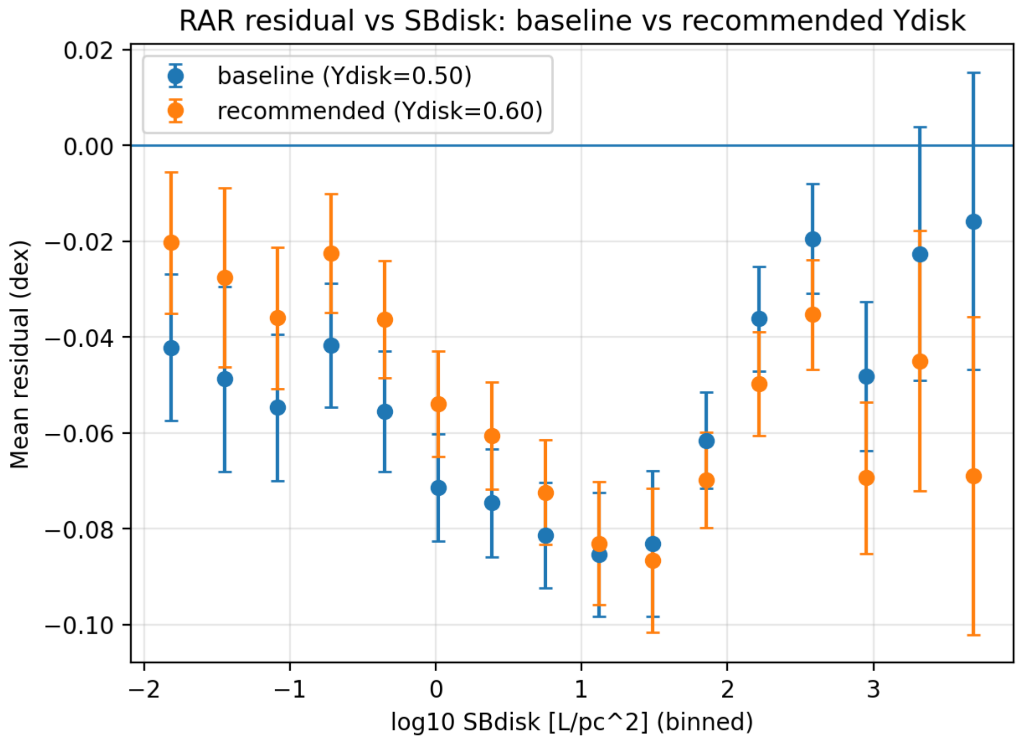

Figure 2: Binned mean residual versus SBdisk for baseline and recommended Υ_{disk}.

