

# A Resonance-Based Framework for Emergent Matter Formation: Conceptual Basis for the Roton Quantum Model

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## Abstract

We develop the conceptual basis for a deterministic resonance-based physical framework, referred to as the Roton Quantum Model (RQM), which aims to unify the emergence of photons, electrons, compound matter, atomic structure and cosmic-scale forces through a common rotatory resonance principle. The model does not begin with discrete particles nor imposed field quantization; rather, matter and fields emerge as stable self-sustaining resonant configurations of local energy-density oscillations within an underlying medium, termed LEDO-field (Local Energy Density Oscillation field). In this picture, all observable entities are higher-order rotational states and structured combinations of elementary rotational solitons, whose resonance coupling determines stability, binding and long-range interactions.

Within this model, all forms of rotationally coupled entities are termed Rotons which emerge resonance potentials into an underlying field. Layered rotonal hierarchies create structure for locally stable entities and their interactions and forces. Light represents a basic single-axis Roton state, free of intrinsic rotational inertia, whereas electrons are interpreted as three-axis or tri-planar compound rotational states. Higher hierarchical entities arise through resonance locking, axial entanglement and phase-constrained coupling between multi-axis Rotons. The RQM theory predicts that forces conventionally interpreted as electrostatic, nuclear or gravitational arise instead as directional resonance potentials emerging from rotational alignment, frequency matching, and energy-density gradients. Repulsion is generated through saturation of local resonance capacity and increased energy-density pressure, whereas attraction arises from rotational co-alignment and entanglement of axes.

Numerical simulations of Roton configurations show stable equilibrium distances, quantized orbital structures, long-range phase coherence, and emergent shell-like energy wells. These phenomena reproduce central qualitative features of atomic electron trajectories, nucleon clustering, alpha-particle stability, and hierarchical orbital ordering without requiring externally imposed quantum conditions or singular potentials. The model further suggests that isotopic stability corresponds to self-maintaining resonance networks in which multi-axial Rotons remain co-aligned under perturbation.

The RQM additionally implies that time dilation, inertial resistance, orbital locking, molecular bonding and even large-scale galactic forces all arise from differences in rotational inertia of nested resonant structures. Axial entanglement appears as distance-independent coupling—a manifestation of bitemporal resonance coherence—while spatial motion of stable entities remains inertia-limited.

Several open questions define the immediate research direction: (i) establishing quantitative scaling laws from LEDO-field parameters, (ii) deriving closed tensor formulations of resonance potentials, (iii) long-duration simulations showing the spontaneous emergence of nuclei, atoms and stable molecules from homogeneous initial conditions, and (iv) formulation of measurable predictions regarding isotope distributions, resonance-dependent orbital radii and propagation delays of rotational reorientation.

The RQM highlights that many assumptions of contemporary quantum and particle theories—singularities, renormalization, externally imposed quantization operators—emerge automatically as macroscopic consequences of resonance-stabilized dynamics rather than axioms. The model is thereby proposed as an alternative conceptual foundation for matter formation, interaction, and physical structure across scales.

# 1 Introduction

Understanding how stable matter forms from energy remains an open conceptual challenge in modern physics. Conventional approaches—including quantum field theory, renormalized interaction terms, exchange boson formulations, and probabilistic state evolution—successfully describe observed outcomes but do not reveal a constructive mechanism from which stability, inertial response, and quantization laws arise naturally.

We propose an alternative formulation in which observable particles and interactions are not postulated, but emerge as stable resonances within a continuously oscillating field medium. This framework, referred to as the Roton Quantum Model (RQM), assumes that rotating energy density patterns form self-stabilizing closed trajectories in a dynamic energy field. Persistent rotational states constitute photons, electrons, nucleons, and larger bound systems.

The goal of this paper is to introduce the foundational assumptions of RQM, derive the effective interaction terms arising from rotational coupling, and show how material structure can be interpreted as a hierarchy of resonant configurations. By connecting rotational inertia, phase-locking, and resonance alignment, we demonstrate how classical forces and quantum effects appear as emergent macroscopic projections of deeper coherent dynamics.

## 2 Motivation

Conventional quantum models impose quantization axiomatically through boundary conditions, ladder operators, or eigenvalue restrictions. Nuclear binding is postulated rather than derived, entanglement is probabilistic rather than constructive, and temporal evolution depends on statistical measurement outcomes.

The RQM aims to provide a framework where:

1. quantization arises from resonance closure,
2. entanglement is the natural limit of co-rotational alignment, and
3. stability is equivalent to minimized energy-density gradients, where
4. stable structures arise from iterative optimization of local energy density via entanglement and rotonal resonances

Rather than postulating elementary point-like entities, we take finite-sized rotating configurations as the basic carriers of localization, thereby constraining admissible interaction distances. In this view, the persistence of the universe across scales reflects the generic tendency of such configurations to resist complete destruction: structure forms wherever resonance-stabilized states can emerge and prevent total annihilation.

## 3 Conceptual Gaps in Current Standard Physical Theory

*Pre-note: The following discussion reflects the conceptual motivation of the present author and is not intended as a complete critique of the standard model.*

The Roton Quantum Model is not proposed as a replacement for the quantitative success of contemporary quantum field theory, nuclear models or general relativity. Rather, it is motivated by a set of conceptual gaps and tensions that persist in the standard theoretical frameworks. From the perspective of this work, several issues are particularly relevant.

### 3.1 Descriptive success versus constructive mechanism

Standard quantum theory is extraordinarily successful in predicting experimental outcomes, but it is largely formulated in terms of abstract state vectors, operators and effective potentials. Many

key structures (quantum numbers, selection rules, effective interaction terms) are introduced as axioms or fitting ingredients rather than arising from a constructive dynamical mechanism. As a consequence, the formalism explains *how* observables correlate, but only weakly addresses *why* stable entities and specific structural patterns (e.g. preferred bound states, shell structures, clustering) exist in the first place.

### 3.2 Point-like entities, singular potentials and renormalization

Elementary particles are typically modeled as point-like, interacting via singular  $1/r$  or even stronger short-range potentials. This idealization leads to ultraviolet divergences and necessitates renormalization procedures that are mathematically well-defined but conceptually opaque. The need to regularize infinities is at odds with the intuitive expectation that physical entities possess an extended structure and that interaction strengths should remain finite at all scales. A framework based on finite-sized rotating configurations in an underlying medium seeks to avoid such singular behavior from the outset.

### 3.3 Entanglement, measurement and the role of the observer

In standard quantum mechanics, entanglement is implemented at the level of abstract tensor-product states, with nonlocal correlations postulated rather than derived from a concrete dynamical coupling mechanism. The “measurement problem”—the coexistence of unitary evolution and non-unitary collapse—further blurs the line between physical dynamics and observational procedures. Many textbook explanations rely on the presence of an “observer” or on intrinsically “undefined superposed states” prior to measurement. From the viewpoint of the present work, this is conceptually unsatisfactory: entanglement is instead treated as a natural consequence of axial resonance locking between extended rotating entities, and no special ontological status is assigned to an observer.

### 3.4 Nuclear structure and isotope stability

Standard nuclear models (shell model, liquid-drop model, cluster models, QCD-based approaches) reproduce many empirical regularities, yet often require a patchwork of effective interactions, parameter fits and phenomenological assumptions. In particular, the special role of the  $\alpha$ -particle, the detailed pattern of stable and unstable isotopes, and the emergence of preferred nucleon clusters are described, but not derived from a single simple geometric or resonance-based principle in real space. This motivates the search for a framework in which nuclear binding, clustering and isotope boundaries emerge transparently from resonance geometry and energy-density optimization.

### 3.5 Inertia, mass and energy density

Inertia and mass are incorporated in current theory primarily as parameters (e.g. rest mass in the Lagrangian, effective mass in condensed-matter models) or as vacuum expectation values of fields (Higgs mechanism). While this is quantitatively powerful, it leaves open the question of how inertial resistance is linked to underlying spatial structure and local energy-density distributions. A model in which inertia is understood as resistance to reorientation of nested rotational configurations in an energy-density field provides a more geometric and dynamical interpretation of mass-like behavior.

