

Triangular-n Postmaster: From the Triangular Primitive to the Completed Source Frontier

Volume I — The Reading Volume – v6.3

TRIANGULAR ROOT TO COMPLETED SOURCE FRONTIER

1 · TRIANGULAR ROOT

$$T_n, \quad j_n = 2n + 1$$

Odd layers, midpoint tails, reciprocals

2 · ANALYTIC COORDINATE

$$x = 2T_{s-1}, \quad D_x = R^{-1}D_s$$

Sine, Gamma, Bessel derivatives

3 · COMPLETED FOLD

$$q = s(1 - s), \quad S_\xi, \quad h = xS_\xi$$

Reflection with both sheets retained

4 · RUNGS AND MATRICES

$$W_k \leftrightarrow B_{2k-1, k-1}$$

Exact entries; full matrix quantifiers

5 · EXACT SOURCE ENERGY

$$\mathcal{E}_N = \sum_j B_{N,j}^2$$

Circle and Laguerre norms agree

6 · OPEN FULL-PRIME CAP

$$\mathcal{E}_N[P](2) \leq (1 + \log 2 + \pi/6)^2$$

Every degree; cutoff obstructions in Dossier 166C

The connecting identities are proved; the final source estimate remains open

Jeffery Huckstead

ORCID 0009-0007-0234-2177

Cerebral Graphix

October 2026

RH STATUS: OPEN

DOI 10.5281/zenodo.23510962

Contents

Abstract	1	R7. Reflection, conjugation, and the Cayley circle	29
Start here	2	R8. The self-dual Mellin magnitude . .	30
A triangle you already know	2	Part III. Completion and the folded zero resolvent	31
Put a sign on it	3	R9. The completed function	31
What each row is for	3	The folded-state contract	33
Why zeta cares	4	R9A. The first zero, in these coordinates	33
Where this work sits in the classical lit- erature	5	R10. Heat, Stieltjes, and complete Bern- stein representations	35
Master status key — where this volume actually stands	6	R10A. Positive realizations: trace and finite-vector forms	37
The live frontier: one line per route . . .	7	R10B. What an off-line orbit leaves in the heat trace	38
Reader's study spine	8	R10C. One orbit, four coordinates . . .	40
How to read this volume	8	Part IV. The Widder ladder and the sector geometry	43
Notation visible at every analytic interface	9	R11. Carrier, Cayley complement, and rungs	43
Terms used in this volume	9	R12. One ladder: explicit rungs, bound- ary moments, and proof channels .	45
Part I. The triangular coordinate	10	R12A. The same rungs in the shifted- zeta basis	50
R1. Discrete primitive and centered square	10	R13. Height-to-sector theorem and the full finite rectangle	55
R1A. The general discrete primitive and its reflection	12	R13A. How far the ladder is from the hypothesis, in one number	57
R2. Odd and even power sums	14	R13B. A narrower sector from an ex- plicit zero-free region	59
R3. Factorial switch and diagonal defect	15	R13C. One frontier number, and an as- sumed half-plane	61
R4. Reciprocal triangular numbers as moments	15	R14. One prescribed scale and the Haus- dorff theorem	63
R4A. Euler's constant on the triangular coordinate	17	Part V. Li data, Löwner matrices, and the source-energy construction	64
R5. The triangular coordinate as a real analytic chart	21	R15. The central-Pascal boundary dic- tionary	64
R5C. The even-triangular rail and the half-step sequence	22	R16. What L_Γ and L_P actually mean .	67
R5D. One real coordinate, several roles for π	24		
R5E. The half-step and the reflected pair	25		
Part II. From the half-step to the com- plex fold	26		
R6. Folding the two axes of $s = \sigma + it$.	26		
R6A. Sum to product, and the model in which the hypothesis is true . .	27		

R17. The Gamma triangular scaffold— and why it is not L_Γ	70	R18B. A varying-endpoint Gram candi- date	84
R17A. The completed spectral zeta and its source signature	71	R19. Why stationary symbols are blind	85
R17B. Regularized triangular values: the fraction sequence	71	R20. Reflection contour and the missing conjugation	85
R17C. The odd-coordinate pole ladder and the determinant	73	R21. The one-node strict defect	87
R17D. What the triangular–Volterra benchmark establishes	74	R21A. Strict defects and the Green boundary	89
R17E. What the continuation retains about primes	76	R21B. Heat, transverse distance, and source-energy growth	90
R17F. The completed Bernstein row	77	Part VII. Results and the research boundary	91
R17G. The same row as a positive energy proves	78	R22. Results and their quantifiers	91
R17H. What the prime-cutoff attack proves	78	R23. The first unsupported lines, by route	92
R17I. Exact divisors and one denomina- tor residual	80	R24. Proof map and reading routes	94
Part VI. Translation defects and reflec- tion contours	82	Part VIII. What this approach cannot do	97
R18. Positive defects with a negative scalar anchor	82	R25. No-go theorems and what they leave open	97
R18A. Beta and Volterra forms side by side	83	Summary: the object, the results, and the remaining line	98
		References	99

Abstract

The triangular primitive $T_n = n(n+1)/2$ becomes a reflection-invariant coordinate after centering at the half-step. Its analytic continuation gives $q = s(1-s) = -2T(s-1) = 1/4 - (s-1/2)^2$. This volume follows that coordinate from finite arithmetic into the completed Riemann function, its folded resolvent, and the exact positivity criteria it supports. Throughout, $[\rho] = \{\rho, 1-\rho\}$ is one functional-equation reflection orbit with multiplicity m_ρ : an off-line quartet supplies two conjugate folded nodes, not one full-symmetry state. The reciprocal coordinate $1/q$ retains the folded node; taking a real part is a separate operation and is not part of this fold.

The central identities express every reduced Widder rung as one finite row of the signed Pascal triangle and connect the folded moments to Li's coefficients. The source establishes the first six rungs, analytically at W_1 and by interval certificates at W_2 – W_6 . A separate verified-height argument establishes a much longer finite prefix. Neither channel supplies the all-order quantifier. The all-node inequality $L_\Gamma - L_P \succeq 0$, the next independent source rung W_7 , and the stated source-energy and exact-divisor bounds retain their distinct open obligations. The Riemann hypothesis is not proved here.

A calibration marks what a finite prefix can show. A Dirichlet series with the reflection $F(s) = F(1-s)$ of ξ , a different Gamma factor and no Euler product passes every computed rung through $k = 16,588$ and fails at $k = 16,589$ (Dossier §69A). So a long finite rung prefix does not by itself rule out off-line zeros. Interval certificates fix both signs on stated ranges (Dossier §69D).

The verified-height channel is carried as far as its inputs reach. With a published zero-free region as a second input, the sector rectangle holds through index 4,772,432,051,943 at every scale (§R13B). With a published zero count as a second input, the fixed-scale array is positive in every column, at every scale $0 < x \leq H^2/10^6$, through row 4,500,262,999,199 (§R13C). Both ranges are finite.

One external claim is taken as an assumption and traced through the volume: a release of 6 October 2026 states that ζ has no zero with $\Re s > 7/8$ [128]. It was read and not verified. Section R13C proves what follows from assuming it: the open statement $\Delta < 1$ of §R13A, and both ranges longer by about a third. $\Delta = 0$, the hypothesis, does not follow.

Start here

A triangle you already know

Stack bowling pins. Count handshakes in a room. Add up $1 + 2 + \cdots + n$. The same numbers appear:

$$1, 3, 6, 10, 15, 21, 28, 36, 45, 55, \dots \quad \boxed{T_n = \frac{n(n+1)}{2}} \quad (\text{R.1})$$

Two facts about them are usually met once and then walked past.

The triangular numbers are a column of Pascal's triangle. Not a resemblance — an identity, and one Pascal knew [90]:

$$\binom{k}{2} = \frac{k(k-1)}{2} = T_{k-1} \quad (\text{R.1a})$$

Read Pascal's triangle down its third column and you are reading $1, 3, 6, 10, 15, \dots$ exactly. The next column over is the running sum of *those*: $\binom{k}{3} = T_1 + T_2 + \cdots + T_{k-2}$.

And they collide with the rest of the triangle in a way nobody can fully explain.

The number $3003 = T_{77}$ occupies four distinct positions $\binom{3003}{1} = \binom{78}{2} = \binom{15}{5} = \binom{14}{6} = 3003$. Each of those four positions has a mirror copy, so 3003 occurs **eight** times in all. No integer is known to occur more often, and whether any does is open (Singmaster's problem [89]). Figure 14 of this volume prints the row where that happens.

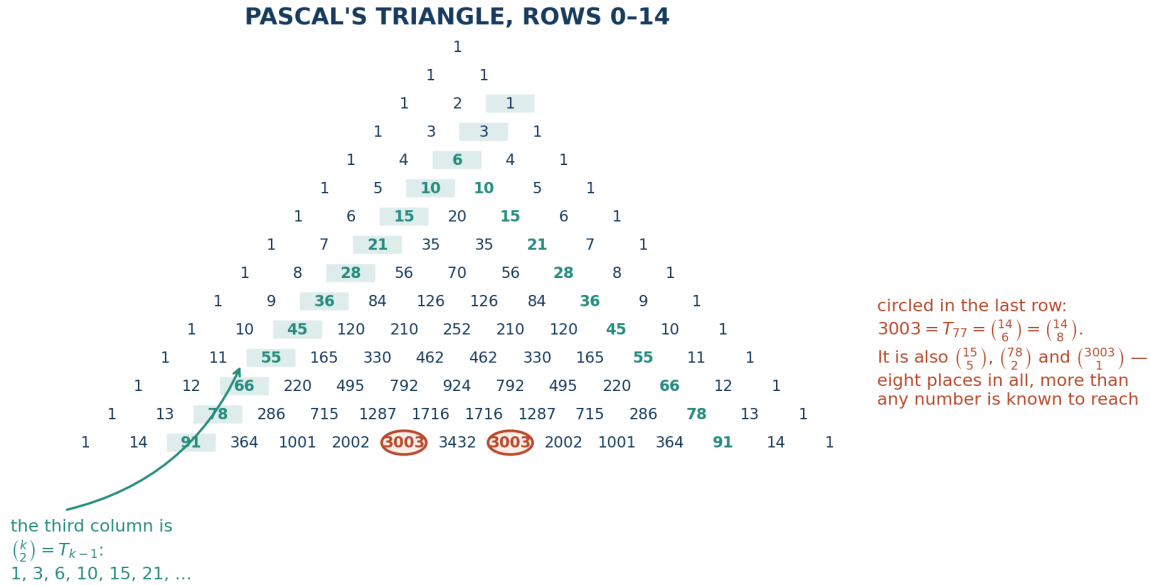


Figure 1: The familiar triangle, before any sign is attached. The tinted column is the triangular numbers themselves; the circled row is the one that makes 3003 famous. Both features survive into the signed grid this volume actually uses.

These are not decorations. This volume is about what one signed version of that same triangle does when it is pointed at the Riemann zeta function.

Put a sign on it

Alternate the signs along each row:

$$\boxed{c_{k,j} = (-1)^j \binom{k}{j}}, \quad \sum_{j=0}^k c_{k,j} z^j = (1-z)^k \quad (\text{R.1b})$$

Row k is nothing more exotic than the coefficient list of $(1-z)^k$. Row 6 reads 1, -6, 15, -20, 15, -6, 1. Every row is generated from the one above it by a single subtraction, $c_{k+1,j} = c_{k,j} - c_{k,j-1}$, from the seed $c_{0,0} = +1$. You can write row 17 without computing rows 1 through 16. Nothing in this grid is hard, and nothing in it is approximate.

What each row is for

Zeta's zeros are hard to look at directly. Fold them. With $q = s(1-s)$ — the same reflection $n \mapsto -n-1$ that centres T_n , now on the complex plane — every zero ρ of the completed function ξ becomes a single point q_ρ , and its mirror partner $1-\rho$ lands on top of it. Build the resolvent of that folded set,

$$S_\xi(x) = \sum_{[\rho]} \frac{m_\rho}{x + q_\rho}, \quad Z_r(x) = \sum_{[\rho]} \frac{m_\rho}{(x + q_\rho)^r} \quad (\text{R.1c})$$

so $Z_1 = S_\xi$ and each Z_r is one more derivative of it; the sum runs over folded zero orbits $[\rho]$ with multiplicity m_ρ (§R10).

Now the point of the grid. Define the k -th **rung**

$$W_k(x) = (-1)^{k-1} D_x^{2k-1} [x^k S_\xi(x)] = (2k-1)! \sum_{[\rho]} m_\rho \left(\frac{q_\rho}{(x + q_\rho)^2} \right)^k \quad (\text{R.3})$$

and row k of the signed triangle is exactly its recipe, the identity (SW.4b) established in §R12A:

CLOSED FORM *Every rung is a finite row of the grid*

$$\frac{W_k(x)}{(2k-1)!} = \sum_{j=0}^k c_{k,j} x^j Z_{k+j}(x) = Z_k - kxZ_{k+1} + \binom{k}{2} x^2 Z_{k+2} - \cdots$$

This is an identity, not an approximation and not a truncation. The rung W_k is a $(k+1)$ -term combination of consecutive derivatives of one function, and the coefficients are read straight off row k . The grid is not computationally irreducible, and no simulation is hiding in it.

Why zeta cares

Look at the right-hand side of (R.3). It is a sum of k -th powers of one quantity, the **carrier** (11.1) of §R11,

$$u_x(q) = \frac{q}{(x + q)^2}$$

On the critical line $\Re s = 1/2$ the carrier is a squared modulus, so $u_x \geq 0$ and every power of it is nonnegative. Off the critical line it need not be, and its powers can rotate. Widder's characterization of Stieltjes functions [16, 115] converts the whole family into an exact statement with nothing left over:

RH-EQUIVALENT *Exact criterion*

$$\text{RH} \iff W_k(x) \geq 0 \text{ for every } k \geq 1 \text{ and every } x > 0 \quad (\text{R.4})$$

So the Riemann hypothesis, in this volume's coordinates, reads:

Does every row of a signed Pascal triangle, applied to the derivatives of one explicit function, come out nonnegative?

Both quantifiers are essential. **No finite collection of rungs is an RH statement.** Nothing in this volume treats one as such, and every place a finite result could be mistaken for the full one is marked.

Where this work sits in the classical literature

Most of the machinery in this volume is classical, and the argument depends on that. The table maps each layer to its classical sources and states what this volume adds. “Adds” means a construction, an exact identity in the volume’s coordinates, a certificate or a NO-GO theorem. It is not a claim of priority. No systematic MathSciNet or zbMATH search has been made, so read every entry in the last column as “proved or organized here,” not as “new.”

layer (sections)	classical sources	what this volume adds
Triangular numbers, Pascal’s column, power sums (§§R1–R3)	Nicomachus [83]; Pascal [90]; Faulhaber [84]; Jacobi [85]; Knuth [86]; Singmaster [89]	one chart for the mirror $n \mapsto -n - 1$ (T_n fixed, $j_n \mapsto -j_n$); the adjacent-pair identities (TDP.1)–(TDP.5); the factorial diagonal defect
Reciprocal triangular numbers and the Basel sum (§R4)	Mengoli [91]; Euler [92]; Hausdorff [19, 20]	the dyadic telescope; the moment (Hausdorff and Hankel) reading of $1/T_k$
Euler’s constant (§R4A)	Euler [93]; Stirling [94]; Raabe [95]; Cesàro [96]; Ramanujan [119], with Villarino and Chen [97–99]; DeTemple and Wang [100, 120]; Boya [101]; Nyman and Beurling [106, 107]	the mirror explanation of Ramanujan’s expansion; four readings of $\log 2\pi - \gamma_E$; a simplex ladder
Completion and folding (§§R6–R9A)	Riemann [74]; Hadamard [110]; von Mangoldt [111]; Davenport [112]; Edwards [118]	the folded coordinate $q = s(1 - s) = -2T(s - 1)$ as the working variable; genus zero in q
Stieltjes, Bernstein and heat representations (§§R10–R10B)	Stieltjes [113]; Bernstein [114]; Schilling, Song and Vondraček [23]	explicit positive realizations of the folded resolvent; the heat defect left by an off-line zero
The rung criterion (§§R11–R14)	Widder [16, 115]; Hausdorff [19, 20]; Pringsheim [21]; Platt and Trudgian [42]	each rung is one row of the signed Pascal triangle (SW.4b); the height-to-sector theorem; computer-assisted source certificates for W_2 – W_6
Li coefficients and Löwner matrices (§§R15–R17E)	Li [4]; Keiper [58]; Bombieri and Lagarias [5]; Löwner [22]; Dobsch [43]; Donoghue [44]	the central-Pascal boundary dictionary; the Gamma/prime Löwner split and the limits of that split
Energy, cutoffs and exact divisors (§§R17F–R17I)	Nyman [106]; Beurling [107]; Báez-Duarte and coauthors [25, 108, 109]; M. Riesz [24]; Eisenberg [60]	the completed Bernstein row and its energy; exponential cutoff theorems; the taper exponent (DIV.3a)
Explicit formula and reflection (§§R18–R21B)	Weil [116]; Connes and coauthors [48–50]	the reflection-contour normal form; the one-node strict defect; why stationary symbols are blind
Limits of the approach (§R25)	—	a table of unconditional NO-GO theorems

Every row keeps the status tags of its own sections. A classical source is cited for what it proves. It is never cited as evidence for the Riemann hypothesis.

