Reinterpreting Galactic Rotation Curves

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Abstract

This paper presents a novel framework for modeling galactic rotation curves without invoking dark matter. By substituting relativistic mass for rest mass in Newton's gravitational law and redefining radial distance as a time-dilated metric (ct), the model accounts for observed stellar velocities using baryonic matter alone. A numerical simulation of the Milky Way demonstrates close alignment with empirical data, suggesting that relativistic effects—particularly gravitational time dilation and photon frequency shifts—can explain discrepancies traditionally attributed to dark matter. The model also offers a reinterpretation of black hole dynamics, proposing that extreme time dilation, rather than event horizons, governs the behavior of ultra-dense galactic cores.

1. Introduction

The rotation curves of spiral galaxies have long posed a challenge to classical gravitational theory. Observations consistently show that stars orbit at higher velocities than predicted by Newtonian dynamics, given the visible mass distribution. This discrepancy has led to the widespread hypothesis of dark matter—an invisible substance that exerts gravitational influence but does not interact electromagnetically.

While dark matter remains the dominant explanation, its nature is still unknown, and direct detection has proven elusive. This paper explores an alternative approach grounded in relativistic physics. Specifically, it investigates the consequences of using **relativistic mass**—which increases with velocity—in place of rest mass in the gravitational force equation. Additionally, it introduces a redefinition of radial distance as **ct**, a time-dilated metric derived from photon frequency shifts in strong gravitational fields.

These modifications yield a gravitational model that aligns with observed galactic rotation curves using only baryonic matter. A detailed simulation of the Milky Way demonstrates that the apparent need for dark matter may arise from misinterpreting relativistic effects on mass and distance. The model also challenges the traditional concept of black holes, suggesting that extreme time dilation can mimic their observational signatures without requiring event horizons.

This paper is organized as follows: Section 2 outlines the theoretical framework, including derivations involving relativistic mass and gravitational energy. Section 3 introduces the ct metric and its implications for gravitational force. Section 4 presents the Milky Way model and compares its predictions to observational data. Section 5 discusses elliptical orbits and time

dilation effects near galactic centers. Section 6 explores broader implications and potential challenges, and Section 7 concludes with a summary and suggestions for future research.

2.1 Energy and Time Dilation Calculations

Traditional gravitational models use rest mass as the source of gravitational force. However, in relativistic physics, the mass of a moving object increases with velocity, leading to the concept of relativistic mass. This section explores the consequences of substituting relativistic mass into Newton's law of gravitation.

Consider a falling mass m approaching a large mass M. As it traverses a small radial distance Δr, it gains energy due to gravitational acceleration. Let G be the gravitational constant and c be the speed of light. The energy gained is ΔE, as mass m falls through the distance Δr:

$$\Delta E = (GM * m / r^2) * \Delta r$$

This energy increase corresponds to a change in relativistic mass, given by:

$$c^2 * \Delta m = (GM * m / r^2) * \Delta r$$

Let m_i be the rest mass, which starts falling towards mass M from infinity. Rearranging, I get:

$$\Delta(m/m_i)/(m/m_i) = (GM / (r^2 * c^2)) * \Delta r$$

Integrating r from infinity to a finite radius R, and from rest mass m_i to relativistic mass m_R, yields:

$$\ln (m_R / m_i) = GM / (c^2 * R)$$

$$m_R / m_i = \exp (GM / (c^2 * R))$$

This exponential relationship shows how relativistic mass increases as a function of gravitational potential. Importantly, this formulation applies not only to massive particles but also to the mass-equivalent of the energy of photons. In place of m in the above equations, substitute $f * h / (c^2)$, where f is the photon's frequency and h is Planks constant. The result is:

$$f_R / f_i = \exp (GM / (c^2 * R))$$

This result implies that photons approaching a massive object experience a frequency increase (blueshift), while those escaping experience a decrease (redshift). The gravitational time dilation observed at radius R is the inverse of this ratio:

$$T_d = f_i / f_R = m_i / m_R$$

At the Schwarzschild radius, defined as $R_s = 2GM / c^2$, the time dilation becomes:

$\ln(m_R / m_i) = GM / (c^2 * R_s) = 1/2$

$m_R / m_i = \exp(0.5) \approx 1.6487$

Thus, the time dilation factor is approximately 0.6065—finite and nonzero. This contrasts with traditional models that predict infinite time dilation and zero frequency at the event horizon, suggesting that black holes may not be true singularities, but rather ultra-dense regions from which light can escape with extreme energy loss.

