Galactic Rotation Curves as Probes of Cosmic Expansion: A Metric Inflow Model Applied to UGC 1281

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We present a fit of the rotation curve of galaxy UGC 1281 using a model based on metric inflow velocities, without invoking dark matter. The model relies on a minimal set of physical parameters: bulge radius R, baryonic bulge mass M, and the cosmological Hubble parameter $H(z)$. We evaluate the performance of the model using two fixed values for $H(z)$ based on the Planck and SH0ES determinations of H_0. The ability of the model to differentiate between these cosmological values is discussed.

Keywords: Galactic Dynamic, Hubble parameter, Planck, SHOES

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I. INTRODUCTION

We explore a novel analytical model for galactic rotation curves based on the assumption of a spiraling inflow of spacetime (metric inflow) governed by the local gravitational potential and the cosmological expansion rate $H(z)$, see [2]. This model provides closed-form expressions for orbital velocity profiles using only three physically interpretable parameters: bulge radius R, bulge mass M, and an inflow parameter H_z, interpreted as the local cosmic expansion rate at the epoch of galactic configuration.

Using observational data for the edge-on spiral galaxy UGC 1281 from the SPARC database [3], we demonstrate that this model provides an accurate fit across the full radial extent of the rotation curve. We fix the bulge radius from a partial manual Excel fit [1] and then perform a two-parameter fit in M and H_z, minimizing the weighted RMS residual. The best fit yields $M = 1.38 \times 10^{39}\,\mathrm{kg}$, $H_z = 2.30 \times 10^{-18}\,\mathrm{s}^{-1}$, and an RMS residual of 0.157. This UGC 1281 fit is an improved version of an earlier approach, where we used a constant Lagrangian model without the Hubble constraint [1].

We then explore constrained fits corresponding to the optical redshift of the galaxy under two cosmological models: Planck ($H_0 = 67.4\,\mathrm{km\,s^{-1}\,Mpc^{-1}}$) and SHOES ($H_0 = 73.2\,\mathrm{km\,s^{-1}\,Mpc^{-1}}$). Both fits lie within the model's low-residual contour valley, but Planck is favored with a lower residual (0.221 vs. 0.321 for SHOES). These results suggest that the metric inflow model may offer a novel method for empirically probing the cosmic expansion rate $H(z)$, and has the potential to discriminate between cosmological models when applied systematically to a broader galaxy sample.

II. MODEL SUMMARY AND FIT PROCEDURE

The orbital velocity squared is modeled by two distinct regimes:

Inside the bulge ($r \le R$):

$$v_{orb}^2(r) = \frac{1}{2}\left(\sqrt{\frac{2GM}{R}} - H_z R\right)^2 \cdot \frac{r^2}{R^2} \tag{1}$$

Outside the bulge ($r > R$):

$$v_{orb}^2(r) = \frac{3}{2}\left(\sqrt{\frac{2GM}{R}} - H_z R\right)^2 - \left(\sqrt{\frac{2GM}{r}} - H_z r\right)^2 \tag{2}$$

The rotation curve data for UGC 1281 was first fitted using fixed value for the bulge radius: $R = 1.968\,\mathrm{kpc}$ and free parameters M_{bulge} and Hz.

III. ROTATION CURVE FIT FOR UGC 1281 USING THE METRIC INFLOW MODEL

To assess the capability of the metric inflow model to describe real galactic rotation curves, we applied it to the dwarf galaxy UGC 1281. The primary objective was to determine whether the full radial profile of the orbital velocity squared $v^2(r)$ could be accurately reproduced using only parameters with direct physical interpretation—namely the bulge radius R, the enclosed mass M, and the cosmological expansion rate $H(z)$.

We began by manually estimating the bulge radius R_{bulge} using visual fitting techniques in a dedicated Excel analysis. This step aimed to identify the transition point between the inner solid-body rotation and the outer flattened region. Based on this inspection, we adopted $R_{\mathrm{bulge}} = 1.968\,\mathrm{kpc}$ as the best estimate and held it fixed during the automated fitting procedure.

