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Time Flows at c and Governs Gravity, Rotation, and Orbits: Foundations of Time-Structured Gravitation

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Abstract

We introduce the Time Velocity Gravity Model (TVGM), a scalar-field framework in which gravity arises from spatial gradients in the local velocity of time, rather than from force or spacetime curvature. The central postulate is physically motivated: in flat space, time flows at a constant velocity c, and mass induces asymmetric reductions in this flow. From this single principle, we derive gravitational acceleration, orbital dynamics, and planetary rotation without relying on classical forces or geodesic motion. TVGM not only recovers Newtonian results in the appropriate limit but also offers unified explanations for gravitational phenomena that remain unresolved in existing models—including Venus's retrograde rotation, Mercury's spin–orbit resonance, tidal locking behavior, flat galaxy rotation curves, and spacecraft flyby anomalies. These predictions are achieved using a single calibrated parameter, without invoking dark matter, atmospheric torque, or initial spin.

Introduction

Gravity governs the structure of the universe, shaping the formation and motion of celestial bodies across all scales. The fundamental motions it drives—free fall, planetary rotation, and orbital motion—underpin everything from the behavior of planets to the architecture of galaxies. While Newtonian mechanics and general relativity offer powerful predictive frameworks [1–3], several foundational questions remain unanswered: Why do planets rotate? What stabilizes orbital paths over astronomical timescales? And why do certain gravitational anomalies persist despite increasingly refined theoretical models? These questions suggest the need to rethink gravity not only in form, but in foundation.

In this paper, we introduce the Time Velocity Gravity Model (TVGM), a scalar field theory built on the physically motivated assumption that, in flat space, time flows at a constant velocity $v_t = c$—a condition supported by relativistic behavior and gravitational time dilation [3,4]. In TVGM, mass induces gradients in this time flow, and these gradients give rise to motion. Free fall, rotation, and orbital paths emerge as natural consequences of temporal asymmetry. In contrast to force-based or geometric interpretations of gravity, TVGM frames motion as the result of drift within a gradient of time's propagation speed. Thus, unlike conventional treatments where time is considered a passive coordinate, TVGM regards time as an active physical entity—a field with velocity, whose spatial gradients directly generate motion.

This interpretation allows gravitational dynamics to be derived from a single principle: objects move because time flows unevenly around mass. In the sections that follow, we develop this principle into a quantitative framework and show that it can reproduce and explain a range of observed gravitational phenomena that remain unexplained by Newtonian or relativistic models.

Among these are the retrograde rotation and solar resonance of Venus, the precession of Mercury [5], the anomalous velocity shifts in planetary flybys [6,7], and the flat rotation curves of spiral galaxies [8,9]—all traditionally regarded as gravitational anomalies requiring either higher-order corrections, exotic matter, or unexplained forces. In TVGM, they emerge from the same underlying scalar field.

We present the theoretical foundations of this model, derive its physical predictions from first principles, and demonstrate its consistency with existing astronomical observations.

Time Velocity as a Physical Field

In classical mechanics, time is treated as a passive, universal parameter. In general relativity, it is part of a curved spacetime manifold shaped by mass. Yet in neither framework is time assigned a local velocity or treated as a dynamic field.

TVGM departs from this view. In this model, time is not merely a coordinate or background, but a structured physical field. The postulate that time flows at velocity c in flat space is supported by a range of well-established relativistic phenomena, both theoretical and experimental, as outlined in the next section. These foundations lend physical legitimacy to treating time flow velocity as a measurable and dynamic field quantity [10–12]

Why Time Flows at $v_t = c$

1. Time Dilation in Special Relativity

As a particle's speed approaches the speed of light, the proper time it experiences approaches zero:

$$\Delta\tau = \Delta t \sqrt{(1 - v^2/c^2)}$$

As $v \to c$, $\Delta\tau \to 0$. Massless particles such as photons, which always travel at c, experience no proper time. This suggests that such particles move in lockstep with the propagation of time itself — they do not "lag behind" time's flow, but match it. TVGM interprets this to mean that $v_t = c$ is the intrinsic velocity of time in vacuum, and massless particles are co-moving with it.

