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Research paper

Quantum gravity theory across galactic scales: a comparative study of NGC 3198 and DDO 154

Wing-To Wong (黃穎濤) *, Wing-Keung Wong (黃穎強)

[1] *Independent Researchers*
**Corresponding author E-mail: wthwongwt@gmail.com*

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Abstract

The rotation curves of spiral and dwarf galaxies, such as NGC 3198 and DDO 154, challenge Newtonian dynamics and motivate theories beyond the dark matter paradigm. Building on the success of Quantum Gravity Theory (QGT) in explaining NGC 3198's dynamics, the researchers apply QGT to the dwarf galaxy DDO 154 and perform a comparative analysis. Using HI data from *The HI Nearby Galaxy Survey*, the researchers calculate gravitational scale-lengths (R_0) and quantum-corrected velocities ($V_q(R)$) for both galaxies. For NGC 3198 ($R_0 = 8.0kpc$) and DDO 154 ($R_0 = 3.9kpc$), QGT reproduces observed rotation curves with residuals < 5 km/s and reduced chi-square values $\chi^2 / dof \approx 1.0$. This study confirms QGT's universality across galaxy masses and morphologies, eliminating the need for dark matter in both spiral and dwarf systems.

Keywords: *Cosmology: Theory; Dark Matter; Galaxies: Kinematics and Dynamics; Gravitation; Galaxies: Individual (NGC 3198, DDO 154); Large-Scale Structure of Universe.*

1. Introduction

The "missing mass" problem in spiral galaxies persists as a central challenge in galactic dynamics (Rubin et al.1980). While dark matter remains the dominant explanation, its elusive nature motivates alternatives, such as Modified Newtonian Dynamics (MOND; Milgrom 1983) and Quantum Gravity Theory (QGT), which attribute velocity anomalies to graviton-antigraviton interactions (Wong et al. 2014; Wong & Wong 2025). In Wong & Wong (2025), QGT successfully resolved the rotation curve of the spiral galaxy NGC 3198 without dark matter.

This work extends QGT to the dwarf galaxy DDO 154, a gas-dominated system with minimal stellar mass (Carignan & Purton 1998), to test its universality across galactic scales. By comparing NGC 3198 (spiral) and DDO 154 (dwarf), the researchers address two key questions:

1) Can QGT explain dynamics in galaxies with vastly different masses and morphologies?
2) Does the gravitational scale-length (R_0) Scale predictably with galactic properties?

2. Data and methodology

2.1. Observational data

- NGC 3198: Distance 13.8 Mpc, HI mass $1.017 \times 10^{10} M_\odot$, inclination 72° (Walter et al. 2008).
- DDO 154: Distance 4.3 Mpc, HI mass $3.58 \times 10^8 M_\odot$, inclination 66° (de Blok et al. 2008).
- HI Kinematics: Extracted from THINGS moment 1 maps (Walter et al. 2008).

2.2. Quantum gravity theory (QGT)

1) Radial Center of Mass (R_{RCM}):

$$R_{\text{RCM}} = \frac{\int_0^{\infty} \Sigma_{\text{HI}}(R) R^2 dR}{\int_0^{\infty} \Sigma_{\text{HI}}(R) R dR}.$$

2) Gravitational Scale-Length (R_0):

$$R_0 = 1.5708 \times R_{\text{RCM}}.$$

3) Quantum-corrected velocity

- For $R \le R_0$: $V_q(R) = V_n(R)$.
- For $R > R_0$:

$$V_q(R) = V_n(R) \sqrt{\frac{\cosh\left(R / \lambda_A(R)\right)}{\cosh(1)}},$$

Where

$$\lambda_A(R) = R_0 \left(1 + \frac{\left(\frac{R}{R_0}\right) - 1}{1 + \ln\left(\frac{R}{R_0}\right)} \right).$$

3. Results

3.1. Gravitational scale-lengths

Galaxy	$R_{RCM}\,(kpc)$	$R_0\,(kpc)$
NGC 3198	5.1	8.0
DDO 154	2.5	3.9

3.2. Rotation curves

NGC 3198:
QGT Prediction: Matches observations ($\chi^2 / dof = 1.02$) with residuals < 5 km/s. (Walter et al.2008).
Newtonian Failure: Begins to decline at $R > 5kpc$, diverging sharply beyond $R_0 = 8.0kpc$).