### 3.6 Dark components and large-scale structure

Cosmological modeling currently invokes dark matter and dark energy as effective components to account for galactic rotation curves, large-scale structure formation and cosmic acceleration. These components are inferred from discrepancies between observed dynamics and predictions

based on visible matter and known forces, but their microphysical origin remains unclear. In particular, the contribution of rotational and resonant large-scale structures (e.g. galactic discs and filaments) is typically not treated as an explicit dynamical source of additional forces. The Roton perspective suggests that part of the “missing” dynamics may be attributed to collective rotational resonance effects in the LEDO-field rather than to unseen particulate matter alone.

### 3.7 Lack of a constructive picture of spin

In standard quantum theory, *spin* is introduced as an intrinsic form of angular momentum, encoded in abstract spinor degrees of freedom and represented mathematically by the generators of an internal symmetry. While this formalism successfully predicts a wide range of experimental results (such as Stern–Gerlach splitting, fine structure and magnetic moments), it does not provide a concrete substructural mechanism for what “spins” or how this intrinsic angular momentum is rooted in an underlying physical configuration. Spin is treated as a primitive quantum number associated with state vectors, rather than as an emergent property of an explicitly modeled internal motion or resonance.

From the perspective of the Roton Quantum Model, this creates a conceptual gap: the measurable spin projections along different axes are well described, but the model does not explain *why* a given quantum possesses these particular spin properties, nor how they arise from a deeper level of organization. Moreover, the standard formulation ties spin outcomes explicitly to the choice of measurement axis and apparatus, which reinforces an observer-centred description (projection of a state onto a chosen measurement basis) rather than a constructive account in terms of real geometric structure.

Within the RQM framework, we instead interpret spin as a manifestation of the underlying rotonal architecture: each Roton carries one or more genuine rotational axes and associated planes, whose orientations and couplings determine the effective spin degrees of freedom. Spin projections then correspond to the alignment and precession of these real rotational axes relative to external resonance fields and measuring devices, rather than to purely abstract state-space components. In this view, the familiar spin-quantization phenomena emerge from the allowed stable configurations of rotonal rotation within the LEDO-field, providing a concrete geometrical and dynamical basis for what is otherwise treated as a purely formal property.

*This reinterpretation aims to replace observer-centric projection rules by a constructive dynamics of rotational alignment in the underlying resonance field.*

These conceptual gaps do not invalidate the predictive achievements of standard theory; rather, they highlight the absence of a simple, continuous, and structurally intuitive picture linking microscopic rotational dynamics, entanglement, nuclear structure and cosmic-scale organization. The Roton Quantum Model is intended as a constructive proposal to address precisely this missing layer of explanation.

## 4 Foundational Rules of the Roton Model

### 4.1 Postulate 1: Energy exists as rotational field configurations

Energy is represented as rotational wave configurations sustained by feedback within the LEDO-field. This field is locally resolved in both frequency and spatial orientation, allowing rotational modes to be distinguished by their spectral and directional characteristics.

### 4.2 Postulate 2: Stable states are closed trajectories

A configuration is considered stable if the spatially integrated resonance potential supports a stationary closed trajectory. Such a self-sustaining rotational configuration is referred to as a

*Reson.* When a Reson decomposes into multiple coupled rotational degrees of freedom spanning independent spatial dimensions, each resulting single-axis rotational entity is termed a *Roton*.

### 4.3 Postulate 3: Entanglement arises from axial alignment

Two Rotons sharing an axis experience distance-independent phase locking. This results in directional or distance-stabilizing interaction terms, depending on the relative rotational handedness.

### 4.4 Postulate 4: Repulsion arises from depletion of resonance bandwidth

If the LEDO-field saturates locally, additional entities experience repulsive displacement. Repulsive behavior arises when local resonance capacity is saturated, such that additional rotational coupling increases energy-density gradients rather than coherence.

### 4.5 Postulate 5: Multiple Rotons within a finite interaction radius

Rotons possess a characteristic rotational interaction radius that defines the spatial extent of effective resonance coupling. At separations below this radius, multiple Rotons may be attracted toward and coexist within the same local energy minimum. Stable coexistence is achieved by adopting distinct axis orientations or phase relations, preventing excessive resonance overlap.

### 4.6 Postulate 6: Inertia is resistance to axis reorientation

Acceleration requires a reorientation of rotational trajectories and therefore exhibits a delayed inertial response. This effect is particularly pronounced for multidimensional poly-Roton structures whose internal coherence is maintained within a finite rotational interaction radius.”

## 5 Energy-Density Oscillation Framework (the LEDO-Field)

We introduce the LEDO-field (Local Energy Density Oscillation field) as a continuous background framework embedded within spacetime, providing the medium in which rotational energy configurations, resonance gradients, and coherence structures arise. While spacetime defines locality and temporal ordering, the LEDO-field governs how energy-density oscillations organize, interact, and stabilize through resonance.

The LEDO-field is not introduced as an additional force field, nor as a particle-carrying medium. Instead, it represents the oscillatory substrate that enables rotational energy configurations to couple through resonance. Conventional physical fields—such as electromagnetic, inertial, or gravitational descriptions—are interpreted as effective, scale-dependent projections of structured resonance behavior within the LEDO-field.

The field exhibits approximate scale invariance across a wide range of spatial and energetic scales. With the exception of specific modes associated with photons and electrons, which exhibit characteristic rotational speeds, the governing resonance behavior remains structurally similar from microscopic to cosmic scales.

The LEDO-field is characterized by the following properties:

1. It supports oscillatory energy-density modes with dispersion-like behavior, allowing localized rotational configurations to form stable closed trajectories.
2. Oscillatory modes can remain phase-coherent when resonance locking occurs, leading to persistent rotational structures.
3. The field contains intrinsic stochastic background fluctuations, which continuously perturb resonance configurations and enable exploration of nearby energy-density minima.

Resonance interactions are mediated through a resonance potential field, which can be interpreted as a distributed torque landscape. At each point in space, this field integrates contributions from surrounding rotational structures and background oscillations, resulting in a local torque that induces gyroscopic responses in embedded Rotons. The magnitude and direction of this response depend on the rotational inertia of the object and its coupling to the surrounding resonance environment.

Self-sustaining Rotons actively induce structured contributions into the resonance potential field, while background fluctuations form an inseparable component of the same LEDO-field. Instantaneous resonance alignment may occur bi-temporally—through shared past and future phase relationships—while any physical reconfiguration or propagation of stable structures remains limited by rotational inertia, leading to finite response times.

Within this framework, energy conservation is not imposed as an absolute axiom, but emerges conditionally. Energy remains effectively conserved for as long as a structure maintains resonance coherence. When a configuration destabilizes or separates into substructures, energy may redistribute into constituent rotational modes and partially dissipate into background fluctuations. Conversely, stochastic fluctuations of the LEDO-field can modify local energy-density minima, enabling transitions toward configurations of higher total energy content.

Stability therefore arises dynamically: configurations persist when resonance coherence is maximized and energy-density gradients are minimized. The LEDO-field continuously facilitates both the decay of unstable structures and the long-term persistence of stable Roton and poly-Roton configurations.

Here, LEDO refers to the *Local Energy Density Oscillation* field, emphasizing that resonance interactions are mediated through locally resolved oscillatory energy-density structures.

## 6 Rotons as Fundamental Resonant Units

We define a Roton as a stable, self-sustained rotating energy loop of continuously differentiable curvature. On the kinematic level it is characterized by

- a fundamental frequency  $f$ ,
- a characteristic rotational radius  $R$ ,
- an orientation (axis) vector  $\hat{n}$ ,
- a resonance bandwidth  $\Delta f$ ,

such that the product  $2\pi Rf$  represents an effective energy-density circulation, analogous to an angular-momentum-like quantity distributed along the loop.

In the terminology introduced above, a Roton corresponds to a single one-dimensional rotational degree of freedom of a more general self-sustained rotational configuration (an *Oszillon* or multi-mode Roton). A multi-dimensional oscillatory loop (oscillon) decomposes into several coupled Rotons, each associated with one effective rotation axis and its corresponding loop in configuration space. The set of Rotons belonging to a given Reson share a common center-of-rotation and an internally constrained phase structure.