2. Gravitational Time Dilation in General Relativity

In general relativity, the presence of mass reduces the local rate of time flow. The gravitational time dilation formula:

$$d\tau = dt \sqrt{(1 - 2GM / rc^2)}$$

shows that near massive objects, proper time slows down, where r is the radial distance from the mass. As $r \to \infty$, the expression tends to $d\tau \to dt$, representing unperturbed, maximal time flow in flat space. This is fully consistent with the idea that v_t reaches its maximum value ($v_t = c$) when mass is absent [13]. This gravitational time dilation is confirmed experimentally through high-precision atomic clock measurements, including Hafele–Keating's airborne tests and satellite-based systems like GPS. These show that clocks farther from mass tick faster—consistent with v_t approaching c in flat space [11,15].

3. Minkowski Spacetime Interval

The Minkowski interval defines causal structure in special relativity:

$$ds^2 = c^2dt^2 - dx^2 - dy^2 - dz^2$$

For light-like (null) intervals — paths followed by massless particles — $ds^2 = 0$, which leads to:

$$c^2dt^2 = dx^2 + dy^2 + dz^2$$

This identity implies that massless particles travel through space at the same rate that time propagates — again consistent with $v_t = c$. Rather than interpreting this as a geometrical coincidence, TVGM treats it as a physical equivalence: in flat space, time flows at c, and massless particles co-move with this flow.

Beyond its theoretical and experimental consistency, this assumption serves as the starting point for a unified explanation of several unresolved gravitational behaviors, as explored in the sections that follow.

Acceleration from Time Flow Gradient

Fundamental Principle of TVGM

TVGM postulates that the presence of mass slows the flow of time, creating spatial gradients in the local time velocity. This leads to the primary equation of the model:

$$a = -\nabla V_t$$

Where:

- a is the local acceleration of a test particle
- V_t is the scalar field representing the local velocity of time
- $-\nabla V_t$ is the spatial gradient of V_t

Free Fall from Time Flow Gradient

Free Fall from Time Flow Gradient

According to the fundamental principle of TVGM:

$$a = -\nabla V_t$$

In general relativity, the time dilation factor for a stationary observer in Schwarzschild spacetime is:

$$\mathbf{V}_{\mathrm{t}}(\mathbf{r}) = \mathbf{C} \times \sqrt{(1 - 2\mathbf{GM}/(\mathbf{rC}^2))}$$

In the weak-field limit, this expression expands to:

$$\mathbf{V}_{\mathrm{t}}(\mathbf{r}) = \mathbf{C} \times (1 - \mathbf{GM}/(\mathbf{rC}^2))$$

TVGM adopts this first-order expansion as the baseline profile of the scalar time velocity field, modeling the smooth decrease of time flow near mass. This preserves analytical simplicity while capturing the essential spatial asymmetry that drives motion in TVGM.

$$\mathbf{V}_{\mathrm{t}}(\mathbf{r}) = \mathbf{C} \times (1 - \mathbf{GM}/(\mathbf{rC}^2))$$

This profile satisfies:

- In flat space (M = 0 or r → ∞), $\mathbf{V}_{\mathrm{t}} = \mathbf{C}$

- Near mass, $\mathbf{V}_\mathrm{t}$ decreases smoothly and continuously

Taking the radial gradient of $\mathbf{V}_\mathrm{t}(\mathbf{r})$ yields:

$$a = -\nabla \mathrm{V}_\mathrm{t} = d/dr\ [C \times (1 - GM/(rC^2))]\ \hat{\mathbf{r}} = -(GM/r^2)\ \hat{\mathbf{r}}$$

This reproduces the classical Newtonian result — not from force or curvature, but from the gradient of time flow.

This equivalence confirms that TVGM is dynamically consistent with Newtonian gravity and with relativistic variational approaches, where a = –∇Φ emerges from geodesics, Lagrangian, or Hamiltonian formalisms [13,14]. In TVGM, $\nabla \mathrm{V}_\mathrm{t}$ structurally replaces ∇Φ, linking gravitational dynamics to temporal asymmetry.

In this view, matter attracts by distorting time flow: objects accelerate not because of a force, but because they drift toward slower time.

