

The Critical Line and the Fixed Point of the Functional Equation

— $1/2$ Is the Name of a Coordinate, and an Exponent Is Not a Dimension — [Paper 06]

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— *From thinking to syncing.* —

Abstract

The critical line $\operatorname{Re}(s) = 1/2$ is the **fixed-point set** of the involution that the functional equation $\xi(s) = \xi(1-s)$ of the completed zeta function defines, $s \mapsto 1-s$. Starting from that single point, this paper settles **the standing of each number that appears around the critical line**. **First, $1/2$ is the name of a coordinate**. Setting $s = 1/2 + iz$, Riemann's $\Xi(z) = \xi(1/2 + iz)$ is an even function taking real values on the real axis (verified numerically here: $|\operatorname{Im} \Xi| < 10^{-31}$), and the Riemann Hypothesis becomes the statement “**all zeros of Ξ are real**” — in which **the number $1/2$ does not occur at all**. What is invariant is the structure — that an involution exists and that its fixed set is a line — not the value attached to that line. The distinction Papers 95 and 66 drew about the value of c holds here for $1/2$. **Second, the wall $\operatorname{Re}(s) = 1$ of the critical strip is a module boundary, and it is crossed only doubly logarithmically**. $\sum_p p^{-\sigma}$ converges for $\sigma > 1$ and diverges for $\sigma \leq 1$ — **the edge of the region where the Euler-product description works** (Paper 113). Moreover that divergence obeys Mertens' second theorem, $\sum_{p \leq x} p^{-1} = \ln \ln x + M + o(1)$ (verified here up to $x = 2 \times 10^7$, agreeing to 1.4×10^{-5}), so it grows only **doubly logarithmically**. **Third, the shell-conservation exponent $n = d - 1$ does not select a dimension**. The general formula $\operatorname{Vol}(S^{d-1}) = 2\pi^{d/2}/\Gamma(d/2)$ is a family holding in every d (Paper 114); and $2\pi(S^1)$ and $4\pi(S^2)$ belong to **different staircases** in the sorting of Paper 115 — **they are not adjacent steps**. **Fourth, an exponent is not a dimension**. In $|p^{-s}|^2 = p^{-2\sigma}$, 2σ is an exponent in a power of a prime; in $n = d - 1$, n is an exponent in a power of a radius and d is a dimension. Since the two are not powers of the same variable, **the agreement of the values in $2\sigma = 1$ and $n = 1$ is not a correspondence**. This is the same category **distinction** Paper 28 drew when it wrote that “ $3/2$ is an exponent, not a dimension”. **Fifth, the Hilbert–Pólya programme's home is Paper 102**. It is an **inverse spectral problem** (“can one hear the shape from the spectrum?”), where Kac's non-uniqueness theorem and Connes's noncommutative geometry already stand. **The core lies in the fact that $H = (xp + px)/2$ has continuous spectrum**.

Scope of this paper (scope note): This paper is a **structural interpretation** that sorts the numbers around the critical line within established number theory and geometry (Layer 2). Known: the functional equation and the critical line (Riemann 1859), the Euler product, Mertens' second theorem (1874), the absence of zeros on $\sigma = 1$ and the prime number theorem (Hadamard, de la Vallée Poussin 1896), the Riemann–von Mangoldt formula, the agreement of zero spacings with GUE (Montgomery 1973, Odlyzko 1987), drums of different shape with the same spectrum (Gordon–Webb–Wolpert 1992), the $H = xp$ proposal (Berry–Keating 1999), and Connes's trace formula (1999). **The Riemann Hypothesis is a Clay Millennium Prize Problem and is unsolved. This paper claims neither its proof, nor a partial proof, nor a route to one, and constructs no Hilbert–Pólya operator.** The appearance of the same number in several contexts is not treated as evidence of a common origin (Papers 48, 86, 100, 101, 115). Relation to earlier papers: the distinction between fact and convention comes from Papers 95 and 66, module boundaries from Paper 113, the census of structures that select a dimension from Paper 114, the two staircases of sphere volumes from Paper 115, the category distinction between exponent and dimension from Paper 28, and the inverse spectral problem from Paper 102 (the inverse-problem lineage is Papers 89 and 99). What this paper adds is **the standing of the numbers that appear at the critical line** — $1/2$ is the name of a coordinate, $\text{Re}(s) = 1$ is a boundary where the description switches, $n = d - 1$ is a family that selects no dimension, and 2σ and n are quantities with no ground of comparison.

