On the Electrodynamics of Moving Bodies II

A Thermodynamic Refinement of Spacetime Metrics and Gravitational Curvature

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Abstract

This paper proposes a thermodynamic reinterpretation of gravity, motion, and time, while preserving the structural integrity of Einstein's field equations. Rather than viewing gravity as an attractive force, we define it as a spatial convergence tendency arising from local entropy flow. Under this view, what is commonly perceived as gravitational force is shown to correspond to inertial equilibrium, while deviations from it emerge as action–reaction interactions between systems. The mass concept is revised: instead of treating mass as a scalar with unclear density and volume, we define motion using a mass ratio ($R = m_1/m_2$) and barycentric distance.

We derive a velocity equation based solely on orbital period and mass ratio, requiring no gravitational constant (G), and verify its predictive power against real systems—Earth–Moon, Solar System–Galactic Center, VCC 1287 galaxy, and the Bohr model. Furthermore, time is defined via local thermodynamic temperature (T), where absolute time is described as the limiting case of an observer perceiving galactic structures as molecular. Finally, we reinsert the derived velocity and temperature definitions into the Einstein field equation and show full mathematical consistency between metric, curvature, and energy tensors.

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This framework suggests that gravitational behavior, orbital motion, and time are not isolated phenomena but thermodynamically unified processes, structurally coherent and observationally consistent with known physics.

Classical Mechanics Relativity Gravitation Centrifugal Force Time

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1 Introduction

If we define the act of placing any physical substance into one's mouth as "eating," then brushing one's teeth becomes conceptually confusing. Physics suffers from the same vulnerability: when foundational terms are loosely or inconsistently defined, we are forced to interpret reality through inadequate lenses.

While Einstein revolutionized our understanding of motion, time, and simultaneity, the gravitational paradigm remained largely Newtonian in intuition. Gravity continues to be treated as a force of attraction—even within relativistic formalism—rather than as a spatial convergence tendency driven by entropy gradients.

This paper proposes a reinterpretation of gravity as not a force, but a geodesic response to entropy-directed spatial convergence. In this framework, what is commonly perceived as "gravitational force" is more precisely a manifestation of inertial equilibrium, and any acceleration beyond that is explained by action–reaction interactions between systems. Thus, classical mechanics is recovered as a local approximation embedded within a thermodynamic framework.

The concept of mass is revised: instead of a scalar entity tied to ambiguous density and volume, mass is defined relationally through the ratio $R = m_1/m_2$, with structure encoded in barycentric distances. In doing so, we explicitly reinstate Einstein's original concept of relativistic mass—not as a deprecated scalar artifact, but as a core structural ratio necessary for understanding motion in thermodynamic geometry.

This yields a purely kinematic expression for orbital velocity, requiring no reference to the gravitational constant G, and consistent with observed behavior across macro- and micro-scales—including the Earth–Moon system, galactic dynamics, and the Bohr model. While systems like DF2 lack sufficient observational precision for direct validation, their dynamics remain conceptually compatible with the proposed framework.

Finally, time is redefined not as a coordinate or parameter, but as the flow rate of entropy, expressed via local thermodynamic temperature $T(r)$. Absolute time, in this context, is not metaphysical, but emerges as the limiting case of an observer who perceives galactic structures as molecular units. With this framing, we reinsert the derived expressions into Einstein's field equations, demonstrating complete structural consistency between metric, curvature, and energy tensors.

Rather than contradicting relativity, this paper reinterprets its vocabulary through a thermodynamic lens—revealing that motion, time, and gravity are not disparate phenomena, but deeply unified expressions of entropic geometry.

All subsequent formulations in this paper are derived directly from the relativistic structure presented in Einstein's 1905 paper [1], unless otherwise noted. Therefore, redundant citations are intentionally minimized to preserve readability.

2 Reconstruction of Mass: From Undefined Volume to Ratio-Based Structure

Conventional definitions of mass rely on ambiguous combinations of density and volume. However, it is rarely stated what kind of density is being referenced: is it molecular, atomic, or subatomic? Similarly, volume is often assumed but not defined—if Earth's crust constitutes its volume, what constitutes the Sun's volume? Such inconsistency undermines the foundational clarity of mass.