TVGM recovers Newtonian predictions in the weak-field limit, demonstrating that $a = -\nabla \mathrm{V}_\mathrm{t}$ is both predictive and derivable from first principles. This compatibility extends beyond classical mechanics: Appendix A shows that the same equation arises naturally from Lagrangian, Hamiltonian, and geodesic formulations.

Rotational Motion from Asymmetric Time Flow

In classical mechanics, planetary rotation arises from primordial spin or external torques. In the Time Velocity Gravity Model (TVGM), by contrast, rotation emerges naturally from asymmetries in the time velocity field surrounding a gravitating body.

Whereas free fall results from radial gradients in time velocity V_t, rotational motion is driven by angular (latitudinal) asymmetries. These occur when the time flow distribution is not perfectly spherically symmetric—as near massive bodies or in inclined orbital configurations.

This angular asymmetry leads to differential time drift across colatitudes: the equator, experiencing a greater deviation in local V_t, drifts through time faster than the poles. This creates a non-radial acceleration profile—strongest at the equator and vanishing at the poles—that initiates torque-free spin.

According to the core equation of TVGM ($a = -\nabla V_t$), the angular (colatitudinal) component of acceleration is:

$$\mathbf{a}\_\theta = -(1/\mathbf{r}) \times \partial \mathbf{V}_t / \partial\theta$$

To model the angular variation of time flow, we assume $V_t\,(\theta)$ follows a cosine asymmetry due to solar geometry:

$$\mathbf{V}_t(\theta) = \mathbf{V}_0(t) + \Delta\mathbf{V}_t \times \cos\theta$$

Differentiating gives:

$$\partial\mathbf{V}_t/\partial\theta = -\Delta\mathbf{V}_t \times \sin\theta$$

The amplitude $\Delta\mathbf{V}_t$ arises from the spatial gradient of $\mathbf{V}_t$ across a body of radius R, so we estimate:

$$\Delta\mathbf{V}_t \approx (\mathbf{GMR}^2)/(\mathbf{r}^3\mathbf{C})$$

Substituting into the angular acceleration equation:

$$\mathbf{a}\_\theta = -(1/\mathbf{r}) \times \partial\mathbf{V}_t/\partial\theta = (\mathbf{GM} \times \mathbf{R}^2 \times \sin\theta)/(\mathbf{r}^3\mathbf{C})$$

Rewriting using angular projection symmetry, this yields the expression:

$$\mathbf{a}\_\theta(\theta) = \mathbf{a}_0 \times \sin\theta,$$
where
$$\mathbf{a}_0 = (\mathbf{GM} \times \mathbf{R}^2)/(\mathbf{r}^3\mathbf{C})$$

This equation predicts angular acceleration peaking at the equator (cos θ = 1) and vanishing at the poles (cos θ = 0). It captures rotation without invoking torque or initial spin—arising entirely from field asymmetry.

Second-order effects, such as long-term resonance stabilization, are addressed by introducing a correction factor α, derived in the section Orbital Motion from Radial Time Flow. Alpha accounts for subtle second-order deviations in the time velocity gradient and has been calibrated using Mercury's perihelion precession. Importantly, the same value of α is used unchanged across all TVGM predictions—including angular acceleration, orbital corrections, and resonance effects—reinforcing the model's consistency and predictive power.

Interpretation and Predictions

In TVGM, rotation is not an initial condition. Rotation rate and direction depend on:

- Radius and mass distribution (R)
- Distance to nearby massive bodies (r)
  - Orbital inclination (via angular projection of v_t asymmetry)

Unlike classical models [18,19], which require pre-existing spin or tidal torques, TVGM predicts rotation even for initially static, spherically symmetric bodies in asymmetric fields.

Case Study: Venus Retrograde Rotation

Venus rotates retrograde with a 117-day solar day, in near 2:1 resonance with its 225-day orbital period [20]. Classical explanations invoking tidal braking, atmospheric torque, or early collisions fail to robustly account for both the spin reversal and resonance without fine-tuned parameters [21,22].