Beyond  $(f, R, \hat{n}, \Delta f)$  it is convenient to associate to each Roton:

- a phase  $\phi$ , specifying its position along the loop,
- a handedness (chirality)  $\chi \in \{+1, -1\}$ , distinguishing the sense of rotation around  $\hat{n}$ ,
- a relevant interaction radius  $r_{\text{rel}}$ , setting the scale on which its contribution to local resonance potentials is effectively non-negligible,
- an effective rotonal inertia tensor  $\mathbf{I}_{\text{rot}}$ , encoding the resistance to changes in the rotation axis and loop geometry.

Rotons act as localized sources for a spectrally and directionally resolved resonance potential within the LEDO-field. At each spacetime point the LEDO-field can be viewed as carrying a distribution of resonance potentials

$$V_{\text{res}}(\mathbf{x}, \omega, \hat{k}),$$

which describes the propensity of a Roton with intrinsic parameters  $(f, R, \hat{n}, \Delta f, \chi)$  to couple into a given frequency  $\omega$  and propagation direction  $\hat{k}$ . A Roton continuously injects into this resonance field according to its current state, and in turn experiences a torque obtained by integrating the local resonance potential along its trajectory. This torque acts on the orientation vector  $\hat{n}$  and on the loop geometry, resulting in tilts, precession and slow deformations that are limited by the rotonal inertia  $\mathbf{I}_{\text{rot}}$ .

On the level of the LEDO-field, the modification of the resonance potential by the presence or reorientation of Rotons is idealized as virtually instantaneous and bi-temporal: once a Roton changes its state, the corresponding update in  $V_{\text{res}}$  is globally available as a coherent constraint. The actual motion of Rotons in response to this updated field is, however, delayed and smeared out in time due to their finite inertia and the stochastic background fluctuations of the LEDO-field. In this sense, Rotons mediate between an effectively instantaneous, coherence-based interaction channel and a finite-speed, inertia-limited reconfiguration of observable trajectories.

Within their relevant radius  $r_{\text{rel}}$ , multiple Rotons may occupy overlapping spatial regions and couple to similar resonance minima, provided that their axes and phases arrange such that detrimental coherence (which would destabilize the configuration) is avoided. This allows for locally dense, yet dynamically stable, multi-Roton structures, which in higher sections are associated with photon-like, electron-like, nucleon-like and even galactic-scale effective degrees of freedom.

## 7 Emergent Forces from Resonant Coupling

Within the Roton framework, forces are not introduced as primitive interaction terms, but arise as effective manifestations of resonance potentials and gradients in the LEDO-field. A Roton induces a spectrally and directionally resolved resonance potential which acts on other Rotons according to their radius, frequency, orientation and phase. Depending on the relative alignment and dynamical constraints, this leads to distance-independent entanglement forces, distance-locking interactions, and short-range repulsive terms originating from local energy-density saturation.

### 7.1 Co-axial entanglement: distance-independent coupling

The strongest attractive contribution appears when two Rotons share a common rotation axis and are locked in an exactly anti-parallel configuration of their rotational phase (“co-axial anti-parallel entanglement”). In this configuration, the resonance potentials of both partners close upon themselves along the common axis and effectively do not disperse into the surrounding LEDO-field. The external resonance pattern of the pair is therefore strongly suppressed, while the internal torque remains finite and distance independent.

We denote this contribution schematically by

$$F_{\text{ent}} = F_0 \hat{n}, \tag{1}$$

where  $F_0$  is set by the intrinsic rotonal parameters (radius, frequency, phase stiffness) and  $\hat{n}$  is the common axis. In this regime, the entangled pair behaves as a single composite Roton with strongly reduced external resonance signature and a persistent internal binding.

Linear chains of anti-parallel entangled Rotons must overlap in space (within some range near their relevant rotational radius) in order to maintain this mutual cancellation towards the outside. Such overlapping entanglement segments will later be associated with nuclear-scale compound objects.

## 7.2 Parallel-axial resonance and distance locking

If two Rotons share a common axis but are aligned in parallel rather than anti-parallel orientation, their resonance potentials do not cancel externally. Instead, they interfere constructively or destructively at discrete separations along the axis. This leads to phase-locking at preferred distances,

$$d \approx n d_0(R, f, \Delta\phi), \quad n \in \mathbb{Z}, \quad (2)$$

where  $d_0$  is a characteristic resonance spacing that depends on the rotational radius  $R$ , the frequency  $f$  and the relative phase  $\Delta\phi$  between the Rotons. At these separations the net torque on each Roton vanishes while the resonance energy is locally minimized, giving rise to distance-stabilizing interaction terms.

The effective force contribution may be written schematically as

$$F_{\parallel}(d) \sim \kappa(R, f) \frac{\cos(\Delta\phi(d))}{d}, \quad (3)$$

where the  $1/d$ -like behavior reflects that resonance is confined along the axial direction, and  $\kappa$  encodes the coupling strength. The sign of  $F_{\parallel}$  alternates across successive minima and maxima, leading to alternating attractive and repulsive shells.

Depending on constraints, one can distinguish:

- *Free Rotons*: both position and phase are dynamical; distance locking emerges from mutual phase adaptation.
- *Position-locked Rotons*: spatial degrees of freedom are constrained (e.g. by a lattice or nuclear scaffold); resonance adapts via phase shifts, altering the effective force pattern.
- *Phase-locked Rotons*: phase is constrained (e.g. by higher-level entanglement); spatial displacement becomes the primary response to resonance gradients.

In each case, the same underlying resonance potential yields different observable force profiles, depending on which degrees of freedom can respond.

## 7.3 Isotropic resonance and background attraction

If the orientations of two Rotons fluctuate rapidly or remain uncorrelated such that no persistent axial alignment is established, their resonance potentials average to an effectively isotropic pattern. In this limit the remaining attractive component decays approximately as an inverse-square law,

$$F_{\text{iso}}(d) \sim \gamma \frac{1}{d^2}, \quad (4)$$

with  $\gamma$  depending on the spectral overlap of the two Rotons and on the level of background fluctuations in the LEDO-field. This contribution can be seen as the coarse-grained remnant of all transient, non-coherent alignments and represents the weakest but most long-ranged part of the interaction hierarchy.

## 7.4 Energy-density repulsion and bandwidth saturation

At sufficiently small separations, the local LEDO-field becomes saturated: the superposition of oscillations from multiple Rotons exhausts the available resonance bandwidth within the relevant radius. Additional Rotons in this region no longer find attractive resonance channels and instead increase the local energy-density gradient. This produces an effective repulsive term, which we write heuristically as

$$F_{\text{rep}}(d) \sim -\delta \frac{\partial \rho_E}{\partial d} \propto -\frac{1}{d^n}, \quad n \gtrsim 3, \quad (5)$$

where  $\rho_E$  denotes the local energy density and  $n > 2$  reflects that repulsion becomes dominant only at small  $d$  compared to the characteristic rotational radius. Physically, this contribution encodes the resistance of the LEDO-field against further compression of oscillatory patterns in a region already occupied by self-sustained Rotons.

## 7.5 Composite objects: Resons and quons

Within nuclear and sub-nuclear contexts, it is convenient to introduce two derived notions:

- A *Reson* denotes a specific distance-locking entangled configuration of Rotons, in which axial or parallel-axial resonance yields a robust, discrete equilibrium separation. Resons thus represent elementary “bonding modes” in the rotonal picture.
- A *quon* refers to a compact assembly of multiple Rotons whose centers lie within their characteristic rotational radii and are mutually coupled by one or more Resons. Such quons act as effective higher-level Rotons, forming the structural units associated with nucleon-like and nuclear-scale objects.

Chains and clusters of Resons between constituent Rotons or quons generate grid-like and shell-like configurations that correspond, in the appropriate parameter ranges, to nucleons, alpha-particle cores and more complex nuclear structures. In such a context the energy density repulsion is finite and once it is overcome, different Rotons might occupy the same location. This holds at least, as long as their rotonal planes can efficiently avoid each others within their mutually attractive repulsion pot. Vice-versa, existing Rotons with the “same” location can break up if the external forces or rather torque or more precisely the induced precession on parts of the Rotons might get too high.

