

The Yamagishi Macroscopic Superposition Limit Theory

— 3rd ed.: The Density Correction Never Reached the Table of Radii, and $E_G = Gm^2/R$ Hides the Separation —

[Paper 55]

Yuuki YAMAGISHI (山岸 勇輝)

Yamagishi Complexity Torus Lab, Japan

August 2026 (Third Edition)

— *From thinking to syncing.* —

ABSTRACT

Against the problem of the limit of macroscopic superposition, epitomised by Schrödinger's cat, this paper offers the picture of an automatic state commit in a universe OS and estimates its critical particle number N_{crit} using existing objective-collapse models. **It claims no new physics whatever.** Through the second edition it was shown that the first edition's 2^N memory model **disagrees with its own claimed value by eight orders of magnitude** (Theorem 2.1, Corollary 2.2), that the CSL N^2 law holds only within the correlation length r_C , and that the effective density of the Penrose table is not a solid density. What the third edition adds is the observation that **the second edition's own correction was never carried back to the other place the same error affects. First, the density correction never reached the table of radii.** Section 3.2 of the second edition noted that “the effective density of the table is about 62 kg/m^3 , not a solid density”, and corrected τ accordingly. **Yet the table of radii in the note to Section 3.1 was left constructed in exactly the same way.** Recomputed at solid density, every radius shrinks by $(2000/62)^{1/3} = 3.18$, and the “exceeds r_C by about nine times” at $N = 10^{11}$ becomes **about 2.7 times**. Further, the range in which the N^2 law holds exactly is not $N \lesssim 10^8$ but $N \lesssim 5 \times 10^9$, thirty-two times wider (Observation 3.4, both verified numerically). **The conclusion survives; the figures do not. Second, $E_G \approx Gm^2/R$ hides the separation of the superposition.** Penrose's E_G is the difference in gravitational self-energy between the two superposed mass distributions; for a sphere of radius R displaced by d , it is $\sim Gm^2/R$ when $d \gtrsim R$ but $\sim Gm^2 d^2/R^3$ when $d \ll R$. **The table silently takes $d \sim R$ — the choice that makes collapse fastest — and at $d = 0.1R$ the time τ is a hundred times longer (Observation 3.5). Both reinforce the conclusion of Corollary 3.3, that N_{crit} is not uniquely fixed; and both push the actual transition region to larger N than the second edition wrote.**

Scope of this paper: every model used is pre-existing (GRW--CSL, Penrose 1996, the holographic bound, Fein et al. 2019).

NO NEW THEOREM AND NO PREDICTION. What this paper does is give the first edition's unsupported figure a physical basis and **write out, to the end, where its indeterminacy comes from**. Section 7 (the universe-OS reading) is quarantined as **Layer 3 (non-scientific)**, and Sections 2 to 5 depend on none of it.

1. Introduction: the heart of the measurement problem

On the collapse of quantum superposition, environmental decoherence theory (Zeh 1970; Zurek 2003) gives a precise mechanism for the rapid decay of interference terms. **But decoherence does not explain why a single classical state is finally selected.** What decoherence delivers is a diagonal density matrix (a mixture), not a process by which one particular outcome is realised. That distinction is the heart of the measurement problem and the starting point here.

This paper pictures the selection process as an **automatic state commit** in a universe OS — a mechanism by which the system writes a single definite state once the cost of maintaining a superposition reaches a ceiling — and examines its critical scale quantitatively.

2. The 2^N memory model and its limits

2.1 The first edition's formulation

The first edition introduced a thread memory cost proportional to the dimension $D = 2^N$ of the state space of N entangled particles,

$$\mathcal{M}_{\text{thread}}(N) = \mathcal{M}_0 \cdot 2^N$$

held that the automatic commit fires when this exceeds a ceiling, and claimed $N_{\text{crit}} \approx 10^{11}$.

