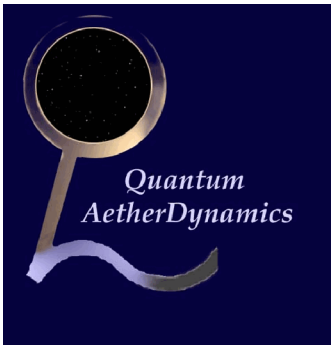


**Quantum AetherDynamics Institute (QADI)**

# Bipolar Trumpet-Coil Saturation Boundaries in the Aether Physics Model

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It develops the Aether Physics Model (APM)

**Abstract**

This paper develops a saturation-layer interpretation of galactic black holes within the Aether Physics Model (APM) and Quantum Measurement Units (QMU). Rather than treating singularities as points of infinite density, the model proposes that gravitational collapse terminates when local Aether occupancy reaches a maximum allowable state. The limiting density is determined by the Aether maximum mass and quantum volume. The resulting structure is a finite saturation layer whose idealized boundary may be represented as a saturation surface. The Bipolar Trumpet Coil Model is reinterpreted as the rotational geometry assumed by Aether units as occupancy approaches unity. Larger galactic centers do not require densities beyond the Aether limit; additional mass is accommodated by recruiting additional saturated Aether units and increasing the extent of the trumpet-coil layer. The paper introduces an occupancy coordinate, derives the maximum-density boundary condition, relates saturation geometry to QMU curl structure, and provides an appendix defining the concept of a universal closure coordinate without asserting that the present model completes such a program.

**Keywords:** Aether Physics Model; Quantum Measurement Units; black holes; galactic centers; saturation layer; trumpet-coil geometry; occupancy coordinate; universal closure coordinate

# 1 Introduction

Black-hole theory traditionally permits the language of singularity, divergence, and infinite density. Such language is mathematically useful in exact solutions of gravitational field equations, beginning with the Schwarzschild solution and later extended to rotating black holes by the Kerr metric [Einstein, 1916, Schwarzschild, 1916, Kerr, 1963, Wald, 1984]. Observational evidence for compact galactic-center objects, including Event Horizon Telescope imaging of M87* and Sgr A*, motivates continued examination of the physical structure associated with black-hole boundaries [Event Horizon Telescope Collaboration, 2019, 2022].

The Aether Physics Model approaches the same problem from a finite geometric ledger. In the APM, Aether structure is not treated as a continuum that may be compressed without limit. It has a maximum Aether mass, a quantum volume, a magnetic charge structure, and rotational closure relations expressed in QMU [Thomson, 2024, 2025c,a]. The present paper develops the consequence of that finite structure for galactic-center collapse.

The central hypothesis is that a galactic black hole is not an infinite-density point. It is a saturation layer formed when local Aether occupancy approaches its maximum allowable state. The ideal limiting surface of that layer is called a saturation surface. The Bipolar Trumpet Coil Model for black holes supplies the corresponding rotational boundary geometry [Thomson, 2025b].

This paper is a companion to the dual-boundary cosmology treatment, which distinguished local maximum-density closure boundaries from observer-relative cosmological horizons [Thomson, 2026]. The present work focuses only on the local limit. The cosmological redshift consequences of path-integrated space creation are deliberately reserved for a separate paper.

## 2 QMU Premises and Ledger Units

The QMU formulation begins with discrete base quantities such as electron mass $m_{\mathrm{e}}$, Compton length $\lambda_C$, quantum frequency $F_q$, electrostatic charge $e^2$, magnetic charge ${e_{\mathrm{emax}}}^2$, and the Aether unit $A_u$. These quantities are used as ledger units rather than as late-stage dimensional decorations.

Two identities are central to the present paper. The quantum volume is

$$\mathrm{volm} = {\lambda_C}^3. \tag{1}$$

The Aether maximum mass is

$$m_a = \frac{{\lambda_C}^3 {F_q}^2}{G}. \tag{2}$$

The first expression defines the quantum spatial cell. The second defines the maximum mass associated with an Aether unit in the gravitational sector. These definitions lead directly to a maximum Aether density.