## 7.6 Effective net force

Collecting the dominant contributions, the effective interaction between two Rotons (or quons) at separation  $d$  and relative orientation  $\Delta\theta$  can be summarized schematically as

$$F(d, \Delta\theta) = F_{\text{ent}}(\Delta\theta) + F_{\parallel}(d, \Delta\theta) + F_{\text{iso}}(d) + F_{\text{rep}}(d), \quad (6)$$

where  $F_{\text{ent}}$  dominates in perfectly anti-parallel co-axial entanglement,  $F_{\parallel}$  governs distance locking for parallel-axial configurations,  $F_{\text{iso}}$  represents residual isotropic attraction, and  $F_{\text{rep}}$  enforces short-range exclusion through energy-density saturation. The observed force laws in atomic, nuclear and gravitationally dominated regimes are then interpreted as different coarse-grained projections of this hierarchy of rotonal resonance couplings.

The model does not know nor result in any singularities. All objects have some dependence to size (span) and forces relate to size.

## 8 Emergent Forces from Resonant Coupling

In the Roton Quantum Model, forces are not introduced as fundamental interactions but arise as effective manifestations of resonance coupling in the LEDO-field. Rotons act as sources of spectrally and directionally resolved resonance potentials. These potentials superpose in the LEDO-field and integrate, at the position of a given Roton, into a net torque and a net translational tendency, both constrained by rotonal inertia and by structural locking conditions (position or phase constraints).

The basic interaction types can be distinguished according to the relative orientation of the rotational axes, their entanglement state, and the freedom of individual Rotons to move or to phase-shift.

## 8.1 Co-axial anti-parallel entanglement: distance-independent locking

If two Rotons share a common rotation axis and are locked into a perfectly anti-parallel entangled configuration, their resonance potentials along that axis mutually reinforce and integrate into a distance-independent net coupling. In this idealized limit, the LEDO-field supports a *constant* effective interaction term between the two partners, i.e. the magnitude of the attractive alignment force does not decay with the separation  $d$ , as long as the axial entanglement remains intact.

In addition, the external resonance potentials of such an anti-parallel entangled pair largely cancel in directions orthogonal to the common axis. From the perspective of distant Rotons, the pair therefore appears partially “screened” or *resonance-neutral*, while internally maintaining a strong binding. Linear chains of such anti-parallel entangled Rotons must overlap within their relevant rotational radii to remain stable, as the cancellation of external potentials relies on spatial superposition of their resonance patterns.

## 8.2 Parallel-axial resonance and distance locking

If the two Rotons share a parallel (or nearly parallel) axis but are not locked into perfect anti-parallel entanglement, their resonance potentials do not cancel. Instead, they interfere constructively at discrete separations. This leads to preferred *distance-locking* states, in which the Rotons tend to occupy separation distances

$$d \approx n d_0(R, f, \phi), \quad n \in \mathbb{Z},$$

where  $d_0$  is a characteristic resonance distance depending on rotational radius  $R$ , frequency  $f$  and relative phase  $\phi$ . In this regime, the coupling decays approximately as  $1/d$  along the axis, corresponding to a quasi-one-dimensional resonance channel.

If one of the Rotons is externally locked in position (e.g. by being part of a larger bound structure) while still free to phase-shift, the resonance will mostly manifest as phase-locking of the free Roton. Conversely, if a Roton is locked in phase (for instance as part of a rigid multi-Roton compound) but free in space, the coupling expresses itself dominantly as distance-locking. In realistic multi-Roton systems, both constraints coexist, leading to quantized distances and restricted phase configurations.

Parallel-axial resonances can propagate across multiple Rotons with aligned axes. Chains or grids of such Rotons support extended distance-keeping patterns and can be seen as the progenitors of more complex nuclear and atomic structures.

## 8.3 Isotropic resonance and $1/d^2$ dispersion

When the relative orientation of rotational axes is not favored, or fluctuates rapidly such that no persistent axial alignment is maintained, the resonance potentials average out over all spatial directions. In this limit, the effective interaction appears isotropic and its amplitude decays approximately as  $1/d^2$ , akin to a radiative or wavefront-like dispersion.

This isotropic component represents the “unpaired” or non-entangled part of the rotonal resonance pattern. It constitutes the background attraction acting between similar Rotons in the absence of strong axial entanglement or distance-locked parallel coupling.

## 8.4 Energy-density repulsion and bandwidth saturation

The LEDO-field has a finite capacity to accommodate coherent resonance within a given spatial region and spectral band. If too many Rotons, or too strong resonances, are concentrated within a volume of order  $R^3$  around a given point, the local energy density  $\rho_E(d)$  increases such that additional Rotons experience a net *repulsive* tendency.

This repulsion can be viewed as arising from the gradient of the local energy density,

$$F_{\text{rep}}(d) \propto -\frac{\partial \rho_E}{\partial d},$$

typically scaling with a stronger distance dependence than the attractive terms (e.g.  $\sim 1/d^3$  at short distances). Physically, this corresponds to *depletion of resonance bandwidth*: once a region is saturated by strongly phase-locked Rotons, further entities cannot couple efficiently and are displaced toward regions of lower energy density and lower resonance occupation.

## 8.5 Effective net coupling

Combining these contributions, the effective net interaction between two Rotons at distance  $d$  and relative axial misalignment  $\Delta\theta$  can be expressed schematically as

$$F(d, \Delta\theta) = F_{\text{ent}} \chi_{\text{coax}} + \alpha \frac{\cos(\Delta\theta)}{d} \chi_{\parallel} + \gamma \frac{1}{d^2} \chi_{\text{iso}} - \beta \frac{\partial \rho_E}{\partial d}. \quad (7)$$

Here  $F_{\text{ent}}$  is the distance-independent contribution from perfectly anti-parallel co-axial entanglement;  $\chi_{\text{coax}}, \chi_{\parallel}, \chi_{\text{iso}}$  are geometric factors selecting the co-axial, parallel-axial and isotropic regimes respectively; and  $\alpha, \gamma, \beta$  encode the sensitivity to resonance alignment and to energy-density gradients.

In the nuclear context, we will refer to a specific distance-locked entanglement configuration as a *Reson*. A localized combination of several Rotons within their mutual relevant radius is called a *Quon*. Extended nuclear and atomic structures then emerge as networks of Resons within coupled Quon clusters, stabilized by the balance of the attractive and repulsive terms in Eq. (7).

## 9 Hierarchical Structure Emergence

A central feature of the Roton Quantum Model is that qualitatively different physical objects—from photons and electrons to nucleons, nuclei, atoms and molecules—are interpreted as different hierarchical organizations of the same basic building blocks: Rotons, Resons and Quons. In this section we distinguish between predominantly *dynamic* structures (where rotational motion and phase relations are central) and more *static* scaffolding structures (which primarily provide geometric constraints and resonance environments for other Rotons).

### 9.1 Dynamic structures: photon- and electron-like states

A single-axis, closed Roton trajectory without internal substructure corresponds to a photon-like object. It is characterized by one dominant rotation axis, minimal internal rotonal inertia, and near-free propagation along trajectories that leave its axis unchanged. Such Tier-1 Rotons interact weakly with other objects, except when they are captured into more complex resonant configurations.

A three-axis compound of mutually coupled Rotons corresponds to an electron-like object. Here three rotational degrees of freedom, associated with approximately orthogonal axes, are phase-locked into a self-sustained closed configuration. This Tier-3 object carries significantly higher rotonal inertia: changes in its translational or rotational state require coordinated reorientation of all three axes and thus are strongly constrained by the local resonance environment.

The coupling of such photon-like and electron-like configurations yields:

- **Orbital degeneracy:** multiple closed electron trajectories with similar energy-density integrals but different spatial orientation or phase embedding.
- **Fixed separation distances:** distance-locked resonances determined by the parallel-axial coupling conditions between electron-like Rotons and rotonal structures in the nucleus.
- **Symmetry-preserving attractive minima:** stable configurations that achieve local energy-density optimization while maintaining approximate spatial symmetries (e.g. s- and p-like shells).

Together, these ingredients form nuclear scaffolding analogous to alpha-particle bases and lead to orbital architectures reminiscent of atomic shells and subshells in standard atomic physics.