2.2 Confronting it with the holographic bound

Theorem 2.1 (the critical value the 2^N model gives)

Specifying a general N -particle superposition requires 2^N complex amplitudes. Bounding this by the holographic information capacity of the universe, $I_{\text{max}} \sim 10^{122}$ bits,

$$2^N \leq 10^{122} \implies N \leq \frac{122}{\log_{10} 2} \approx 405$$

(verified numerically: **405.3**).

Proof Take base-ten logarithms and solve $N \log_{10} 2 \leq 122$.

Corollary 2.2 (an internal contradiction in the first edition)

The consequence $N \approx 4 \times 10^2$ disagrees by about eight orders of magnitude with the first edition's claimed $N_{\text{crit}} \approx 10^{11}$. The first edition presented as its critical value a number different from the one its own memory model yields. **So long as the 2^N model is adopted, 10^{11} is not supported.**

2.3 Doubts about the 2^N model itself

There is a more basic problem. The picture of “storing” 2^N amplitudes presupposes that a **classical computational substrate is simulating quantum mechanics**. It is true that simulating a quantum system on a classical computer costs exponentially; but if the substrate is itself quantum, no such cost arises.

The overflow argument therefore rests on the additional strong assumption that the universe OS is a **classical** substrate. This paper does not adopt it, and moves the basis of the critical value to existing physical collapse models.

3. Estimating N_{crit} from collapse models

3.1 The CSL (continuous spontaneous localisation) model

In the GRW--CSL model, the collapse rate of a rigid body containing N nucleons within the correlation length $r_C \approx 10^{-7}$ m follows the amplification law $\Gamma = \lambda N^2$. For the standard parameter $\lambda_{\text{GRW}} = 10^{-16} \text{ s}^{-1}$ and Adler's alternative $\lambda_{\text{Adler}} \approx 10^{-8} \text{ s}^{-1}$, the collapse time $\tau = 1/\Gamma$ is as follows (verified numerically).

N	$\tau (\lambda = 10^{-16})$	$\tau (\lambda = 10^{-8})$
10^4	10^8 s (3.2 yr)	1 s
10^8	1 s	10^{-8} s
10^{11}	10^{-6} s	10^{-14} s
10^{23}	10^{-30} s	10^{-38} s

Proposition 3.1

Under the standard CSL parameter, $N = 10^{11}$ corresponds to $\tau \approx 1 \mu\text{s}$. The first edition's $N_{\text{crit}} \approx 10^{11}$ can thus be read as the scale at which superposition is lost on a microsecond timescale.

[Second-edition note, unchanged: the validity of the N^2 law]: The amplification law $\Gamma = \lambda N^2$ is a result for N nucleons contained within the correlation length r_C . Once the body exceeds r_C , distant nucleons no longer add coherently and the N -dependence becomes weaker than N^2 (dividing into correlation volumes, the contribution goes over to roughly linear in N). The rows at larger N are therefore extrapolations of the N^2 law, and the actual collapse times are longer.

3.2 Penrose gravitational collapse

Penrose (1996) proposed that the collapse time is set by the gravitational self-energy difference E_G between the two superposed states,

$$\tau \approx \frac{\hbar}{E_G}, \quad E_G \approx \frac{Gm^2}{R} \quad (3)$$

Taking an atomic spacing of $\sim 3 \times 10^{-10}$ m and treating N as the number of lattice points at that spacing (verified numerically):

N	mass m	radius R	τ
10^4	1.7×10^{-23} kg	4.0 nm	2.3×10^{13} s
10^8	1.7×10^{-19} kg	86 nm	4.9×10^6 s
10^{11}	1.7×10^{-16} kg	0.86 μm	49 s
10^{15}	1.7×10^{-12} kg	19 μm	1.1×10^{-5} s
10^{23}	1.7×10^{-4} kg	8.6 mm	4.9×10^{-19} s

Proposition 3.2

Under the Penrose criterion, $N = 10^{11}$ corresponds to $\tau \approx 49$ s, and the quantum--classical transition sits near $N \sim 10^{15}$ ($\tau \sim 10 \mu\text{s}$).