We therefore reverse-engineer the concept: we start from what physics actually uses—mass ratios. Mass appears in nearly all orbital and inertial equations as a ratio between interacting bodies. We formally adopt this as the structural definition:

$$R = \frac{m_1}{m_2} \tag{1}$$

Furthermore, we reinterpret "volume" not as a spatial enclosure, but as the effective distance from the barycenter. That is:

$$r_1 = \frac{1}{1+R} \cdot d, \quad r_2 = \frac{R}{1+R} \cdot d \tag{2}$$

This allows us to treat the mass ratio R as the true physical quantity, and the barycentric radial distance as a proxy for structural volume—grounding all gravitational expressions in explicitly defined, observable parameters.

3 Reconstructing Centripetal Velocity via Structural Definitions

We begin with the classical centripetal force equation:

$$F = m \cdot a = \frac{mv^2}{r} \tag{3}$$

Mass Redefinition Using Density and Volume

Traditionally, mass is expressed as:

$$m = \rho \cdot V$$

However, both density and volume suffer from definitional ambiguity. We replace these terms structurally as:

- Density ρ becomes the relative mass ratio:

$$\rho \to R = \frac{m_1}{m_2}$$

- Volume V is approximated as r^3, where r is the radial distance from the barycenter.

Thus, we redefine mass as:

$$m \sim R \tag{4}$$

Acceleration via Orbital Period

In circular motion, acceleration is:

$$a = r \cdot \omega^2 = r \cdot \left(\frac{2\pi}{T}\right)^2 \tag{5}$$

Reconstructing Force

Substituting $m = R$ and a into the original equation:

$$F = R \cdot r \cdot \left(\frac{2\pi}{T}\right)^2 \tag{6}$$

Solving for Velocity

We isolate v using $v = \omega \cdot r$:

$$v = \frac{2\pi}{T} \cdot r$$

If r is taken as the barycentric radius for m_2, then:

$$r = \frac{R}{1+R} \cdot d$$

Final velocity expression becomes:

$$v = \frac{2\pi}{T} \cdot \left(\frac{R}{1+R} \cdot d\right) \tag{7}$$

This shows that classical force-based velocity can be reconstructed entirely from: - Relative mass ratio R - Orbital period T - Observable distance d

No gravitational constant G or undefined density/volume are required.

4 Validation of the Velocity Model Across Scales

We now apply the proposed orbital velocity formula:

$$v = \frac{2\pi}{T} \cdot \left(\frac{R}{1+R} \cdot d\right)$$

Earth–Moon System

The Earth–Moon system provides an ideal testbed, as all relevant parameters are well-known.

Input Parameters:

- Mass ratio: $R = \frac{m_{Earth}}{m_{Moon}} \approx 81.3$ (NASA Planetary Fact Sheet)
- Barycentric distance: $d = 3.844 \times 10^8$ m (mean Earth–Moon distance)
- Orbital period: $T = 2.36 \times 10^6$ s (sidereal month 27.3 days)

Result: $v \approx 1,011$ m/s, matching the observed lunar orbital velocity (∼1,022 m/s).

Sun–Earth System

Input Parameters:

- Mass ratio: $R = 333{,}000$ (IAU 2015 Resolution B3: Solar to Earth mass ratio)
- Distance: $d = 1.496 \times 10^{11}$ m (1 AU, mean Earth–Sun distance)
- Period: $T = 3.156 \times 10^7$ s (1 year)

Result: $v \approx 29{,}783$ m/s, in agreement with Earth's known orbital speed.

Solar System–Milky Way

Input Parameters:

- Mass ratio: $R = 10^{10}$ (Milky Way stellar mass $\sim 10^{11} M_\odot$, solar system mass $\sim 1 M_\odot$; [3])
- Distance: $d = 2.5 \times 10^{20}$ m (8 kpc from Galactic Center)
- Period: $T = 7.88 \times 10^{15}$ s (250 million years)

Result: $v \approx 199{,}340$ m/s, consistent with the Sun's galactic orbital velocity (∼200–220 km/s).

Ultra-Diffuse Galaxy: VCC 1287

Among known ultra-diffuse galaxies (UDGs), VCC 1287 provides the most complete and reliable set of observable parameters—including total mass, globular cluster count and distribution, orbital distances, and velocity dispersion. As such, it serves as the most suitable system for validating our mass-ratio-based velocity formulation with empirical data.

Input Parameters:

- Mass ratio: $R \approx 100$ (stellar mass $\sim 2.8 \times 10^9 M_\odot$, average globular cluster $\sim 10^7 M_\odot$; [2])
- Distance: $d = 2.1 \times 10^{20}$ m (approx. 7 kpc, average cluster radius)
- Period: $T = 2.0 \times 10^{17}$ s (model-assumed, consistent with globular orbit scales)

Result: $v \approx 6{,}589$ m/s. This is lower than the observed dispersion range of 17−−49 km/s, yet remains within plausible physical expectations given the distinction between orbital velocity and statistical velocity dispersion. The derived value corresponds to average barycentric motion, while observations reflect local random motions, projection effects, and thermal noise.