Master status key — where this volume actually stands

This is the **single status key for the Reading Volume and Dossier**. Later **PROVED**, **CERTIFIED**, **RH-EQUIVALENT**, **EVIDENCE** and **OPEN** tags stand on their own and refer back here; the legend is not repeated elsewhere.

PROVED	proved here or cited as proved: an unconditional theorem or an exact identity.
CERTIFIED	rigorous but computer-assisted, or dependent on verified zero heights; the finite region it certifies is stated with it.
RH-EQUIVALENT	logically equivalent to the Riemann hypothesis. An equivalence is not a proof in either direction.
OPEN	not proved anywhere in this work, and not implied by any finite result in it.
EVIDENCE	numerical or empirical support only. It never upgrades a status.

the claim	status
Every rung is a finite row of the grid, (SW.4b)	PROVED closed form
$\text{RH} \iff W_k \geq 0$ for all $k \geq 1, x > 0$, (R.4)	RH-EQUIVALENT
$W_1, \dots, W_6 > 0$ for all $x > 0$, from the source	PROVED analytic (W_1); CERTIFIED computer-assisted, through $F^{(12)}$ (W_2 – W_6)
$W_k > 0$ for all $x > 0$, every $k \leq 4,712,664,392,502$	CERTIFIED verified-height channel
$W_k > 0$ for all $x > 0$, every $k \leq 4,772,432,051,943$, (13B.3)	CERTIFIED verified-height channel, with the published zero-free region [125] as a second external input
$G_{n,k}(x) > 0$ for every $k \geq 0$, every $0 < x \leq H^2/10^6$ and every $n \leq 4,500,262,999,199$, (13C.4)	CERTIFIED verified-height channel, with the published zero count [130] as a second external input
$4x - 1 < R_x$ at every fixed scale, (13A.2); $\Delta < 1$ is <i>not</i> proved	PROVED analytic, pointwise in x
$\Delta < 1$, equivalently a zero-free half-plane $\Re s > \theta_0$ with $\theta_0 < 1$; claimed externally with $\theta_0 = 7/8$ [128], read and not verified, and used only as an assumption (§R13C)	OPEN in this edition
$W_7 \rightsquigarrow F^{(14)}$ from the independent source	OPEN
$W_k > 0$ for all $x > 0$, every $k \geq 1$	OPEN
$L_\Gamma - L_P \geq 0$ on every finite node set, (23.1)	RH-EQUIVALENT OPEN
$\mathcal{C}_N[P](2) \leq 5$ for every degree N , (166B.12a)	RH-EQUIVALENT OPEN
A real finite test sees an off-line folded pair only at second order, (TW.1)	PROVED
The functional-equation twin of Dossier §69A fails some Widder rung	PROVED
Twin rungs positive through $k = 16,588$ where computed; $W_{16589} < 0$; Löwner failure first at $N = 105$ (exact, best tested centre)	EVIDENCE
Twin: $W_k^F > 0$ for all $x > 0$, every $1 \leq k \leq 244$ (Dossier §69D)	CERTIFIED computer-assisted, on the interval-certified census to height 280
Twin: $W_{16589}^F < 0$ and $W_{16588}^F > 0$ at every $x \in [7139.83, 7140.28]$ (Dossier §69D)	CERTIFIED computer-assisted, on that interval only
Twin: whether $W_k^F > 0$ for all $x > 0$ at every $245 \leq k \leq 16,588$; the first globally failing rung is not identified	OPEN

Where the certificates are. The five certified source rungs rest on one certificate, kept in the source archive of this volume and executed on two independent arithmetic backends (Dossier §74A). The enclosures of q_1 , q_2 and λ_1 printed in §R12 come from the same build (Dossier §96A.5). These certificates are in the source archive, with their saved outputs and

checksums. They were not run again for this edition. The verified-height row uses the external input named in §R13. Software versions, precisions and run dates are recorded in that archive and are not carried in the text.

How far the criterion has been checked — and why that is not progress. The K_H row is not a sample. Section R13 proves that if every zero up to a height H lies on the critical line, then every rung with index at most $\lfloor \pi/(2 \arctan(1/H)) \rfloor$ is positive at every $x > 0$. Platt and Trudgian’s verified height puts the lowest 12,363,153,437,138 zeros on the line, and the resulting index, exact at (13.6), is

$$K_H = 4,712,664,392,502.$$

Thus (R.4) holds for the first four and a half trillion rungs, and the first **six** also have an independent source certificate. It is still not evidence for RH: (R.4) quantifies over every k , and a larger verified height only makes a finite prefix larger. Section R13B does exactly that from the same height: a published zero-free region narrows the sector and moves the index to 4,772,432,051,943. The symbol K_H keeps its meaning (13.6). The live pair is

$$W_7 \rightsquigarrow F^{(14)} \quad \text{and} \quad L_\Gamma - L_P \succeq 0 \text{ on every finite positive node set.} \quad (\text{R.2})$$

The first is the next scalar source rung; the second is RH-equivalent. They are not equal in reach. The Davenport–Heilbronn function has the reflection $F(s) = F(1-s)$ of ξ with a different Gamma factor, no Euler product, and zeros off the line. By the argument behind (R.4), some rung of its ladder fails. **PROVED** Computed, it passes W_7 and every rung through W_{16588} and first fails at W_{16589} (Dossier §69A). **EVIDENCE** *First* means first on the ranges scanned. The interval certificates of Dossier §69D cover less and say it exactly: every twin rung through $k = 244$ is positive at every $x > 0$, and W_{16589} is negative on a whole interval of x . The first globally failing rung is not identified. So a proof of W_7 extends a finite prefix that this twin also passes. The reason is exact. A real test at real nodes sees an off-line pair only at second order in its displacement, (TW.1). The second line’s finite sections detect the twin, but only at about a hundred nodes (first failure $N = 105$ at the best tested centre) and with deciding eigenvalues near 10^{-141} . By the fitted detection scale (TW.3), an off-line zeta zero just above the verified height would first break the ladder near $k \sim 10^{27}$, far beyond K_H .

The live frontier: one line per route

What remains is **one line per route, and no reduction between the routes is known**. Section R23 lists the live targets and marks each one as equivalent, sufficient, or necessary. The principal matrix route asks for

$$L_\Gamma - L_P \succeq 0 \quad \text{for every finite positive node set.}$$

Here L_Γ and L_P are the Gamma and prime Löwner blocks built in §§R16–R17E. That inequality is RH-equivalent, but it is not proved to subsume the distinct curvature, fixed-scale energy, or exact-divisor routes. The unconditional implications actually known between

targets are recorded in the lattice at §R12; Part VIII collects the routes that have been closed by NO-GO theorems.

Reader's study spine

Why read this. Triangular coordinates lead to the completed source of the Riemann zeta function, to exact criteria stated in that coordinate, and to the proof obligations that remain. The Riemann hypothesis remains open.

TRIANGULAR ROOT TO COMPLETED SOURCE FRONTIER



The connecting identities are proved; the final source estimate remains open

Figure 2: The reading map for this volume. Arrows give the reading order, not an implication from a finite certificate to RH. Section R12 controls the rung status; §R23 states the all-node frontier.

How to read this volume

The work is published in two documents: this **Reading Volume**, the continuous argument in reader sections §R1–§R25 across Parts I–VIII, and the **Technical Dossier**, the proofs, certificates and empirical context in plain numbered sections with lettered insertions; see §R24. **A number without an R is in the Dossier.** Equation tags are global, so (SW.4b) and (166C.25) name the same equations in both. Every reader section states its own quantifiers, and this volume can be read straight through before the Dossier is opened.

The dependency route is root to frontier: triangular coordinate → fold and completion →

Widder/Hausdorff rungs $\rightarrow$ Li/Löwner source split $\rightarrow$ source energy and exact-divisor residual $\rightarrow$ reflection defects $\rightarrow$ the live targets of §R23 and the NO-GO theorems of §R25. The section-level map is printed once, in §R24.

About this edition. The volume is written to be read on its own, in order. What each edition changed is recorded in the source archive deposited with it, and is not repeated in the text.

How to cite. Use the concept DOI 10.5281/zenodo.21968915, which always resolves to the newest version, and name the version you read.

Notation visible at every analytic interface

The Riemann variable will never be allowed to hide its two real axes:

role	notation	exact reading
point	s	$s = \sigma + it$
reflection	$1 - s$	$(1 - \sigma) - it$
conjugate	$\bar{s}$	$\sigma - it$
reflected conjugate	$1 - \bar{s}$	$(1 - \sigma) + it$
folded coordinate	$q = s(1 - s)$	$\sigma(1 - \sigma) + t^2 + it(1 - 2\sigma)$
analytic triangular coordinate	$T(s - 1) = s(s - 1)/2$	$(\sigma^2 - \sigma - t^2)/2 + it(\sigma - 1/2)$
safe real source branch	s_x	$(1 + \sqrt{1 + 4x})/2 > 1$
source Jacobian	R	$R = 2s_x - 1 = \sqrt{1 + 4x}$
integer odd coordinate	j_n	$j_n = 2n + 1$
rung odd coordinate	j_k	$j_k = 2k + 1$

The symbols s , ρ , and s_x distinguish an arbitrary point, a zero, and the safe source branch by mathematical role. Reflection $s \mapsto 1 - s$ and conjugation $s \mapsto \bar{s}$ coincide exactly on $\sigma = 1/2$; identifying the two off that line is the positivity problem of §R20.

One letter, one meaning. This volume, its Technical Dossier and the companion paper [133] read the shared letters the same way. $T(z) = z(z + 1)/2$ is the triangular polynomial at any argument and T_n its value at an integer. The fold is $q = s(1 - s) = \mathfrak{f}(s)$, where $\mathfrak{f}(w) = w(1 - w)$; the safe sheet coordinate is $x = s(s - 1) = -q$; and $u = z + \frac{1}{2}$ is the half-index displacement, so that $T(z) = u^2/2 - 1/8$. The zero count $N_0(t)$ counts the zeros with $0 < \gamma \leq t$, and $\overline{N}(t)$ is its smooth part. A letter used inside one section only is declared there.

Terms used in this volume

A few ordinary words carry a narrow technical meaning in this volume. Each is defined once here.

term	meaning in this volume
mirror	the involution $n \mapsto -n - 1$; equivalently $u = n + \frac{1}{2} \mapsto -u$, or $s \mapsto 1 - s$
fold	the substitution $q = s(1 - s) = -2T(s - 1)$, which sends s and $1 - s$ to one point; on integers it is $T_n = T_{-n-1}$

term	meaning in this volume
source	the defining formula (9.5): the Gamma factor and the prime sum, evaluated where both converge, with no zero data
source-side proof	a proof that uses only the source, and never zero locations or verified heights
zero-assisted	a result that uses the rigorously verified location of finitely many zeros (§R13)
rung W_k	the k -th Widder sign condition (R.3); all rungs together are equivalent to RH (R.4)
carrier	$u_x(q) = q/(x+q)^2$, whose powers the rungs sum (§R11)
rail	a progression of distinguished points, such as the even-triangular rail $2T_{2n}$ of §R5C
computer-assisted theorem	a rigorous finite certificate in interval arithmetic, joined to an analytic proof for the remaining range
firewall	a proved statement that blocks a tempting but invalid inference
NO-GO	an unconditional theorem showing that a proposed route cannot work as stated
frontier	the first inequality on a route that is not proved

Part I. The triangular coordinate

The triangular coordinate, its half-step reflection and its Pascal column supply the arithmetic vocabulary for the analytic constructions that follow. All identities in this Part stand independently of zeta zeros.

R1. Discrete primitive and centered square

Triangular numbers integrate the integer sequence by one forward difference:

$$T_n - T_{n-1} = n \quad T_n = 1 + 2 + \cdots + n \quad (1.1)$$

A square displays both triangular copies at once. Split an $(n+1) \times (n+1)$ grid into the entries above the diagonal, the entries below it, and the diagonal itself:

$$\boxed{2T_n + (n+1) = (n+1)^2 \quad T_n + T_{n+1} = (n+1)^2} \quad (\text{SQ.1})$$

The two strict triangular halves each contain T_n cells, and the shared diagonal contains $n+1$. The border ending at n^2 and the border beginning there are consecutive members of one odd sequence:

$$\boxed{n^2 - (n-1)^2 = 2n-1, \quad (n+1)^2 - n^2 = 2n+1} \quad (\text{SQ.2})$$

Summing the first identity gives $n^2 = \sum_{k=1}^n (2k-1)$. Equivalently $n^2 = T_{n-1} + T_n$; taking successive differences of this adjacent-triangle identity gives the same borders. Thus $2n-1$ and $2n+1$ describe the incoming and outgoing layers at the same square, with the index shift

stated explicitly.

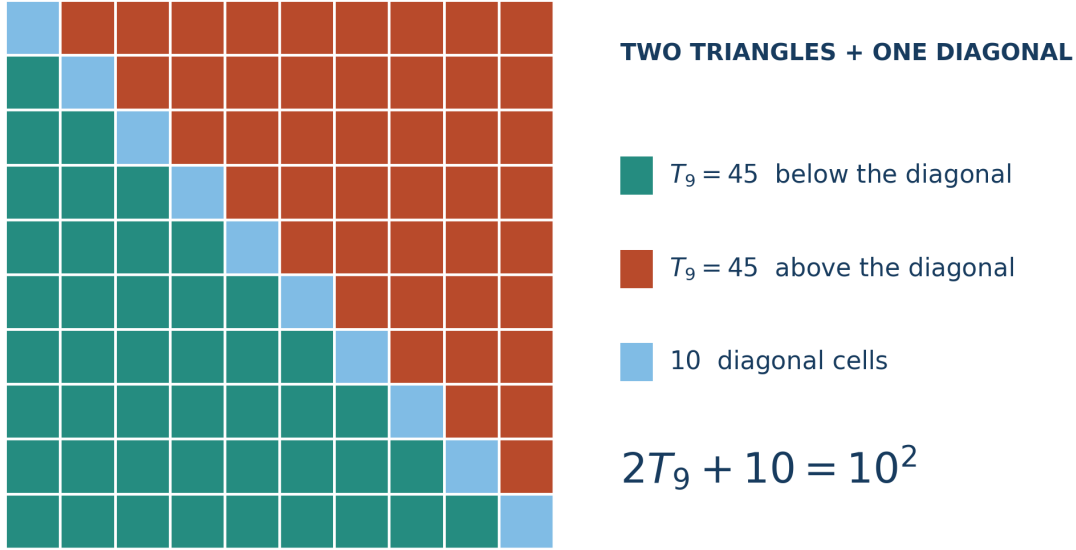


Figure 3: A 10 by 10 square splits into two 45-cell triangles and a 10-cell diagonal: $2T_9 + 10 = 100$. The diagonal is counted once. This exact counting diagram also prepares the reflected index pairs used later in matrices.

Introduce the centered odd coordinate

$$j_n := 2n + 1 \quad (1.2)$$

Then

$$8T_n + 1 = j_n^2, \quad T_n = \frac{j_n^2 - 1}{8} = \frac{1}{2} \left(n + \frac{1}{2} \right)^2 - \frac{1}{8} \quad (1.3)$$

The reflection $n \mapsto -n - 1$ becomes $j_n \mapsto -j_n$ while T_n is fixed. Thus T_n is the invariant coordinate and j_n is its signed sheet coordinate. This is the elementary model for the analytic fold used later. In particular the two border counts in (SQ.2) are j_{n-1} and j_n . Their squared difference recovers the primitive exactly: $j_n^2 - j_{n-1}^2 = 8(T_n - T_{n-1}) = 8n$. The same mirror reflects the completed function in §R9, and §R4A gives it a third role: it is a parity of the harmonic numbers, which is why Ramanujan's expansion of H_n is a series in $1/T_n$.

The paper will keep three exact readings beside one another whenever doing so exposes structure rather than adding notation:

mainstream form	triangular form	centered form
$n(n+1)$	$2T_n$	$(j_n^2 - 1)/4$
$n + (n+1)$	$T_{n+1} - T_{n-1}$	j_n

mainstream form	triangular form	centered form
$n \mapsto -n - 1$	$T_n \mapsto T_n$	$j_n \mapsto -j_n$

This “three-language line” is an editorial convention, not a claim that every formula becomes simpler after triangularization.