[Second-edition note, unchanged: the effective density of the table]: The table computes mass as $m = N \times m_{\text{nucleon}}$ and volume as N lattice points, using the same N in two different senses — nucleon count in the first, atom count in the second. The effective density is therefore about 62 kg/m^3 throughout (verified: **61.9**), not a solid density ($\sim 2000 \text{ kg/m}^3$). Recomputed at solid density, τ is uniformly about **3.2 times shorter** (verified: **3.18**; at $N = 10^{11}$, $49 \rightarrow 15 \text{ s}$; at $N = 10^{15}$, $1.1 \times 10^{-5} \rightarrow 3.3 \times 10^{-6} \text{ s}$). The order-of-magnitude discussion is unaffected.

3.3 [Third edition] That correction was never carried back to the table of radii

Observation 3.4 (the same error occurred twice and only one instance was fixed)

The second edition found the density error in Section 3.2 and corrected τ . Yet the table of radii in the note to Section 3.1 was left constructed in exactly the same way — N lattice points at $3 \times 10^{-10} \text{ m}$. If the density is wrong, the radius is wrong.

Recomputed at solid density 2000 kg/m^3 , every radius shrinks by $(2000/61.9)^{1/3} = 3.18$ (verified numerically):

N	radius (2nd ed.)	radius (solid)	R/r_C (2nd ed. $\rightarrow$ corrected)
10^4	4.0 nm	1.3 nm	0.040 $\rightarrow$ 0.013
10^8	86 nm	27 nm	0.86 $\rightarrow$ 0.27
10^{11}	0.86 μm	0.27 μm	8.6 $\rightarrow$ 2.7
10^{15}	19 μm	5.8 μm	186 $\rightarrow$ 58
10^{23}	8.6 mm	2.7 mm	$8.6 \times 10^4 \rightarrow 2.7 \times 10^4$

The row at $N = 10^{11}$, which the second edition described as “exceeding by about nine times”, in fact exceeds by about 2.7 times. The conclusion survives; the figure does not — $N = 10^{11}$ still exceeds r_C .

And the range in which the N^2 law holds exactly moves too. Solving $R(N) = r_C$ (verified numerically):

$$N_{r_C} = 1.6 \times 10^8 \text{ (2nd edition's density)} \quad \longrightarrow \quad N_{r_C} = 5.0 \times 10^9 \text{ (solid density)}$$

So where Corollary 3.3(4) said “the N^2 law holds exactly for $N \lesssim 10^8$ ”, it understated the range by the same factor of thirty-two. The correct figure is $N \lesssim 5 \times 10^9$.

Both of these are consequences of an error the second edition itself found one subsection later. A correction was made in one place and not carried back to the other place the same error affects — a shape this corpus keeps meeting, and this

paper is one instance of it.

3.4 [Third edition] What $E_G \approx Gm^2/R$ hides

Observation 3.5 (the table silently takes “separation $\approx$ size of the body”)

In Penrose's criterion the E_G of (3) is the **difference** in gravitational self-energy between the two superposed mass distributions. **It is not the self-energy of one body.**

For a uniform sphere of radius R in a superposition of two positions separated by d , that difference behaves as

$$\Delta E_G \sim \frac{Gm^2}{R} \quad (d \gtrsim R) \quad \text{versus} \quad \Delta E_G \sim \frac{Gm^2 d^2}{R^3} \quad (d \ll R)$$

Writing $E_G \approx Gm^2/R$ is equivalent to taking $d \sim R$ — that the body is superposed at a separation comparable to its own size, the situation in which collapse is fastest.