2.2 Time-Dilated Distance and Modified Gravitational Force

The above logic deals with falling masses and approaching photons that are gaining energy as they approach mass M. The next phase of this project is to deal with gravitational forces where little or no energy is gained. This is the attraction between some mass M and its satellite.

In traditional gravitational models, the force between two masses is calculated using the inverse square of the radial distance r:

$F = GMm / r^2$

However, this formulation assumes that r is measured uniformly across all reference frames. In strong gravitational fields, time dilation affects how observers perceive distances and velocities. To account for this, we introduce a modified distance parameter, ct, which represents the time-dilated distance as measured by a laser range finder. The parameter r is defined to be the distance between the centers of gravity of the two masses, as measured by laying meter-sticks end to end. The parameter ct is defined as that distance as measured by a laser range finder. This metric reflects the increased number of photon wavefronts required to span a given distance in a gravitational field where frequency has increased and wavelength has decreased.

The modified gravitational force equation becomes:

$F = GMm / (ct)^2$

This formulation ensures that gravitational acceleration remains consistent across observers in both weak and strong gravitational fields. For example, an observer on the surface of a neutron star—experiencing significant time dilation—would perceive a satellite to be moving faster than an observer in a weak field. The increased velocity implies a stronger centrifugal force, which must be balanced by a correspondingly stronger gravitational force. Using ct instead of r allows this balance to be maintained because the above observer would see proportionately less time elapsing as light traveled the distance r.

There is precedent for this approach in the behavior of gravitational waves, which propagate at the speed of light. Their influence on distant objects diminishes with the square of the light-travel

distance, not the coordinate distance. This supports the idea that gravitational interactions may be governed by ct² rather than r².

As the radius of a massive object shrinks and its density increases, ct becomes significantly larger than r for an observer in a weak gravitational field. However, any observer in a strong field will have a slow clock, and thus see ct to have a value that is smaller than r. For the distant observer in the weak field, ct being larger than r leads to a reduction in the observed gravitational acceleration. Consequently, the rotation speed of stars in the outer regions of a galaxy appears slower than expected from traditional models. This effect can explain the observed rotation curves without invoking dark matter, provided the central mass is sufficiently compact and baryonic.

3. Modeling the Milky Way

To test the viability of this relativistic framework, a numerical model of the Milky Way galaxy was constructed using known mass distributions and observed rotation velocities. The goal was to determine whether the observed rotation curve could be reproduced using only baryonic matter, once relativistic mass and time-dilated distance (ct) were incorporated.

3.1 Visible Matter and Traditional Velocity Calculations

Diagrams of the Milky Way rotation curve vary, but one commonly referenced plot shows the contribution of visible mass and total mass to stellar velocities. According to this diagram, the velocity at the galaxy edge due to visible matter is approximately 140 km/sec, increasing to 160 km/sec at the radius of the Sun.

Using traditional Newtonian methods and the visible mass of 1.2×10^{41} kg (equivalent to 6.0×10^{10} solar masses), the calculated acceleration at the galaxy edge is:

a = 4.686×10^{-11} m/sec²

This yields a velocity of:

v = 139 km/sec

which closely matches the diagram's value of 140 km/sec.

At the Sun's radius (2.507×10^{20} meters), assuming that 81% of the visible mass lies within that radius, the calculated velocity is:

v = 161 km/sec

with an associated acceleration of:

a = 1.0315×10^{-10} m/sec²

These values confirm that the model accurately reflects the gravitational influence of visible matter alone.

3.2 Total Velocity and Required ct

The same diagram shows that the observed velocity at both the galaxy edge and the Sun's radius is approximately 225 km/sec. This corresponds to a total centrifugal acceleration of:

$a = v^2 / R = 1.226 \times 10^{-10}$ m/sec²

Subtracting the visible matter's contribution leaves:

$a = 7.577 \times 10^{-11}$ m/sec²

to be accounted for by the central mass. Using the modified gravitational equation:

$a = GM / (ct)^2$

and a central baryonic mass of 2.88×10^{42} kg, the required ct from the galaxy edge to the center is:

$ct = 1.592 \times 10^{21}$ meters

This is significantly larger than the actual galaxy radius of 4.133×10^{20} meters, indicating substantial time dilation effects.