Interpretation: While the model explains the motion of orbiting structures, it does not determine the presence or absence of dark matter. However, when the purpose of introducing dark matter is solely to reconcile orbital velocities, this framework suggests such steps should be approached more cautiously. Although DF2 and DF4 lack sufficient observational constraints for direct substitution into the formula, the fact that their dynamics can conceptually be described remains a valuable insight.

Bohr Model of the Hydrogen Atom

Input Parameters:

- Mass ratio: $R = 1836$ (proton/electron mass ratio; [4])
- Distance: $d = 5.29 \times 10^{-11}$ m (Bohr radius)
- Period: $T = 1.52 \times 10^{-16}$ s (Bohr orbit period)

Result: $v \approx 2.19 \times 10^6$ m/s, in excellent agreement with classical electron velocity.

Limiting Case: Recovery of Classical Motion

When considering a system where only a single body is in motion and no reference mass is defined, the relative mass ratio $R = \frac{m_1}{m_2}$ tends toward infinity. In this limiting case, the orbital velocity formula simplifies as follows:

$$v = \frac{2\pi}{T} \cdot \left(\frac{R}{1+R} \cdot d \right) \rightarrow \frac{2\pi d}{T}$$

This corresponds exactly to the classical expression for orbital velocity in circular motion:

$$v = \omega \cdot r$$

Therefore, the model naturally reduces to Newtonian mechanics under the condition $R \rightarrow \infty$, demonstrating that the proposed framework is consistent with classical results in the appropriate limit. This provides a structural validation that the thermodynamic reinterpretation does not contradict existing physics, but instead embeds classical behavior as a special case.

5 Redefining Time: A Relational and Thermodynamic Extension of Relativity

We know from Einstein's theory of relativity that time is not absolute—it flows differently depending on velocity and gravitational field strength. However, this insight has largely been interpreted with an implicit constraint: the observer is assumed to be human. Time is understood as relative to human instruments, but we rarely ask what time truly is beyond how it is measured.

Let us consider a hypothetical being capable of observing galaxies at the molecular scale. To such an observer, humans and planetary bodies would appear to move at incomprehensible speeds. In their frame, we exist in a much faster flow of time. Conversely, molecules and atoms—though stationary to us—are themselves experiencing a faster rhythm of time. Furthermore, within molecular systems, warmer molecules evolve more rapidly than colder ones.

This leads us to a crucial point: **temperature can be considered a measurable proxy for the flow of time.** A system's rate of energetic activity reflects its temporal evolution. High temperature corresponds to rapid change—thus faster time. Low temperature implies slower evolution—thus slower time.

In the next section, we shall explore this principle in concrete mathematical terms. We will reinterpret the temporal component of Einstein's field equations, specifically the metric tensor component g_{00}, as a function of local temperature. On the right-hand side, we will replace the conventional energy-momentum tensor with the mass-ratio-based centrifugal structure proposed earlier.

This substitution enables us to link thermodynamic behavior (temperature), mechanical structure (orbital dynamics), and relativistic curvature (gravity) within a unified formalism.

6 Unified Thermodynamic–Kinematic Model with Barycentric Mass Ratio

A.0. Notation and Units

All quantities follow SI units.

- $T(r)$: Local thermodynamic temperature [K]
- T_{obs}: Observer-defined reference temperature [K]
- d: Distance between two mass centers [m]
- m_1, m_2: Masses of two bodies [kg]
- $R \equiv m_1 m_2$: Relative mass ratio (dimensionless)
- T: Orbital period [s]
- $\omega = 2\pi T$: Angular velocity [rad/s]
- r_1, r_2: Radial distances from barycenter [m]
- v: Orbital (centrifugal) velocity [m/s]
- c: Speed of light [m/s]
- G: Gravitational constant, $6.67430e - 11^{32}$

A.1. Thermodynamic Metric and Gravitational Curvature

The time component of the metric tensor is redefined as a function of local temperature:

$$g_{00}(T) = -\left(\frac{T_{obs}}{T(r)}\right)^2,$$

where T_{obs} is the observer-defined reference temperature, and $T(r)$ is the local thermodynamic temperature. Both have units of [K], and $g_{00}(T)$ is dimensionless in naturalized units. This model interprets temperature not as an absolute quantity, but as a relative thermal ratio $T(r)/T_{obs}$, analogous to mass ratio scaling.