For smaller d the time τ is longer by $(R/d)^2$ (verified: $4\times$ at $d = 0.5R$, $100\times$ at $d = 0.1R$, $10^4\times$ at $d = 0.01R$). **In real interference experiments the separation is usually far smaller than the size of the object, and then τ is much longer than the table's value.**

This does not invalidate the table. As an order-of-magnitude guide, $\tau \approx \hbar R/(Gm^2)$ is the form Penrose himself used, and this paper follows it. **What is corrected is the failure to say that a second variable, d , is hidden in the table.** Read as a function of N alone, the table gives **the fastest case.**

3.5 Summary of the estimates

Corollary 3.3 (with (4) and (5) revised in the third edition): Both models point to $N \sim 10^{11}\text{--}10^{15}$ as the quantum--classical transition region, and the first edition's 10^{11} is **a reasonable order at the lower end** of it. But the exact value depends on

1. the collapse model adopted (CSL or Penrose);
2. the model parameters (λ carries eight orders of uncertainty);
3. the time criterion for counting the state as “collapsed”;
4. **the validity conditions of the model** — the CSL N^2 law holds only inside r_C , and **at solid density it becomes an extrapolation for $N \gtrsim 5 \times 10^9$** (Observation 3.4; the second edition put this at 10^8);
5. **[Third edition] the separation d of the superposition** — the Penrose table silently takes $d \sim R$, and for smaller d the time τ is longer by $(R/d)^2$ (Observation 3.5)

and is not uniquely fixed.

Items (4) and (5) act in the same direction — both make collapse slower, so the actual transition region is likely at higher N than stated above.

4. The experimental situation

The state of the art in molecular interferometry is the oligoporphyrin of Fein et al. (2019), of mass $25\{,\}000$ amu (about $2\{,\}000$ atoms, of order $N \sim 10^4$ nucleons). Current experiments therefore reach $N \sim 10^3\text{--}10^4$, far short of testing $N_{\text{crit}} \sim 10^{11}$. As the tables of Section 3 show, in this region the standard CSL parameter gives collapse times of years, consistent with experiment.

The paper's claims about N_{crit} are thus **neither confirmed nor refuted experimentally at present**, though parts of the CSL parameter space are already constrained and future tests are possible.

5. Correction record and the standing of the claims

Correction record 5.1 (first edition, unchanged): The first edition presented $N_{\text{crit}} \approx 10^{11}$ without support. The second edition made explicit that the 2^N memory model yields $N \approx 405$, inconsistent with 10^{11} (Theorem 2.1, Corollary 2.2); that the 2^N model itself presupposes a classical substrate simulating quantum mechanics (Section 2.3); and that 10^{11} is a reasonable order at the lower end of the transition region on existing collapse models (Propositions 3.1, 3.2, Corollary 3.3). **N_{crit} is not derivable from the OS picture alone; it requires a specific collapse mechanism.**

Correction record 5.2 (first edition, unchanged: on the many-worlds interpretation): The first edition said this mechanism makes “the many-worlds interpretation and consciousness-based accounts unnecessary”. **That wording stands withdrawn.** The automatic commit is an **objective-collapse theory** of the same kind as GRW, CSL and Penrose. Objective collapse and many-worlds are both coherent positions on the measurement problem, and no experiment currently decides between them. The proper standing of this paper is therefore **one alternative to** many-worlds, not a proof of its dispensability.

Correction record 5.3 (third edition: repair of corrupted characters): The text of the second edition contained **control characters (tabs)** in **all four files** (Japanese and English, tex and html). The openings of `\textbf` and `\tau` had been lost, so item (4) of the conclusion did not display “**and the validity conditions of the model**” or “ **τ** ” correctly. **The third edition repairs this and verifies that every file is free of control characters.**

6. [Third edition] What this paper returns to the corpus

Observation 6.1

The second edition of this paper found two errors in the first — the effective density, and the validity condition of the N^2 law. **And having found the former, it did not carry the consequence back to the table of the latter.** A radius is determined by a density; if the density is wrong, so is the radius. The second edition did not take that step.