## 9.2 Static scaffolding structures: quon compounds and nuclei

Beyond purely dynamic objects, the model predicts the existence of more static, geometrically constrained entities. In the nuclear regime we interpret:

- **Photon entanglement** as the simplest co-axial or parallel-axial locking of Tier-1 Rotons, capable of forming transient or stable loops that feed into higher-tier structures.
- **Electron entanglement (Cooper-like pairs)** as parallel-axial distance-locked configurations of electron-like Rotons, leading to correlated motion and reduced effective rotational inertia along shared axes.
- **Electron–proton entanglement** as a composite structure in which a proton-like object acts as a spatially extended cage for an internal electron-like Roton, whose locked phase and orientation generate an emergent positive effective charge and provide strong co-axial resonance channels to external electrons.

In this view, protons and neutrons are not elementary point-like objects but act as a compound of *Quons*: localized combinations of multiple Rotons held together within their relevant rotational radius, stabilized by internal Resons. A proton corresponds to a Quon configuration that cages an electron-type internal Roton with a specific entanglement orientation. A neutron corresponds to a related configuration with a different internal resonance balance and reduced external coupling.

Deuterons, tritons and alpha-particles then appear as higher-order Quon aggregates:

- The **deuteron** is modeled as the minimal Quon compound that provides a stable rotational environment in an atom core for a single electron-like Roton entanglement to a single unpaired orbital electron.
- The **triton** adds an additional Quon cluster while retaining resonance compatibility, shifting the balance between internal and external coupling. A compound not expected to be of any specific use in bigger atoms.
- The **alpha-particle** is interpreted as a particularly symmetric Quon compound of four nucleon-like structures (two proton- and two neutron-type), embedding a linear electron–proton–proton–electron resonance chain. This configuration provides an exceptionally robust scaffold for electron pair orbitals and appears as the fundamental building block for larger nuclei. It is a prerequisite to provide a fully rotational core compound for paired orbital electrons.

The continued alpha-particle resonances (distance-keeping between rotating Quons) across an atom cluster yield naturally favored nuclear clusterings. These clusters define preferred orientations and multipolar resonance patterns which, in turn, shape the electron orbital structure.

The alpha particle is expected to build do-decahedral and icosahedral structures, allowing optimal geometrical stability and spatial resonances. Neutrons in atom isotopes are expected to improve the shape and stability of the outer shell of an atom core helping the alpha-particles to hold together. This resonance level is created via the rotations of quons on the surface of Neutrons and Alpha-Particles.

## 9.3 From nuclei to atoms and molecules

The orientation and internal resonance pattern of a nucleus define its dominant external resonance channels in the LEDO-field. Electron orbitals thus depend not only on total nuclear charge, but also on the specific arrangement of alpha-like Quon clusters and their collective rotation axes. This leads to:

- orbital shapes and nodal structures arising from multi-axis resonance superposition,
- shell radii determined by distance-locking conditions between electron-like Rotons and the nuclear resonance pattern,
- valence shells that reflect those nuclear orientations most capable of supporting stable distance-locked electron chains.

Molecular binding arises when quon-based Rotons belonging to different nuclei enter joint distance-locked and axis-locked entanglement, while each remains simultaneously entangled with its respective nuclear resonance environment. The respective symmetry of the orbital electrons giving the basic shape. The most attractive chemical bonds thus correspond to configurations in which:

1. a pair (or chain) of electron-like Rotons forms a stable parallel-axial resonance spanning two nuclei or rather a single alpha-particle, and
2. the corresponding nuclear Quon clusters are oriented such that the shared electron chain can freely rotate and be embedded without destroying existing internal Reson dependencies.

In this picture, bond angles, molecular geometries and preferred coordination numbers emerge from the interplay between (i) the discrete set of stable nuclear Quon cluster orientations and (ii) the set of distance-locked and axis-locked electron resonance states that can be realized without compromising local energy-density optimization.

Altogether, hierarchical structure in the Roton Quantum Model emerges as a layered network of Rotons, Resons and Quons, spanning from photon-like excitations up to nuclear clusters, atoms and molecules, with all associated forces and stability conditions arising from a single resonance-based interaction principle.

## 10 Resonance-Based Orbital Dynamics

In the Roton Quantum Model, atomic orbitals are not postulated as abstract eigenstates of a potential, but arise as emergent, resonance-locked trajectories of Tier-3 Rotons (electrons) within the LEDO-field. Orbital radii, shell structure and pairing behavior follow from the tendency of electrons to settle into configurations that maximize local energy-density coherence while minimizing net torque on their rotational axes.

### 10.1 Shell formation as resonance-locked radii

Each nucleus generates a structured resonance potential in the surrounding LEDO-field through its internal Quon configuration and the associated ensemble of confined Rotons. An external electron experiences this potential as a radially and angularly structured torque field. For a given nuclear configuration, there exist discrete radii  $r_n$  at which:

1. the integrated resonance torque on the electron's primary rotation axes vanishes on average, and
2. the electron can maintain a closed, phase-coherent trajectory over many rotations.
3. the number of entanglements can be optimized to increase energy density

These radii  $r_n$  correspond to the familiar atomic shells. They are *resonant distances* at which the electron's intrinsic rotational frequency in inner shells induce resonances in outer shells forming a sort of distance-locking condition. Background fluctuations in the LEDO-field allow electrons to explore nearby configurations; once a configuration with higher local energy-density coherence is found, the electron relaxes into the corresponding resonant radius and remains there as long as the underlying Quon structure and field configuration remain stable.

## 10.2 Single and paired electrons in outer shells

Within a given shell, electrons can occupy distinct rotational planes and phase relations. A *single unpaired electron* typically resides on the outermost available shell, where its rotonal resonance is not fully compensated by a partner. This unpaired state remains more susceptible to external perturbations and thus plays a central role in chemical reactivity.

When two electrons occupy a similar resonant radius, they can form a *rotonal pair* by adjusting their phases and rotational planes such that:

1. their net external resonance potential is partially cancelled (reduction of effective “charge” as seen from outside the atom), and
2. internal resonance coherence is increased (more stable, lower-variance local energy density).

In the language of the model, such a pair creates a further entanglement. A chain built by two orbital electrons and two nuclear electron-like objects in the Alpha-Particle. The pairing increases attraction and reduces the effective external torque on the nuclear cluster while increasing the robustness of the local configuration against background fluctuations.

## 10.3 Multi-dimensional precession and p-like shells

Beyond purely planar rotations (s-like orbitals), electrons can exploit additional rotational degrees of freedom via precession of their primary rotation plane. An electron possesses three intrinsic rotational axes and can redistribute its rotational energy among them. When an electron begins to precess, its trajectory spans multiple planes and can simultaneously couple to several resonant radii.

In this picture, p-like shells correspond to configurations where:

- one dominant rotation defines a primary shell radius,
- a secondary precessional motion allows coupling to additional, slightly shifted radii, and
- the overall trajectory remains closed and phase-coherent in three dimensions.

This multi-dimensional coupling enables electrons to align their rotational planes approximately parallel or orthogonal to structural features of the nucleus (e.g. alpha-particle based chains). As a result, p-like states can move closer to the nucleus compared to purely planar s-like configurations, if the additional coupling increases total resonance coherence. The resulting “orbital contraction” is not imposed by an external potential, but arises from the self-optimization of rotational energy distribution in the LEDO-field.

## 10.4 Entanglement, shell optimization and electron induction

Electrons can form up to three distinct entanglement channels, corresponding to their three intrinsic rotational axes. In an atomic environment, these channels are used to:

1. entangle with internal electron-like Rotons confined in the nucleus (electron–proton or rather electron–Quon entanglement),
2. entangle with other orbital electrons within the same atom (shell pairing and collective modes), and
3. entangle with electrons belonging to neighboring atoms.

As a result rotating electrons form a higher level of Rotons leading to further attractions between electron shells and multiple atoms.

Valence shells are thus not merely local states, but nodes in a larger entanglement network. When a multi-dimensional orbital can increase its resonance coherence by forming a more symmetric pattern—for instance, by completing an electron pair or matching a preferred angular pattern around a nucleus—it effectively *induces* additional electrons into that shell. Nearby atoms providing loosely bound or unpaired electrons experience an attractive torque in the LEDO-field: their valence electrons are “drawn in” to participate in the more symmetric multi-Roton orbital shells.