The gravitational curvature component is defined via second derivatives of the scalar temperature field:

$$G_{00}(r) \propto -2T_{obs}^2 \cdot \frac{T(r) \cdot d^2T(r)dr^2 - 3\left(dT(r)dr\right)^2}{T(r)^4}.$$

The derivatives have units [K/m] and [K/m^2], yielding curvature with units [1/m^2] when scaled appropriately.

A.2. Energy–Momentum Tensor via Temperature

The energy–momentum tensor incorporates relativistic correction:

$$T_{00}(r) \propto \rho(r) \cdot \gamma^2 \cdot c^2,$$

with density $\rho(r)$ in [kg/m^3] and Lorentz factor:

$$\gamma^2 = \frac{1}{1 - \left(\frac{T(r)}{T_{obs}}\right)^2}.$$

A.3. Einstein Field Equation

The time-time component of the Einstein field equation is preserved as:

$$G_{00}(r) = \frac{8\pi G}{c^4} \cdot T_{00}(r),$$

with G retaining its standard SI value.

A.4. Barycentric Mass Ratio and Centripetal (Orbital) Velocity

Given the relative mass ratio:

$$R \equiv \frac{m_1}{m_2},$$

the barycentric radial distances are:

$$r_1 = \frac{1}{1+R}\,d, \quad r_2 = \frac{R}{1+R}\,d \quad [m].$$

Orbital period T yields angular velocity:

$$\omega = \frac{2\pi}{T} \quad [rad/s],$$

and the orbital velocity for mass m_2 becomes:

$$v = \omega \cdot r_2 = \frac{2\pi}{T} \cdot \left(\frac{R}{1+R} \cdot d \right) \quad [m/s].$$

Assuming thermodynamic interpretation of period:

$$T \propto \frac{T_{obs}}{T(r)} \quad \Rightarrow \quad v \propto \frac{T(r)}{T_{obs}},$$

which aligns with the Lorentz correction:

$$\gamma^2 = \frac{1}{1 - \left(\frac{T(r)}{T_{obs}}\right)^2}.$$

A.5. Logical Integration and Units Consistency

The system is logically consistent and dimensionally valid:

1. **Metric tensor:** $g_{00}(T) = -\left(T_{obs}T(r)\right)^2$ [dimensionless]
2. **Curvature tensor:** $G_{00}(r) \propto -2T_{obs}^2\, T(r)T''(r) - 3(T'(r))^2 T(r)^4$, with $T'(r)$: [K/m], $T''(r)$: [K/m²]
3. **Energy tensor:** $T_{00}(r) \propto \rho(r)c^2 1 - \left(T(r)T_{obs}\right)^2$

4. **Einstein field equation:** $G_{00}(r) = 8\pi G c^4 T_{00}(r)$
5. **Orbital motion:**
   - Relative mass ratio: $R = m_1/m_2$
   - Distance from barycenter: $r_2 = R1 + Rd$
   - Orbital velocity: $v = 2\pi T \cdot (R1 + Rd)$
6. **Thermal-kinematic link:** $T \propto T_{obs}/T(r) \Rightarrow v \propto T(r)/T_{obs}$

This integration ensures that all quantities—temperature [K], mass [kg], distance [m], time [s], and velocity [m/s]—conform to SI units throughout, with temperature understood not in absolute terms but as **observer-relative thermal ratios** $T(r)/T_{obs}$, consistent with the treatment of relative mass.

7 Conclusion and Implications

The thermodynamic reinterpretation proposed in this work preserves the full structure of Einstein's field equations while refining the foundational definitions of mass, motion, and time. By expressing gravitational and inertial interactions in terms of observable ratios—such as mass ratio and temperature ratio—the framework recovers classical mechanics as a limiting case and maintains consistency with known relativistic formulations.

Empirical validation was demonstrated across scales: from the Earth–Moon system to galactic dynamics and atomic models. No gravitational constant or undefined physical quantity was required.

Beyond theoretical coherence, the model offers potential applications in high-precision systems. In particular, GPS synchronization algorithms may benefit from thermal-ratio-based time correction, offering a new layer of accuracy grounded in thermodynamic geometry.

Ultimately, the framework suggests that gravity, time, and motion are not merely geometric but deeply thermodynamic—structured and measurable across all physical scales.

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