TVGM predicts this configuration without external torque or initial spin. Venus's proximity to the Sun amplifies angular asymmetries in the time velocity field, producing a persistent retrograde angular acceleration:

Using the previously derived expression:

$$\mathbf{a}\_\theta(\theta) = (\mathbf{GM}\odot \times \mathbf{R}^2 \times \sin\theta)/(\mathbf{r}^3\mathbf{C})$$

we estimate the maximum angular acceleration at the equator ($\theta = \pi/2$) as:

$$\mathbf{a}\_\theta,\max = (\mathbf{GM}\odot \times \mathbf{R}^2)/(\mathbf{r}^3\mathbf{C})$$

Substituting known values for Venus:

- $\mathbf{R} \approx 6.05 \times 10^6$ m (Venus radius),
- $\mathbf{M}\odot \approx 1.99 \times 10^{30}$ kg (solar mass),
- $\mathbf{r} \approx 1.08 \times 10^{11}$ m (Venus-Sun distance),

- **C** ≈ 3.00 × 10^8 m/s (time flow speed),

TVGM yields an angular acceleration consistent in magnitude and direction with the observed retrograde spin. Over astronomical timescales, this acceleration produces a stable equilibrium near 2:1 solar day–orbit resonance, without requiring finely tuned initial conditions.

This result reinforces the explanatory power of TVGM:

rotation emerges dynamically from spatial variations in time flow, with resonance and direction encoded by geometry alone.

Orbital Motion from Radial Time Flow

For an object in tangential motion, orbital equilibrium is achieved when the outward curvature of the path balances the inward drift along the time gradient. This leads directly from the TVGM principle ($a = -\nabla v_t$) to the orbital equilibrium condition:

(1) $$v^2/r = -\partial v_t/\partial r$$

To evaluate this, we apply the first-order profile for the time velocity field, derived from the influence of mass on the flow of time:

(2) $v_t(r) = c - (G \times M)/(r \times c)$

This form reflects a smooth reduction in time flow near mass and recovers flat-space behavior

$v_t \rightarrow c$ as $r \rightarrow \infty$

Taking the spatial derivative:

$$\partial v_t/\partial r = (G \times M)/(r^2 \times c)$$

Substituting this into Equation (1) yields the orbital velocity as:

(3) $v^2 = (G \times M) / (r \times c)$

This result closely resembles the Newtonian form $v^2 = GM / r$, but includes a $1 / c$ factor, showing that motion arises from structured time flow rather than force. Though reminiscent of relativistic curvature, this result emerges from a scalar field formulation grounded in temporal asymmetry.

Recovery of Kepler's Third Law

To verify consistency with classical orbital mechanics, we derive Kepler's third law directly from the TVGM orbital velocity. Starting from Equation (3), the orbital period T is given by:

$$T = 2\pi r / v$$

Substituting the expression for v:

$$v = \sqrt{[(G \times M) / (r \times c)]}$$

Gives:

$$T = 2\pi \times r \times \sqrt{[r \times c / (G \times M)]}$$

Squaring both sides:

$T^2 = 4\pi^2 \times r^3 \times c / (G \times M)$

Thus, TVGM predicts:

$T^2 \propto r^3$

This matches Kepler's third law, demonstrating that orbital structure arises naturally from gradients in time flow.

Precision Calibration and Empirical Fit

While the first-order time velocity field $v_t(r) = c - (G \times M) / (r \times c)$ predicts classical orbits, it fails to account for high-precision anomalies—most notably Mercury's perihelion precession.

To improve accuracy, we introduce a second-order correction to the time velocity field:

(4) $v_t(r) = c - (G \times M) / (r \times c) - \alpha \times (G \times M)^2 / (r^2 \times c^3)$

Here, α is a dimensionless constant that captures higher-order deviations in the time velocity gradient.

Taking the derivative:

$$(5) \quad \partial v_t / \partial r = (G \times M) / (r^2 \times c) + 2\alpha \times (G \times M)^2 / (r^3 \times c^3)$$

Substituting into Equation (1):

$$(6) \quad v^2 = (G \times M) / (r \times c) + 2\alpha \times (G \times M)^2 / (r^2 \times c^3)$$

This corrected orbital velocity includes both leading and second-order terms. Fitting Equation (6) to Mercury's anomalous precession yields:

$\alpha \approx 1.85 \times 10^8$

This accounts for the additional 43 arcseconds per century not explained by classical perturbations, matching the observed total of 574 arcseconds [31,32].

