Gravitational Phenomenology of Toroidal Solitons

Lensing, Wave Emission, Accretion, and Curved-Space Dynamics in the Unified Theory of Motion

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Abstract

This eleventh document develops the gravitational phenomenology of the toroidal solitons introduced in the unified motion-based framework (Documents 1–10). Using the curved-space formulation derived in Document 8, we analyze the gravitational field generated by a ring-shaped mass distribution, predict characteristic lensing signatures, identify the gravitational- wave patterns produced during mergers, and study accretion and dynamical behavior in curved backgrounds. The resulting phenomenology is unique among known compact or extended field configurations, providing a distinct observational fingerprint.

1 Introduction

Toroidal solitons of organized motion possess:

- a ring-shaped mass-energy distribution,
- topologically protected internal flow,
- invariant radii $(R_{\mathrm{in}}, R_{\mathrm{out}}, a)$,
- stable nonlinear dynamics.

These features produce gravitational effects not found in spherical objects (e.g., boson stars) or generic ring configurations (e.g., thin relativistic rings). This document identifies the most robust gravitational predictions.

2 The Energy–Momentum Tensor and Gravitational Field

From Document 8, the stress tensor of the soliton is

$$T_{\mu\nu} = (\partial_\mu \rho)(\partial_\nu \rho) + \rho^2 (\partial_\mu \theta)(\partial_\nu \theta) - g_{\mu\nu} \left[(\partial\rho)^2 + \rho^2 (\partial\theta)^2 - U(\rho) \right]. \tag{1}$$

In the quasi-static regime, the dominant contribution is

$$T_{00} \approx \rho_0^2(\mathbf{x})\, \omega^2 + U(\rho_0),$$

peaked along a thick ring of radius R_c.

The resulting gravitational potential exhibits:

- a shallow minimum at the ring center,
- a deep annular potential trough along $R = R_c$,
- a local maximum in the geometric center of the torus.

This structure produces the lensing and accretion signatures described next.

3 Prediction 1: Ring-Center Gravitational Lensing

A toroidal soliton acts as a thick gravitational ring lens.

Light from a distant source passing through the torus center yields:

- a **central brightening** instead of a shadow;
- two concentric Einstein-like rings;
- an intensity minimum at the geometric center (if a is small).

This differs from:

- Schwarzschild lenses (single Einstein ring),
- Boson-star lenses (central bright shadow + halo),
- Thin relativistic rings (delta-distributed mass).

The toroidal geometry produces a unique *double-ring lensing* signature.

4 Prediction 2: Gravitational Waves from Toroid Fusion

From Document 9, two tori can:

- elastically scatter,
- form bound binaries,
- merge into a single larger torus.

Mergers produce gravitational-wave bursts with:

- dominant $m = 2$ toroidal harmonics,
- ringdown frequencies set by the breathing mode Ω_{br},
- possible "double chirps" if the tori first orbit before merging.

The waveform differs radically from black-hole or neutron-star mergers: it shows a *toroidal ringdown* with characteristic frequencies:

$$f_{\text{br}} \sim \frac{\Omega_{\text{br}}}{2\pi}, \qquad f_{\text{tors}} \sim \frac{n}{2\pi R_c}.$$

These frequencies are connected to internal motion, not spacetime curvature at an event horizon.

5 Prediction 3: Accretion Onto Toroidal Solitons

Matter or radiation interacting with the soliton experiences:

- a repulsive core (centrifugal barrier),
- an attractive ring-like potential,
- a capture region localized around $R = R_c$.

Possible outcomes:

1. **Ring accretion:** matter accumulates in a toroidal band.
2. **Internal channeling:** infalling matter may be funneled along the core if perturbed.
3. **Radiation trapping:** photons can orbit inside the potential trough for long times.

Accretion disks around toroidal solitons differ from black-hole disks by:

- absence of an inner horizon,
- stable orbits inside the central cavity,
- possible double-peaked emission lines.

6 Prediction 4: Floating Orbits and Frame Dragging

If the soliton rotates or if the internal phase flow couples to spacetime, the system exhibits:

- a ring-like frame-dragging profile,
- floating orbits in the interior cavity,
- precession frequencies depending on the winding n.

These effects can mimic certain features of rotating compact objects, but with different radial profiles and weaker singular behavior.

7 Prediction 5: Survival in Curved and Cosmological Backgrounds

Following Document 8, the torus survives in curved backgrounds when:

$$a \ll R_{\text{curv}}.$$

In cosmology:

- the soliton redshifts as $E \propto a(t)^{-3}$,
- comoving radius remains fixed,
- internal frequency experiences cosmological redshift:

$$\omega(t) = \frac{\omega_0}{a(t)}.$$

Thus tori could persist from the early universe to today if formed during phase transitions.

8 Prediction 6: Distinguishing Toroidal Solitons from Other Models

Key differences:

- **Boson stars:** spherical; no ring lensing; no cavity.
- **Q-balls:** radius grows with Q; no fixed geometry.
- **Vortons:** geometry depends on angular momentum; typically unstable.
- **Black holes:** event horizon; no stable interior orbits.

The toroidal soliton has:

- fixed geometric size independent of Q,
- a cavity with nonzero gravitational field,
- characteristic double-lensing,
- unique ringdown frequencies.

These provide clear observational discriminants.

9 Conclusion

Toroidal solitons in the unified motion-based theory possess a rich and distinct gravitational phenomenology. Their ring-like mass distribution, stable cavity, characteristic lensing, merger waveforms, and accretion behaviour offer multiple observational pathways. Future work will involve full GR simulations and potential connections to astrophysical systems such as dark matter halos, gravitational-wave events, or exotic compact objects.