Triangular numbers are both a discrete primitive and a centered split square

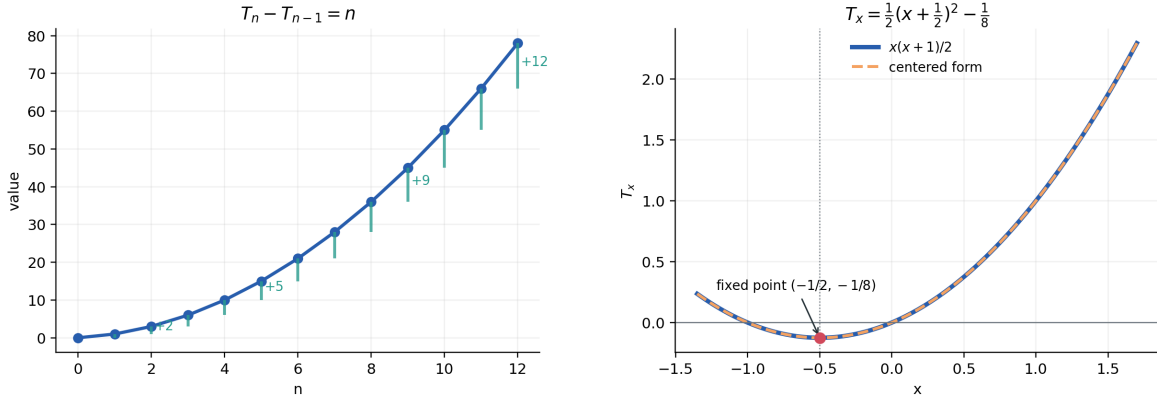


Figure 4: Triangular numbers are the discrete primitive; centering at the half-step turns reflection into a sign change.

R1A. The general discrete primitive and its reflection

The same polynomial identities hold for real or complex inputs. For complex z define

$$T(z) = \frac{z(z+1)}{2}, \quad j(z) = 2z+1,$$

so that $T_n = T(n)$ and $j_n = j(n)$ at integers.

Then

$$T(z) - T(z-1) = z, \quad T(z+1) - T(z) = z+1, \quad \Delta^2 T(z) = 1$$

while the adjacent sum is

$$\boxed{T(z) + T(z-1) = z^2} \quad (\text{TDP.1})$$

Factoring through the primitive difference gives the cubic identity

$$\boxed{T(z)^2 - T(z-1)^2 = (T(z) - T(z-1))(T(z) + T(z-1)) = z^3} \quad (\text{TDP.2})$$

The same adjacent pair also resolves the square index:

$$s = \sigma + it$$

$$\boxed{T(z^2) = T(z-1)^2 + T(z)^2} \quad (\text{TDP.3})$$

Indeed, the right side is $z^2((z-1)^2 + (z+1)^2)/4 = z^2(z^2+1)/2$.

The forward adjacent product and its reflection can be kept on one line:

$$\boxed{2T(z) = (T(z) - T(z-1))(T(z+1) - T(z)), \quad T(-z-1) = T(z)} \quad (\text{TDP.4})$$

With $j(z) = 2z + 1$, the centered sheet coordinate is visible without a new symbol collision:

$$\boxed{T(z) = \frac{j(z)^2 - 1}{8} = \frac{1}{2} \left(z + \frac{1}{2} \right)^2 - \frac{1}{8}} \quad (\text{TDP.5})$$

Thus the half-shift and the value $-1/8$ are not numerical coincidences. They are the split-norm coordinates of two consecutive counting legs.

The half index. With $u = z + \frac{1}{2}$, (TDP.5) reads $T(z) = u^2/2 - 1/8$, and the reflection $z \mapsto -z - 1$ of (TDP.4) is $u \mapsto -u$. The vertex is the half index $z = -\frac{1}{2}$: there $j(-\frac{1}{2}) = 0$ and $T(-\frac{1}{2}) = -\frac{1}{8}$, which on the completed coordinate is the vertex $q = \frac{1}{4}$ of the fold at $s = \frac{1}{2}$. The same point continues the triangular product

$$\Pi_n(y) = \prod_{i=1}^n (1 + iy) = \sum_{k=0}^n e_k(n) y^k.$$

Each coefficient $e_k(n)$ is a polynomial in n , with $e_1(n) = T_n$, and at the half index

$$\boxed{e_k(-\frac{1}{2}) = 1, -\frac{1}{8}, \frac{1}{128}, \frac{5}{1024}, -\frac{21}{32768}, -\frac{399}{262144}, \dots \quad (k = 0, 1, 2, \dots)} \quad (\text{TDP.6})$$

These are the coefficients of the classical expansion of $y^{-1/2}\Gamma(1/y + \frac{1}{2})/\Gamma(1/y + 1)$ as $y \rightarrow 0^+$, the function behind the central binomial coefficients. Dossier §6 proves (TDP.6) and shows that the same product carries the successor-prime gate of §R3 [133].

More generally, for a fixed gap $D \geq 0$,

$$z(z+D) = \left(z + \frac{D}{2} \right)^2 - \left(\frac{D}{2} \right)^2$$

This is the common null-coordinate grammar behind the Casimir square, complementary phase states, and reciprocal uniformization. It is a scalar grammar; a shared operator must still be proved separately in each family.

The square-index recurrence and the two Pell constructions are proved in Dossier §5 (Theorems TDP-A–TDP-C); the identities above are the algebraic reference used below.

R2. Odd and even power sums

Let $S_p(n) = \sum_{k=1}^n k^p$. Reflection about $n = -1/2$ forces the classical Faulhaber parity split [84–86]

$$\boxed{S_{2m+1}(n) = P_m(T_n), \quad S_{2m}(n) = j_n Q_m(T_n), \quad j_n = 2n + 1} \quad (2.1)$$

for polynomials P_m, Q_m , with $m \geq 0$ in the odd formula and $m \geq 1$ in the even formula. The case $S_0(n) = n$ is excluded from the even formula. The first examples are

$$\begin{aligned} S_1 &= T_n & S_2 &= \frac{j_n T_n}{3} = \frac{(2n+1)T_n}{3} \\ S_3 &= T_n^2 & S_4 &= \frac{j_n T_n (6T_n - 1)}{15} \\ S_5 &= \frac{T_n^2 (4T_n - 1)}{3} & S_6 &= \frac{j_n T_n (12T_n^2 - 6T_n + 1)}{21} \end{aligned} \quad (2.2)$$

The square-sum formula follows from these same adjacent quantities, without a separate counting hypothesis. Set $A(n) = j_n T_n$. Then

$$A(n) - A(n-1) = (2n+1)T_n - (2n-1)T_{n-1} = 3n^2 \quad (2.2a)$$

Since $A(0) = 0$, summation proves $3S_2(n) = j_n T_n$, which is the case $r = 1$ of a product decomposition of Witula and coauthors [87, (13)]. Factoring $T_n^2 - T_{n-1}^2$ uses the same primitive difference n and adjacent sum n^2 , giving (2.3). The square and cube branches therefore follow from one adjacent-triangle calculation.

In the half-step variable $u = n + 1/2$, odd power sums are polynomials in u^2 while even sums are u times polynomials in u^2 . The factor $j_n = 2n + 1$ is therefore not an accessory: it records the odd sheet of the same centered geometry.

The cubic identity, known to Nicomachus [83], is the cleanest instance:

$$\boxed{T_n^2 - T_{n-1}^2 = n^3, \quad 1^3 + \cdots + n^3 = T_n^2} \quad (2.3)$$

The same adjacent pair resolves a square-index triangular number:

$$\boxed{T_{n^2} = T_{n-1}^2 + T_n^2} \quad (2.4)$$

Classical forms of the split. Write $S_{2m+1}(n) = P_m(T_n)$ as in (2.1). Faulhaber's inverse form [86] expresses the powers of T_n through odd power sums,

$$2^{m-1} T_n^m = \sum_{j \geq 1} \binom{m}{2j-1} S_{2m-2j+1}(n), \quad \text{for example} \quad T_n^2 = S_3, \quad 4T_n^3 = 3S_5 + S_3, \quad (2.5)$$

and the even sums follow by differentiation [86]:

$$S_{2m}(n) = \frac{1}{2m+1} \frac{d}{dn} S_{2m+1}(n) = \frac{n + \frac{1}{2}}{2m+1} P'_m(T_n). \quad (2.6)$$

The factor $n + \frac{1}{2} = dT_n/dn = j_n/2$ is the Jacobian of the triangular chart; it returns as the source Jacobian $R = 2s - 1$ in (5.1). Inverting the other way, $n^{p+1} = \sum_{j=0}^p (-1)^{p-j} \binom{p+1}{j} S_j(n)$: the matrix that turns power sums back into powers is a signed Pascal triangle, the same array that carries the rungs in (SW.4b). Derby [88] computes the power-sum coefficients by inverting a matrix of Pascal rows.

R3. Factorial switch and diagonal defect

The factorial form makes the triangular polynomial appear by exact cancellation:

$$\boxed{\frac{(n+1)!}{2(n-1)!} = \binom{n!}{2} \left(\frac{n+1}{(n-1)!} \right) = \frac{n(n+1)}{2} = T_n} \quad (3.1)$$

The two-variable continuation

$$F_{\Delta}(x, y) = \frac{\Gamma(y+2)}{2\Gamma(x)} \quad (3.2)$$

restricts to $T(x)$ on the diagonal. At regular points with $T(x) \neq 0$, its exact relative defect is

$$\boxed{\frac{F_{\Delta}(x, y)}{T(x)} = \frac{\Gamma(y+2)}{\Gamma(x+2)}, \quad \frac{F_{\Delta}(x, x+\varepsilon) - T(x)}{T(x)} = \varepsilon\psi(x+2) + O(\varepsilon^2)} \quad (3.3)$$

The reduced factor $(n+1)/(2(n-1)!)$ still carries the successor-prime numerator gate before multiplication. After the factorial cancellation, the whole expression is the integer T_n ; the reduced-numerator signal is not a separate invariant of the product.

The gate has a second exact home. The interior coefficients $e_1(n), \dots, e_{n-1}(n)$ of the product $\Pi_n(y)$ of §R1A have greatest common divisor $n+1$ when $n+1$ is prime and 1 otherwise, so the successor-prime gate is also the interior gcd of the product. Across consecutive n the reduced denominators of $T_n/n!$ change by exactly three ratios, one for each branch of the gate (Dossier, Proposition 6.2).

R4. Reciprocal triangular numbers as moments

The reciprocal triangle starts with Mengoli's telescope [91],

$$\frac{1}{T_n} = \frac{2}{n(n+1)} = 2 \left(\frac{1}{n} - \frac{1}{n+1} \right), \quad \sum_{n \geq 1} \frac{1}{T_n} = 2. \quad (4.1)$$

The adjacent pair retains the centered coordinate $j_n = 2n + 1$:

$$\frac{1}{n} - \frac{1}{n+1} = \frac{1}{2T_n}, \quad \frac{1}{n} + \frac{1}{n+1} = \frac{j_n}{2T_n}. \quad (4.2)$$

Squaring and summing gives an exact bridge to Euler's Basel sum [92]

$$\boxed{\sum_{n \geq 1} \frac{1}{T_n^2} = 8\zeta(2) - 12, \quad \zeta(2) = \frac{3}{2} + \frac{1}{8} \sum_{n \geq 1} \frac{1}{T_n^2}.} \quad (4.4)$$

The cubic reciprocal identity needed later is

$$\boxed{\sum_{n \geq 1} \frac{1}{T_n^3} = 8 - 6 \sum_{n \geq 1} \frac{1}{T_n^2} = 80 - 48\zeta(2).} \quad (4.4f)$$

More generally, with $R_m(n) = n^{-m} + (n+1)^{-m}$, the adjacent roots $1/n$ and $1/(n+1)$ give

$$R_m(n) = \frac{j_n}{2T_n} R_{m-1}(n) - \frac{1}{2T_n} R_{m-2}(n), \quad R_0 = 2, \quad R_1 = \frac{j_n}{2T_n}. \quad (4.4b)$$

Thus the higher reciprocal identities are one recurrence, not isolated simplifications. The distinction between reciprocating each term and reciprocating a completed sum is retained throughout the volume.

Finally the reciprocal triangle is already a compact moment sequence:

$$\boxed{\frac{1}{T_{k+1}} = \int_0^1 u^k 2(1-u) du.} \quad (4.5)$$

This positive Hausdorff measure [19, 20] later supplies Hankel and Gram models. It is an auxiliary triangular measure and must not be identified with the signed Gamma or completed-zero measures. Section R4A uses the same moments to reach Euler's constant.

The law $1/(2T_n)$ and its entropy. Halving (4.1) gives a probability law on the positive integers, with mass $1/(2T_n) = 1/n - 1/(n+1)$ at n . Its entropy is a sum over the even zeta values:

$$\boxed{H = \sum_{n \geq 1} \frac{\log(2T_n)}{2T_n} = -2 \sum_{k \geq 1} \zeta'(2k) = \log 2 + 2 \sum_{k \geq 1} \frac{\zeta(2k) - 1}{2k - 1} = 2.0462774528 \dots} \quad (4.6)$$

in nats, or 2.9521543... bits. It is the classical entropy of the Lüroth map [134], and Dossier §94 proves (4.6). The two-outcome case sits on the fold. For $0 < s < 1$ the coordinate $q = s(1-s)$ is the variance of a coin that shows heads with probability s , and the coin's entropy $h(s) = -s \log s - (1-s) \log(1-s)$ satisfies $h''(s) = -1/q$. Its maximum, $\log 2$, is at the vertex $q = \frac{1}{4}$ [133].

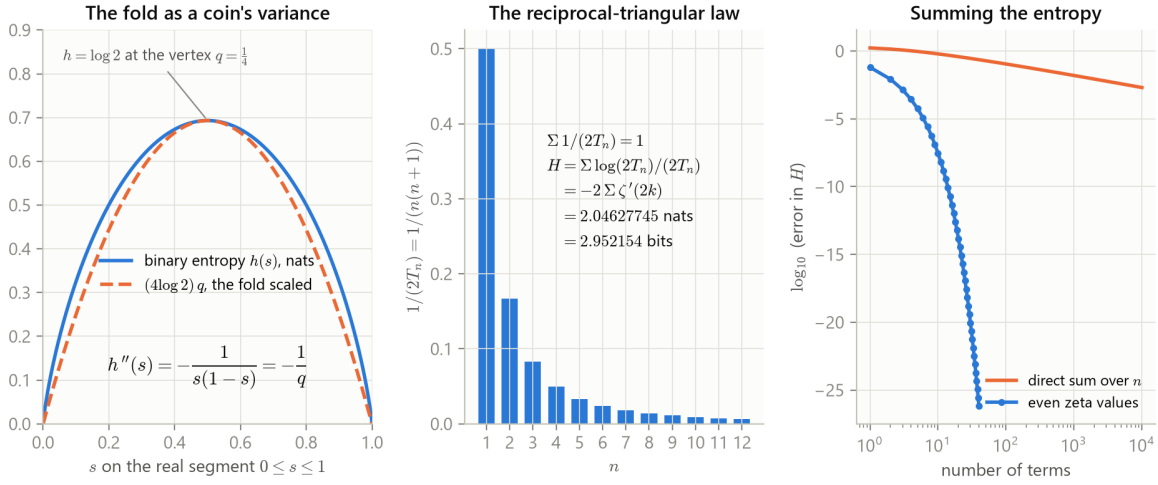


Figure 5: Left: on $0 \leq s \leq 1$ the binary entropy $h(s)$ meets the scaled fold $(4 \log 2) q$ at the vertex $q = \frac{1}{4}$, and $h'' = -1/q$ for $0 < s < 1$. Centre: the law $1/(2T_n)$ and its entropy (4.6). Right: the error in H after a given number of terms, for the direct sum over n and for the sum over the even zeta values.

R4A. Euler's constant on the triangular coordinate

Euler's constant, $\gamma_E = \lim_{n \rightarrow \infty} (H_n - \log n) = 0.5772156649 \dots$ [93, 103], first appears in this volume inside the first Li coefficient (9.8). It can already be seen in Part I. Three classical facts connect it to the triangular coordinate, and each follows in a few lines from what Part I has established. They also give a third reason for the mirror $n \mapsto -n - 1$ of (1.3). The mirror folds the index, and it reflects the completed function. It is also a parity of the harmonic numbers.

Nothing in this section concerns where the zeros lie. The full proofs, the coefficient tables and an interval-arithmetic check are in Dossier §96A. Every statement below is **PROVED**. None is claimed as new; no priority search beyond the cited literature has been made.

The mirror in the harmonic numbers. Put $u = n + \frac{1}{2} = j_n/2$. By (1.3), $2T_n = u^2 - \frac{1}{4}$, and the mirror is $u \mapsto -u$. The digamma expansion with shift $\frac{1}{2}$ [2, §5.11] involves only Bernoulli polynomials evaluated at $\frac{1}{2}$. Those of odd order vanish there, because $B_k(1-x) = (-1)^k B_k(x)$. So once the logarithm is centered at $\frac{1}{2} \log(2T_n) = \frac{1}{2} \log(u^2 - \frac{1}{4})$, the harmonic numbers see only even powers of u :

$$H_n - \gamma_E - \frac{1}{2} \log(2T_n) \sim \sum_{m \geq 1} \frac{c_m}{u^{2m}}, \quad c_m = \frac{(1 - 2^{1-2m})B_{2m} + 2^{-2m}}{2m}. \quad (\text{GA.1})$$

Since $u^2 = 2T_n + \frac{1}{4}$, the right side is a series in $1/T_n$. It is Ramanujan's expansion, Entry 9 of Chapter 38 in Berndt's edition of the notebooks [119], with modern proofs and error bounds in [97–99]; its first two terms go back to Cesàro [96].