The rotational identity used as a QMU sanity check is

$$A_u\,\mathrm{curl} = {F_q}^2\,{\lambda_C}^2. \tag{3}$$

This identity expresses the product of Aether structure and rotational curl as the square of Aether propagation.

## 3 Maximum Aether Density

The maximum Aether density is defined as the Aether maximum mass per quantum volume:

$$\rho_A = \frac{m_a}{\mathrm{volm}}. \tag{4}$$

Substituting Eqs. (1) and (2) gives

$$\rho_A = \frac{{\lambda_C}^3 {F_q}^2/G}{{\lambda_C}^3} = \frac{{F_q}^2}{G}. \tag{5}$$

This result is important because it makes the limiting density independent of additional galactic mass. In this model, the maximum density is not a variable that increases with collapse. It is a structural limit of the Aether ledger:

$$\rho \le \rho_A. \tag{6}$$

Equation (6) is the fundamental departure from infinite-density singularity language. The galactic-center boundary is not a point at which density diverges. It is a region in which occupancy approaches its limiting value.

## 4 Occupancy Coordinate

The local occupancy coordinate is defined by

$$\chi_{\mathrm{loc}} = \frac{\rho_{\mathrm{loc}}}{\rho_A}. \tag{7}$$

By construction,

$$0 \leq \chi_{\mathrm{loc}} \leq 1. \tag{8}$$

The coordinate $\chi_{\mathrm{loc}}$ is more fundamental than density in the present interpretation. Density is a derived expression:

$$\rho_{\mathrm{loc}} = \chi_{\mathrm{loc}} \rho_A. \tag{9}$$

The limiting cases are therefore direct geometric states:

$$\chi_{\mathrm{loc}} \to 0 \qquad \text{dilute occupancy,} \tag{10}$$

$$\chi_{\mathrm{loc}} \to 1 \qquad \text{saturation occupancy.} \tag{11}$$

A galactic-center saturation layer forms as

$$\chi_{\mathrm{loc}} \to 1. \tag{12}$$

## 5 Saturation Layer and Saturation Surface

It is useful to distinguish the physical wall region from its idealized mathematical boundary. The physical region is a saturation layer:

$$\mathcal{S}_{\mathrm{layer}} = \{x : \chi_{\mathrm{loc}}(x) \approx 1\}. \tag{13}$$

The ideal saturation surface is the limiting set:

$$\partial\mathcal{S}_{\mathrm{layer}} = \{x : \chi_{\mathrm{loc}}(x) = 1\}. \tag{14}$$

This distinction avoids treating the galactic-center wall as a zero-thickness shell. The Bipolar Trumpet Coil Model already implies finite rotational structure, finite curvature, and finite torsion. A saturation layer is therefore more appropriate than a mathematically thin surface.

At saturation,

$$\rho_{\mathrm{loc}} = \rho_A. \tag{15}$$

Further gravitational loading cannot be accommodated by increasing local density beyond $\rho_A$. It must instead be accommodated by increasing the number of saturated Aether units participating in the boundary layer.

## 6 Relation to Bipolar Trumpet-Coil Geometry

The Bipolar Trumpet Coil Model describes black holes as rotational Aether structures with a bipolar trumpet-like geometry [Thomson, 2025b]. The present paper interprets that geometry as the form assumed by Aether units in the saturation layer.

The QMU curl unit is

$$\text{curl} = \frac{{e_{\text{emax}}}^2}{m_{\text{e}}\lambda_C}. \tag{16}$$

The reciprocal is

$$\text{perm} = \frac{1}{\text{curl}}. \tag{17}$$

These relations associate the black-hole boundary with rotational and magnetic-charge structure rather than with passive density alone. The trumpet-coil geometry is therefore not introduced as a visual analogy. It is treated as a QMU-compatible rotational closure geometry.

In compact form, the proposed sequence is

$$\rho_{\text{loc}} \to \rho_A \quad \Rightarrow \quad \chi_{\text{loc}} \to 1 \quad \Rightarrow \quad \mathcal{S}_{\text{layer}} \quad \Rightarrow \quad \mathcal{T}_{\text{coil}}. \tag{18}$$

Density saturation initiates the boundary condition. The trumpet coil supplies the rotational geometry of that boundary.