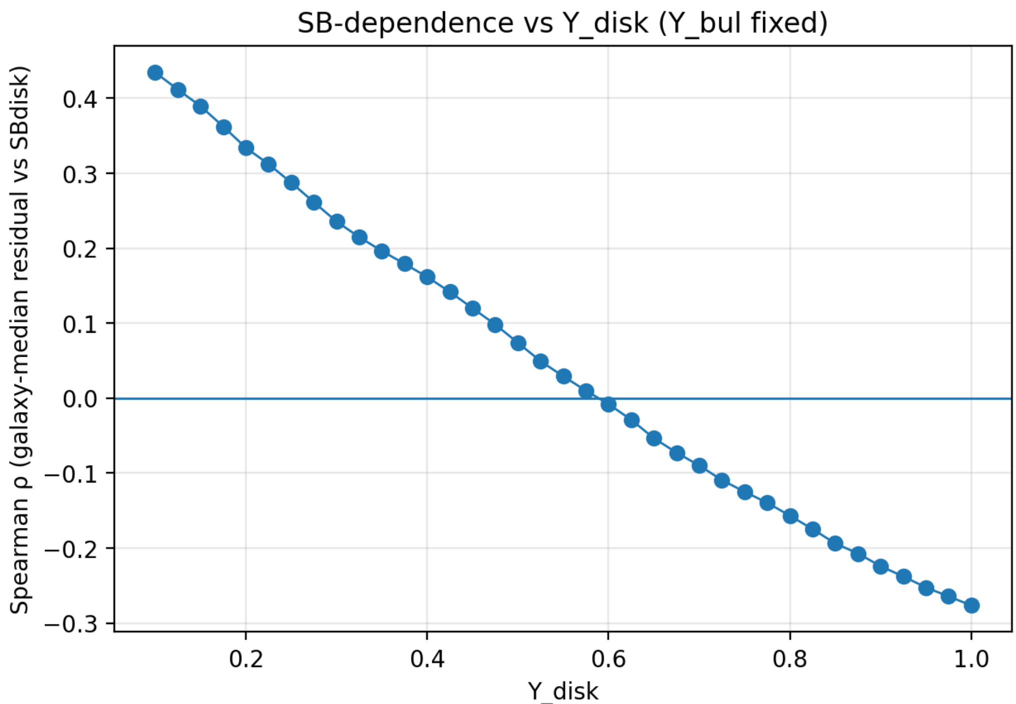

Figure 3: Residual–SBdisk dependence (Spearman ρ on galaxy medians) versus Υ_{disk}.

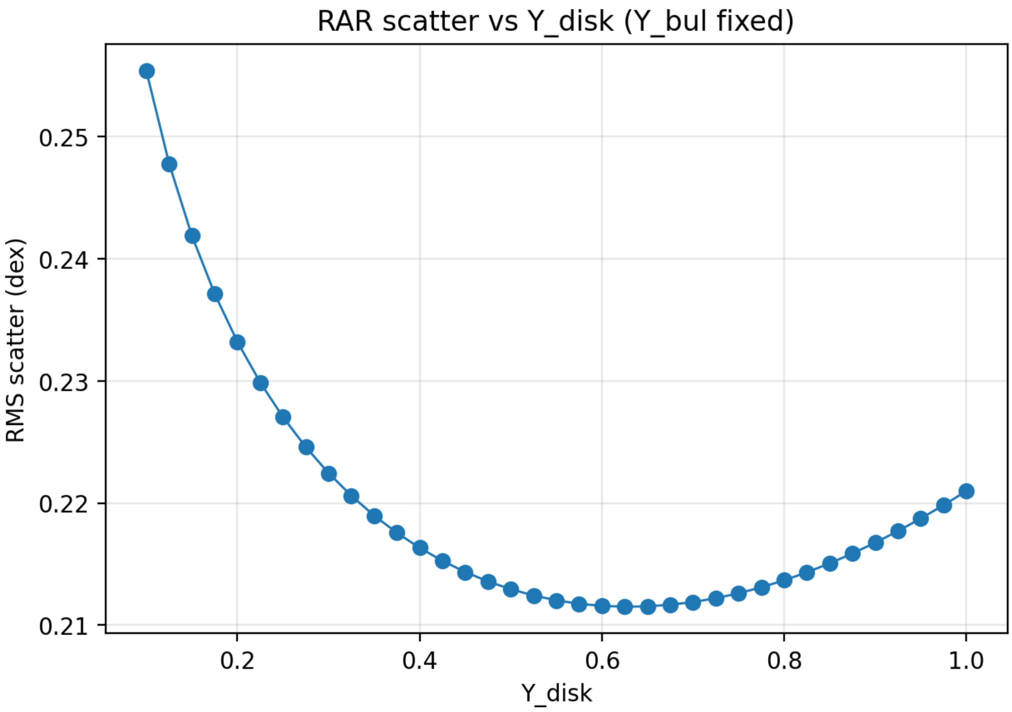

Figure 4: RAR scatter (RMS in dex) versus $\Upsilon_{\rm disk}$.

One point per galaxy

To avoid overweighting galaxies with many radial points, we compress the dataset to one point per galaxy using the median of $\log g_{\rm bar}$ and $\log g_{\rm obs}$. Figure 5 shows that the RAR remains clear in this compressed representation.

For the recommended setting, the RMS scatter around the point-level fit is ~ 0.216 dex in the galaxy-median space, and refitting a_0 on the galaxy medians yields a reduced scatter of ~ 0.196 dex.