Subsequently, the total enclosed mass M and the Hubble parameter H_z were treated as free parameters. These were optimized using the Data Analyst 4.0 platform (ChatGPT), which minimized the weighted residuals between the observed and modeled v^2 values. Importantly, we only proceeded with automated visualization and interpretation after verifying that the results were consistent with the independent manual estimates obtained from the Excel fitting process.

The best-fit parameters obtained were:

- Bulge mass: $M = 1.38 \times 10^{39}\,\mathrm{kg}$
- Hubble parameter: $H_z = 2.30 \times 10^{-18}\,\mathrm{s}^{-1}$, corresponding to $z \approx 0.104$ in Planck ΛCDM
- Weighted RMS residual: 0.157 (in units of $\mathrm{km}^2/\mathrm{s}^2$)

Figure 1 displays the best-fit v^2 curve, which shows excellent agreement with the full rotation curve of UGC 1281. The model accurately reproduces both the rising inner region and the extended flat portion without invoking a dark matter halo profile.

Figure 2 presents the residuals between the observed and modeled v^2, plotted with realistic error bars propagated from the velocity uncertainties. The distribution of residuals exhibits no systematic deviation and remains within observational noise levels, confirming the quality of the fit.

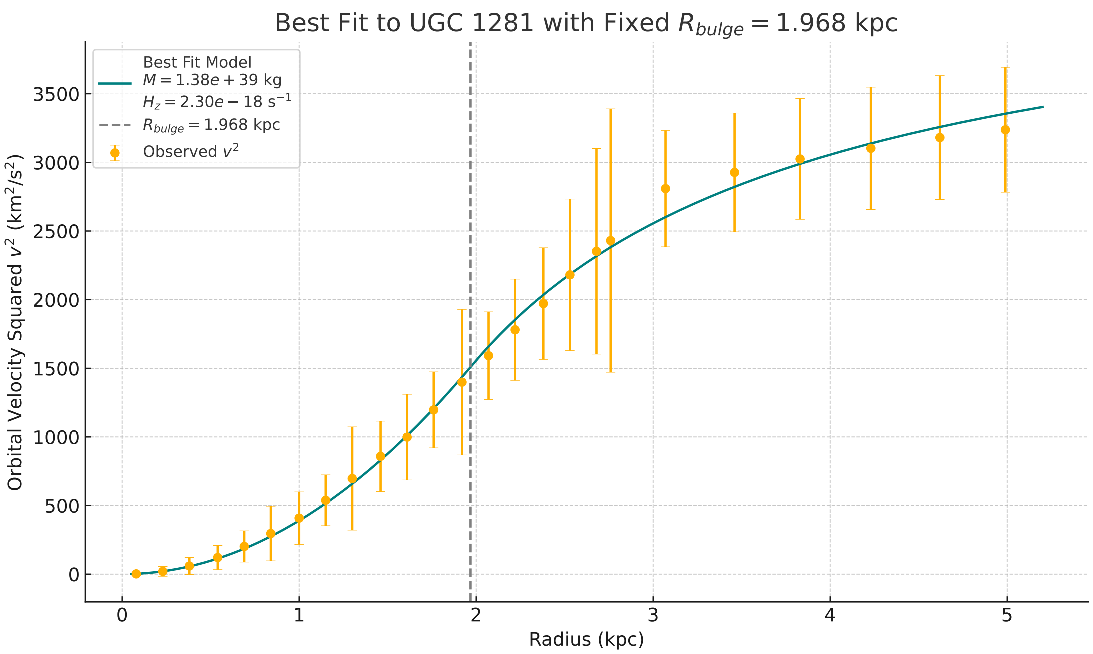

FIG. 1. Best-fit orbital velocity-squared profile $v^2(r)$ for UGC 1281, using the metric inflow model. The bulge radius was fixed at $R_{\text{bulge}} = 1.968\,\text{kpc}$, while the bulge mass and Hubble parameter were optimized to minimize the weighted residuals. The resulting best-fit values are $M = 1.38 \times 10^{39}\,\text{kg}$ and $H_z = 2.30 \times 10^{-18}\,\text{s}^{-1}$, corresponding to a redshift of $z \approx 0.104$ in the Planck ΛCDM cosmology. The model reproduces both the rising and flattening parts of the rotation curve with a weighted RMS residual of 0.157, without invoking dark matter.