3.3 Velocity at the Sun's Radius

To calculate ct from the Sun to the galactic center, subtract the distance from the Sun to the galaxy edge (1.627×10^{20} meters) from the total ct:

$ct = 1.592 \times 10^{21} - 1.627 \times 10^{20} = 1.430 \times 10^{21}$ meters

This yields an acceleration due to central mass of:

$a = GM / (ct)^2 = 9.398 \times 10^{-11}$ m/sec²

Adding the visible matter's contribution gives a total acceleration of:

$a = 1.971 \times 10^{-10}$ m/sec²

and a velocity of:

$v = 222$ km/sec

which closely matches the observed value of 225 km/sec.

3.4 Central Mass Compression and Photon Behavior

To produce the required ct, the central baryonic mass must be compressed into a sphere of radius:

$R_s = 1.931 \times 10^{14}$ meters

This radius is less than 1/20th of the Schwarzschild radius, implying extreme density without forming a traditional black hole. At this configuration, the frequency ratio f_R / f_i is:

At galaxy edge: 1.0000052   At Sun's radius: 1.0000085   At surface of central mass: 6.4129×10^4

This means that an approaching photon's wavelength shrinks to less than 1/64,000 of its original value, requiring a laser range finder located in the visible star portion of the galaxy to emit many more wavefronts to span the same physical space. Thus, ct as seen by an observer in a weak gravitational field, becomes significantly larger than R.

3.5 Internal Frequency and Integration of ct Within the Mass

To complete the model, we must calculate the frequency shift of photons traveling within the compressed central mass and determine how this affects the time-dilated distance ct. For simplicity, we assume the central mass has a constant density.

Inside a sphere of uniform density, the gravitational force at radius r is proportional to the enclosed mass, which scales as $(r / R_s)^3$. Define the constant K as:

$K = GM / c^2$

The frequency ratio f_r / f_i for a photon at radius r inside the mass is given by:

$f_r / f_i = \exp[\ K / R_s + (K / (2 * R_s)) * (1 - (r / R_s)^2)\ ]$

At the center of the mass (r = 0), this simplifies to:

$f_0 / f_i = \exp(3K / (2 * R_s)) \approx 1.624 \times 10^7$

This means that a photon at the center has a frequency more than 16 million times greater than its original value, implying an extremely short wavelength and a correspondingly large ct.

To calculate the total ct from the galaxy edge to the center of the mass, we break the integration into two parts:

1. **From the galaxy edge to the surface of the central mass**

   $ct = \int$ from R to Rs of $[\ \exp(K / r) / \exp(K / R)\ ]$ dr

Solving this integral for the Milky Way model yields:

$ct \approx 4.147 \times 10^{20}$ meters

2. **From the surface to the center of the central mass**

$ct = \int$ from Rs to 0 of $[\exp(K / Rs + (K / (2 * Rs)) * (1 - (r / Rs)^2)) / \exp(K / R)]$ dr

Using Simpson's rule to estimate this integral gives:

$ct \approx 1.1803 \times 10^{21}$ meters

Adding both contributions results in a total ct of approximately 1.5950×10^{21} meters, which is within round-off error of the required ct of 1.592×10^{21} meters (shown in section 3.2). This confirms that the model's internal frequency structure and mass distribution can produce the necessary time-dilated distance to match observed galactic rotation velocities.

4. Elliptical Orbits and Time Dilation

The S stars orbiting near the center of the Milky Way provide a compelling observational test for any gravitational model. These stars follow highly elliptical paths and reach extreme velocities, with one of them completing an orbit in just sixteen Earth years. Traditional models suggest that such orbits would bring the star's perihelion within the Schwarzschild radius of the central mass, implying that it should not be visible. However, observations confirm its continued visibility, challenging the notion of a true event horizon.

In the relativistic framework presented here, the central mass is not a black hole in the traditional sense. Instead, it is a highly compressed baryonic core with extreme time dilation but no singularity. This allows light to escape, albeit with significant energy loss, and permits the S stars to remain observable throughout their orbits.