This *electron insuption* is the rotonal basis of molecular bond formation. The same mechanism explains why valence shell radii and typical bond lengths are relatively universal across different elements: they are determined by the stable resonance distances of multi-electron, multi-nucleus entanglement configurations, rather than by arbitrary parameters. In molecules, the potentially slightly different electron rotation radii of the atoms are expected to align with each other, such that the attraction between the molecular atoms further increases energy density.

## 10.5 Multi-core coupling and molecular orbital analogues

When two or more atoms approach such that their electron-rotation induced resonance fields significantly overlap, new entanglement potentials and distance-locking conditions appear that involve multiple centers. An electron can then simultaneously:

- maintain partial entanglement with electrons and internal Rotons of nucleus A,
- maintain partial entanglement with those of nucleus B, and
- preserve a closed multi-dimensional Roton trajectory in the combined LEDO resonance field.

This constitutes the Roton-model analogue of a molecular orbital: a single electron forming a coherent resonance path that spans multiple atoms and entanglements to multiple nuclear centers. Distance locking between the nuclei is then governed by the requirement that the shared electron trajectory remains axial-coherent and phase-coherent with all participating cores. Stable molecular geometries emerge as those configurations in which:

1. the entanglement network of valence electrons is maximally symmetric,
2. the integrated torque on each nucleus vanishes on average, and
3. local energy-density gradients are minimized.

In this view, familiar chemical concepts such as lone pairs, bond angles and hybridization patterns are reinterpreted as manifestations of resonance-based orbital dynamics: electrons self-organize into multi-Roton oscillation paths that optimize energy density coherence within the LEDO-field, subject to the geometric constraints imposed by the nuclear Quon scaffolding.

## 11 Validated Phenomenology

Within the present state of development, the Roton Quantum Model (RQM) has been explored predominantly by conceptual analysis and numerical proof-of-principle simulations. While no quantitative parameter fit to high-precision data has been attempted yet, several robust and repeatable qualitative phenomena emerge consistently from the same small set of rotational and resonance rules. In this sense, the model already reproduces a range of “validated phenomenology”: qualitative features of atomic, nuclear and large-scale structure that are otherwise known from experiment or established theory, but here arise as emergent consequences of the resonance framework.

### 11.1 Stable orbital radii and harmonic locking

Numerical experiments with Rotons constrained to move within a LEDO-field potential reveal that their equilibrium separations do not form a continuum of admissible distances. Instead, the system relaxes into a discrete set of preferred radii, which are approximately related by small integer ratios. In particular, radius-locking configurations of the form

$$R_n \approx n R_1, \quad n \in \mathbb{N},$$

and sub-harmonic relationships  $R_{m:k} \approx (m/k) R_1$  emerge as stable attractors of the local energy-density optimization dynamics. Perturbations away from these radii tend to be damped by the combined action of resonant attraction and energy-density repulsion, driving the system back into one of the discrete minima.

This harmonic distance locking provides a natural qualitative analogue to quantized atomic shells and orbital radii: the allowed distances are not imposed by boundary conditions or operator spectra, but are selected by the interplay between rotational inertia and resonance-mediated energy-density minimization.

### 11.2 Co-axial resonance locking and entanglement stability

For Rotons whose rotational axes are co-linear or nearly co-linear, the model exhibits a robust co-axial resonance locking. If two Rotons share the same axis with suitable phase relations, the resulting axial resonance potential becomes effectively distance-independent at the level of the underlying LEDO-field—i.e. the torque terms do not decay with spatial separation as long as the axial alignment persists and the background fluctuations remain moderate.

Such co-axial configurations behave as entangled pairs: small perturbations of orientation or phase in one partner are mirrored by corresponding compensating responses in the other, mediated by the LEDO-field resonance potentials. This reproduces, at a qualitative level, the phenomenology associated with long-distance quantum entanglement, without invoking an external measurement postulate or a collapse mechanism. In the RQM, “collapse” corresponds to a disruption of the co-axial resonance beyond the stability tolerance of the coupled Roton system.

### 11.3 Localized energy-density minima and shell formation

When multiple Rotons interact within a confined region, the superposition of their resonance potentials generically produces a discrete set of local minima in the effective energy-density landscape. Numerical relaxation dynamics show that Rotons subject to small stochastic perturbations and LEDO-field background fluctuations tend to accumulate in these minima, forming shell-like or lattice-like structures rather than uniform or random distributions.

These localized energy-density minima:

- organize Rotons into concentric layers around a central structure,
- stabilize preferred angular orientations and symmetry axes,
- and suppress continuous drift in radius or angle.

This behaviour parallels the emergence of atomic shells and preferred nucleon configurations in conventional nuclear and atomic physics, but here arises from resonance-based self-organization rather than from imposed quantum numbers.

### 11.4 Emergent alpha-particle-like building blocks

Simulations and analytical considerations of small clusters of Rotons with strong mutual coupling show that certain configurations are markedly more stable than others. In particular, compact

arrangements of four proton-like cages containing electron-like sub-Rotons, arranged in a highly symmetric pattern, form a robust, low-energy building block. This object behaves in the model as an analogue of the observed alpha-particle:

- it supports two strongly coupled electron/positron-like loops,
- it exhibits enhanced binding relative to neighbouring configurations,
- and it can tile into larger structures while preserving its internal symmetry.

Larger nuclei assembled from such alpha-like units inherit characteristic distance-locking and angular couplings, which then feed into the resonance conditions for orbital electrons. In this way, the model reproduces the empirical importance of alpha-particle clustering for nuclear stability in a purely geometric-resonant manner.

### 11.5 Distance-keeping electron chains and conduction-like behaviour

Within the RQM, electrons are interpreted as multi-axis Roton composites capable of forming chain-like co-rotational structures. When several electron-like Rotons align their main rotational axes and share a common direction of propagation, the resonance potentials generate distance-stabilizing forces along the chain. The electrons maintain approximately constant separations while moving collectively, with only modest sensitivity to local perturbations from intermediate charges.

This behaviour provides a natural qualitative picture of conduction paths and correlated electron motion in lattices: free or weakly bound electrons can form extended rotonal chains whose internal distance-locking dominates over individual coupling to nearby proton-like cages, consistent with the idea of delocalized conduction bands.

### 11.6 Filamentary large-scale structures

At much larger scales, when galaxies are modelled as effective Rotons—rotating energy-density accumulations embedded in the LEDO-field—the same resonance rules generate filamentary and network-like structures. Rotating mass distributions tend to align their angular momenta and lock into distance-keeping configurations that minimize the combined resonance and repulsion functional. The resulting structures resemble flowing filaments and nodes, qualitatively analogous to the observed cosmic web of galaxy filaments and clusters.

In this picture, part of the phenomenology attributed to “dark matter” can be reinterpreted as arising from resonance-based forces associated with large-scale rotational structures, rather than from additional unseen particle species. The RQM thus offers a unified conceptual mechanism for both microscopic binding and macroscopic filament stability.

### 11.7 Predictions

Beyond these qualitative agreements with known phenomena, the RQM yields a number of concrete, falsifiable predictions and testable tendencies. We summarize several central examples:

1. **Resonance-dependent isotopic stability.** The stability of nuclear isotopes is predicted to correlate with the existence of closed rotonal resonance networks within the nucleus. In particular, nuclei that can be decomposed into an integer number of alpha-like Roton clusters plus a small number of auxiliary Rotons are expected to be significantly more stable than configurations requiring frustrated or incomplete resonance loops. This suggests a structural explanation for magic numbers and for the clustering of stable isotopes in regions where such alpha-like tilings are possible.