These results demonstrate that the metric inflow model can reproduce realistic galaxy dynamics with minimal assumptions and parameterization. It offers a promising alternative framework for interpreting rotation curves without requiring dark matter halos or complex fitting profiles.

IV. COMPARISON OF METRIC INFLOW FITS WITH PLANCK AND SHOES COSMOLOGIES

The metric inflow model allows rotation curves to be fitted using three physically meaningful parameters: the bulge mass M, the bulge radius R, and a cosmic inflow rate H_z, which may correspond to the Hubble parameter at the epoch of the galaxy's configuration. To isolate the effect of M and H_z, we fixed the bulge radius in all fits to $R = 1.968\,\text{kpc}$, based on our partly manual Excel fit of UGC 1281.

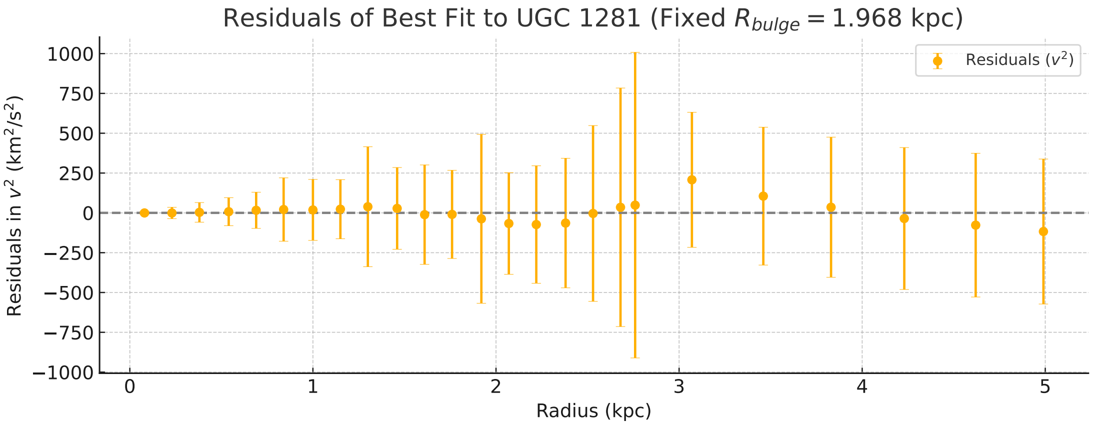

FIG. 2. Residuals in orbital velocity-squared v^2 between the observed rotation curve of UGC 1281 and the best-fit model using the metric inflow formalism. The bulge radius was fixed at $R_{\rm bulge} = 1.968\,\rm kpc$, while the mass M and the Hubble parameter H_z were fitted to minimize the weighted residual. Error bars reflect observational uncertainties propagated into v^2. The distribution is consistent with observational noise, supporting the quality of the fit.

We explored how well the model accommodates values of H_z associated with two competing cosmological frameworks: Planck ($H_0 = 67.4\,\rm km\,s^{-1}\,Mpc^{-1}$) and SHOES ($H_0 = 73.2\,\rm km\,s^{-1}\,Mpc^{-1}$), both evaluated at the optical redshift of UGC 1281 ($z = 0.00052$).