CLOSED FORM *Ramanujan's expansion, and why it is a series in T_n*

$$H_n \sim \gamma_E + \frac{1}{2} \log(2T_n) + \frac{1}{12T_n} - \frac{1}{120T_n^2} + \frac{1}{630T_n^3} - \frac{1}{1680T_n^4} + \cdots \quad (\text{GA.2})$$

The mirror $n \mapsto -n - 1$ fixes T_n , and it leaves this expansion unchanged.

The mirror now appears in three roles: as the invariance of the folded index (1.3), as the reflection $\xi(s) = \xi(1-s)$ with $T(s-1) = T(-s)$ (SC.2), and as the parity of an asymptotic expansion. The half-integer approximation of DeTemple and Wang [100, 120], which subtracts $\log(n + \frac{1}{2})$, is the same parity with a differently centered logarithm, and Villarino derives (GA.2) from it [97]. With six terms, the error at $n = 10$ is below 10^{-15} (Figure 6).

One warning. The first two coefficients equal $-\zeta(-1)$ and $-\zeta(-3)$, but the third is $1/630$, not $-\zeta(-5) = 1/252$. The pattern does not continue.

A reciprocal-triangular zeta series. By (4.5), $1/T_k = \int_0^1 u^{k-1} 2(1-u) du$. The Taylor series $\sum_{k \geq 2} \zeta(k) u^{k-1} = -\gamma_E - \psi(1-u)$ turns the sum over k into one digamma moment, and Raabe's integral $\int_0^1 \log \Gamma = \frac{1}{2} \log 2\pi$ [95] evaluates it:

$$\sum_{k \geq 2} \frac{\zeta(k)}{T_k} = \log(2\pi) - \gamma_E = 1.2606614015 \dots \quad (\text{GA.3})$$

This is Boya's relation [101]; the ingredients are in Whittaker and Watson [102, Ch. 12]. The reciprocal generating function (94.3) gives a second proof, with an exact finite form. For the truncated zeta function $\zeta_M(k) = \sum_{m \leq M} m^{-k}$,

$$\sum_{k \geq 2} \frac{\zeta_M(k)}{T_k} = 2M - H_M - 2 \log \frac{M^M}{M!}. \quad (\text{GA.4})$$

Stirling's formula [94] and $H_M - \log M \rightarrow \gamma_E$ then return (GA.3), with error $-1/(3M) + O(M^{-2})$. Replacing every $\zeta(k)$ by 1 gives Mengoli's $\sum_{k \geq 2} 1/T_k = 1$ [91].

The same constant as a norm. Term by term, (GA.4) is a sum of integrals over unit intervals:

$$\sum_{k \geq 2} \frac{m^{-k}}{T_k} = \int_{m-1}^m \left(\frac{\{x\}}{x} \right)^2 dx \quad (m \geq 1). \quad (\text{GA.5})$$

Now sum over m . For $0 < \Re s < 1$, Titchmarsh's formula [3, (2.1.5)], after the substitution $x \mapsto 1/x$, reads $\zeta(s)/s = -\int_0^\infty \{1/x\} x^{s-1} dx$, and the Mellin–Plancherel theorem [117] applies on $\Re s = \frac{1}{2}$. Together these give four expressions for one constant:

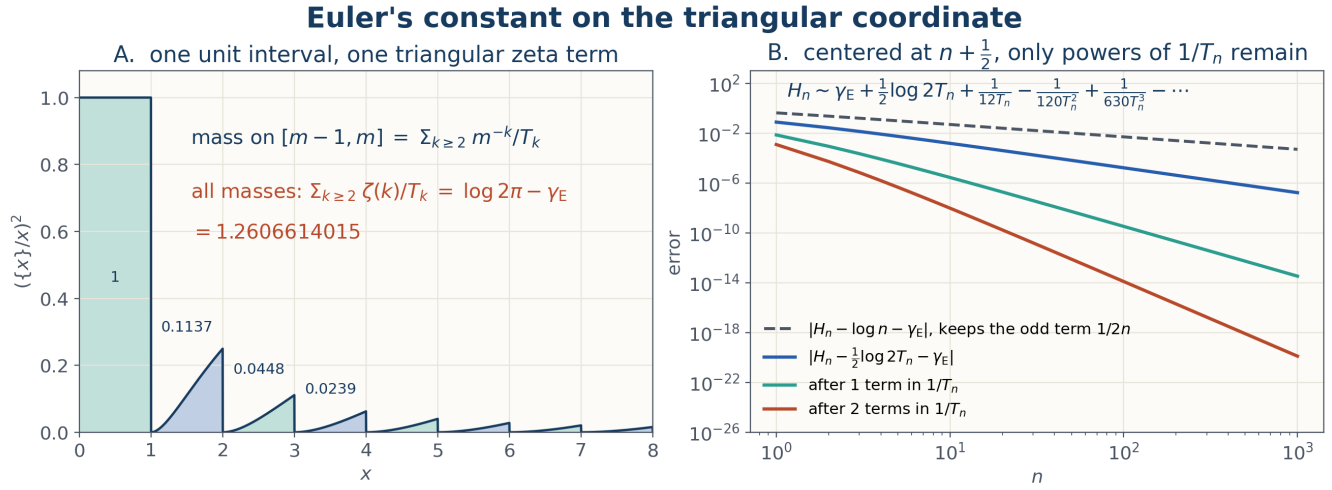


Figure 6: Euler's constant on the triangular coordinate. A: the squared fractional part $(\{x\}/x)^2$ carries, on each unit interval $[m-1, m]$, exactly the mass $\sum_{k \geq 2} m^{-k}/T_k$ of (GA.5); the masses add up to $\log(2\pi) - \gamma_E$. B: subtracting $\log n$ leaves the odd term $1/2n$, while subtracting the centered logarithm $\frac{1}{2} \log(2T_n)$ leaves a series in $1/T_n$ whose first few terms are already very accurate, as in (GA.2); like every such asymptotic series, it does not converge.

CLOSED FORM *one constant, four readings*

$$\begin{aligned}
 \log(2\pi) - \gamma_E &= \sum_{k \geq 2} \frac{\zeta(k)}{T_k} = \int_0^1 \left(\frac{\{x\}}{x} \right)^2 dx \\
 &= \frac{1}{2\pi} \int_{-\infty}^{\infty} \frac{|\zeta(\frac{1}{2} + it)|^2}{\frac{1}{4} + t^2} dt = \sum_{n \geq 0} (b_n^{\text{den}})^2.
 \end{aligned}
 \tag{GA.6}$$

The weight $\frac{1}{4} + t^2$ is the folded coordinate $q = s(1-s)$ on the critical line (9.2). The fractional-part function is the one in the Nyman–Beurling approximation problem [106–108]. The last expression is the denominator norm of §R17I, where the same constant returns. (GA.6) is an identity about $|\zeta|^2$ on the critical line. It says nothing about where the zeros are.

A simplex ladder. The moment formula (4.5) is the case $d = 2$ of the Beta identity $1/\binom{k+d-1}{d} = d \int_0^1 u^{k-1} (1-u)^{d-1} du$ for the d -dimensional simplex numbers. The same argument then gives, for every $d \geq 2$,

$$\sum_{k \geq 2} \frac{\zeta(k)}{\binom{k+d-1}{d}} = d(d-1) \int_0^1 u^{d-2} \log \Gamma(u) du - \gamma_E.
 \tag{GA.7}$$

The moments of $\log \Gamma$ on the right are classical [104]. The first three rungs are

$$\begin{aligned}
d = 2 \text{ (triangular)} : & \quad \log(2\pi) - \gamma_E, \\
d = 3 \text{ (tetrahedral)} : & \quad \frac{3}{2} \log(2\pi) - 6 \log A - \gamma_E, \\
d = 4 \text{ (pentatope)} : & \quad 2 \log(2\pi) - 12 \log A + \frac{3\zeta(3)}{\pi^2} - \gamma_E.
\end{aligned}$$

Here A is the Glaisher–Kinkelin constant, $\log A = \frac{1}{12} - \zeta'(-1)$ [105]. Written in the constants $\log(2\pi)$, γ_E and $\zeta'(-j)$, the pattern is fixed:

- every rung contains $\frac{d}{2} \log(2\pi)$, and it contains $-\gamma_E$ with coefficient exactly one;
- rung d adds one new constant, $\zeta'(2-d)$;
- $\zeta(3)$ first enters at $d = 4$, because $\zeta'(-2) = -\zeta(3)/(4\pi^2)$ is a derivative taken at a trivial zero.

With every $\zeta(k)$ replaced by 1, the left side of (GA.7) becomes the reciprocal simplex telescope of Dossier §76, whose full sum from $k = 1$ is $d/(d-1)$.

Where Euler's constant meets the zeros. The first Li coefficient (9.8) is $\lambda_1 = \sum_{[\rho]} m_\rho/q_\rho = 1 + \gamma_E/2 - \log(2\sqrt{\pi})$, the classical value of $\sum_\rho \rho^{-1}$ [112, Ch. 12; 118]. Adding twice λ_1 to (GA.3) cancels both γ_E and $\log \pi$:

$$\boxed{\sum_{k \geq 2} \frac{\zeta(k)}{T_k} + 2 \sum_{[\rho]} \frac{m_\rho}{q_\rho} = \sum_{k \geq 1} \frac{1}{T_k} - \log 2 = 2 - \log 2.} \quad (\text{GA.8})$$

A series of zeta values over reciprocal triangular numbers and a series over the folded zeros add up to an elementary constant. This is the folded form of the classical evaluation of $\sum_\rho \rho^{-1}$. It is an identity between two convergent sums, not a sign condition. $\lambda_1 > 0$ is known unconditionally, and it is only the first of the infinitely many Li conditions of §R15.

What is classical, and what this section adds. The substance of (GA.1)–(GA.8) is classical:

- (GA.2): Ramanujan and Cesàro [96–99, 119];
- (GA.3): Boya, with Raabe's integral and the classical Gamma-function series [95, 101, 102];
- the setting of (GA.6): Titchmarsh, Nyman, Beurling, and Báez-Duarte, Balazard, Landreau and Saias [3, 106–109];
- the moments in (GA.7): Espinosa and Moll [104];
- λ_1 : Hadamard and Davenport [110, 112].

This volume's contribution is organizational:

- the mirror reading of (GA.1)–(GA.2);
- the interval identity (GA.5), which joins the reciprocal telescope to the fractional-part norm;
- the simplex normalization of (GA.7);
- the identification of the §R17I denominator constant with (GA.3).

The program `provenance/v5_0/qa/audit_gamma_bridge.py` in the source archive checks every display in this section, including an interval-arithmetic enclosure of λ_1 .

R5. The triangular coordinate as a real analytic chart

Replace the integer index by a real source variable $s > 1$ and define

$$x = s(s-1) = 2T(s-1) \quad R = 2s-1 = \sqrt{1+4x} \quad (5.1)$$

At $s = n+1$ this reads

$$\boxed{x = 2T_n, \quad R = 2n+1} \quad (5.2)$$

Thus the repeatedly occurring $2n+1$ is the Jacobian dx/ds of the folded safe-axis coordinate. The integer centered coordinate and the analytic source Jacobian are the same object on this lattice. Writing $R(x) = \sqrt{1+4x}$ makes both neighboring values visible, for $n \geq 2$ on the open source half-line:

$$R(2T_{n-1}) = 2n-1, \quad R(2T_n) = 2n+1, \quad D_x = \frac{1}{R} D_s \quad (5.2a)$$

This is the route by which the elementary odd coordinate enters the source derivatives. Dossier §34 uses this differential operator to obtain the rung denominators, and §146 derives its Bessel polynomials.

A noninteger example makes the interpolation visible:

$$\boxed{T_3 = 6 < T(\pi) = \frac{\pi(\pi+1)}{2} < 7, \quad T(\pi) \approx 6.5055985273} \quad (5.3)$$

Indeed, $T(z)$ is increasing for real $z > -1/2$, and $3 < \pi < 22/7$ gives $6 < T(\pi) < T(22/7) = 319/49 < 7$. The value lies close to, but above, the midpoint 6.5. At $s = \pi+1$, the source chart has $x = 2T(\pi)$; the same reflection identity holds exactly: $T(\pi) = T(-\pi-1)$.

Value scaling and horizontal-coordinate scaling must be separated. The polynomial $T(z)$ has zeros at $z = -1, 0$; its reciprocal has poles there. Multiplying its value by 2 leaves those locations fixed. Replacing the horizontal coordinate by $v = 2z$ changes the displayed locations:

expression	symmetry center	zeros; poles of its reciprocal
$T(z) = z(z+1)/2$	$z = -1/2$	$z = -1, 0$
$2T(z) = z(z+1)$	$z = -1/2$	$z = -1, 0$
$2T(v/2) = v(v+2)/4$	$v = -1$	$v = -2, 0$

The general coordinate rule, for $a > 0$, is

$$T(v/a) = \frac{v(v+a)}{2a^2}, \quad \frac{1}{T(v/a)} = \frac{2a^2}{v(v+a)}, \quad v_{\text{center}} = -\frac{a}{2} \quad (\text{SC.1})$$

The centered coordinate carries the same change explicitly. In the shifted input s used by the completed function,

$$j(s-1) = 2s-1, \quad 8T(s-1) + 1 = (2s-1)^2 \quad T(s-1) = T(-s) \quad (\text{SC.2})$$

The symmetry center is now $s = 1/2$, with reciprocal poles at $s = 0, 1$. For the particular squared-root condition $(2s-1)^2 = 2$, the two branches are $s = (1 \pm \sqrt{2})/2$ and $T(s-1) = 1/8$. Squaring removes the sign of the centered coordinate; keeping $j(s-1)$ retains the branch. This is why the integer $2n+1$, its shifted real version, and the imaginary $2it$ will continue to be printed beside the triangular fold.

Equations (5.1)–(5.2) are the safe-axis specialization of the full discrete primitive and centered split recorded in §R1A, especially (TDP.4)–(TDP.5).

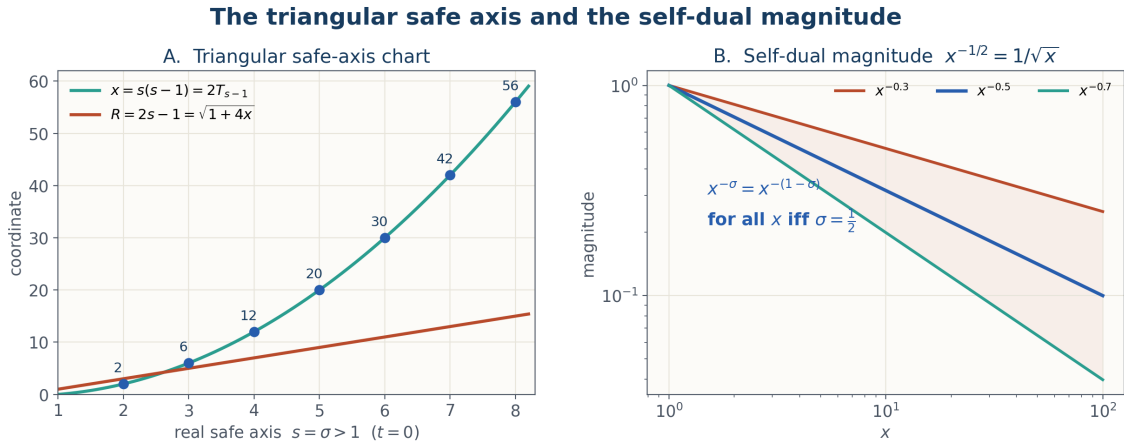


Figure 7: The real triangular safe axis $x = s(s-1) = 2T(s-1)$ with its inverse $R = 2s-1 = \sqrt{1+4x}$, and the self-dual magnitude: $x^{-\sigma}$ and $x^{-(1-\sigma)}$ agree for every x exactly at $\sigma = \frac{1}{2}$. The reflection and conjugation involutions and the two components of the fold are in §R10C, where they move with one orbit.

R5C. The even-triangular rail and the half-step sequence

The even-index subsequence deserves its own visible line. For $n \geq 1$, put

$$a_n = 2n + \frac{1}{2} = \frac{j_{2n}}{2}, \quad a_n^2 - \frac{1}{4} = 2n(2n+1) = 2T_{2n} \quad (\text{TR.1})$$

Geometrically, $2T_{2n}$ is the $2n$ by $(2n+1)$ rectangle formed by two equal triangles. Centering the two side lengths at a_n writes its area as $a_n^2 - (1/2)^2$. This is why the quarter-square

and odd coordinate occur together. The even indices also pair successive factors in the odd factorial, as (PR.6) will show. Its reciprocal sequence is

$$A_n := \frac{1}{2T_{2n}} = \frac{1}{2n} - \frac{1}{2n+1} = \frac{1}{a_n^2 - 1/4} \quad (\text{TR.2})$$

n	even triangle T_{2n}	adjacent product $2T_{2n}$	reciprocal A_n	centered root a_n
1	3	6	1/6	5/2
2	10	20	1/20	9/2
3	21	42	1/42	13/2
4	36	72	1/72	17/2
5	55	110	1/110	21/2

The same fractions have two useful sums:

$$\log 2 = 1 - \sum_{n \geq 1} A_n, \quad \zeta(2) = 3 - 2 \log 2 + \sum_{n \geq 1} A_n^2 \quad (\text{TR.3})$$

The first follows from the alternating harmonic series. For the second, square the adjacent reciprocal difference and use $\sum_{n \geq 1} [(2n)^{-2} + (2n+1)^{-2}] = \zeta(2) - 1$. These are ordinary convergent sums of positive terms.