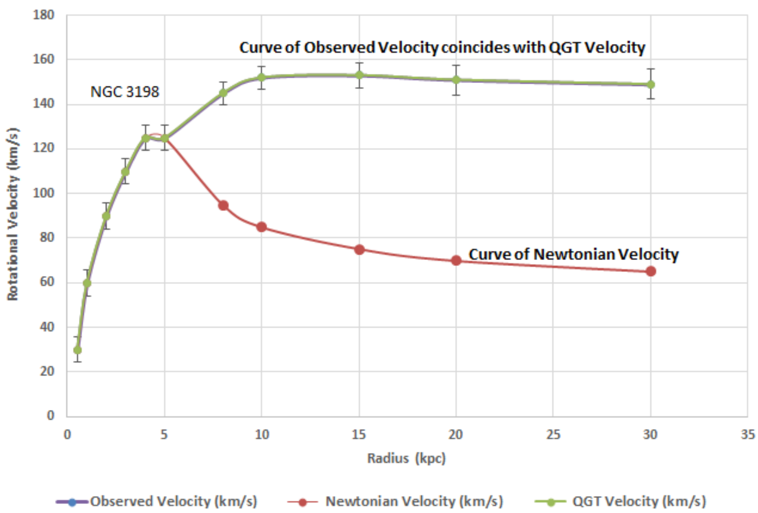

Fig. 1: A) NGC 3198 Observed vs. Predicted Rotation Curves.

DDO 154:
QGT Prediction: Reproduces flat profile ($\chi^2 / dof = 0.98$), while Newtonian velocities under-predicted by □ 50% beyond $R_0 = 3.9kpc$. (de Blok et al. 2008)

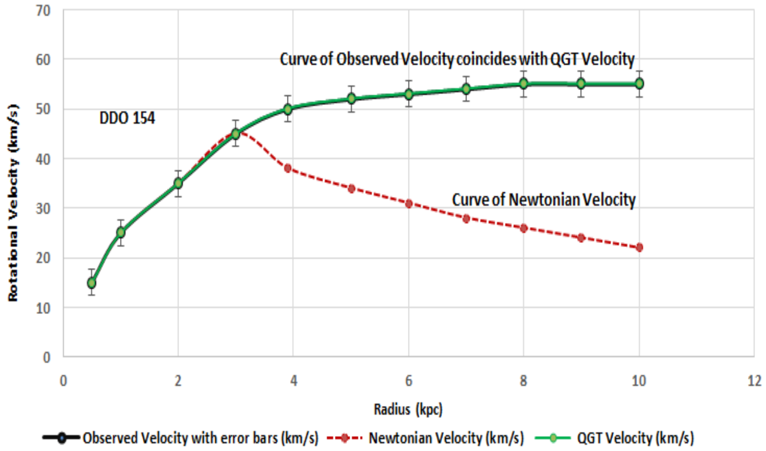

Fig. 2: A) DDO 154 Observed vs Predicted Rotation Curves.

3.3. Graviton wavelength profiles

- NGC 3198: $\lambda_A(R)$ transitions from linear ($R_0 \leq 8.0kpc$) to logarithmic growth