1. Introduction: where the critical line comes from

The line $\text{Re}(s) = 1/2$ of which the Riemann Hypothesis speaks is not a number handed down from nowhere. **It is the fixed point of a symmetry.**

Established Fact 1.1 (The critical line is the fixed point of the functional equation)

The completed zeta function

$$\xi(s) = \frac{1}{2} s(s-1) \pi^{-s/2} \Gamma\left(\frac{s}{2}\right) \zeta(s)$$

satisfies the functional equation

$$\xi(s) = \xi(1-s)$$

(Riemann 1859). The fixed point of the involution $s \mapsto 1-s$ is

$$s = 1-s \iff 2s = 1 \iff s = \frac{1}{2}$$

and for the real part, $\sigma = 1-\sigma \iff 2\sigma = 1$.

Numerical check (computed here at **30** digits):

s	$ \xi(s) - \xi(1-s) $
$2 + 3i$	1.1×10^{-31}
$-1 + 0.7i$	2.0×10^{-31}
$0.3 + 12i$	6.0×10^{-33}
$5 - 2i$	2.0×10^{-31}

Corollary 1.2 (Quadruples of zeros)

For a non-trivial zero ρ , the numbers $1 - \rho$, $\bar{\rho}$ and $1 - \bar{\rho}$ are also zeros, forming a quadruple. **The Riemann Hypothesis is equivalent to the statement that this quadruple degenerates onto the fixed line $\text{Re}(s) = 1/2$.**

So the condition $2\sigma = 1$ itself follows from the functional equation without any geometric assumption whatever. Why the critical line is special is already explained inside number theory. **What is being asked is not “why the line is special” but “whether the zeros lie on it”.**

2. $1/2$ is the name of a coordinate

Theorem 2.1 ($1/2$ disappears under a change of coordinate)

Set $s = \frac{1}{2} + iz$ and define Riemann’s Ξ function

$$\Xi(z) \equiv \xi\left(\frac{1}{2} + iz\right)$$

Then $\xi(s) = \xi(1-s)$ translates into $\Xi(z) = \Xi(-z)$ (an even function), and the symmetry of ξ about the real axis, $\overline{\xi(\bar{s})} = \xi(s)$, translates into Ξ taking real values on the real axis. Hence

$$\text{Riemann Hypothesis} \iff \text{all zeros of } \Xi(z) \text{ are real}$$

and the number $1/2$ does not occur in this statement.

Numerical check (computed here):

z	$\Xi(z)$	$ \operatorname{Im} \Xi(z) $
0.5	0.4942569879	5.4×10^{-33}
3	0.4031652073	4.6×10^{-32}
14.1347	3.48×10^{-8}	1.3×10^{-38}
40	2.12×10^{-11}	2.2×10^{-41}

Further, $|\Xi(-7) - \Xi(7)| = 3.6 \times 10^{-32}$ (confirming evenness). At $z = 14.1347$, Ξ is nearly 0 because that is the first zero.

Observation 2.2 (What is invariant and what is coordinate-dependent)

Invariant (fact): that the completed ξ admits an involution $s \mapsto 1 - s$, that its **fixed-point set is a line**, and that **zeros are carried into zeros by that involution**. None of this depends on the choice of coordinate.

Coordinate-dependent (the number): the value $1/2$ attached to that line. In the s coordinate it is $1/2$; in the z coordinate it is 0 (the real axis).

What should be read as structure is therefore not the number $1/2$ but the existence of the involution.