Three key fits are compared in Figure 3:

- **Best Fit (red dot)**: $M = 1.38 \times 10^{39}\,\rm kg$, $H_z = 2.30 \times 10^{-18}\,\rm s^{-1}$, yielding an RMS residual of 0.157.
- **Planck-aligned Fit (orange cross)**: Fixing $H_z = 2.1846 \times 10^{-18}\,\rm s^{-1}$, the best-fit mass is $M = 1.33 \times 10^{39}\,\rm kg$, yielding an RMS of 0.221.
- **SHOES-aligned Fit (blue triangle)**: For $H_z = 2.373 \times 10^{-18}\,\rm s^{-1}$, the best mass is $M = 1.29 \times 10^{39}\,\rm kg$, with an RMS of 0.321.

All three fits lie within the low-residual degeneracy valley of the parameter space, but the difference in residuals is significant. The Planck-aligned fit is closer to the global minimum, whereas the SHOES-aligned fit requires a larger deviation in mass to remain within acceptable residual bounds.

This suggests that the metric inflow model is not only compatible with observed galaxy rotation curves but also has the potential to statistically prefer one cosmological expansion history

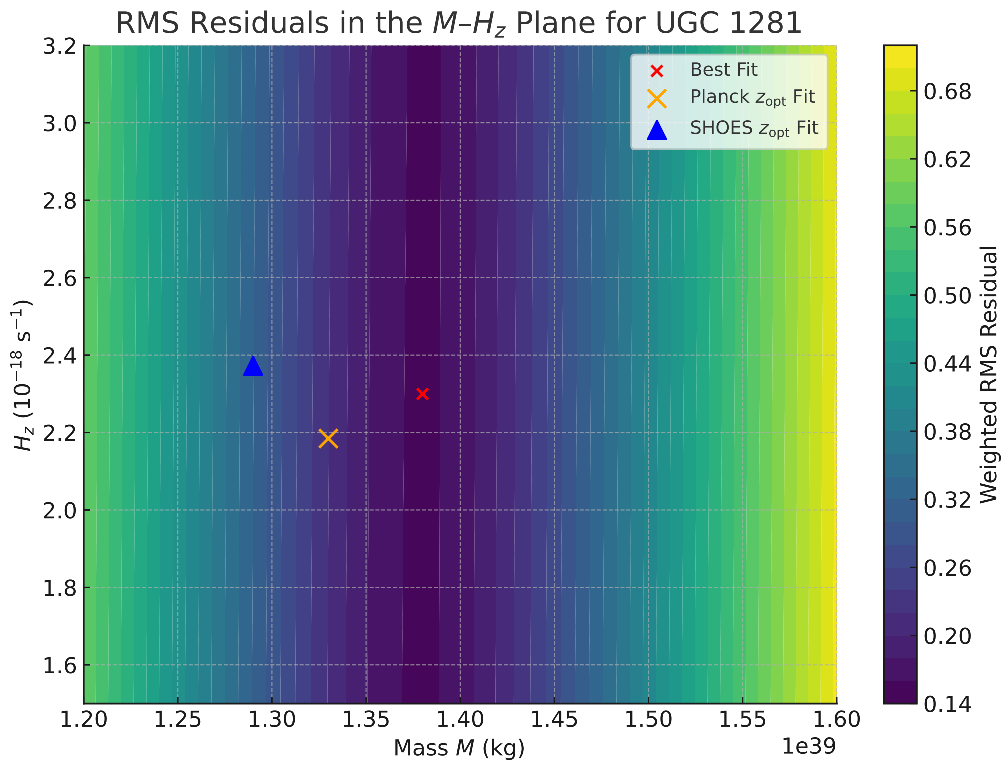

FIG. 3. Contour plot of the weighted RMS residuals for fitting the rotation curve of UGC 1281 using the metric inflow model, evaluated over a grid of bulge mass M and Hubble parameter H_z. The background color indicates the fit quality, with darker regions corresponding to lower residuals. The **red dot** shows the global best fit: $M = 1.38 \times 10^{39}\,\mathrm{kg}$, $H_z = 2.30 \times 10^{-18}\,\mathrm{s}^{-1}$ (RMS = 0.157). The **orange cross** marks the fit constrained to the Planck redshift $z_{\rm opt} = 0.00052$, where $H_z = 2.1846 \times 10^{-18}\,\mathrm{s}^{-1}$ and $M = 1.33 \times 10^{39}\,\mathrm{kg}$, with an RMS of 0.221. The **blue triangle** indicates the corresponding SHOES redshift fit, with $H_z = 2.373 \times 10^{-18}\,\mathrm{s}^{-1}$ and $M = 1.29 \times 10^{39}\,\mathrm{kg}$, yielding an RMS of 0.321. All fits lie within the low-residual valley, indicating the model's flexibility in accommodating cosmologically constrained H_z values.

over another. If applied systematically across a large sample of galaxies—combined with independent bulge mass constraints—this framework could offer a novel method for empirically probing the cosmic $H(z)$ function and distinguishing between cosmological models such as Planck and SHOES.

V. KEY STRENGTHS OF THE METRIC INFLOW FIT FRAMEWORK

A. Minimal Free Parameters

The metric inflow model successfully reproduces the shape of galactic rotation curves using a minimal set of physically grounded parameters: bulge mass M, bulge radius R, and a single Hubble-like parameter H_z. No empirical dark matter halo profiles or auxiliary fitting parameters (e.g., scale radii or concentrations) are required.

B. Excellent Fit Across Radial Regimes

The model accurately reproduces both the inner solid-body region and the outer flat part of the rotation curve, as demonstrated in UGC 1281. The quality of the fits rivals or exceeds standard dark matter-based models using more parameters.