## 7 Growth of Saturation Boundaries

The key consequence of the model is that larger galaxies need not possess denser central walls. All saturated regions obey

$$\rho_{\text{wall}} = \rho_A. \tag{19}$$

Let $N_{\text{wall}}$ denote the number of saturated Aether units participating in the galactic-center wall. Then the wall mass is

$$M_{\text{wall}} = N_{\text{wall}} m_a. \tag{20}$$

Let $A_u^{(\text{surf})}$ denote the effective surface contribution of one saturated Aether unit. The effective wall area is then

$$A_{\text{wall}} = N_{\text{wall}} A_u^{(\text{surf})}. \tag{21}$$

Equations (20) and (21) state the minimal scaling principle. Additional mass increases the population of saturated wall elements and the extent of the saturation layer. The paper does not require a premature commitment to a specific astronomical scaling law such as $A_{\text{wall}} \propto M_{\text{wall}}$ or $A_{\text{wall}} \propto M_{\text{wall}}^{2/3}$. Those relations are observational targets for later work.

The important result is local:

$$\frac{M_{\text{wall}}}{N_{\text{wall}}} = m_a, \qquad \frac{A_{\text{wall}}}{N_{\text{wall}}} = A_u^{(\text{surf})}. \tag{22}$$

A larger black-hole boundary is produced by increasing $N_{\text{wall}}$, not by violating the density bound $\rho \le \rho_A$.

## 8 Stability of Saturated Aether Structures

The APM treats stable physical structures as persistent geometric configurations within the Aether. The longevity of stable particles is consistent with the existence of durable Aether arrangements occupying states below saturation. In occupancy language, such stable structures occupy regions for which

$$0 < \chi < 1. \tag{23}$$

Saturation layers represent the limiting case:

$$\chi \to 1. \tag{24}$$

The galactic-center wall is therefore interpreted as a terminal stability regime rather than a density divergence. Stable Aether units hold the boundary as long as the surrounding configuration remains within the allowable closure structure. When local collapse drives occupancy to unity, the system becomes a wall element rather than a further-compressible medium.

## 9 Relation to Dual Boundary Cosmology

The dual-boundary cosmology paper distinguished two different apparent cosmic edges [Thomson, 2026]. The first is a local physical boundary at maximum Aether occupancy. The second is an observer-relative boundary produced by photon-reach failure across accumulated local expansion.

The present paper develops the first limit:

$$\chi \to 1. \tag{25}$$

The cosmological horizon corresponds to an effective observational dilution limit, which may be represented schematically as

$$\chi_{\text{eff}} \to 0. \tag{26}$$

The two limits should not be conflated. A galactic-center saturation layer is a physical boundary. A cosmological observation horizon is an observer-relative communication boundary. Their shared use of an occupancy coordinate suggests that closure coordinates may be useful across multiple APM domains, but that broader possibility is presented cautiously in Appendix A.

## 10 Predictions and Research Directions

The saturation-layer model implies several testable and theoretically useful consequences.

First, the model predicts no physically realized infinite-density state:

$$\rho \leq \rho_A. \tag{27}$$

Second, black-hole growth should be interpreted as an increase in saturation-layer population rather than an increase in limiting density:

$$\Delta M_{\text{wall}} = m_a \, \Delta N_{\text{wall}}. \tag{28}$$

Third, larger galactic centers should correspond to larger effective saturation layers or trumpet-coil extents:

$$\Delta A_{\text{wall}} = A_u^{(\text{surf})}\, \Delta N_{\text{wall}}. \tag{29}$$

Fourth, the relevant future observable is not merely galactic-center mass, but the relation between inferred mass, rotation, magnetic activity, jet structure, and effective boundary extent. The trumpet-coil interpretation suggests that rotational and magnetic features may carry information about the saturation layer.

Finally, the paper identifies a future theoretical task: derive $A_u^{(\text{surf})}$ from QMU geometry rather than leaving it as an effective surface contribution.