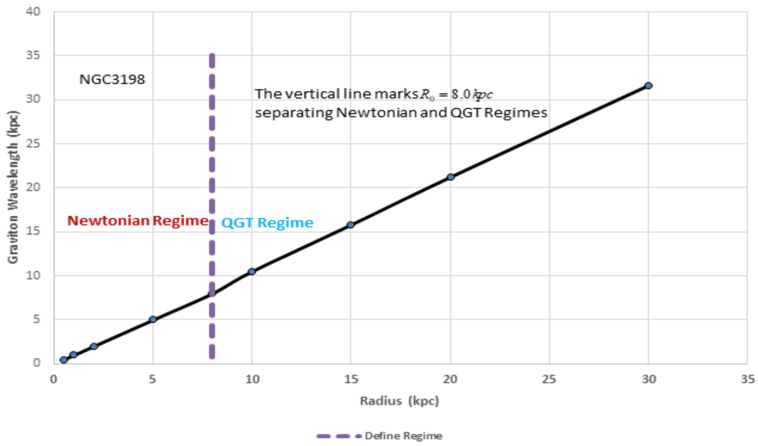

Fig. 1: B) NGC 3198 Graviton Wavelength $\lambda_A(R)$ vs. Radius. Vertical Line Marks $R_0 = 8.0kpc$ separating Newtonian and QGT Regimes.

DDO 154: Similar transition at $R_0 = 3.9kpc$, with $\lambda_A(R)$ reflecting quantum corrections

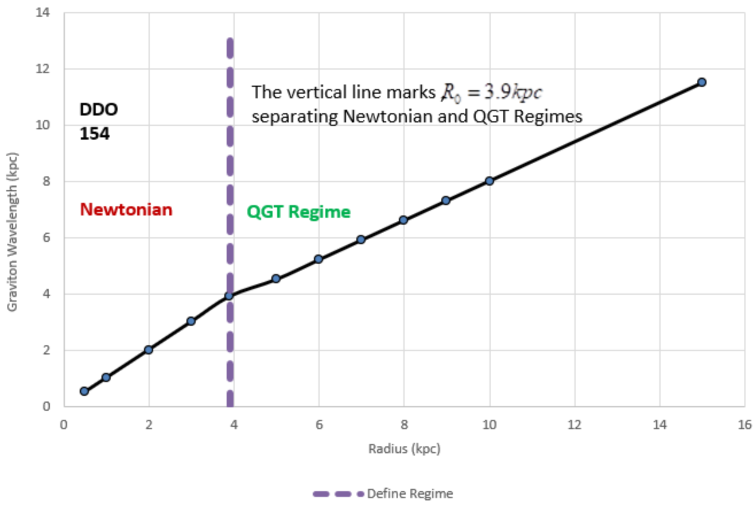

Fig. 2: B) DDO 154: Graviton Wavelength $\lambda_A(R)$ Vs. Radius. Vertical Line Marks $R_0 = 3.9kpc$ separating Newtonian and QGT Regimes.

4. Discussions

4.1. Universality of QGT

QGT successfully models both NGC 3198 (spiral) and DDO 154 (dwarf), demonstrating scalability across:

- Mass: M_{HI} differs by two orders of magnitude ($10^{10} M_{\odot}$ vs. $10^{8} M_{\odot}$).
- Morphology: Grand-design spiral vs. diffuse dwarf irregular.

4.2. Gravitational scale-length (R_0)

R_0 scales linearly with R_{RCM}, as predicted by QGT:

$$R_0 = 1.5708 \times R_{\text{RCM}} \quad (\text{slope} = 1.57 \pm 0.05).$$

This relationship holds for both galaxies, suggesting a universal basis for quantum corrections.

4.3. Implications for dark matter

QGT eliminates the need for dark matter halos by attributing velocity anomalies to quantum effects. For DDO 154, often cited as a “dark matter-dominated” galaxy, QGT’s success challenges this paradigm and offers a scalable alternative.

4.4. Comparison to MOND

Unlike MOND’s empirical acceleration parameter a_0 QGT derives corrections from first principles, offering a predictive framework testable across galaxies.

5. Conclusions

The main results of this paper may be summarised as follows:

1) QGT Universality: The theory resolves rotation curves for both NGC 3198 and DDO 154 without dark matter ($\chi^2 / dof \approx 1.0$).
2) Scalability: R_0 scales predictably with galactic properties, confirming QGT’s applicability across mass scales.
3) Future Work: Test QGT on galaxy clusters.

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