As a result it printed a figure — “about nine times over” — that is **off by more than a factor of three**, and understated the validity range of the N^2 law **by a factor of thirty-two. Neither changes a conclusion; both are checkable errors.**

The shape is this: **when you find an error in one quantity, re-examine everything computed from it.** Fix the density, and fix the radius that comes from it; fix the radius, and fix the comparison with r_G that used it. **A correction is complete only when it has been carried to everywhere it propagates.**

7. Interpretation in the universe OS — Layer 3 (non-scientific)

What follows is interpretation, not theorem, and is quarantined as Layer 3 (non-scientific). Nothing above uses any of it. The automatic-state-commit picture gives objective-collapse theory a computational vocabulary. Maintaining a superposition carries some cost, and once the scale passes a threshold the system settles on a single state — a picture consistent with the structure that both the CSL amplification law ($\Gamma \propto N^2$) and the Penrose gravitational criterion ($\tau \propto 1/E_G$) display, namely that collapse accelerates with scale. **But this paper does not claim that the picture has predictive power beyond the existing collapse models.** What is established is Theorem 2.1 of Section 2 and the quantitative estimates of Section 3 from existing models, the latter holding independently of this corpus. The contribution is to give the first edition's unsupported figure a physical basis and **to write out, to the end, where its indeterminacy comes from.**

8. Conclusion

This paper establishes the following.

1. The heart of the measurement problem: decoherence explains the loss of interference but not the selection of a single outcome (Section 1).

2. The first edition's 2^N memory model, confronted with the holographic bound, gives $N \approx 405$, **eight orders from the claimed 10^{11}** , and presupposes a classical substrate (Theorem 2.1, Corollary 2.2, Section 2.3).
3. The basis of N_{crit} was moved to collapse models, with quantitative tables from CSL and Penrose. $N = 10^{11}$ corresponds to $\tau \approx 1 \mu\text{s}$ under the standard CSL parameter and $\tau \approx 49 \text{ s}$ under the Penrose criterion (Propositions 3.1, 3.2; every figure re-verified in the third edition).
4. **[Third edition] The second edition's density correction was never carried back to the table of radii** (Observation 3.4). At solid density every radius is **3.18** times smaller, and “exceeds r_G by about nine times” at $N = 10^{11}$ becomes **about 2.7 times**. The range in which the N^2 law holds exactly is not $N \lesssim 10^8$ but $N \lesssim 5 \times 10^9$. **The conclusion survives; the figures do not.**
5. **[Third edition] $E_G \approx Gm^2/R$ hides the separation d** (Observation 3.5). Penrose's E_G is the **difference** in self-energy between the two states, going as $\sim Gm^2 d^2/R^3$ for $d \ll R$. The table silently takes $d \sim R$, so **read as a function of N alone it gives the fastest case**. At $d = 0.1R$, τ is a hundred times longer.
6. Item (5), the separation, was added to Corollary 3.3. **Items (4) and (5) both make collapse slower, so the actual transition region is likely at higher N than the second edition wrote.**
7. Experiments reach $N \sim 10^3\text{--}10^4$ (Fein et al. 2019), with no capacity yet to test the region in question (Section 4).
8. **[Third edition] The control characters (tabs) present in all four files of the second edition were repaired** (Correction record 5.3).

Closing: The second edition found two of its own errors. **And having fixed one, it did not go to the other place that fix reaches.** What the third edition adds is not new physics but a single point: **a correction is complete only when it has been carried to everywhere it propagates.**

This paper completes the trilogy on the three great difficulties of quantum mechanics (Paper 53: the Born rule; Paper 54: the time operator; Paper 55: macroscopic superposition). The policy shared by all three was **to make the correspondence with established physical mechanisms explicit, and to keep what belongs to this corpus separate from what does not.**

Revision Record

Added in the third edition (August 2026)

1. **The title is unchanged; only the subtitle was replaced.** The main title stands as it is.
2. **Observation 3.4 added:** the second edition's density correction was never carried back to the table of radii. At solid density every radius is **3.18** times smaller, the excess over r_G at $N = 10^{11}$ is **about 2.7** rather than about nine times, and the exact validity range of the N^2 law is 5×10^9 rather than 10^8 (both verified numerically).
3. **Observation 3.5 added:** $E_G \approx Gm^2/R$ silently takes $d \sim R$. For $d \ll R$, $\Delta E_G \sim Gm^2 d^2/R^3$ and τ is longer by $(R/d)^2$.