2. **Composition-dependent effective inertia.** Because inertia in the RQM is interpreted as resistance of multi-level Roton configurations to rotational axis reorientation, the effective inertial response of a macroscopic body is predicted to depend not only on total mass, but also on its internal rotonal composition and long-range resonance environment. Bodies with different internal resonance architectures may exhibit small but in principle measurable differences in inertial response or weight when placed in distinct large-scale LEDO-field configurations (e.g., in different gravitational or galactic environments).
3. **Nonlinear photon trajectories at constant speed.** The model predicts that photons can propagate along curved trajectories without loss of speed, provided their internal rotation axis remains fixed and curvature occurs in a plane orthogonal to this axis. This offers a specific rotonal interpretation of gravitational lensing: deflection of photon paths arises from reorientation of the embedding LEDO-field resonance structure rather than from a local variation of the photon's intrinsic speed.
4. **Electron entanglement chains in solids.** The tiered structure of electron-like Rotons (with three independent entanglement axes) implies that even in solids, electrons can form extended entangled chains that maintain phase relations over distances larger than individual lattice spacings. This leads to the prediction that under suitable conditions, correlated transport and phase-locking should persist over mesoscopic scales, potentially observable as nonlocal coherence effects or unusual response of conduction paths to localized perturbations.
5. **CMB-scale correlations with atomic-size resonances.** The RQM links the characteristic size of atomic orbitals to background LEDO-field fluctuations. It thus predicts that the spectral features of the cosmic microwave background (CMB) encode information about the fluctuation spectrum that also fixes the preferred atomic length scale. In particular, the model suggests that changes in the LEDO-field background on cosmological timescales would be accompanied by coherent shifts in preferred atomic sizes, although such changes are expected to be extremely small within the observable epoch.
6. **Dark-matter-like rotation curves from rotonal forces.** At galactic scales, the RQM predicts that additional centripetal forces arise from resonance locking of rotating mass distributions to the LEDO-field, without invoking new particle species. These rotonal forces are expected to produce flat or slowly declining rotation curves in disk galaxies similar to those usually attributed to dark matter halos. Detailed modelling of specific galaxies within the RQM would therefore allow a direct quantitative test against astronomical rotation curve data.

These predictions are intentionally formulated at a level that invites both numerical exploration and experimental or observational challenge. They delineate where the Roton Quantum Model can be decisively supported or falsified once its parameters are constrained by quantitative comparison with data.

## 12 Simulation Evidence & Numerical Indicators

The current numerical experiments are designed as proof-of-concept studies to test whether the local rotonal rules introduced in the previous sections can (i) generate stable self-organized structures and (ii) avoid singular behaviour such as unbounded accelerations or collapse to point-like states. Although the present data set is not yet sufficient for quantitative comparison with experimental observables, several robust qualitative patterns already emerge.

## 12.1 Numerical setup (conceptual outline)

In the present simulations, Rotons are represented as point-like centers of extended rotational trajectories. Their interactions are governed by resonance-based forces derived from the LEDO-field framework, combining:

- an attractive contribution driven by spectral and axial resonance matching,
- a short-range repulsive contribution associated with local energy-density saturation, and
- stochastic background fluctuations mimicking LEDO-field noise.

Configurations are evolved in time using a standard time-stepping integrator (e.g. velocity-Verlet or symplectic schemes), ensuring that effective energy and total momentum remain numerically well behaved. In many runs a weak global confinement potential is used to keep the system within a finite simulation volume, while allowing for free local rearrangements.

## 12.2 Emergence of stable Roton clusters

Across a broad range of initial conditions and noise levels, the basic Roton rules lead to the spontaneous emergence of bound clusters rather than runaway behaviour. Rotons starting from random positions and random phases tend to self-organize into localized aggregates with:

1. finite and non-vanishing minimal separations,
2. bounded local energy densities, and
3. long-lived relative configurations under background fluctuations.

Notably, no singularity-like effects are observed: neither the inter-Roton distance nor the local acceleration approaches zero or diverges unboundedly within numerically accessible time frames. This is consistent with the underlying assumption that all effective forces within the Roton radius remain finite.

## 12.3 Distance locking and shell-like patterns

A recurrent feature of the simulations is the formation of preferred inter-Roton distances. Nearest-neighbour separations tend to accumulate around discrete multiples of a characteristic length scale set by the underlying resonance conditions (e.g. a preferred radius  $R$  or base resonance distance  $D$ ). Qualitatively, one observes:

- *distance locking*: pairs or chains of Rotons maintain nearly constant separations over extended times,
- *shell-like structures*: in larger clusters, subsets of Rotons arrange on approximately spherical or ring-like shells at favored radii, and
- *grid-like substructures*: within these shells, quasi-regular patterns reminiscent of lattice segments or polyhedral nets can emerge.

These effects constitute a first indication that the resonance-based interaction can produce hierarchical distance organization, which in the full model is interpreted as a precursor to nuclear and orbital shells.

## 12.4 Higher-level rotational binding across clusters

When the simulation includes multiple pre-formed subclusters (e.g. small distance-locked aggregates), additional slow collective rotational modes can emerge. Groups of clusters may enter into relative rotation while preserving their internal structure, indicating that:

1. distance-locked subunits can themselves become elements of higher-level rotational bindings, and
2. the effective interaction range and strength can depend on the internal resonance state of the subclusters.

This behaviour is consistent with the conceptual picture of "nucleus grids" whose internal Roton distance locking allows for an additional layer of rotational coupling between nuclei or nucleon-like structures.

## 12.5 Proposed numerical indicators

To make future simulations quantitatively testable and comparable, it is useful to define a set of numerical indicators. Even though only a subset has been explored so far, the following observables naturally arise from the current framework:

- **Distance spectra:** histograms of pairwise distances  $p(d)$ , in particular the distribution of nearest-neighbour distances  $p_{nn}(d)$ , to identify preferred resonance distances and their harmonic structure (e.g. peaks near  $d \approx nD$ , with  $n \in \mathbb{N}$ ).
- **Cluster persistence times:** the mean lifetime of identified bound clusters before significant reconfiguration, as a function of noise amplitude and initial energy density.
- **Alignment order parameters:** measures such as  $\langle \cos^2 \theta \rangle$ , where  $\theta$  denotes the angle between Roton axes, to quantify co-axial resonance locking and the degree of global or local alignment.
- **Local energy-density statistics:** distributions of the effective energy-density  $\rho_E(\vec{r}, t)$  inferred from the resonance potentials around each Roton, to characterize the emergence and stability of local minima.
- **Inertia-related response times:** characteristic time scales for the reorientation of Roton axes or for changes in distance-locked configurations after a perturbation, which relate directly to the model notion of rotonal inertia.

From a phenomenological viewpoint, these indicators create a bridge between the Roton-level simulation and macroscopic observables: preferred distances can be associated with orbital radii or nucleon separations, alignment parameters with spin- or bonding-like correlations, and persistence times with decay or relaxation scales. A systematic numerical exploration of these quantities is an essential next step towards a quantitative confrontation of the Roton model with experimental data.

## 13 Open Research Directions

The present formulation of the Roton Quantum Model (RQM) is intentionally minimalistic at the axiomatic level but rich in emergent structure. Several concrete research directions arise naturally from the current state of development, spanning analytical work, numerical simulations, phenomenology, and possible experimental access to rotonal sub-structure.

**1. Analytical formulation of resonance tensors and scaling laws.**

A first major task is the derivation of closed analytical expressions for the resonance-induced interaction tensors in the LEDO-field. This includes (i) explicit functional forms for axial, parallel-axial and isotropic components of the resonance potentials, (ii) their dependence on frequency, radius and phase of underlying Rotons, and (iii) scaling relations connecting microscopic parameters (Roton radius, frequency, bandwidth) to effective macroscopic couplings (e.g. atomic-scale binding energies or galactic-scale rotational forces). A consistent tensorial formulation would enable direct comparison with existing field-theoretic formalisms and provide a route to continuum-limit descriptions.

**2. Long-time simulations of spontaneous structure formation.**

Current numerical experiments mainly confirm that the basic rotatorial rules do not lead to singularities and already yield distance-locking and cluster formation. A crucial next step is to perform large-scale, long-time simulations starting from quasi-homogeneous initial conditions of Rotons and background fluctuations, and to study under which conditions the system spontaneously nucleates: (i) electron-like multi-axis entities, (ii) nucleon-like clusters, (iii) alpha-particle-like composite structures, and eventually (iv) stable atomic and molecular aggregates. Of particular interest is whether an "atom-forming cascade" can emerge as an attractor of the dynamics without imposing any scale-specific tuning.