This selection by even index is distinct from the gcd selection in Dossier §170. The latter groups rational rays and their multiplicities; here we select a specific adjacent-product sequence. Both remain rooted in $T(z)$. In the later real source chart the same entry is $x = 2T_{2n}$, $s = 2n + 1$, and $R = 2s - 1 = 4n + 1 = 2a_n$.

Later, the Gamma scaffold has poles at $-2T_{2n}$ (§R17). Voros's auxiliary half-step sequence is precisely a_n [56, equation (59)]. Equation (TR.1) therefore supplies an exact triangular dictionary for that sequence. The analytic continuation built from A_n will be introduced only after the completed source has been defined (§R17A). Its regularized values are a different operation from the convergent sums in (TR.3).

Consecutive squares. The rail also has an elementary arithmetic face. For every $n \geq 1$, the $n + 1$ consecutive squares that start at T_{2n} add up to the next n squares, as in $3^2 + 4^2 = 5^2$ and $10^2 + 11^2 + 12^2 = 13^2 + 14^2$:

$$\sum_{j=0}^n (T_{2n} + j)^2 = \sum_{j=n+1}^{2n} (T_{2n} + j)^2. \quad (\text{TR.4})$$

The starting point is forced. For a run that starts at p , the left side minus the right side is $(p - T_{2n})(p + n)$, so the only positive start is the even-triangular value in the table above. For first powers the runs start at n^2 , as in $4 + 5 + 6 = 7 + 8$. Derby [88] derives the starting point and searches for analogues in higher powers; the quadratic printed there has the wrong sign on its linear term.

R5D. One real coordinate, several roles for π

The polynomial chart accepts real input without inventing a new interpolation:

$$T(z) = \frac{z(z+1)}{2} = \frac{\Gamma(z+2)}{2\Gamma(z)} = \frac{(2z+1)^2 - 1}{8}. \quad (\text{PR.1})$$

At $z = \pi$, the adjacent reflected values satisfy $T(\pi) - T(-\pi) = \pi$ and $T(\pi) + T(-\pi) = \pi^2$; these identities describe the input rather than evaluate it. An evaluation from integer triangular numbers follows instead from (4.4) and Euler's Basel identity:

$$\pi = 3 \sqrt{1 + \frac{1}{12} \sum_{n \geq 1} \frac{1}{T_n^2}} = \sqrt{10 - \frac{1}{8} \sum_{n \geq 1} \frac{1}{T_n^3}}. \quad (\text{PR.4a})$$

The square root acts on the whole expression. This is the only reading used later when the same constant enters the source-energy cap.

Wallis's product reads the same constant on the odd squares $8T_n + 1 = j_n^2$ of §R1:

$$\pi = 4 \prod_{n \geq 1} \frac{8T_n}{8T_n + 1} = 4 \prod_{n \geq 1} \left(1 - \frac{1}{j_n^2}\right). \quad (\text{PR.4b})$$

Each factor is $2n(2n+2)/(2n+1)^2$, and the partial products decrease to $\pi/4$. Dossier §76 derives (PR.4b) from Euler's cosine product.

Euler's sine product gives the analytic bridge from ordinary integers to the even triangular subfamily:

$$\frac{\sin(\pi x)}{\pi x} = \sum_{m \geq 0} \frac{(-1)^m (\pi x)^{2m}}{(2m+1)!} = \prod_{n \geq 1} \left(1 - \frac{x^2}{n^2}\right), \quad (\text{PR.5})$$

and

$$(2m+1)! = \prod_{r=1}^m (2r)(2r+1) = \prod_{r=1}^m 2T_{2r}. \quad (\text{PR.6})$$

The same normalization gives

$$(2m+1)! = T_{2m+1}(m!)^2 C_m, \quad \frac{4^m (m!)^2}{(2m+1)!} \frac{C_m}{4^m} = \frac{1}{T_{2m+1}}, \quad (\text{PR.7a})$$

where C_m is the m th Catalan number. These coefficient identities are comparison structure; no completed-source sign follows from them.

Gamma reflection supplies the normalized sine directly,

$$\frac{\sin(\pi x)}{\pi x} = \frac{1}{\Gamma(1+x)\Gamma(1-x)}. \quad (\text{PR.8})$$

The half-step constants that recur in the later determinant and pole calculations are

$$\boxed{\Gamma(1/2) = \sqrt{\pi}, \quad \Gamma(3/2) = \frac{\sqrt{\pi}}{2}}, \quad (\text{PR.10a})$$

and

$$\boxed{\frac{\Gamma(m+3/2)}{\Gamma(m+1/2)} = m + \frac{1}{2} = \frac{j_m}{2}, \quad \frac{\Gamma(m+1/2)}{m!\Gamma(1/2)} = \frac{\binom{2m}{m}}{4^m}}. \quad (\text{PR.10b})$$

The first pair is used in the triangular determinant calculation (PC.7) of §R17C; the normalized ratio supplies the pole coefficients (PC.1) of the same section. The central-binomial row is also the local inverse-Jacobian series

$$R(x)^{-1} = (1+4x)^{-1/2} = \sum_{m \geq 0} (-1)^m \binom{2m}{m} x^m, \quad |x| < \frac{1}{4}. \quad (\text{PR.10c})$$

A final centered product closes the elementary loop:

$$\boxed{\pi = 4 \prod_{n \geq 1} \frac{8T_n}{8T_n + 1} = 4 \prod_{n \geq 1} \frac{(2n)(2n+2)}{(2n+1)^2}}. \quad (\text{PR.10d})$$

Changing logarithmic scale does not alter the Mellin phase if its Jacobian is retained. For $v = \log_{10} n$,

$$n^{-s} = 10^{-\sigma v} e^{-it(\ln 10)v}, \quad \overline{n^{-s}} = 10^{-\sigma v} e^{+it(\ln 10)v}. \quad (\text{PR.11})$$

A longer catalog of angle and decimal examples is archived in the version chain of this record. This Reading Volume keeps only the identities that re-enter the analytic argument.

R5E. The half-step and the reflected pair

The finite odd-factorial product has an integer upper limit. Its analytic continuation is supplied separately by Gamma duplication:

$$\mathcal{C}(m) := \frac{1}{\Gamma(2m+2)} = \frac{\sqrt{\pi}}{2^{2m+1}\Gamma(m+1)\Gamma(m+3/2)}. \quad (\text{HS.1})$$

Now make the shift explicit, $m = s - 1$. On the critical line,

$$s = \frac{1}{2} + it \implies m = -\frac{1}{2} + it, \quad T_m = -\frac{1}{8} - \frac{t^2}{2}, \quad q(s) = -2T_m = \frac{1}{4} + t^2. \quad (\text{HS.2})$$

The conjugate pair has the exact positive Gamma product

$$\boxed{\mathcal{C}(-\tfrac{1}{2} + it)\mathcal{C}(-\tfrac{1}{2} - it) = \frac{\sinh(2\pi t)}{2\pi t} = \prod_{n \geq 1} \left(1 + \frac{4t^2}{n^2}\right)}. \quad (\text{HS.3})$$

This is a Gamma identity, not the completed zeta source: the Euler-prime term has not disappeared.

Three involutions recur later and should not be conflated: conjugation $z \mapsto \bar{z}$, inversion $z \mapsto 1/z$, and reflection $z \mapsto 1 - z$. Conjugation and reflection agree on $\Re s = 1/2$; the Cayley coordinate of §R7 converts reflection into inversion. Away from those loci they remain different operations.

For the fold $q = s(1 - s)$,

$$(2s - 1)^2 = 1 - 4q = 1 + 8T(s - 1), \quad s = \frac{1 \pm \sqrt{1 - 4q}}{2}. \quad (\text{HS.8})$$

Reflection exchanges the two inverse branches. If $q > 1/4$ is real they are the conjugate pair $1/2 \pm i\sqrt{q - 1/4}$; for complex q , conjugation also moves q to $\bar{q}$. This branch distinction is the only part of the power-tower comparison needed downstream; the longer fixed-point discussion is archived in the version chain of this record.

Part II. From the half-step to the complex fold

The fold $q = s(1 - s)$ identifies the reflection pair, the Cayley chart expresses it as inversion, and the Mellin factor fixes the weight $1/\sqrt{n}$. Equation (6.4) is the key conclusion: a folded zero is real exactly when its zero lies on the critical line.

R6. Folding the two axes of $s = \sigma + it$

Define

$$q = q(s) = s(1 - s) = \sigma(1 - \sigma) + t^2 + it(1 - 2\sigma) \quad (6.1)$$

The centered identity is

$$\boxed{q = \frac{1}{4} - \left(s - \frac{1}{2}\right)^2} \quad (6.2)$$

This is the analytic continuation of the centered split in (TDP.5): the signed coordinate $2s - 1$ is squared and the two sheets s and $1 - s$ fold to the same q .

Three specializations should be kept side by side:

locus in the s -plane	condition	folded image
critical line	$s = 1/2 + it$	$q = 1/4 + t^2 \in \mathbb{R}_{>0}$
real safe sheet	$s > 1, t = 0$	$q = -s(s - 1) = -x < 0$
general point	$s = \sigma + it$	$\Im q = t(1 - 2\sigma)$

There is no omitted real-zero branch. For $0 < \sigma < 1$, the alternating Dirichlet eta function satisfies

$$\eta(\sigma) = (1 - 2^{1-\sigma})\zeta(\sigma) > 0 \quad (6.3)$$

Since $1 - 2^{1-\sigma} < 0$, one has $\zeta(\sigma) < 0$. Thus every nontrivial zero $\rho = \beta + i\gamma$ has $\gamma \neq 0$, and

$$q_\rho \in \mathbb{R} \iff \gamma(1 - 2\beta) = 0 \iff \beta = \frac{1}{2} \quad (6.4)$$

Therefore RH is exactly the assertion that all folded zero orbits land on the positive real q -axis.

R6A. Sum to product, and the model in which the hypothesis is true

Equation (6.4) says RH is the assertion that every folded orbit q_ρ is real and positive. Before six Parts are spent on it, it is worth writing down the assertion's **model**: a node set for which it holds, whose product is closed in elementary terms, and which the volume has been carrying since Part I without saying what it was for.

One dictionary. Let $A = \{a_j\}$ be positive with multiplicities m_j and $\sum_j m_j/a_j < \infty$. Put

$$E_A(x) = \prod_j \left(1 + \frac{x}{a_j}\right)^{m_j}, \quad S_A(x) = \frac{E'_A(x)}{E_A(x)} = \sum_j \frac{m_j}{x + a_j}, \quad \exp\left(-\int_0^x S_A\right) = \frac{1}{E_A(x)} \quad (6A.1)$$

Sum becomes product here by one operation: integrate the resolvent and exponentiate. Three objects are compared through it.

instance	nodes a_j	resolvent	product
triangular ladder	$2T_n = n(n+1)$	(6A.3)	(6A.2), closed
folded zeros	$q_\rho = \rho(1-\rho)$	S_ξ , (9.5)	$X(-x)/X(0)$, §12B
primes	<i>not a node product</i>	P , §R16	$\zeta(s_x)/\zeta(2)$, Euler

The prime row is the odd one, and the distinction is not cosmetic: its passage from sum to product is unique factorization, a product over primes rather than over the nodes of a resolvent, absolutely convergent only for $\Re s > 1$. Its three cutoffs must be kept apart: the prime-power cutoff, the truncated Euler product and the finite Dirichlet sum are three different objects, equal at $X = 2$ to $\exp(2^{-s})$, $(1 - 2^{-s})^{-1}$ and $1 + 2^{-s}$. The two node rows are what this section compares.

The triangular instance is closed, and it is already proved. Dossier §11 evaluates $\Pi_\Delta(u) = \prod_n (1 - u/T_n) = 1/[\Gamma(1+s)\Gamma(2-s)]$ under $u = s(s-1)/2$. That substitution is the fold: $x = -2u = s(1-s) = q(s)$. In the fold coordinate, with $\nu = \sqrt{x - \frac{1}{4}}$ (imaginary for $x < \frac{1}{4}$), the same identity reads

CLOSED FORM *the triangular model*

$$\prod_{n \geq 1} \left(1 + \frac{x}{2T_n}\right) = \frac{\sin \pi s}{\pi q(s)} = \frac{\cosh \pi \nu}{\pi x}, \quad \sum_{n \geq 1} \frac{1}{x + 2T_n} = \frac{\pi \tanh \pi \nu}{2\nu} - \frac{1}{x} \quad (6A.2-6A.3)$$

the second being the logarithmic derivative of the first, and Γ reflection carrying one form to the other. The removable values are 1 at $x = 0$ and $4/\pi$ at $x = \frac{1}{4}$.

Keep the parameter signs visible. The numerator $\cosh \pi \nu$ is entire of order one-half in this model parameter; its zeros are exactly $x = -2T_n$ for $n \geq 0$. Division by πx removes the zero mode. The model's reflection variable gives $z = q(s)$ and $E_\Delta(q(1/2)) = 4/\pi$. The completed source instead uses $x = -q(s)$, so its centered value is $E_\xi(-1/4) = X(1/4)/X(0)$. At the common positive comparison parameter $x = 1/4$, its value is $X(-1/4)/X(0)$. These are distinct evaluations, not an identification of spectral measures.

The completed determinant $E_\xi(x) = X(-x)/X(0)$ also has order one-half, but the property shared with the triangular model is a zero-set condition:

$$\text{RH} \iff E_\xi(x) = X(-x)/X(0) \text{ has all its zeros on the negative real axis.} \quad (6A.4)$$

Equal order does not mean equal type. Dossier Section 12B proves, unconditionally, $\log E_\Delta(x) \sim \pi\sqrt{x}$ whereas $\log E_\xi(x) \sim \sqrt{x} \log x/4$. The model has finite type π ; the completed determinant has infinite type at order one-half. An independent positive realization of the completed product remains missing.

A multiplicity-one operator. Dossier Section 12A realizes the product by $A_\Delta = -d^2/d\theta^2 - 1/4$ on $(0, \pi)$, with $f(0) = 0$, $f'(\pi) = 0$. Its normalized half-integer sine eigenfunctions have

eigenvalues $2T_m$; removing $m = 0$ gives $\det(I + xA_+^{-1})$ equal to (6A.2). Unlike the full spherical Laplacian, this realization uses each positive degree once.

The same modes are unitary images of the reflected polynomials in Section R15. With $n = 2m + 1$ they satisfy

$$\frac{1}{n} \mathcal{P}_m \left(4 \sin^2 \frac{\pi u}{n} \right) = \frac{\text{sinc}_\pi(u)}{\text{sinc}_\pi(u/n)} \longrightarrow \text{sinc}_\pi(u). \quad (6A.5)$$

Their squares are finite Fejer kernels: the pair counts give $n + 2T_{n-1} = n^2$. The finite sine projection has an interior sine-kernel limit; at the boundary its reflected-sum term survives. Section 61A matches its bandwidth to $N \sim T^2 \log(T/(2\pi))/2$. This is a proved comparison limit, not a completed-source kernel limit or a theorem about zeta pair correlation. The latter prediction uses $1 - \text{sinc}_\pi(u)^2$, not the nearest-neighbor gap density [79].

Three entries, with their status.

quantity	triangular model	folded zeros
$\sum_j m_j/a_j$	$\sum_n 1/(2T_n) = 1$ exactly	$S_\xi(0) = \lambda_1 = 0.0230957 \dots$ (9.8)
at comparison parameter $1/4$	$E_\Delta(1/4) = 4/\pi$	$E_\xi(1/4) = X(-1/4)/X(0)$
odd-factorial layer	$(2m+1)! = \prod_r 2T_{2r}$ (PR.6)	rung weight $(2k-1)!$ (13A.3)

The model nodes start at 2, while the zeta nodes start near 200. The shared odd-factorial and hyperbolic identities therefore identify constructions, not their measures: nothing transfers without a source theorem, and no bound on Δ of (13A.2) follows from the model. An operator with spectrum q_ρ has not been supplied. That is precisely the input this volume cannot supply for ζ .

R7. Reflection, conjugation, and the Cayley circle

Use the global Cayley coordinate

$$z_C(s) = \frac{s}{1-s} \quad s = \frac{z_C}{1+z_C} \quad q = \frac{z_C}{(1+z_C)^2} \quad (7.1)$$

Then

$$\boxed{\frac{1}{q} = 2 + z_C + \frac{1}{z_C}} \quad (7.2)$$

This is the reciprocal coordinate of Dossier §171: $y_C = z_C + z_C^{-1}$. The same Pascal recurrence now has coefficients expressed through $q(s)$, so the arithmetic reciprocal fold returns here as an exact analytic identity, with its inverse branches retained.