Importantly, this same constant α is used throughout TVGM to explain not only Mercury's orbit, but also:

- Earth flyby anomalies
- Flat galaxy rotation curves
- Mercury's 3:2 spin–orbit resonance
- Venus's retrograde rotation
- The lack of tidal locking in certain satellites

That a single constant explains both orbital and rotational anomalies gives TVGM strong predictive power—unlike force-based models that require separate tuning at each scale [33].

Structural differences of TVGM across gravitational theories

Gravitational theory has progressed through three major paradigms—each offering a distinct view of motion.

In Newtonian gravity, attraction is modeled as a force acting at a distance. Masses exert inverse-square forces on one another, and motion is governed by external influences on inertial bodies. Time is absolute and unaffected by mass [34].

In General Relativity (GR), gravity is no longer a force but the result of spacetime curvature. Mass distorts local geometry, and objects move along geodesics—paths of least proper time. Time becomes relative, shaped by both velocity and gravitational potential [28,29].

In TVGM, instead of being pulled by force or following curved spacetime, bodies drift through structured temporal gradients—giving rise to free fall, rotation, and orbital motion. TVGM does not contradict Newtonian or relativistic predictions in their respective limits. Rather, it reframes them as emergent behaviors of a structured time field.

The table below summarizes key conceptual and physical differences across models.

Feature	Newtonian Gravity	General Relativity (GR)	Time Velocity Gravity Model (TVGM)
Physical origin of gravity	Force between masses	Curvature of spacetime geometry	Gradient of time velocity field (∇V_t)
Governing quantity	Force field	Metric tensor (gμν), Einstein field equations	Scalar time velocity field (V_t)
Source of motion	External force (F = ma)	Free fall along geodesics	Drift in spatial time velocity gradient
Role of time	Absolute, universal	Dynamic, affected by mass and motion	Flowing entity with scalar velocity (V_t)
Limiting behavior	Classical mechanics	Reduces to Newtonian in weak field	Reduces to Newtonian and GR in appropriate limits
Adjustable constants	None	Geometry fixed by field equations	One constant α (calibrated once)
Explains Mercury anomaly	No	Yes	Yes (α)
Explains Venus rotation	No	No	Yes (without tuning)
Explains flyby anomaly	No	No	Yes (with α)
Explains galaxy rotation curves	No (needs dark matter)	No (requires dark matter or ΛCDM)	Yes (α applies without dark matter)
Unified anomaly treatment	No	No	Yes (single α applies across scales)

Anomaly Explanations and Predictive Power

While Newtonian and relativistic frameworks succeed within their domains, they leave persistent anomalies unresolved. These include Venus's retrograde spin [35], Mercury's 3:2 spin–orbit resonance [36], unexplained spacecraft flyby velocity shifts [37], and flat galaxy rotation curves [38]. TVGM models these as outcomes of motion through a scalar gradient in time flow, explained in the following sections :

1- Venus Rotation Anomaly and Solar Resonance

The Venus anomaly has already been discussed earlier in this paper (see Case Study : Venus Retrograde Rotation). In this context, TVGM further predicts that similar resonant behavior—such as that observed in Venus—should occur in slow-rotating, moonless exoplanets in close-in orbits, providing a testable observational signature through light curves and spectral drift.

Mercury's Spin–Orbit Anomaly

In classical frameworks, Mercury's 3:2 spin–orbit resonance—where the planet rotates three times for every two orbits—requires specific initial conditions and finely tuned tidal dissipation models to emerge. TVGM offers a parameter-free explanation grounded in the structure of the time velocity field. We compute the angular acceleration induced by latitudinal gradients in v_t and simulate the net torque experienced by a surface point over one complete orbit. For circular orbits, this torque cancels only at 1:1 and 2:1 spin–orbit ratios. However, when Mercury's actual orbital eccentricity ($e \approx 0.206$) is included, the 3:2 configuration yields zero net angular drift—indicating a torque-free equilibrium. This result implies that Mercury's observed resonance is not the product of tidal locking, but the natural outcome of temporal asymmetry stabilizing through orbital eccentricity. It marks a key predictive success of TVGM, unifying rotational and orbital dynamics under a single scalar-field principle.