**3. Mapping isotope boundaries as resonance stability edges.**

The RQM naturally suggests that isotope stability is governed by the existence of robust resonance networks between nucleonic Rotons and orbital electrons. Systematic exploration of multi-Roton configurations with varying proton/electron counts and rotational orientations could identify regions in parameter space where small perturbations either decay back to a stable configuration or trigger structural breakdown. These "stability edges" may be mapped against known nuclear charts, providing a quantitative test of the model and potentially yielding explanations for observed magic numbers, alpha clustering and the scarcity of stable high- $Z$  isotopes.

**4. Relating LEDO background fluctuations to cosmological observables.**

The model posits that background fluctuations in the LEDO-field at atomic scales set preferred orbital radii and energy-density minima. One open direction is to connect the spectral and spatial properties of these fluctuations to cosmological signatures, such as the cosmic microwave background (CMB) and large-scale filamentary structures. This could involve reconstructing an effective fluctuation spectrum consistent with both atomic-scale constraints and astrophysical observations, thereby testing whether a single underlying oscillation framework can coherently bridge microscopic and cosmological scales.

**5. Higher-order multi-Roton aggregates and novel material phases.**

Beyond simple tri-axial (Tier-3) electron-like structures, the RQM allows for higher-order multi-Roton compounds (e.g. more complex Quon aggregations of Quons with 4 or 5 resonance potentials) within a shared relevant rotational radius. Systematic classification of the topology and stability of such multi-Roton configurations may reveal new classes of quasi-particles or collective excitations, with potential implications for condensed-matter systems. For instance, certain higher-order Quons might correspond to particularly dense or topologically protected arrangements, suggesting analogues of new phases of matter characterized by rotonal connectivity rather than by conventional lattice order.

**6. Multi-scale inertia coupling and rotonal spectroscopy.**

A further avenue is the exploration of how changes in higher-level rotational states (e.g. atomic or molecular reorientation under external fields) back-react on lower-level rotonal sub-structures via inertia and precession. If external perturbations (intense electromagnetic fields, ultrafast pulses, strong gradients) can induce characteristic re-alignment dynamics,

then subtle shifts in response times, resonance frequencies or decoherence patterns might serve as indirect probes of underlying Roton and Reson configurations. This suggests the possibility of a "rotonal spectroscopy", in which measured macroscopic relaxation or dephasing signatures are interpreted as integral responses of nested rotational degrees of freedom.

#### 7. **Controlled manipulation of entanglement patterns.**

The model attributes entanglement to persistent axial alignment and shared bitemporal coherence between Rotons. A systematic study of how different boundary conditions (e.g. confinement geometries, external rotation fields, structured backgrounds) influence the creation, persistence and decay of these entanglement patterns could lead to new insights into controllable long-range correlations. On the quantum-technology side, this may inspire proposals for engineered environments where entanglement is stabilized or enhanced by tailored rotonal matching rather than by purely Hamiltonian engineering in standard Hilbert-space formulations. This might open paths for possibilities of practical real instantaneous communication. A multi-entangled higher-level compound might provide acceleration based methods of interacting with entangled sub-level compounds.

#### 8. **Bridging to existing quantum and field-theoretic formalisms.**

Finally, it is essential to connect the geometric, resonance-based language of the RQM to established mathematical structures in quantum mechanics and quantum field theory. This includes: (i) identifying effective Hilbert-space representations of stable Roton configurations, (ii) deriving approximate Hamiltonians that reproduce RQM dynamics in suitable limits, and (iii) comparing RQM-induced effective potentials with known interaction terms (Coulomb, Yukawa-like, or spin-orbit couplings). Such a bridge would not only facilitate comparison with existing data but could also highlight which phenomena are genuinely novel predictions of the rotonal framework and which merely re-interpret known results in a more constructive geometric manner.

## 14 Conclusions

This work has introduced the Roton Quantum Model as a resonance-based, deterministic framework for the emergence of quantum phenomena, matter, interactions, and large-scale structure. Starting from two minimal conceptual premises—rotational self-interaction of energy and the primacy of quantum entanglement—the model demonstrates how a wide range of physical phenomena arise naturally as stable, energy-optimized resonance configurations.

Rather than postulating particles, forces, or quantization rules a priori, the presented approach shows that many established physical structures emerge as necessary consequences of rotational resonance, axial alignment, and energy-density optimization. In this sense, the model shifts the explanatory focus from phenomenological descriptions of *how* interactions occur to constructive mechanisms addressing *why* stable structures exist at all.

The foundational thought experiments guiding the development of the model can be summarized as follows:

1. What dynamical structures arise if energy undergoes rotation while remaining resonantly coupled to its own past and future states? Under this assumption, photons appear naturally as self-sustained rotational entities without intrinsic inertia.
2. If quantum entanglement consistently manifests at microscopic scales, it should be regarded not as an exceptional phenomenon, but as the default mode of interaction at those scales. The model therefore adopts entanglement as a foundational organizing principle rather than a derived or measurement-induced effect.

From these premises, a broad set of physical phenomena emerges without additional assumptions:

1. A coherent structural and dynamical interpretation of photons and light as single-axis rotational entities.
2. A constructive model of electrons as multi-axis rotational compounds, naturally accounting for inertia, charge behavior, and interaction limits.
3. The spontaneous formation of stable spatial structures—including nucleons, atomic nuclei, atoms, and molecules—as resonance-optimized configurations of coupled Rotons.
4. An alternative formulation of electromagnetic interactions arising from directional resonance alignment rather than abstract field mediation.
5. A natural interpretation of electron–positron duality based on rotational orientation, phase locking, and gyroscopic inertia.
6. A reinterpretation of the proton as a stabilizing confinement structure for an electron-like entity, with positive charge emerging from constrained spatial and phase degrees of freedom.
7. The emergence of the alpha particle as a fundamental structural unit required for stable higher-order atomic configurations, enabling paired orbital electron states.
8. Intuitive explanations for large-scale attractive effects commonly attributed to dark matter, arising instead from rotational resonance dynamics at galactic scales and explaining the long-term stability of cosmic filaments.
9. A fully deterministic account of quantum entanglement phenomena that does not rely on external observers, wavefunction collapse postulates, or inherently undefined superposed states.

Beyond reproducing known qualitative features of physical systems, the Roton Quantum Model (RQM) offers a unifying conceptual framework in which matter, forces, inertia, time dilation, and large-scale structure arise from the same underlying resonance principles. Importantly, the model remains free of singularities, point-like entities, and externally imposed quantization rules, replacing them with finite, geometrically interpretable rotational structures.

At the same time, this work represents an initial formulation rather than a closed theory. Open challenges include the derivation of fully quantitative scaling relations, systematic comparison with high-precision experimental data, long-duration simulations demonstrating spontaneous structure formation from homogeneous initial conditions, and the identification of clear experimental predictions capable of falsifying the model.

In summary, the Roton Quantum Model proposes a shift in perspective: from a universe constructed of particles embedded in predefined fields, to one in which structure, interaction, and stability emerge from resonance, rotation, and entanglement as fundamental organizing principles. Whether this framework can ultimately complement or revise existing physical theories remains an open question—but it offers a coherent, intuitive, and testable pathway toward a deeper understanding of physical reality.

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## Companion Website and Further Material

A non-technical introduction, extended explanations, graphical illustrations and ongoing discussions of the Roton Quantum Model are available on the project website:

- Roton Quantum Model – intuitive overview and guided tour: <https://ledoigt.ch>
- Technical notes, simulations and updates: <https://ledoigt.ch/ledoigt/notes>
- Discussion and feedback channel: <https://ledoigt.ch/ledoigt/discuss>

These resources are intended as a more accessible companion to the present article, offering step-by-step motivation, visualizations, and evolving refinements of the model.

## Data and Code Availability

Simulation scripts, illustrative numerical experiments and example configurations of Rotons used to explore the qualitative behavior reported in this work are (or will be) made available at:

- Code repository (numerical experiments): <https://github.com/ledoigt>
- Supplementary animations and figures: <https://ledoigt.ch/ledoigt/collections/>

Interested readers are invited to reproduce, extend and critically test the presented ideas.

## Author's Note

This work is intended as an open invitation to the theoretical physics and complex-systems communities to examine, challenge and refine the Roton Quantum Model. The author explicitly welcomes critical assessments, alternative formulations and concrete proposals for experimental or numerical tests, which may help to clarify the model's scope, limits and possible connections to established frameworks.