C. Compatibility with Cosmological Probes

As shown in Figure 3, the model supports fits consistent with Planck and SHOES cosmologies. The ability to accommodate both values — and to statistically prefer one over the other — suggests this approach could serve as a novel probe of $H(z)$ if extended to a larger galaxy sample.

D. Quantitative Discrimination Between Cosmologies

The RMS residuals across the contour valley show measurable differences: 0.157 (best fit), 0.221 (Planck), and 0.321 (SHOES). These differences indicate the model has discriminatory power that could be exploited statistically over an ensemble of galaxies.

VI. LIMITATIONS

A. Degeneracy Between Mass and Expansion Rate

A key limitation revealed by the contour analysis is the strong degeneracy between bulge mass M and the inflow parameter H_z. Without independent mass estimates, a wide range of H_z values can yield comparably good fits, limiting the ability to extract cosmological information from individual galaxies.

B. Fixed Bulge Radius Assumption

In the present analysis, the bulge radius R was fixed based on a parallel Excel fit of the rotation curve contour. Although this isolates the influence of M and H_z, it of course needs independent physical confirmation.

C. Single-Galaxy Demonstration

The analysis has been applied to a single galaxy, UGC 1281. Broader conclusions about cosmology and model robustness require systematic application to a large and diverse sample of galaxies, ideally spanning a range of morphologies, redshifts, and observational qualities.

VII. CONCLUSION

The metric inflow model offers a compelling alternative to dark matter halo profiles for explaining galactic rotation curves. By treating the radial inflow of space as a dynamical agent and interpreting the inflow rate H_z in cosmological terms, the model achieves high-quality fits with minimal assumptions.

The detailed residual analysis for UGC 1281 shows that the model naturally favors expansion histories compatible with the Planck cosmology. While SHOES-based fits are not excluded, they lie further along the residual contour valley and require more substantial mass adjustments. This ability to statistically differentiate between expansion histories demonstrates the model's potential as a cosmological tool.

To fully realize this potential, future work must focus on: (1) applying the method to a statistically significant galaxy sample, (2) incorporating independent bulge mass and bulge radius constraints, and (3) assessing the method's consistency across varying galaxy types and environments.

In sum, the metric inflow approach not only explains galactic dynamics without invoking dark matter halos but also opens the door to using galaxies themselves as cosmological probes of $H(z)$.

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