This is the same distinction as in Paper 95 (Poincaré’s conventionalism) and Paper 66 (local c and coordinate c have distinct roots). For the speed of light c , that it is finite is a fact, while the value 299 792 458 is a convention. $1/2$ sits on the same side — that the involution exists is a fact; calling its fixed line $1/2$ is a choice of coordinate.

What coordinate-dependence means: once ζ is fixed, the critical line cannot be moved about the s plane at will. **Saying it is coordinate-dependent does not mean “it could be anywhere”;** it means **“the number naming that line depends on which chart one draws it in”**. This is the same qualification Paper 95 made when it wrote that a convention is not “anything goes”.

3. The wall $\text{Re}(s) = 1$ — a module boundary

Established Fact 3.1 (Where the Euler product works)

For $\sigma > 1$,

$$\zeta(s) = \prod_p (1 - p^{-s})^{-1}$$

converges absolutely and ζ can be written as **a product over primes**. For $\sigma \leq 1$ the sum $\sum_p p^{-\sigma}$ diverges and that description fails — beyond it one switches to **a different description, analytic continuation**.

Numerical check (partial sums over the primes below 2×10^6 , **148 933** of them, computed here):

σ	$\sum_{p \leq 2 \times 10^6} p^{-\sigma}$
1.5	0.849
1.1	2.001
1.0	2.936
0.9	4.995
0.5	234.79

Observation 3.2 (This is a module boundary in the sense of Paper 113)

Paper 113 wrote that “**a boundary is where some dimensionless quantity crosses 1**”, and lined up as instances the Planck scale (Paper 39), $\Lambda \lesssim 4\pi\nu$ (Paper 09), $\text{Re}_\eta = 1$ (Paper 03), $E_{\text{req}}/E_{\text{avail}}$ (Paper 04) and $\alpha_s \rightarrow 1$ (Paper 05). **$\text{Re}(s) = 1$ is another** — the convergence of $\sum_p p^{-\sigma}$ switches here, and **the description changes**. **There is, however, a decisive difference**. Each earlier instance was **a limit of a description**, whereas for ζ **analytic continuation fixes the far side uniquely** — unlike the physical $\nu \rightarrow 0$ (the singular limit of Paper 03), **there is no other theory beyond the wall; the same function extends in one and only one way. It belongs in this series’ table of modules as the example whose far side can be determined uniquely**.

Established Fact 3.3 (The wall is crossed doubly logarithmically — Mertens' second theorem)

The divergence at $\sigma = 1$ proceeds only at the **doubly logarithmic** rate

$$\sum_{p \leq x} \frac{1}{p} = \ln \ln x + M + o(1), \quad M = 0.2614972 \dots$$

(Mertens 1874).

Numerical check (the primes below 2×10^7 , 1 270 607 of them, computed here):

x	$\sum_{p \leq x} 1/p$	$\ln \ln x + M$	difference
10^2	1.802817	1.788677	$+1.4 \times 10^{-2}$
10^4	2.483060	2.481824	$+1.2 \times 10^{-3}$
10^6	2.887328	2.887289	$+3.9 \times 10^{-5}$
2×10^7	3.083559	3.083545	$+1.4 \times 10^{-5}$

Multiplying x by 100 increases the sum by only about 0.7. This is the mirror image of the discipline set out in Papers 04 and 05 — when the quantity is exponential, report the logarithm. Here the divergence itself is doubly logarithmic, so from any finite computation it scarcely looks like a divergence at all.

Corollary 3.4 ($\operatorname{Re}(s) = 1$ is the line of the prime number theorem)

$\zeta(1 + it) \neq 0$ (for $t \neq 0$) is equivalent to the prime number theorem, proved independently by Hadamard and de la Vallée Poussin in 1896. So the absence of zeros on $\sigma = 1$ is already a theorem, and the Riemann Hypothesis is the assertion that the zero-free region reaches all the way to $\sigma = 1/2$. $\sigma = 1$ (proved) and $\sigma = 1/2$ (open) are two rungs of the same question.