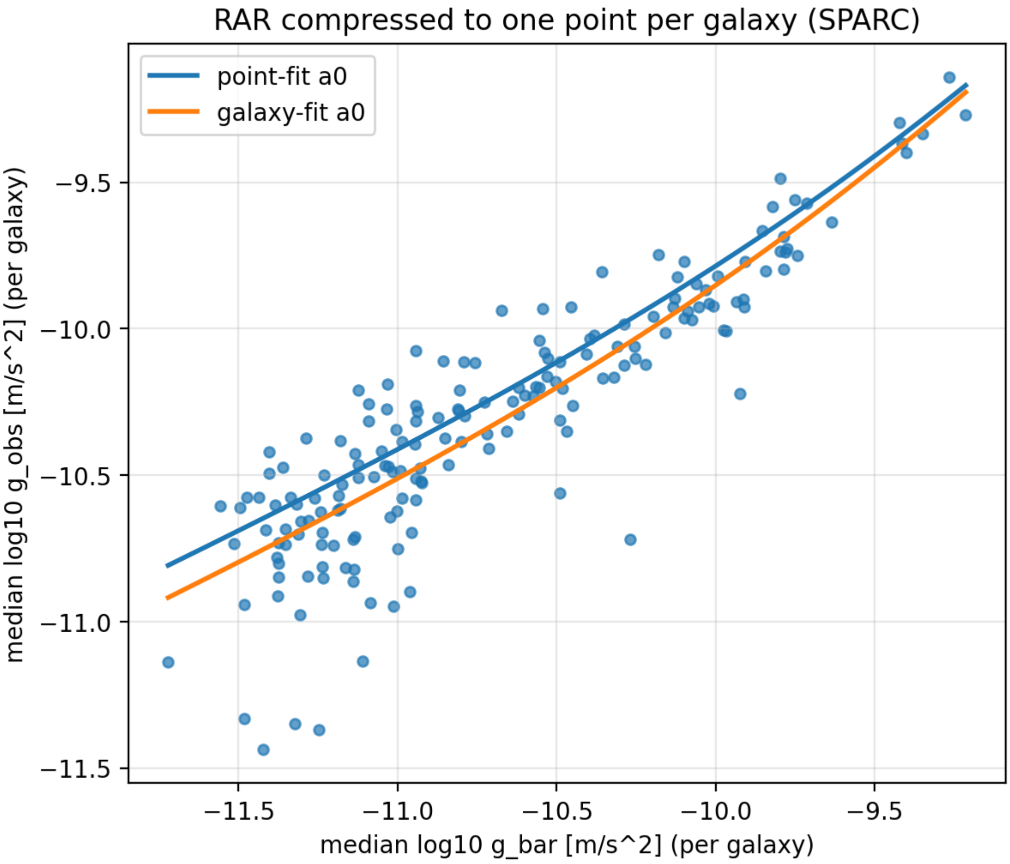

Figure 5: RAR compressed to one point per galaxy (medians in $\log g$).

4 Interpretation: geometry vs particles (minimal statement)

This report establishes one observational fact from public data: **the mapping $g_{\mathrm{bar}} \mapsto g_{\mathrm{obs}}$ is highly regular across many galaxies** and can be summarized by a simple one-parameter curve with small scatter.

Geometric interpretation

A geometric interpretation treats the observed gravitational response as a phenomenological functional of the baryonic configuration, so a tight relation of the form $g_{\mathrm{obs}} = f(g_{\mathrm{bar}})$ is a natural primary object.

Particle-dark-matter interpretation

A particle-dark-matter interpretation constructs g_{obs} as the combined effect of baryons and a dark halo whose structure depends on assembly history and feedback. A tight, nearly universal g_{obs}–g_{bar} mapping is not automatic and requires an explanation for why baryons and the halo co-vary so strongly.

What this test does and does not show

This test does *not* falsify particle dark matter. It *does* provide a clean, reproducible target: any successful explanation must account for the observed regularity and its small scatter.

5 Reproducibility artifacts

This report is accompanied by the following files (produced by the Python workflow):

- `sparc_rar_points_processed.csv`: point-level accelerations and residuals (recommended setting)
- `rar_Ydisk_scan_results.csv`: $\Upsilon_{\rm disk}$ scan summary
- `sparc_rar_galaxy_medians_Yd0p60_Yb0p70.csv`: one point per galaxy
- figures: `fig_rar_points.png`, `fig_resid_sb_binned.png`, `fig_scan_rho_sb.png`, `fig_scan_rms.png`, `fig_rar_galaxy.png`

All quantities are computed from public SPARC `Rotmod_LTG` tables with the definitions fixed above.

6 References

- SPARC database (rotation curves and mass models): http://astroweb.cwru.edu/SPARC/
- McGaugh, Lelli, Schombert (2016), "The Radial Acceleration Relation in Rotationally Supported Galaxies", arXiv:1609.05917.