4. **Item (5), the separation, added to Corollary 3.3, and the figure in (4) corrected.**
5. **Section 6 added:** a correction is complete only when it has been carried to everywhere it propagates.
6. **Correction record 5.3 added:** the control characters (tabs) in all four files of the second edition were repaired, and every file verified free of them.
7. **Section 7 explicitly quarantined as Layer 3.**
8. **Every figure re-verified: 405.3;** four rows of the CSL table; five rows of radii; effective density **61.9** kg/m³; five rows of the Penrose table; the factor **3.18**; $N_{r_C} = 1.6 \times 10^8$ and 5.0×10^9 . **Every figure the second edition printed was reproduced** — what is corrected are quantities the second edition had not computed.
9. **DOIs added to the self-citations and the format unified.**

Limitations added in the second edition (unchanged)

1. The CSL law $\Gamma = \lambda N^2$ is an amplification law confined to the correlation length r_C , so the rows at larger N are extrapolations (note to Proposition 3.1).
2. The Penrose table computes mass from nucleon count and volume from atom count, so its effective density is about **62** kg/m³ rather than a solid density; at solid density τ is uniformly about **3.2** times shorter, leaving the order-of-magnitude conclusion unchanged (note to Proposition 3.2).
3. The first edition's “many-worlds is unnecessary” was withdrawn, and this mechanism placed as one alternative among objective-collapse theories (Correction record 5.2).

References

1. Schrödinger, E. (1935). *Die gegenwärtige Situation in der Quantenmechanik*. *Naturwissenschaften*, 23(48), 807--812.
2. Zeh, H. D. (1970). *On the interpretation of measurement in quantum theory*. *Foundations of Physics*, 1(1), 69--76.
3. Zurek, W. H. (2003). *Decoherence, einselection, and the quantum origins of the classical*. *Reviews of Modern Physics*, 75(3), 715--775.
4. Ghirardi, G. C., Rimini, A., & Weber, T. (1986). *Unified dynamics for microscopic and macroscopic systems*. *Physical Review D*, 34(2), 470--491.
5. Bassi, A., Lochan, K., Satin, S., Singh, T. P., & Ulbricht, H. (2013). *Models of wave-function collapse, underlying theories, and experimental tests*. *Reviews of Modern Physics*, 85(2), 471--527.
6. Penrose, R. (1996). *On gravity's role in quantum state reduction*. *General Relativity and Gravitation*, 28(5), 581--600.
7. Adler, S. L. (2007). *Lower and upper bounds on CSL parameters from latent image formation and IGM heating*. *Journal of Physics A*, 40(12), 2935--2957.
8. Fein, Y. Y., Geyer, P., Zwick, P., Kiálka, F., Pedalino, S., Mayor, M., Gerlich, S., & Arndt, M. (2019). *Quantum superposition of molecules beyond 25 kDa*. *Nature Physics*, 15(12), 1242--1245.

9. Bousso, R. (2002). *The holographic principle*. Reviews of Modern Physics, 74(3), 825--874.
10. Yamagishi, Y. (2026). *The Equals Sign Has Distinct Roots* [Paper 16], 3rd ed. Zenodo. 10.5281/zenodo.21600471
11. Yamagishi, Y. (2026). *The 8π Is an Artefact of the Units* [Paper 17], 3rd ed. Zenodo. 10.5281/zenodo.21600813
12. Yamagishi, Y. (2026). *The Yamagishi Born-Rule Geometric Structure Theory* [Paper 53], 3rd ed. Zenodo. 10.5281/zenodo.21603193
13. Yamagishi, Y. (2026). *The Yamagishi Time-Operator and Clock-Subsystem Theory* [Paper 54], 3rd ed. Zenodo. 10.5281/zenodo.21603325

— *From thinking to syncing.* —

Yuuki YAMAGISHI (山岸 勇輝)

© 2026 Yamagishi Complexity Torus Lab, Japan · Licensed under Creative Commons Attribution 4.0 International (CC BY 4.0)