4. The shell-conservation exponent $n = d - 1$ does not select a dimension

For comparison, the shell-conservation condition of this series is written out in general dimension.

Theorem 4.1 (The shell-conservation exponent in general dimension)

In $\mathbb{R}^d$, a shell with spherically symmetric power-law density $\rho(r) = r^{-n}$ has mass growth rate

$$\frac{dm}{dr} = \text{Vol}(S^{d-1}) r^{d-1-n}, \quad \text{Vol}(S^{d-1}) = \frac{2\pi^{d/2}}{\Gamma(d/2)}$$

and this is independent of r if and only if $n = d - 1$.

Proof.

The volume element of $\mathbb{R}^d$ is $dV = \text{Vol}(S^{d-1}) r^{d-1} dr$. From $dm = \rho(r) dV$ we get $dm/dr = \text{Vol}(S^{d-1}) r^{d-1-n}$, which is independent of r iff $d - 1 - n = 0$.

Observation 4.2 (This formula selects no dimension (Paper 114))

Paper 114 took a census of **which structures select a dimension and which do not**, and **classified $n = d - 1$ on the side that does not**. Indeed the formula **holds in the same form for every d and contains no ground for singling any d out**.

What this formula lets one read is one row of a table: the row $n = 1$ is the row $d = 2$. Which row to choose is decided outside the table, and which row the critical line should be tied to is not written in this formula.

5. 2π and 4π are not adjacent steps of one staircase

Established Fact 5.1 (The two staircases of sphere volumes (Paper 115))

Listing $\text{Vol}(S^{d-1}) = 2\pi^{d/2}/\Gamma(d/2)$ (verified numerically here):

d	$n = d - 1$	$\text{Vol}(S^{d-1})$	value
1	0	2	2.000
2	1	2π	6.283
3	2	4π	12.566
4	3	$2\pi^2$	19.739
5	4	$8\pi^2/3$	26.319
6	5	π^3	31.006

As Paper 115 showed, the power of π rises one step every 2 dimensions — the generation rule $\text{Vol}(S^n) = \frac{2\pi}{n-1} \text{Vol}(S^{n-2})$ strides by 2. There are therefore two staircases:

$$S^1 = 2\pi \rightarrow S^3 = 2\pi^2 \rightarrow S^5 = \pi^3 \text{ (odd spheres)}$$
$$S^0 = 2 \rightarrow S^2 = 4\pi \rightarrow S^4 = 8\pi^2/3 \text{ (even spheres)}$$

Observation 5.2 (Moving from $n = 2$ to $n = 1$ is not a step down one staircase)

Read in order of size, the table has, one row above $n = 2$ (4π , S^2), the row $n = 1$ (2π , S^1), and it looks like “one step down”.

But by the sorting of Paper 115, S^1 and S^2 belong to different staircases. Because the Γ function separates even from odd dimensions, the two are not connected by the generation rule — they look adjacent only when the values are sorted by size.

Moving from $n = 2$ to $n = 1$ is not a shift by one row of the table but a change of family.

6. An exponent is not a dimension

The following two both take the value **1**:

1. the critical-line condition $2\sigma = 1$ (fixed point of the functional equation);
2. the shell-conservation exponent $n = 1$ in two dimensions (dimensional bookkeeping of the volume element).

Observation 6.1 (The two exponents are not powers of the same variable (Paper 28))

Paper 28 wrote that “**3/2 is a scaling exponent, not a dimension — this is a category mistake**”. The same distinction applies here.

In $|p^{-s}|^2 = p^{-2\sigma}$, 2σ is an exponent in a power of a prime. In $n = d - 1$, on the other hand, n is an exponent in a power of a radius, and d is the dimension of space. The two exponents are not even powers of the same variable — one is a power of p (a discrete prime), the other of r (a continuous radius).

The statement “ **2σ and n take the same value**” therefore has no ground of comparison. Before any question of a common derivation, these are not comparable quantities at all.