Reflection becomes inversion $z_C \mapsto 1/z_C$, while conjugation becomes $z_C \mapsto \bar{z}_C$. They agree on the unit circle. Hence

$$\Re s = \frac{1}{2} \iff |z_C| = 1 \iff 1 - s = \bar{s} \quad (7.3)$$

The subscript C distinguishes this global s -plane coordinate from the scale-dependent Cayley complement $c_x(q) = (q - x)/(q + x)$ used in §R11.

This is a useful uniformization, not a proof engine. Differentiating a self-inversive reformulation does not import the Cohn or Speiser one-sided conditions: the derivative zeros of the completed symmetric function inherit inversion symmetry. The point $z_C = -1$ is an isolated essential singularity of $\xi(z_C/(1 + z_C))$, with transformed zeros accumulating there.

The Li coordinate of §R15 is this one inverted and reflected, $w = 1 - 1/s = -z_C^{-1}$, so (7.2) also reads $1/q = 2 - w - w^{-1}$. Section R10C carries that dictionary and what it does to a single orbit.

R8. The self-dual Mellin magnitude

For $n > 0$,

$$n^{-s} = n^{-\sigma} e^{-it \log n} \quad n^{-\bar{s}} = n^{-\sigma} e^{+it \log n} = \overline{n^{-s}} \quad |n^{-s}| = n^{-\sigma} \quad (8.1)$$

Every negative-frequency factor is therefore carried together with its positive-frequency conjugate. Their sum and product are

$$n^{-s} + n^{-\bar{s}} = 2n^{-\sigma} \cos(t \log n) \quad n^{-s} n^{-\bar{s}} = n^{-2\sigma} \quad (8.1a)$$

Reflection and conjugation give two products:

$$n^{-s} n^{-(1-s)} = \frac{1}{n} \quad n^{-s} \overline{n^{-s}} = \frac{1}{n^{2\sigma}} \quad (8.2)$$

They agree for every n exactly at $\sigma = 1/2$. The common factor per side is

$$\boxed{n^{-1/2} = \frac{1}{\sqrt{n}}} \quad (8.3)$$

The conjugate pair $e^{\mp it \log n}$ changes phase but not length. This explains the self-dual $\Lambda(n)/\sqrt{n}$ normalization in the completed explicit formula. It does not identify the Gauss circle error term with the zeta zero problem; the shared square-root scale is geometric, while the arithmetic coefficients and summation problems are different.

Why $1/\sqrt{n}$: the one abscissa where reflection and conjugation agree

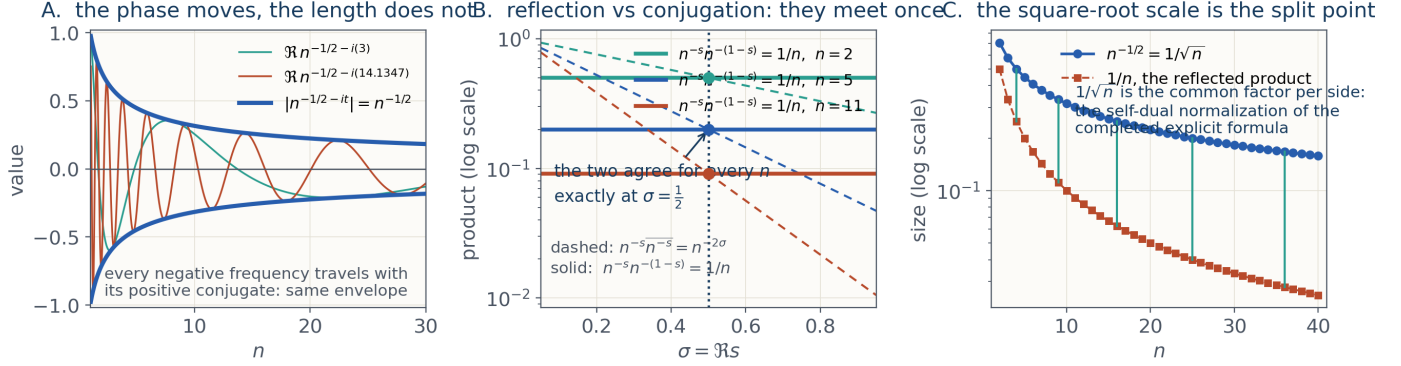


Figure 8: Why $1/\sqrt{n}$. The modulus of n^{-s} does not see the imaginary part; reflection and conjugation give two different products of a term with its partner; and those two products agree, for every n , at exactly one abscissa. The shared square-root scale is geometric, and does not identify two different problems.

Part III. Completion and the folded zero resolvent

Completion removes the pole and trivial zeros of ζ , leaving the entire function ξ with symmetry $s \mapsto 1 - s$. Folding halves its order and gives one point per orbit $\{\rho, 1 - \rho\}$. Its logarithmic derivative is the absolutely convergent simple-pole sum S_ξ in (9.7). Section R9 gives the Gamma-prime source formula; Sections R10–R10B give the zero-side criteria, positive realizations and off-line heat trace. Part IV differentiates this same resolvent.

R9. The completed function

The completed Riemann function is

$$\xi(s) = \frac{1}{2} s(s-1) \pi^{-s/2} \Gamma(s/2) \zeta(s) \quad \xi(s) = \xi(1-s) \quad (9.1)$$

Here the half-Gamma value in (PR.10a) fixes a normalization: $\pi^{-1/2} \Gamma(1/2) = 1$ and $\lim_{s \rightarrow 1} (s-1) \zeta(s) = 1$ give $\xi(1) = 1/2$. On the critical line, however, the argument of this Gamma factor is $s/2 = 1/4 + it/2$. The distinction between the source variable and the Gamma argument matters when using a half-integer identity.

Because it is invariant under reflection, it factors through the fold:

$$\boxed{\xi(s) = X(q), \quad q = s(1-s) = -2T(s-1), \quad 4q = 1 - (2s-1)^2} \quad (9.2)$$

for an entire function X . Define

$$M_\xi(q) = -\frac{X'(q)}{X(q)} \quad S_\xi(x) = M_\xi(-x), \quad x > 0 \quad (9.3)$$

On the safe real sheet

$$s_x = \frac{1 + \sqrt{1+4x}}{2} = \sigma_x + i0 > 1 \quad (9.4)$$

one has the absolutely convergent source formula

$$\boxed{S_\xi(x) = \frac{1}{R} \left[\frac{1}{s_x} + \frac{1}{s_x - 1} - \frac{1}{2} \log \pi + \frac{1}{2} \psi(s_x/2) - \sum_{n \geq 2} \frac{\Lambda_{\text{vM}}(n)}{n^{s_x}} \right]} \quad (9.5)$$

This formula is the source-side entry: Gamma and primes are evaluated where their defining expansions converge.

Where the zeros enter. Write $[\rho]$ for one functional-equation orbit $\{\rho, 1-\rho\}$ and m_ρ for its multiplicity; an off-line quartet contributes two conjugate folded values, each counted once. This convention is used in every folded sum in the volume.

ξ is entire of order one. Since $q = s(1-s)$ is quadratic in s , the entire function X of (9.2) has order one **half** in q , so it has genus zero: its Hadamard product needs no exponential factors and converges absolutely [5, 110],

$$X(q) = X(0) \prod_{[\rho]} \left(1 - \frac{q}{q_\rho}\right)^{m_\rho} \quad (9.6)$$

Taking $-X'/X$ and evaluating at $q = -x$ turns that product into the identity every later Part differentiates:

$$\boxed{S_\xi(x) = \sum_{[\rho]} \frac{m_\rho}{x + q_\rho}, \quad Z_r(x) = \sum_{[\rho]} \frac{m_\rho}{(x + q_\rho)^r}} \quad (9.7)$$

This is what the fold buys, and it is worth being explicit about it. In the s -plane ξ has order one and genus one: the Hadamard product carries a factor $e^{s/\rho}$ at every zero, and $\sum_\rho \rho^{-1}$ needs a symmetric grouping to converge; pairing ρ with $1-\rho$ supplies one. The fold performs that pairing in the variable itself. The order halves, the exponential factors disappear, and $\sum_{[\rho]} m_\rho q_\rho^{-1}$ converges absolutely on its own. The underlying resolvent is an absolutely convergent sum of simple poles at $x = -q_\rho$, all in the open left half-plane. They lie

on the negative real axis exactly under RH. Higher resolvents and derivatives have higher pole orders on the same set; the safe-axis source formulas use $x > 0$.

One number, for orientation. At $x = 0$,

$$S_\xi(0) = \sum_{[\rho]} \frac{m_\rho}{q_\rho} = 1 + \frac{\gamma_E}{2} - \log(2\sqrt{\pi}) = 0.0230957089661 \dots \quad (9.8)$$

with γ_E Euler's constant. The middle expression is the classical value of $\sum_\rho \rho^{-1}$ [112, Ch. 12], and the pairing $\rho^{-1} + (1 - \rho)^{-1} = q_\rho^{-1}$ is why the folded sum reproduces it. This same number returns as the boundary moment μ_0 in §R12 and as Li's λ_1 in §R15. **Three names, one number, and it is the value at $x = 0$ of the function in (9.7).** Section R4A pairs it with a series of zeta values: by (GA.8), twice this number plus $\sum_{k \geq 2} \zeta(k)/T_k$ equals $2 - \log 2$.

The folded-state contract

The definition of $[\rho]$ above is a definition of the index set, not a positivity hypothesis. Conjugation acts on this set: away from the critical line, $[\bar{\rho}]$ is a second orbit and $q_{\bar{\rho}} = \bar{q}_\rho$. Multiplicity is the common zero order of the two members of the reflection pair; it is not multiplied by the size of a four-slot symmetry list. An off-line quartet of multiplicity m therefore contributes $m/q + m/\bar{q}$ to (9.8), while a critical-line reflection pair of multiplicity m contributes m/q .

The fold identifies exactly the two inverse branches. For arbitrary complex s_1, s_2 ,

$$q(s_1) - q(s_2) = (s_1 - s_2)(1 - s_1 - s_2), \quad q(s_1) = q(s_2) \iff s_2 = s_1 \text{ or } s_2 = 1 - s_1. \quad (\text{IF.1})$$

For a nontrivial zero, which is nonreal, critical-line membership is therefore retained by q : it is equivalent to $q \in (1/4, \infty)$. The changes $q \mapsto -q$ and $q \mapsto 1/q$ are invertible on the folded zero set. They do not create a new loss of information. A later real-valued observation, aggregation of conjugate nodes, or probability normalization must be defined separately; none changes what $[\rho]$ means here.

This is the complete interface a downstream construction needs to inherit: the reflection orbit, its multiplicity, the complex folded coordinate, and the absolutely convergent first-Li identity (9.8). Positivity of a separately chosen scalar does not establish the Stieltjes property of the complex folded resolvent. Dossier Section 32 records the same contract.

R9A. The first zero, in these coordinates

The volume is written in q and x and never evaluates them. One worked orbit fixes the scale of everything that follows, and the natural one is the lowest.

The first zero of ζ on the critical line sits at $\gamma_1 = 14.134725141734693790 \dots$, so by (9.2) its folded coordinate is

$$q_1 = \frac{1}{4} + \gamma_1^2 = 200.0404548323868594 \dots = -2T(\rho_1 - 1) \quad (9.9)$$

One orbit, one point, one pole: what the fold buys

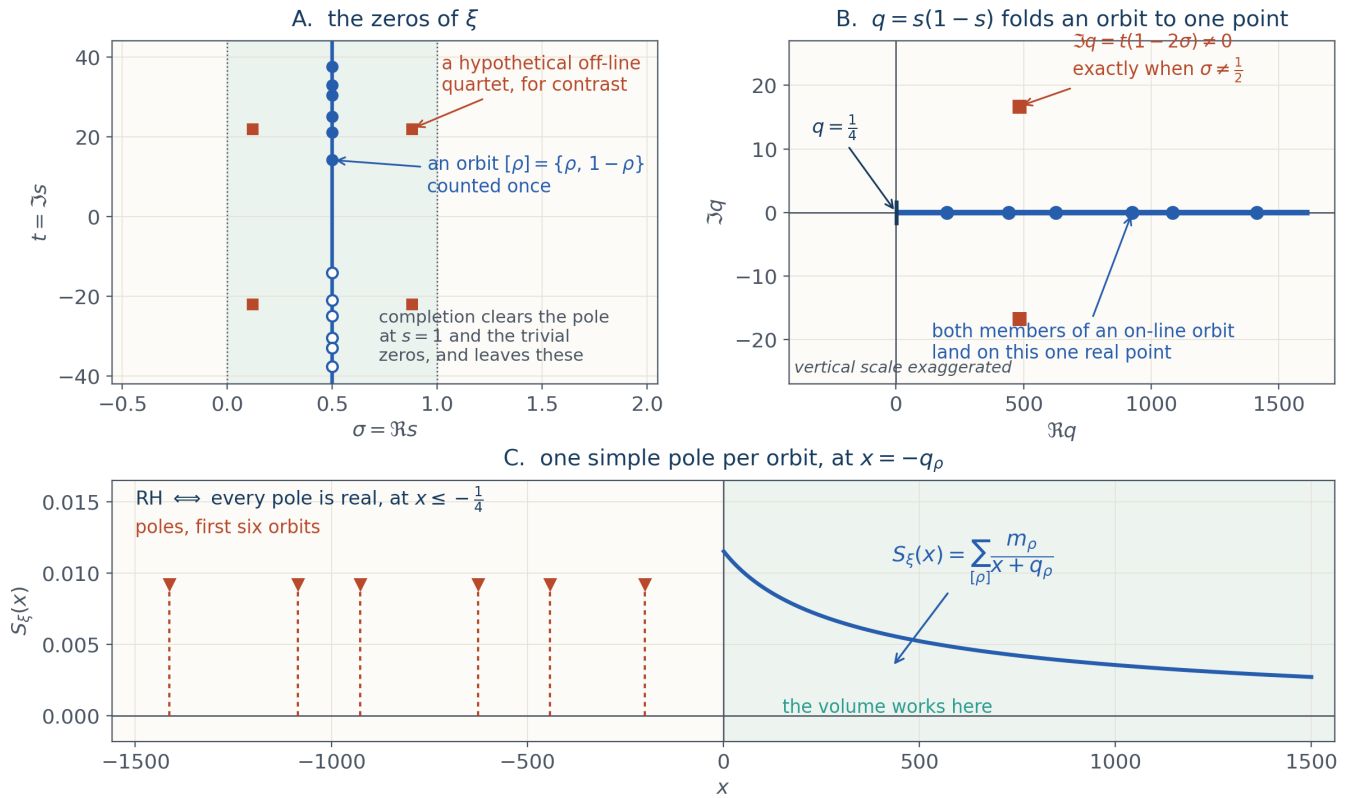


Figure 9: One orbit, one point, one pole. The zeros of ξ come in orbits $\{\rho, 1 - \rho\}$; $q = s(1 - s)$ sends both members of an orbit to a single point, real exactly when the orbit lies on the critical line; and S_ξ has one simple pole per orbit, at $x = -q_\rho$. Every argument in this volume is made to the right of all of them.

The second equality is (9.2) read at $s = \rho_1$: **the folded image of a zero is -2 times the triangular number at its centered index.** For a critical-line zero that index is $-\frac{1}{2} + i\gamma$, and $(-\frac{1}{2} + i\gamma)(\frac{1}{2} + i\gamma) = -(\frac{1}{4} + \gamma^2)$, which is why q is real there and, by (6.4), nowhere else.

What this one orbit carries. By (9.8) the folded resolvent at the origin is $0.0230957\dots$; the first orbit supplies $1/q_1 = 0.004998989\dots$ of it, just under 22%. The second orbit sits at $q_2 = 442.1761\dots$, so the ratio that governs the boundary of the whole ladder is

$$\frac{q_1}{q_2} = 0.4523999\dots \quad (9.10)$$

Section R12 uses exactly this number.

On the prime side the same zero is the slowest wave. In Riemann's formula [74] each zero contributes an oscillation of period $2\pi/\gamma$ in $\log x$, so ρ_1 gives $2\pi/\gamma_1 = 0.4445212\dots$ — the longest wavelength in the prime error, repeating every multiplicative factor $e^{2\pi/\gamma_1} = 1.5597432\dots$ Everything faster comes from higher zeros. The rungs and the primes are reading

the same list of numbers in two different coordinates.

Riemann's own count does not locate it. The smooth part of the zero-counting function is $\overline{N}(T) = \frac{T}{2\pi} \log \frac{T}{2\pi} - \frac{T}{2\pi} + \frac{7}{8}$, which differs from $\theta(T)/\pi + 1$ by $1/(48\pi T) + O(T^{-3})$ (Stirling; this is the 0.0022 between the two heights below), so it first reaches 1 essentially where the Riemann–Siegel angle first vanishes: at $T = 17.8478\dots$, against a first Gram point at $17.8456\dots$. The first zero is at $14.1347\dots$, lower by 3.71. At this height the smooth term is not in charge and the entire discrepancy is carried by the oscillating part $S(T)$ — the term every effective result in the subject has to bound, and the reason a *counting* statement and a *location* statement are different problems.