## 11 Discussion

The strongest result of the paper is not the assertion that black holes have finite density. It is the identification of the degree of freedom that remains after density reaches its limit. Once the bound $\rho \leq \rho_A$ is imposed, increased galactic-center mass must be expressed through saturated population, surface extent, layer thickness, or rotational geometry. The simplest ledger expression is wall population:

$$N_{\text{wall}} = \frac{M_{\text{wall}}}{m_a}. \tag{30}$$

The Bipolar Trumpet Coil Model then supplies the non-spherical rotational geometry through which this population organizes. The saturation layer is not merely a shell. It is a finite rotational boundary region structured by magnetic charge, curl, torsion, and Aether closure.

This interpretation shifts the question of black-hole structure away from "what happens at infinite density?" and toward "what geometry forms when Aether occupancy reaches unity?" That question is better suited to a discrete ledger theory.

## 12 Conclusion

This paper has developed a saturation-layer interpretation of galactic black holes in the Aether Physics Model. The maximum Aether density is

$$\rho_A = \frac{m_a}{\text{volm}} = \frac{{F_q}^2}{G}. \tag{31}$$

The local occupancy coordinate is

$$\chi_{\text{loc}} = \frac{\rho_{\text{loc}}}{\rho_A}, \qquad 0 \leq \chi_{\text{loc}} \leq 1. \tag{32}$$

A galactic-center saturation layer forms as

$$\chi_{\text{loc}} \to 1. \tag{33}$$

Additional galactic mass does not require density beyond $\rho_A$. It increases the number of saturated Aether units:

$$M_{\text{wall}} = N_{\text{wall}} m_a, \qquad A_{\text{wall}} = N_{\text{wall}} A_u^{(\text{surf})}. \tag{34}$$

The Bipolar Trumpet Coil Model is therefore interpreted as the rotational geometry of the saturation layer. The result is a finite, ledger-closed alternative to infinite-density singularity language and a foundation for future work on wall thickness, rotational closure, magnetic charge distribution, and observational scaling laws.

# A The Universal Closure Coordinate

The development of the saturation-boundary model introduced a dimensionless occupancy coordinate,

$$\chi = \frac{\rho}{\rho_A}, \tag{35}$$

where $\rho$ is local occupancy expressed as density and $\rho_A$ is the maximum allowable occupancy of the Aether structure.

By construction,

$$0 \leq \chi \leq 1. \tag{36}$$

This coordinate provides a convenient measure of the degree to which a physical system approaches its limiting geometric state.

## A.1 Closure and Saturation

Within the Aether Physics Model, physical structures are represented by finite geometric relationships. Such structures may be viewed as possessing varying degrees of closure.

The occupancy coordinate provides a quantitative description of this concept.

When

$$\chi \to 0, \tag{37}$$

the system approaches a dilute state far from geometric saturation.

When

$$\chi \to 1, \tag{38}$$

the system approaches complete saturation and maximum closure.

Intermediate values represent partially occupied or partially saturated states. The coordinate therefore acts as a measure of geometric completion.

## A.2 Physical Interpretation

The occupancy coordinate was introduced in this paper to describe galactic-center saturation layers. However, the same mathematical structure appears naturally in several other APM investigations.

Examples include maximum-density galactic-center boundaries, effective cosmological dilution, thermodynamic excitation states, and geometric closure relations among QMU quantities. In each case a system evolves between a limiting dilute condition and a limiting saturated condition. The occupancy coordinate provides a compact representation of this behavior.

## A.3 Closure Coordinates in Physical Models

Many physical theories employ dimensionless parameters that describe the state of a system relative to a limiting condition. Examples include fractional occupancy in statistical systems, normalized order parameters in condensed matter physics, relative density parameters in cosmology, and probability amplitudes in quantum mechanics.

The occupancy coordinate differs from these quantities in that it arises directly from geometric saturation. Rather than describing likelihood, order, or statistical population, it describes the relationship between local occupancy and a geometrically defined maximum occupancy.

## A.4 Universal Closure Coordinates

A coordinate is termed a universal closure coordinate when it satisfies three conditions:

1. It is dimensionless.
2. It possesses bounded limiting states.
3. It appears naturally in multiple independent physical domains.

The occupancy coordinate introduced here satisfies the first two conditions by construction. Whether it ultimately satisfies the third condition remains a question for future investigation.