Observation 6.2 (And 1/2 is coordinate-dependent)

As Section 2 showed, in $2\sigma = 1$ the **1 depends on the coordinate**. In the coordinate $z = -i(s - \frac{1}{2})$ the critical line is $\text{Im}(z) = 0$, and neither 1 nor 1/2 appears. A coordinate-dependent number cannot be matched against a coordinate-free dimensional count.

What the agreement of the two values allows one to say is the following sentence.

On the critical line the prime power spectrum decays as p^{-1} . This is the result of substituting $\sigma = 1/2$ into 2σ , and it carries no further implication.

Numbers agreeing is not the same as a correspondence existing. The discipline this series has repeatedly written about 4π and $16\pi^2$ (Papers 48, 86, 100, 115) applies just as it stands to the **1** of the critical line and the **1** of shell conservation.

7. The Hilbert–Pólya programme’s home is Paper 102

Established Fact 7.1 (The Hilbert–Pólya conjecture and its central difficulty)

The Hilbert–Pólya conjecture: there exists a self-adjoint operator $\hat{H}$ whose eigenvalues coincide with the imaginary parts $\{\gamma_n\}$ of the non-trivial zeros. If $\hat{H}$ is self-adjoint its eigenvalues are real, and **the zeros lie on the critical line automatically.**

Berry and Keating (1999) took the classical Hamiltonian $H = xp$ and proposed its quantisation $\hat{H} = \frac{1}{2}(\hat{x}\hat{p} + \hat{p}\hat{x})$ as a candidate. **But this operator has continuous spectrum on the real line, with range all of $\mathbb{R}$.** Obtaining discrete eigenvalues requires boundary conditions or compactification, and **no implementation of these reproducing the zeros is known. This discretisation is the unsolved core.** Berry and Keating themselves present the proposal as heuristic.

Established Fact 7.2 (Counting the zeros — the Riemann–von Mangoldt formula)

Up to height T , the number $N(T)$ of non-trivial zeros satisfies

$$N(T) = \frac{T}{2\pi} \log \frac{T}{2\pi} - \frac{T}{2\pi} + \frac{7}{8} + S(T) + O(1/T)$$

Numerical check (computed here):

T	zeros counted	smooth part	difference
30	3	3.565	−0.565
50	10	9.423	+0.577
100	29	29.002	−0.002
200	79	79.193	−0.193

The ground of the Berry–Keating proposal is that **a regularised phase-space count reproduces this smooth part.** That, however, is a semiclassical correspondence, not an existence proof for an operator.

Observation 7.3 (This is an inverse spectral problem, and it belongs to the house of Paper 102)

Paper 102 took “**can one hear the shape from the spectrum?**” as its axis, set Kac’s inverse spectral problem beside Connes’s noncommutative geometry, and made of them **a bridge joining the geometric lineage to the inverse-problem lineage. The Hilbert–Pólya conjecture is a resident of that house — the spectrum (the zeros) is given first, and one hunts for the operator that produces it**, which is exactly the shape of an inverse problem. Two tools already stand there. **Kac’s non-uniqueness**: Gordon, Webb and Wolpert (1992) constructed **drums of different shape with the same spectrum — a spectrum does not determine a shape uniquely**. **Connes’s noncommutative geometry**: a formulation placing geometry inside a Dirac operator $\mathcal{D}$, which Connes (1999) himself turned upon the zeta zeros using adele space. **Within this series, Connes (1999) is the road of Paper 102. A caution about distinct roots**: Kac’s non-uniqueness is a theorem about the direction “**from spectrum to shape**”, whereas Hilbert–Pólya asks for **the existence of an operator reproducing the zeros. Existence and uniqueness are different questions, and non-uniqueness does not deny existence**. What is being asked is **existence**.

Observation 7.4 (The standing of the GUE statistics)

The agreement between the zero-spacing statistics of Montgomery (1973) and Odlyzko (1987) and random matrix theory (GUE) is **strong empirical evidence** for the Hilbert–Pólya conjecture. **It is evidence, not proof**. In the vocabulary of Paper 100 it is **not a case of the machinery transferring, but a signature: the statistics agree — no proof machinery has been carried over from random matrix theory to the theory of the zeros**.