One constant, printed three times. The $7/8$ above is not a third $7/8$. It is the same number as the value $\mathfrak{Z}_\xi(0) = 7/8$ computed exactly at (TV.2), and as the coefficient of $1/x$ in the large- x expansion (OP.1) of S_ξ . The three agree for one reason: by the Mellin representation, the coefficient of x^{-1} in $\sum_{[\rho]} m_\rho(x + q_\rho)^{-1}$ is the value at $p = 0$ of $\sum_{[\rho]} m_\rho q_\rho^{-p}$, the regularized number of orbits; and for a spectrum whose counting function is a smooth main term plus $7/8$ plus a mean-zero oscillation, the main term contributes to the *poles* of $\mathfrak{Z}_\xi$ and only the constant survives at the origin. So the constant in Riemann's counting formula, the regularized count of folded orbits, and the $1/x$ coefficient of the source expansion are one number.

The mechanism, displayed. From $(x + q)^{-1} = \frac{1}{2\pi i} \int_{(c)} \frac{\pi}{\sin \pi p} x^{-p} q^{p-1} dp$ ($0 < c < 1$), summing over orbits for $0 < c < \frac{1}{2}$,

$$S_\xi(x) = \frac{1}{2\pi i} \int_{(c)} \frac{\pi}{\sin \pi p} \mathfrak{Z}_\xi(1-p) x^{-p} dp \quad (9.11)$$

Moving the contour right: the double pole of $\mathfrak{Z}_\xi(1-p)$ at $p = \frac{1}{2}$, inherited from the smooth count, gives the $x^{-1/2} \log x$ and $x^{-1/2}$ terms of (OP.1); the simple pole of $\pi/\sin \pi p$ at $p = 1$, where $\mathfrak{Z}_\xi$ is regular by (TV.2), gives $+\mathfrak{Z}_\xi(0)/x = \frac{7}{8}/x$. The oscillating part $S(T)$ contributes to no pole at $p \leq 1$.

That identification is checked in the source archive from the **source side alone**: computing S_ξ from (9.5), with Gamma and primes only and no zero used anywhere, $x(S_\xi(x) - \frac{\log x - 2 \log 2\pi}{8\sqrt{x}})$ takes the value $0.87495\dots$ at $x = 10^7$; the limit as $x \rightarrow \infty$ is $7/8$. A finite evaluation is not the limit, and the two are printed separately.

Status. The identities in (9.9) and (9.10) are exact; their printed decimals are approximations. The prime-side period is classical. The $7/8$ identification is an identity among quantities the volume already carries, confirmed to four digits by an independent computation that uses no zero. **None of it is evidence for or against the hypothesis.** It is the scale of the objects, and it is here because a reader is entitled to see the coordinates carry a number at least once.

R10. Heat, Stieltjes, and complete Bernstein representations

The folded heat trace and its Laplace transform are

$$\Theta_\xi(u) = \sum_{[\rho]} m_\rho e^{-uq_\rho} \quad S_\xi(x) = \int_0^\infty e^{-xu} \Theta_\xi(u) du \quad (10.1)$$

Three classes of function, and what each one contributes. The chain below uses them, and they are worth stating plainly.

- A **Stieltjes function** on $(0, \infty)$ is one of the form $a + \int_0^\infty (x+u)^{-1} d\mu(u)$ with $a \geq 0$ and μ a positive measure: exactly a nonnegative constant plus a superposition of simple poles on the negative axis, with positive weights. Comparing with (9.7), S_ξ is of that shape already — one pole per orbit — and **the whole content of the class membership is that the poles are real and the weights are positive.**
- A **complete Bernstein function** is one whose quotient by x is Stieltjes; equivalently it has an integral representation with the same positive measure, read one power lower. It is the form in which the criterion becomes a statement about $h(x) = xS_\xi(x)$ rather than about S_ξ .
- h is **operator monotone** on $(0, \infty)$ if $A \preceq B$ implies $h(A) \preceq h(B)$ for all positive operators. Among nonnegative functions, Löwner's theorem identifies this class with the complete Bernstein functions. Operator monotonicity alone is not sufficient for that class. The actual $h = xS_\xi$ is positive.

Widder's theorem is the discrete counterpart used from Part IV onward: it characterizes the same class by the sign of every derivative combination $(-1)^{k-1} D^{2k-1}[x^k f]$, which is precisely the family W_k . So the rungs of Part IV are not a new criterion. **They are this same equivalence, read one derivative at a time.**

The exact equivalence chain is

$\begin{aligned} \text{RH} &\iff S_\xi \text{ is Stieltjes} \\ &\iff h(x) := xS_\xi(x) \text{ is complete Bernstein} \\ &\iff h \text{ is operator monotone on } (0, \infty) \end{aligned}$

(10.2)

For positive nodes $x_1, \dots, x_N$, the Löwner matrix of h is

$$[\mathcal{L}_h]_{ij} = \begin{cases} \frac{h(x_i) - h(x_j)}{x_i - x_j}, & i \neq j \\ h'(x_i), & i = j \end{cases} \quad (10.3)$$

Löwner's theorem gives the all-node criterion

$\text{RH} \iff \mathcal{L}_h(x_1, \dots, x_N) \succeq 0 \quad \text{for every finite positive node set}$

(10.4)

This is one global matrix criterion. The scalar Widder rungs of Part IV are local derivative shadows of it. In particular, its one-node entry is $h'(x) = W_1(x)$. Higher W_k are not additional

diagonal entries of this same matrix: their exact connection uses the derivative array and boundary moment matrices developed in §§R12–R15.

R10A. Positive realizations: trace and finite-vector forms

An operator model must reproduce the particular scalar function S_ξ . Two compatible positive representations have different normalizations:

representation	scalar resolvent	Gram vector for $\mathcal{L}_h$
positive trace-class operator D	$\text{Tr}[D(I + xD)^{-1}]$	$D^{1/2}(I + xD)^{-1}$ in Hilbert–Schmidt space
positive operator D and finite vector v	$\langle (I + xD)^{-1}v, v \rangle$	$(I + xD)^{-1}v$ in Hilbert space

In either row, equality with $S_\xi(x)$ for every $x > 0$ supplies a positive Löwner matrix. The proof is the elementary resolvent identity: the divided difference of $x/(1 + xd)$ is $[(1 + xd)(1 + yd)]^{-1}$. The trace route has $\text{Tr } D = \lambda_1$; the finite-vector route has $\|v\|^2 = \lambda_1$, where $S_\xi(0) = \lambda_1$ is the first of Li’s coefficients, defined at (15.1a) and equal to the boundary moment μ_0 .

The source itself fixes which normalization is possible. Expanding (9.5),

$$S_\xi(x) = \frac{\log x - 2\log(2\pi)}{8\sqrt{x}} + \frac{7}{8x} + O\left(\frac{\log x}{x^{3/2}}\right) \quad (\text{OP.1})$$

Consequently $xS_\xi(x) \rightarrow \infty$. A proposed finite-vector formula $S_\xi = \langle D(I + xD)^{-1}v, v \rangle$ would instead imply $xS_\xi \leq \|v\|^2$. It fails even under RH. The extra factor D is valid inside a trace, or for the different finite-vector function $[S_\xi(0) - S_\xi(x)]/x$; it cannot be silently moved between the two rows.

For the canonical folded diagonal C_ξ , the eigenvalues are $d_\rho = 1/q_\rho$, counted once per reflection orbit. It is a normal trace-class operator unconditionally. The classical zero-counting estimate gives

$$C_\xi \in \mathcal{S}_p \iff p > \frac{1}{2} \quad (\text{OP.2})$$

Positivity of this diagonal is equivalent to RH. It is a useful exact spectral representation; an independent positivity theorem is still needed. In particular, an ordered model with $d_n = O(n^{-2})$ has a critical trace sum with at most a simple pole at $p = 1/2$. Section R17A will exhibit the double pole required by the completed source.

A fixed indefinite quartet metric has another limitation. Congruence preserves its inertia, so a matrix of signature $(2, 2)$ cannot become a positive metric merely by changing coordinates. This says nothing against a different positive realization proved from the full source. Zero-indexed representations are not automatically circular; assuming their positivity would be the missing step.

R10B. What an off-line orbit leaves in the heat trace

The triangular imaginary part is an exact off-line marker. Write $q_\rho = a_\rho + ib_\rho$ in this section, with explicitly defined real coordinates

$$\boxed{a_\rho = \gamma^2 + \beta(1 - \beta) > 0, \quad b_\rho = \gamma(1 - 2\beta) = -2\Im T(\rho - 1)} \quad (\text{HT.1})$$

Since $\gamma \neq 0$, $b_\rho = 0$ exactly on the critical line. A conjugate pair of folded orbits contributes

$$\underbrace{2me^{-ua} \cos(ub)}_{\text{heat contribution}} \quad \text{against} \quad \underbrace{2me^{-ua}}_{\text{phase removed}}, \quad u > 0 \quad (\text{HT.2})$$

Thus off-line geometry creates an oscillatory heat contribution. The total heat trace does not vanish under RH; it is then a positive sum of decaying exponentials. The meaningful absence statement concerns the off-line defect, not the whole trace.

Define the real-part envelope and its gap by

$$\Theta_{\text{env}}(u) = \sum_{[\rho]} m_\rho e^{-ua_\rho} \quad \mathcal{D}_H(u) = \Theta_{\text{env}}(u) - \Theta_\xi(u) \quad (\text{HT.3})$$

Conjugate pairing gives the nonnegative identity

$$\boxed{\mathcal{D}_H(u) = \sum_{[\rho]} m_\rho e^{-ua_\rho} [1 - \cos(ub_\rho)] \geq 0} \quad (\text{HT.4})$$

All sums converge absolutely for $u > 0$. Therefore different orbits cannot cancel in this gap. A single orbit can still have a resonant zero at $ub \in 2\pi\mathbb{Z}$. Vanishing throughout any open interval of u excludes every nonzero b , whereas vanishing at one selected time alone does not supply that argument.

A resonance-free version uses the squared imaginary coordinate:

$$\boxed{\mathcal{E}_H(u) := \sum_{[\rho]} m_\rho b_\rho^2 e^{-ua_\rho} = 4 \sum_{[\rho]} m_\rho (\Im T(\rho - 1))^2 e^{-ua_\rho}} \quad (\text{HT.5})$$

For every fixed $u > 0$, each off-line orbit contributes strictly positively. The sum is finite, since $b_\rho^2 \leq \gamma^2$ and Gaussian decay dominates the zero count. Consequently

$$\boxed{\mathcal{E}_H(u) = 0 \iff \text{RH} \quad \text{at any one prescribed } u > 0} \quad (\text{HT.6})$$

This is an exact detector, not an independent source estimate. Its weights still use the unknown transverse zero coordinates. In the language of §R21, it has the regularized distributional representation $\mathcal{E}_H(u) = (4\pi)^{-1} \langle \Delta \log |\xi|, (\Im q)^2 e^{-u\Re q} \rangle$ over the critical strip. This supplies a source representation but leaves the zero-forcing bound unproved.

There is also a direct bridge back to resolvents. Put $S_{\text{env}}(x) = \sum_{[\rho]} m_{\rho}/(x + a_{\rho})$. For $x > 0$,

$$\boxed{\begin{aligned} S_{\text{env}}(x) - S_{\xi}(x) &= \int_0^{\infty} e^{-xu} \mathcal{D}_H(u) du \\ &= \sum_{[\rho]} m_{\rho} \frac{b_{\rho}^2}{(x + a_{\rho})[(x + a_{\rho})^2 + b_{\rho}^2]} \geq 0 \end{aligned}} \quad (\text{HT.7})$$

To prove the displayed fraction, integrate $e^{-(x+a)u}[1 - \cos(bu)]$, obtaining $1/(x+a) - (x+a)/[(x+a)^2 + b^2]$. Every nonzero b gives a strictly positive summand. Thus equality in (HT.7) at one prescribed x is again equivalent to RH. The missing step would be an independent source proof of the reverse inequality $S_{\text{env}}(x) \leq S_{\xi}(x)$, or a source proof that $\mathcal{E}_H(u) \leq 0$. The envelope itself is not presently recovered from an independently positive source model.

The established heat criterion remains

$$\boxed{\text{RH} \iff (-1)^k \Theta_{\xi}^{(k)}(u) \geq 0 \quad \text{for every } k \geq 0, u > 0} \quad (\text{HT.8})$$

This is complete monotonicity, stronger than positivity of the total heat trace. For example, the synthetic folded spectrum with two atoms at 1 and one at each of $2 \pm i$ has $\Theta(u) = 2e^{-u} + 2e^{-2u} \cos u > 0$ for all $u > 0$, despite its nonreal pair. It is not asserted to be the Riemann spectrum.

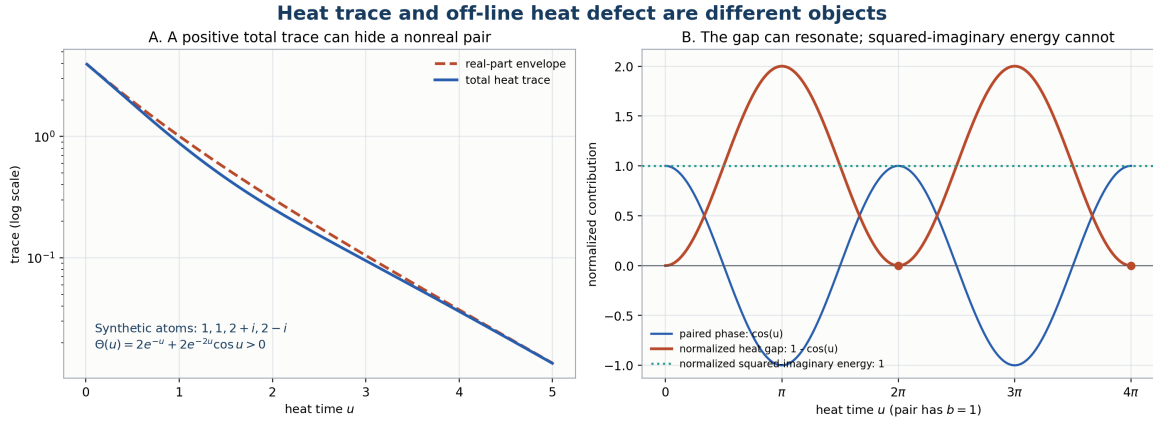


Figure 10: Synthetic heat traces: the total trace stays positive despite a nonreal pair, while the normalized off-line heat gap has isolated resonant zeros. The squared-imaginary-coordinate detector avoids those resonances.

Finally, the source already retains the prime heat term explicitly:

$$\Theta_{\xi}(u) = 1 + \Theta_{\Gamma}(u) - \Theta_P(u), \quad \Theta_P(u) = \frac{e^{-u/4}}{2\sqrt{\pi u}} \sum_{n \geq 2} \frac{\Lambda_{\text{vM}}(n)}{\sqrt{n}} e^{-(\log n)^2/(4u)} \quad (\text{HT.9})$$

The prime term is beyond all algebraic orders as $u \downarrow 0$. This explains why matching the regularized fractions and the complete algebraic short-time expansion need not identify the heat trace itself. Conversely, a hypothetical off-line zero above the verified height contributes the factor e^{-ua_ρ} with $a_\rho > H^2$: at fixed time its signal can be extremely small. Proving its exact absence is a source theorem, not a numerical detection threshold.

R10C. One orbit, four coordinates

Sections R6–R10 have put four names on the same folded zero orbit, in four different places. This section writes the dictionary between them once, because the rung chain of Part IV and the Li chain of §R15 are the same folded data read in two of these coordinates, and the conversion between them is exact.

Fix one orbit $[\rho] = \{\rho, 1 - \rho\}$ with ρ nonreal, and set

$$q = \rho(1 - \rho), \quad p = -q, \quad y = \frac{1}{q} = -\frac{1}{p}, \quad w = 1 - \frac{1}{\rho} \quad (10C.1)$$

- q is the **folded point** of §R6: one point per orbit, because the reflection $\rho \mapsto 1 - \rho$ fixes it.
- $p = -q$ is the **resolvent pole** of §R10: the kernel $(x + q)^{-1}$ summed in (10.1) is singular at $x = p$ and nowhere else, with value $1/q$ at the origin. When $q > 0$ is real, the kernel on $x > 0$ is positive and decreasing; for nonreal q no real-order statement is attached to the individual kernel.
- $y = 1/q$ is the **reciprocal coordinate** of (7.2), the one in which the central-Pascal rows of §R15 are polynomial.
- w is the **Li coordinate** of (15.1a). It is the Cayley coordinate of §R7 inverted and reflected, $w = -z_C^{-1}$, so the reflection $\rho \mapsto 1 - \rho$ acts as $w \mapsto w^{-1}$, exactly as it acts as $z_C \mapsto z_C^{-1}$ there.

The link between the last two is (7.2) rewritten. Substituting $w = -z_C^{-1}$,

$$\boxed{y = \frac{1}{q} = 2 - w - \frac{1}{w}} \quad (10C.2)$$

so the pole position alone fixes w up to the inversion $w \mapsto w^{-1}$ that folding has already quotiented out.