Time dilation plays a critical role in interpreting these orbits. An observer on Earth sees the star complete its orbit in sixteen years, but the local clock near the perihelion—deep within the gravitational well—runs significantly slower. Preliminary calculations suggest that the local time dilation factor at perihelion could be four to five times greater than at aphelion. Even at aphelion, a small but measurable time dilation persists.

This means that while the star's proper orbital period may be shorter, the time observed from Earth is lengthened due to relativistic effects. Conversely, if the orbit were slightly smaller and the proper period reduced to eight or ten years, the time dilation would not increase proportionally. This suggests that a sixteen-year orbital period, as seen from Earth, is entirely plausible within this model.

These findings reinforce the idea that extreme time dilation, rather than event horizons, governs the behavior of ultra-dense galactic cores. They also demonstrate that elliptical orbits in strong

gravitational fields can be reconciled with observational data without invoking non-baryonic matter or singularities.

5. Discussion

The model presented in this paper offers a compelling alternative to the dark matter hypothesis by reinterpreting gravitational dynamics through the lens of relativistic mass and time-dilated distance. Several key implications arise from this framework:

5.1 Rethinking Dark Matter

The primary achievement of this model is its ability to reproduce the observed rotation curve of the Milky Way using only baryonic matter. By accounting for the increase in relativistic mass and the stretching of ct due to gravitational time dilation, the model explains why stars in the outer regions of galaxies orbit faster than predicted by Newtonian gravity. This suggests that the apparent need for dark matter may stem from a misinterpretation of relativistic effects rather than the presence of exotic, undetectable particles.

5.2 Compatibility with Observations

The model aligns closely with empirical data, including:

- Rotation velocities at the galaxy edge and solar radius.
- Mass estimates for visible and total galactic matter.
- Observed behavior of S stars near the galactic center.

These consistencies lend credibility to the framework and demonstrate its potential to unify disparate observations under a single relativistic paradigm.

5.3 Implications for Black Hole Theory

The model challenges the traditional concept of black holes by showing that extreme time dilation can mimic the observational effects of an event horizon without requiring a singularity. Light can escape from ultra-dense regions, albeit with significant energy loss, allowing for continued visibility of orbiting bodies and photon emissions. This reinterpretation may have profound implications for our understanding of galactic cores, gravitational collapse, and the limits of general relativity.

5.4 The Role of ct in Gravitational Physics

Redefining distance as ct introduces a new way to reconcile gravitational acceleration with relativistic observations. It ensures that gravitational and centrifugal forces remain balanced across reference frames, preserving the principle of relativity. This approach also mirrors the behavior of gravitational waves, which propagate at the speed of light and diminish with the square of the light-travel distance.

5.5 Limitations and Future Work

While the model is internally consistent and matches key observations, several areas warrant further investigation:

- Extension to other galaxies with varying morphologies and mass distributions.
- Detailed comparison with general relativistic predictions, especially in strong-field regimes.
- Exploration of gravitational lensing effects under the ct framework.
- Development of observational tests to distinguish between this model and dark matter-based models.

6. Conclusion

This paper presents a novel approach to modeling galactic rotation curves by incorporating relativistic mass and redefining gravitational distance as a time-dilated metric, ct. Through rigorous derivation and numerical modeling, it demonstrates that the observed velocities of stars in the Milky Way can be explained using baryonic matter alone—without invoking dark matter.

Key findings include:

- Relativistic mass increases with gravitational potential and can serve as the source of gravitational force.
- Time dilation affects photon frequency and wavelength, stretching ct far beyond the coordinate radius r.
- A compressed baryonic core, with extreme but finite time dilation, can reproduce the gravitational influence traditionally attributed to dark matter.
- The modified gravitational equation, $F = GMm / (ct)^2$, maintains force balance across reference frames and aligns with the behavior of gravitational waves.
- Observations of fast-moving S stars near the galactic center are consistent with this model, suggesting that black holes may be ultra-dense regions rather than true singularities.

The model is internally consistent, numerically validated, and compatible with key astronomical observations. It offers a fresh perspective on galactic dynamics and opens the door to reinterpreting gravitational phenomena through relativistic principles.

Future work may include extending the model to other galaxies, exploring gravitational lensing under the ct framework, and developing observational tests to distinguish this approach from dark matter-based models. By challenging orthodoxy with rigor and creativity, this framework invites a deeper understanding of the cosmos—one rooted in the known laws of physics and the untapped potential of relativistic insight.