Personal reflection of the author (Layer 3; labelled non-scientific / no claim of mechanism)

What told most in this paper was rewriting things in terms of $\Xi(z)$. **The $1/2$ vanishes**. The number into which I had tried again and again to read a meaning simply leaves the screen when the coordinate changes. **The meaning was never on the side of the number, but on the side of the structure: that an involution exists**.

When the arithmetic agrees, one is reassured and stops asking **whether the two are things one is entitled to compare**. 2σ is an exponent in a power of a prime and n an exponent in a power of a radius; **they are not even about the same variable**. Over the editions of this paper, I came to confirm that with my own hands.

Numbers are where I am most drawn and where I most go wrong. The distinction Paper 95 took from Poincaré — **fact and convention** — was somebody else’s business while I was writing about c . **Writing it about $1/2$ made it my own**.

8. Conclusion

The critical line is the fixed point of the functional equation $\xi(s) = \xi(1-s)$ (Section 1), and the numbers that appear there each have a different standing. **$1/2$ is the name of a coordinate**: passing to $\Xi(z)$ makes it vanish, and the Riemann Hypothesis takes the form “all zeros of Ξ are real” (Section 2). **$\text{Re}(s) = 1$ is a boundary where the description switches**; it is crossed doubly logarithmically, and analytic continuation fixes the far side uniquely. The absence of zeros on $\sigma = 1$ is a theorem equivalent to the prime number theorem (Section 3). **$n = d - 1$ is a family that selects no dimension** (Section 4), and **2π and 4π belong to different staircases** (Section 5). **2σ and n are quantities with no ground of comparison** (Section 6). The Hilbert–Pólya programme has the shape of the inverse spectral problems of Paper 102, and its core is how to discretise the continuous spectrum of $H = xp$ (Section 7).

The structure, by contrast, is a fact. There is an involution $s \mapsto 1-s$, and it has a fixed line. **What is being asked is whether the zeros lie on that line, not why the line is special.**

Revision Record

4th edition (September 2026): brought the format into line with the current template (the positioning and scope are gathered in the scope note directly after the abstract, and the history of the editions is moved to this record). Removed the edition label from the subtitle. Self-citations now carry their actual titles and DOIs, external references are given as author, year, title and journal, and the title of the Berry–Keating paper in SIAM Review (1999) is corrected (The Riemann zeros and eigenvalue asymptotics). The numbers, tables and theorems are unchanged in content.

3rd edition (August 2026): added that **$1/2$ is the name of a coordinate** (the Ξ function), that **$\text{Re}(s) = 1$ is a module boundary** crossed doubly logarithmically, that **$n = d - 1$ selects no dimension**, that **2π and 4π belong to different staircases**, and that the Hilbert–Pólya programme has the shape of an inverse spectral problem, with all numbers computed here. Removed the word “Withdrawal” from the title. Withdrew, as lacking a ground of comparison (Section 6), the correspondence that the 2nd edition had retained as “a numerical coincidence of two independent facts” between the critical-line condition **$2\sigma = 1$** and the two-dimensional shell-conservation exponent **$n = 1$** .

2nd edition (July 2026): withdrew the claim of proof made in the first edition’s title and abstract. The first edition’s chain **$2\sigma = n = 2 \Rightarrow 2\sigma = 1$** sets **$2\sigma = 2$** and **$2\sigma = 1$** on the same line and cannot stand, and what **$n = 2$** corresponds to is not the critical line but **$\text{Re}(s) = 1$** (the convergence boundary of the Euler product). The claim that, on a **$16\pi^2$** torus, **$H = (xp + px)/2$** has the zeros as its eigenvalues came with no proof of discreteness and no proof of agreement with the zeros; **$16\pi^2$** is a number belonging to one-loop measures and has nothing to do with the zeta zeros (Papers 09, 05, 46).

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