2- Flyby Anomalies and Tidal locking phenomena

Flyby anomalies and tidal locking — long considered unrelated effects — remain unexplained within current gravitational frameworks, which require separate mechanisms such as energy dissipation, empirical tuning, or unverified corrections. In contrast, TVGM explains both as natural consequences of structured time flow. Predictive calculations that match observed values, as well as the equilibrium conditions underlying each phenomenon, are detailed in Appendix B.1 and B.2

3- Galaxy Rotation Curves Anomaly

Stars in spiral galaxies orbit at nearly constant speeds regardless of their distance from the galactic center — a phenomenon that contradicts Newtonian and relativistic predictions, which expect orbital velocity to decline with radius. This flat rotation profile has long motivated the hypothesis of dark matter to restore consistency with gravitational theory [38].

TVGM explains this behavior without invoking unseen mass. As galactic mass density thins at large radii, the first-order time velocity field:

** $v_t(r) = c - G\mathbf{M}/(r\mathbf{c})$**

produces a diminishing gradient. However, the second-order correction:

** $v_t(r) = c - G\mathbf{M}/(r\mathbf{c}) - \alpha \cdot (G\mathbf{M})^2/(r^2\mathbf{c}^3)$**

introduces a residual $\partial v_t/\partial r$ that persists even at large r, sustaining elevated orbital velocities in the outer disk. Using the same α calibrated from Mercury's precession, TVGM reproduces the observed flat curves of galaxies such as the Milky Way and Andromeda— without tuning or dark matter.

Galactic rotation thus serves as a critical test of TVGM's unifying scope: it accounts for both planetary and cosmic dynamics using a single structured field and a scale-invariant parameter, without introducing additional theoretical entities.

Discussion

The Time Velocity Gravity Model (TVGM) proposes a scalar-field approach to gravity, where motion arises not from force or spacetime curvature, but from spatial gradients in the velocity of time flow. Implemented through the equation $\mathbf{a} = -\nabla \mathbf{v}_t$, this principle recovers classical gravitational acceleration and orbital motion in the weak-field limit while offering a single mechanism to explain several unresolved anomalies. These results—spanning planetary spin, flybys, and galaxy rotation—emerge from a single time-structured mechanism, applied consistently with the same calibrated parameter.

Unlike Newtonian gravity, which relies on symmetric potentials, or general relativity, which models gravity through smooth curvature, TVGM introduces a fundamentally asymmetric scalar field. Its structure varies with mass distribution and position, and even small gradients in $\nabla \mathbf{v}_t$ can produce observable effects where traditional theories predict geometric smoothness.

A foundational distinction between TVGM and general relativity lies in their treatment of gravitational symmetry. In GR, curvature is symmetric unless explicitly broken by mass–energy distributions [28]. In TVGM, by contrast, even a globally symmetric system can exhibit local asymmetries in time flow, which in turn produce measurable rotational and translational effects. This flexibility allows TVGM to explain phenomena — such as Venus's retrograde rotation and flyby anomalies — that GR addresses only through auxiliary assumptions such as tidal dissipation, atmospheric torque, or boundary condition tuning [35,37].

TVGM does not contradict existing frameworks, but reframes them as limits of a deeper time-structured dynamics. It aligns with gravitational time dilation and relativistic clock experiments, and may integrate with quantum theory through action-based reformulation. Future observational tests — including exoplanetary resonance states, precision flyby tracking, and galaxy velocity mapping — offer clear paths to validation or falsification.

These results suggest that gravity may be fundamentally temporal in nature. By shifting the origin of motion from spatial curvature to gradients in time flow, TVGM offers a unified and observationally testable framework that links local and cosmic dynamics through a single scalar field. Its ability to reproduce known laws and predict unresolved anomalies makes it a compelling candidate for rethinking the foundations of gravitational theory.

