Physical Anchoring of the Unified Theory of Motion

From Dimensionless Toroidal Solitons to Real-World Physical Scales

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Abstract

This seventh document establishes the physical anchoring of the unified motion-based framework developed in Documents 1–6. While those works formulated the ontology of motion, the field-theoretic model, the existence and stability of toroidal solitons, and their interpretation as quanta of organized motion, they did so in dimensionless units. Here we connect the model to physically meaningful scales by analyzing the dimensional structure of the potential, the scaling relations of length and energy, and three representative physical regimes (nuclear, condensed matter, and cosmological). This provides the required bridge between abstract theory and empirically relevant physics.

1 The Dimensional Structure of the Potential

The scalar field potential used in Documents 3–5 has the form

$$U(\rho) = \frac{1}{2}m^2\rho^2 - \frac{g}{3}\rho^3 + \frac{h}{4}\rho^4, \qquad m^2 > 0,\ g > 0,\ h > 0, \tag{1}$$

with natural units $\hbar = c = 1$.

Dimensional analysis yields:

$$[\rho] = \text{mass}, \tag{2}$$

$$[m] = \text{mass}, \tag{3}$$

$$[g] = \text{mass}, \tag{4}$$

$$[h] = \text{dimensionless}, \tag{5}$$

$$[U] = \text{mass}^4. \tag{6}$$

Thus the mass parameter m determines the fundamental physical scale of the theory. The remaining parameters (g, h) set the relative strength of the self-interactions in units of m.

2 Scaling Laws: From Numerical to Physical Units

The numerical simulations performed in Documents 4–5 use the convention $m = 1$. This implies that:

$$\text{length unit:} \qquad \ell_0 = \frac{1}{m}, \tag{7}$$

$$\text{time unit:} \qquad t_0 = \frac{1}{m}, \tag{8}$$

$$\text{energy unit:} \qquad E_0 = m. \tag{9}$$

The toroidal soliton radii obtained numerically were

$$R_c^{(\text{num})} \approx 8, \tag{10}$$

$$a^{(\text{num})} \approx 2, \tag{11}$$

independent of the charge Q.

The corresponding physical radii are:

$$R_c^{(\text{phys})} \approx \frac{R_c^{(\text{num})}}{m}, \qquad a^{(\text{phys})} \approx \frac{a^{(\text{num})}}{m}. \tag{12}$$

Restoring $\hbar, c$,

$$R_c^{(\text{phys})} \simeq R_c^{(\text{num})}\,\lambda_C, \qquad \lambda_C = \frac{\hbar}{mc}, \tag{13}$$

with λ_C the Compton wavelength.

The energy of the configuration scales as

$$E^{(\text{phys})} \approx E^{(\text{num})}\,m. \tag{14}$$

Thus choosing m immediately sets both geometric and energetic scales.

3 Three Representative Physical Regimes

The theory can be anchored to three distinct physical domains, depending on the choice of m.

3.1 Nuclear-scale solitons ($m \sim 100$ MeV)

- $\lambda_C \approx 2 \times 10^{-15}$ m,
- $R_c \approx 8\lambda_C \approx 1.6 \times 10^{-14}$ m,
- $a \approx 4 \times 10^{-15}$ m.

Energetically,

$$E \sim 0.8\, m\, Q \sim 80\text{–}320 \text{ MeV} \quad (Q = 100\text{–}400).$$

The toroidal soliton behaves like a nuclear-scale object with tens to hundreds of MeV of internal motion.

3.2 Condensed-matter / BEC-scale solitons ($m \sim 1$ eV)

- $\lambda_C \approx 2 \times 10^{-7}$ m,
- $R_c \approx 1.6$ μm,
- $a \approx 0.4$ μm.

Energies:

$$E \sim 80\text{–}320 \text{ eV}.$$

The soliton is now a micron-scale object with sub-keV energies, potentially comparable to nonlinear excitations in optical or cold-atom systems.

3.3 Cosmological-scale solitons ($m \sim 10^{-22}$ eV)

- $\lambda_C \sim 2 \times 10^{15}$ m,
- $R_c \sim 10^{16}$ m (tens of light-years),
- $a \sim 3 \times 10^{15}$ m.

Energies remain small unless Q is extremely large. The soliton behaves as a diffuse, astrophysical-scale structure.

4 Interpretation of the Couplings g and h

Once m is fixed, the remaining parameters determine the internal density scale and the ultraviolet stability. A convenient rescaling introduces an intrinsic field amplitude

$$\rho_0 \sim \frac{m^2}{g},$$

leading to a dimensionless potential

$$U(\rho) = m^4 \, \tilde{U}(\tilde{\rho}; \alpha, \beta), \qquad \tilde{\rho} = \frac{\rho}{\rho_0},$$

with

$$\alpha = \frac{g^2}{m^3}, \qquad \beta = h.$$

Thus:

- g sets the density scale of the torus,
- h provides UV repulsion and ensures boundedness,
- different (g, h) alter thickness and internal density but not the geometric invariance under Q.

5 Physical Anchoring as a Component of Validation

This document completes the validation effort of Document 6 by establishing how the dimensionless solutions of the unified motion theory map onto real physical systems. The ability to express radii, energies, and densities in physical units demonstrates that the model is not an abstract mathematical artifact but a scalable framework potentially applicable to nuclear physics, condensed matter, or cosmology.