The recurrence of the same coordinate in multiple APM studies suggests that occupancy-based descriptions may prove useful beyond the specific application developed in this paper. Future work will determine whether the occupancy coordinate represents merely a convenient mathematical normalization or a more general principle underlying geometric closure throughout the Aether Physics Model.

## A.5 Summary

The occupancy coordinate

$$\chi = \frac{\rho}{\rho_A} \tag{39}$$

was introduced as a tool for describing saturation layers and maximum-density boundaries.

Its appearance in multiple independent contexts suggests that closure itself may be a useful organizing principle for describing physical systems. The possibility that occupancy functions as a universal closure coordinate is presented here as an observation rather than a conclusion.

## B QMU-to-SI Bridge Relations

The main derivation is QMU-first. Numerical SI constants are not required for the main argument. If numerical comparison is desired, the relevant bridge values are taken from CODATA recommended constants [Tiesinga et al., 2023]. The principal bridge relations are

$$F_q \, \lambda_C = F_q \lambda_C = c, \tag{40}$$

$$m_a = \frac{{\lambda_C}^3 {F_q}^2}{G}, \tag{41}$$

and

$$\rho_A = \frac{{F_q}^2}{G}. \tag{42}$$

These expressions provide the route for comparing the saturation limit with conventional density scales, while leaving the paper's main derivation entirely in the QMU ledger.

## C SI Bridge for Aether Saturation Density

The main text develops the saturation-layer model in QMU form. This appendix gives an SI bridge for the maximum Aether density so that the scale of the proposed saturation boundary can be compared with familiar astrophysical density scales.

The Aether maximum mass is

$$m_a = \frac{{\lambda_C}^3 {F_q}^2}{G},$$

and the quantum volume is

$$volm = {\lambda_C}^3.$$

Therefore the maximum Aether density is

$$\rho_A = \frac{m_a}{volm} = \frac{{F_q}^2}{G}.$$

Using

$$F_q = \frac{c}{\lambda_C},$$

this may also be written as

$$\rho_A = \frac{c^2}{G {\lambda_C}^2}.$$

Using the electron Compton wavelength and CODATA bridge constants,

$$\lambda_C \approx 2.42631023867 \times 10^{-12}\ \mathrm{m},$$

$$F_q \approx 1.23558996 \times 10^{20}\ \mathrm{s}^{-1},$$

and

$$G \approx 6.67430 \times 10^{-11}\ \mathrm{m}^3, \mathrm{kg}^{-1}, \mathrm{s}^{-2},$$

the corresponding SI value is

$$\rho_A \approx 2.29 \times 10^{50}\ \mathrm{kg}, \mathrm{m}^{-3}.$$

This bridge value places the Aether saturation density far above nuclear-density matter while remaining far below the Planck density. The result is useful because it gives the saturation-layer model a finite density scale rather than an infinite-density singularity.

| Quantity | Approximate SI Value | Interpretation |
|---|---|---|
| Nuclear density | $2.8 \times 10^{17}\,\mathrm{kg\,m^{-3}}$ | Ordinary nuclear matter scale |
| Aether saturation density | $2.29 \times 10^{50}\,\mathrm{kg\,m^{-3}}$ | QMU maximum occupancy bridge |
| Planck density | $5.16 \times 10^{96}\,\mathrm{kg\,m^{-3}}$ | Planck-scale density bridge |

Table 1: Order-of-magnitude comparison of the Aether saturation density with common high-density reference scales.

The important point is not merely the numerical magnitude of $(\rho_A)$, but the fact that the APM saturation model produces a finite limiting density:

$$\rho \leq \rho_A.$$

Thus the galactic-center boundary is not modeled as a mathematical divergence. It is modeled as the limiting occupancy state of the Aether unit structure.

For a wall composed of $(N_{wall})$ saturated Aether units,

$$M_{wall} = N_{wall} m_a.$$

Since each saturated unit preserves the same limiting density, increasing the galactic-center mass does not require

$$\rho_{wall} > \rho_A.$$

Instead, additional mass increases the number of saturated wall elements:

$$N_{wall} = \frac{M_{wall}}{m_a}.$$

This is the SI-bridge expression of the central result of the paper: larger galactic-center structures grow by increasing saturation-layer population and extent, not by exceeding the maximum Aether density.

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