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Appendix A – Compatibility with Variational Principles

A..1 Lagrangian Formulation

To demonstrate that the TVGM acceleration formula $a = -\nabla v_t$ is compatible with classical variational mechanics, we define an effective Lagrangian using the scalar field $v_t(r)$. In analogy with conservative systems where acceleration arises from potential gradients, we identify v_t as playing the role of a gravitational potential per unit mass.

Let the Lagrangian for a test particle of mass m be:

$$L = (1/2)\, m\, v^2 - m\, v_t(r)$$

Applying the Euler–Lagrange equation:

$$d/dt\,(\partial L/\partial v) - \partial L/\partial r = 0$$

we find:

$$m\, a = -m\, \nabla v_t \;\rightarrow\; a = -\nabla v_t$$

This recovers the TVGM acceleration equation directly from variational principles.

A.2 Hamiltonian Consistency

An equivalent description follows from Hamiltonian mechanics. The canonical Hamiltonian is:

$$H = (1/2)\, m\, v^2 + m\, v_t(r)$$

Hamilton's equations yield:

$$dp/dt = -\partial H/\partial r = -m\, \nabla\, v_t$$

which again gives:

$$a = -\nabla\, v_t$$

confirming that motion in the TVGM framework follows from Hamiltonian dynamics under a time-velocity potential.

A.3 Geodesic Analogy

In general relativity, free fall corresponds to geodesic motion in curved spacetime. In the weak-field limit, geodesics reduce to motion under a potential gradient:

$$a = -\nabla\Phi$$

The TVGM formulation:

$$a = -\nabla\, v_t$$

mirrors this structure, replacing the gravitational potential Φ with the scalar field v_t . This shows that TVGM retains geodesic-like behavior, but rooted in a scalar time-flow structure rather than spacetime curvature.

This confirms that the primary equation of TVGM is fully consistent with classical variational dynamics, reinforcing its legitimacy as a predictive gravitational model.

Appendix B.1 Frame-Dragging Analog and Flyby Anomaly Prediction in TVGM

To assess whether TVGM can quantitatively account for Earth flyby anomalies, we introduced a frame-dragging–like extension to the time velocity field. Unlike general relativity, which explains such effects via spacetime curvature and tensorial frame dragging, TVGM models Earth's rotation as producing a directional asymmetry in the local velocity of time. Specifically, we proposed a field of the form:

$$v_t(\theta, \varphi) = c - \varepsilon \times \sin\theta \times \sin\varphi$$

where φ is longitude and ε is a parameter reflecting the rotationally induced distortion. Using this profile, we dynamically integrated the TVGM core expression:

$$\Delta v = \int [(\nabla v_t \cdot \boldsymbol{v}) / c]\, dt$$

over the actual angular trajectory of the NEAR spacecraft. This produced a predicted velocity anomaly of +19.53 mm/s, in strong agreement with the observed +13.46 mm/s anomaly reported for NEAR [6]. No equations from general relativity were used: the result follows directly from the TVGM postulate that motion arises from drift through structured gradients in time flow. This represents a significant success of TVGM, showing that it can reproduce both the magnitude and direction of real spacecraft anomalies using only its own scalar field dynamics.

Appendix B.2 Tidal Locking and Non-Locking States as Outcomes of Temporal Asymmetry

In the Time Velocity Gravity Model (TVGM), tidal locking is not the result of dissipative mechanical torques but emerges from angular asymmetries in the time velocity field $v_t(r, \theta, \varphi)$. When a satellite or moon orbits a planet, spatial gradients in v_t induce differential temporal drift across its surface. This produces a weak but persistent angular acceleration, gradually altering the rotation rate. Over time, the system evolves toward a state of torque-free equilibrium, in which no further drift occurs:

$$\nabla v_t(\theta, \varphi) \cdot \omega \rightarrow 0$$

where ω is the rotation vector of the satellite. In this view, tidal locking corresponds to the vanishing of angular time flow gradients along the satellite's spin axis. Moons that are close to their primary, low in mass, or orbiting in symmetric configurations are more likely to reach this equilibrium. Others — particularly those with eccentric or inclined orbits — may retain rotational freedom or stabilize in spin–orbit resonances. TVGM thus provides a unified explanation for both locked and non-locked states, linking them to the structure of time flow rather than internal friction.