The orbit carries a whole Li column. Write the reflection pair's contribution to the n -th Li coefficient as

$$Q_n(y) = 2 - w^n - w^{-n}, \quad \lambda_n = \sum_{[\rho]} m_\rho Q_n(y_\rho) \quad (10C.3)$$

the second equality being (15.1a) grouped by orbit. Since $w^n + w^{-n}$ satisfies the Chebyshev recurrence with ratio $w + w^{-1} = 2 - y$, so does Q_n :

$$\boxed{Q_0 = 0, \quad Q_1 = y, \quad Q_{n+1} = 2y + (2 - y)Q_n - Q_{n-1}} \quad (10C.4)$$

Every Q_n is therefore a polynomial in y with integer coefficients and no constant term, generated from the single number $y = -1/p$:

$$Q_1 = y, \quad Q_2 = 4y - y^2, \quad Q_3 = 9y - 6y^2 + y^3, \quad (10C.5)$$

that is q^{-1} , $4q^{-1} - q^{-2}$ and $9q^{-1} - 6q^{-2} + q^{-3}$. At $n = 1$ this is (15.1b): $Q_1 = 1/q$ is the value at the origin of that orbit's resolvent kernel, and summing gives $\lambda_1 = S_\xi(0) = \mu_0$. This is the precise sense in which the pole is not merely a location: its reciprocal is the seed and the coefficient of the entire one-orbit Li recurrence.

What the critical line does. For nonreal ρ the fold has $\Im q = t(1 - 2\beta)$, so q is real exactly on $\beta = \frac{1}{2}$ (6.4), where $q = \frac{1}{4} + t^2$. Hence

$$\boxed{\Re \rho = \frac{1}{2} \iff q \in (\frac{1}{4}, \infty) \iff p \in (-\infty, -\frac{1}{4}) \iff y \in (0, 4) \iff |w| = 1} \quad (10C.6)$$

the last equivalence because $|w| = 1$ says $|\rho - 1| = |\rho|$. The four conditions are one condition in four coordinates; the excluded endpoint $y = 4$, $q = \frac{1}{4}$, $w = -1$ is the collision $\rho = 1 - \rho$. On that range the characteristic equation $r^2 - (2 - y)r + 1 = 0$ of (10C.4) has both roots on the unit circle — their product is 1 and their sum $2 - y$ lies in $(-2, 2)$ — so $w = e^{i\theta}$ with $2 \cos \theta = 2 - y$, and (10C.3) becomes

$$Q_n(y) = 4 \sin^2 \frac{n\theta}{2} \geq 0, \quad \sin^2 \frac{\theta}{2} = \frac{1}{4q} \quad (10C.7)$$

Both identities in (10C.7) hold for that orbit only under $\Re \rho = \frac{1}{2}$. Off the line w leaves the unit circle, y leaves $(0, 4)$, q leaves the positive real axis, and Q_n takes complex values whose real parts carry no sign constraint.

The nonnegativity in (10C.7) is not only trigonometric. Dossier §155A factors the same polynomials on the same interval:

$$Q_{2m+1}(y) = y \mathcal{P}_m(y)^2, \quad Q_{2m}(y) = y(4 - y) \mathcal{B}_{m-1}(y)^2 \quad (10C.8)$$

with $\mathcal{P}_m$ the triangular-coefficient polynomials of (155A.2) and $\mathcal{B}_r(y) = U_r(1 - y/2)$ of (155A.4), the second being the diagonal $r = s$ of that identity. The two weights y and $y(4 - y)$ are nonnegative exactly on $[0, 4]$, which is (10C.6) once more. So each individual reflected rung is an algebraic square against an explicit weight, and the first few read

$$Q_1 = y, \quad Q_2 = y(4 - y), \quad Q_3 = y(3 - y)^2, \quad Q_4 = y(4 - y)(2 - y)^2, \quad Q_5 = y(y^2 - 5y + 5)^2. \quad (10C.9)$$

What this does not do. (10C.6) is a statement about one orbit and (10C.8) is an identity in y ; neither locates a zero. The coefficient λ_n is a sum over all orbits, and the criterion is

$\lambda_n \geq 0$ for **every** n (15.1). An orbit on the line contributes nonnegatively to every rung, and an orbit off the line is not by itself in contradiction with any finite set of λ_n : the sum can absorb a negative term. This section is a change of coordinates, not a proof engine, and it leaves the position recorded in §R12 unchanged.

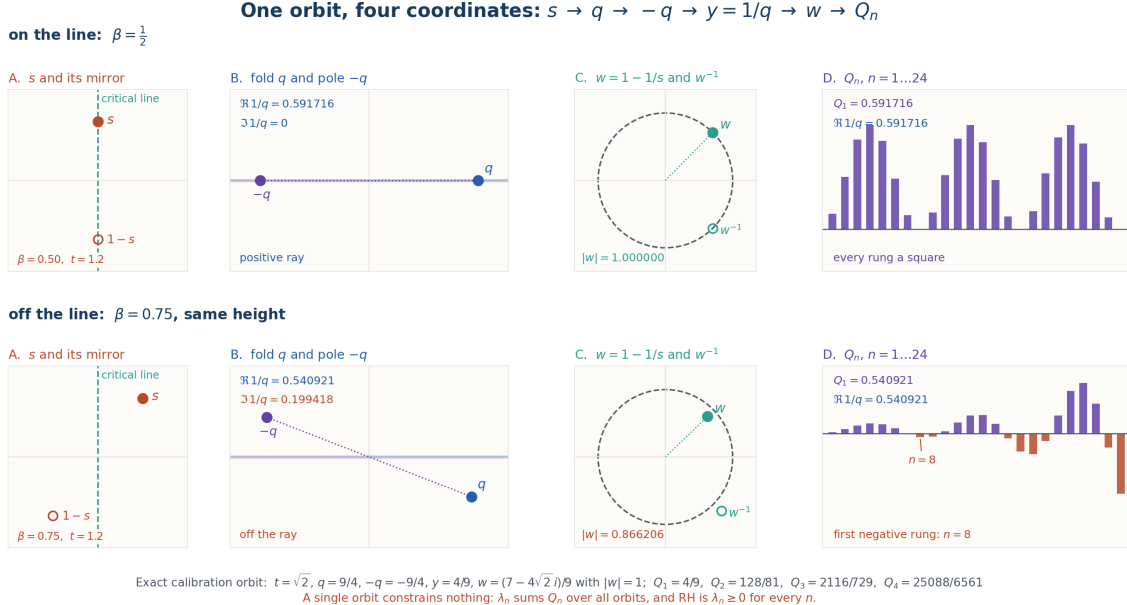


Figure 11: One orbit in the four coordinates of (10C.1), at one height, with β moved off $\frac{1}{2}$. On the line the fold q sits on the positive ray, the Li coordinate sits on the unit circle so that $w^{-1} = \bar{w}$, and every rung Q_n is a square. Off the line the three break together: $\Im(1/q) \neq 0$, $|w| \neq 1$, and the rung column leaves the nonnegative axis. Every printed value is computed from β and t by the formulas of this section, and the rung column is generated from $y = 1/q$ by (10C.4) alone. One orbit constrains nothing; §R12 and (15.1) are unchanged.

Part IV. The Widder ladder and the sector geometry

This Part develops the reduced-Widder rung W_k of (R.3), and the criterion (R.4), proved by Stieltjes characterization in Dossier (33.1). **No finite prefix of this family is an RH statement.** Section R12 states the position once: $W_1, \dots, W_6 > 0$ is proved from the source alone, analytically at the first rung and by one certificate at the next five; a longer but zero-assisted prefix comes from the verified height. Section R11 fixes the carrier, R12A the shifted-resolvent basis, R13 the sector rectangle, and R14 one prescribed scale.

R11. Carrier, Cayley complement, and rungs

Everything in this Part is built from one identity of Part III: S_ξ is the sum of one simple pole per folded orbit, (9.7). Differentiating it produces the resolvents Z_r ; combining those produces the rungs. The object that makes the combination work is the carrier.

For $x > 0$ define

$$\mathcal{F}_x(s) = \frac{1-s}{x+q(s)} \quad u_x(q) = \mathcal{F}_x(s)\mathcal{F}_x(1-s) = \frac{q}{(x+q)^2} \quad (11.1)$$

On the critical line $s = 1/2 + it$,

$$\mathcal{F}_x\left(\frac{1}{2} + it\right) = \frac{\frac{1}{2} - it}{t^2 + x + \frac{1}{4}} \quad u_x(q) = \left| \mathcal{F}_x\left(\frac{1}{2} + it\right) \right|^2 \geq 0 \quad (11.2)$$

The reduced-Widder ladder is

$$W_k(x) = j_{k-1}! \sum_{[\rho]} m_\rho \left(\frac{q_\rho}{(x+q_\rho)^2} \right)^k \quad j_{k-1} = 2k-1 \quad (11.3)$$

Phase and the complete sum. For positive q , the carrier is positive and peaks at $q = x$. A nonreal conjugate pair contributes $2|u_x|^k \cos(k \arg u_x)$. For $q = |q|e^{i\theta}$ and $s_0 = \log(x/|q|)$, $4x|u_x(q)| = 2/(\cosh s_0 + \cos \theta) \leq \sec^2(\theta/2)$, with equality at $x = |q|$, where its phase vanishes. Also $\arg u_x(q) = \theta \tanh(s_0/2) + O(\theta^3)$. At a fixed nonzero phase ϕ , this individual pair first becomes strictly negative at $k = \lfloor \pi/(2|\phi|) \rfloor + 1$. This does not locate the first negative rung of the complete sum.

The correct all-zero evaluation retains the complex shifted ordinate:

The carrier: one rational function whose k -th power is rung k

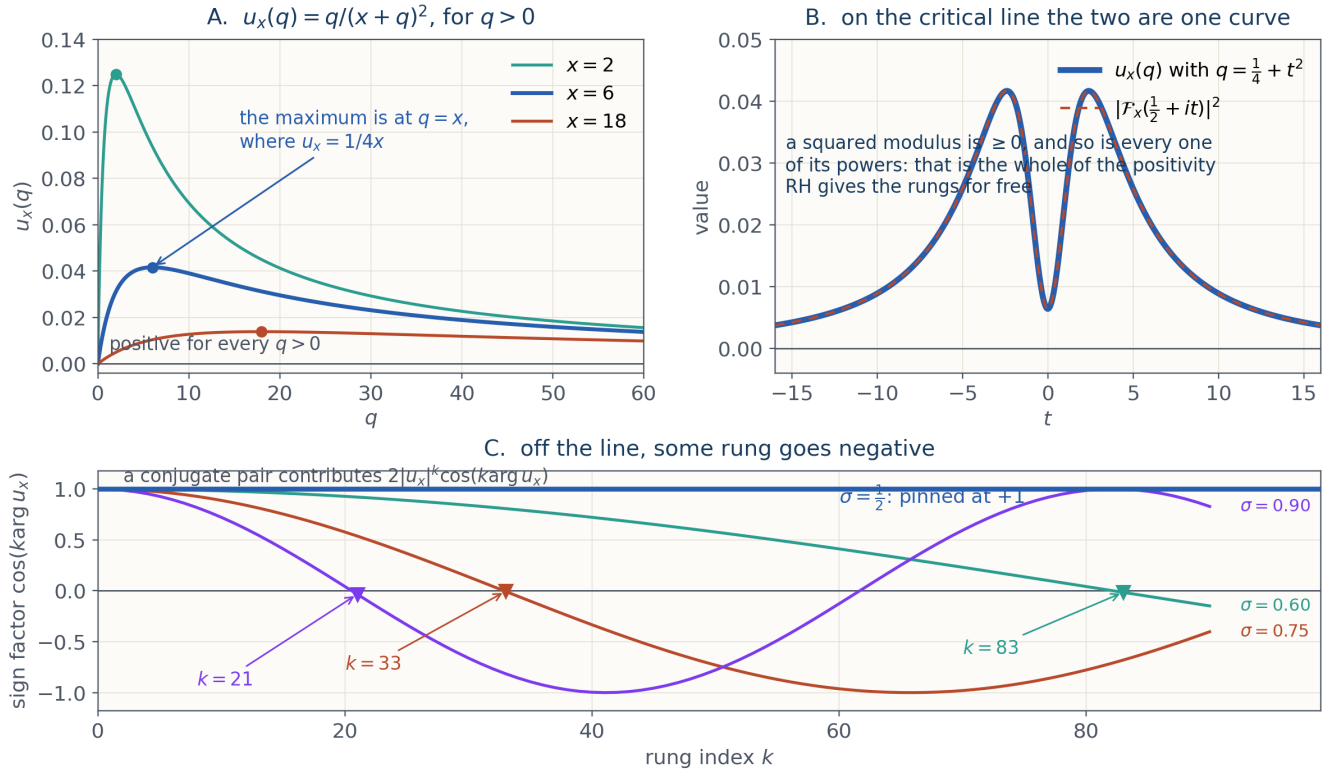


Figure 12: The carrier. **A:** $u_x(q) = q/(x+q)^2$ is positive for every $q > 0$ and peaks at $q = x$. **B:** on the critical line it coincides with $|\mathcal{F}_x(\frac{1}{2} + it)|^2$, so every power of it is nonnegative — that is the whole of the positivity the hypothesis gives the rungs for free. **C:** off the line a conjugate pair contributes $2|u_x|^k \cos(k \arg u_x)$, the sector theorem of §R13 excludes negative complete rungs through its stated finite order.

$$\tilde{\gamma}_\rho = (\rho - 1/2)/i = \gamma + i(1/2 - \beta), \quad q_\rho = 1/4 + \tilde{\gamma}_\rho^2,$$

$$f_{k,x}(t) = \left[\frac{4x(t^2 + 1/4)}{(t^2 + x + 1/4)^2} \right]^k, \quad W_k(x) = \frac{(2k-1)!}{2(4x)^k} \sum_{\rho \text{ all}} m_\rho f_{k,x}(\tilde{\gamma}_\rho). \quad (11.3a)$$

The factor one-half converts all zeros to reflection orbits. Only on the line is $\tilde{\gamma}_\rho$ the real ordinate γ . Theorem 22A.1 proves at least k Fourier sign changes on the positive axis. Its $k = 1$ transform is $\frac{\pi}{a} e^{-a|u|} [4x - \frac{2x^2}{a^2} (1 + a|u|)]$, $a = \sqrt{x + 1/4}$, negative beyond $(1 + 1/(2x))/a$ (below $\log 2$ when $x > 2.68$). The exponential-polynomial transform is not compactly supported. Scalar Fourier nonnegativity cannot prove the rung sign; a completed Weil-form or two-variable source argument is not excluded. The verified-height sector result gives a lower bound on the earliest possible negative rung, not an upper bound on how late it may occur.

The normalized Cayley complement

$$s = \sigma + it$$

$$t_x(q) = 4xu_x(q) = \frac{4xq}{(x+q)^2} \quad (11.4)$$

lies in $(0, 1]$ for $q > 0$. Equivalently, with the scale-dependent coordinate

$$c_x(q) = \frac{q-x}{q+x} \quad (11.5)$$

one has

$$\boxed{u_x(q) = \frac{1 - c_x(q)^2}{4x}, \quad t_x(q) = 1 - c_x(q)^2} \quad (11.6)$$

In the log-scale variable $s = \log(q/x)$ these are hyperbolic functions:

$$\boxed{c_x(q) = \tanh \frac{s}{2}, \quad u_x(q) = \frac{\operatorname{sech}^2(s/2)}{4x}, \quad t_x(q) = \operatorname{sech}^2 \frac{s}{2}} \quad (11.7)$$

and (11.6) is $1 - \tanh^2 = \operatorname{sech}^2$. So the rung (11.3) is a sum of sech^{2k} bumps centred on the orbits in log-scale. The half-maximum interval is exactly $|s| \leq 2 \operatorname{arcosh}(2^{1/2k})$, so the **half**-width is $\sim 1.665109/\sqrt{k}$ and the **full** width is $\approx 3.330218/\sqrt{k}$. Multiplying the full window by the smooth mean density gives a smoothed count $\approx 1.665 k^{-1/2} \sqrt{x} \log(\sqrt{x}/2\pi)/2\pi$ of zeros a rung sees with weight above one half. That is a high-height smoothed estimate and not a bound on the actual count: at $x = q_1$ the first zero carries weight one for every k , so no literal count there is below one. This is the same quadratic complement that appears in the compact Hausdorff/Beta geometry. The disk fact $|c_x(q_\rho)| < 1$ follows already from $\Re q_\rho > 0$ and carries no RH content by itself.

R12. One ladder: explicit rungs, boundary moments, and proof channels

Write $S = S_\xi$. The differential and zero-side definitions are the same object:

$$\boxed{W_k(x) = (-1)^{k-1} D_x^{2k-1} [x^k S(x)] = (2k-1)! \sum_{[\rho]} m_\rho \frac{q_\rho^k}{(x+q_\rho)^{2k}}} \quad (12.1)$$

The first six rows are

$$\begin{aligned}
W_1 &= S + xS' \\
W_2 &= -6S' - 6xS'' - x^2S''' \\
W_3 &= 60S'' + 60xS''' + 15x^2S^{(4)} + x^3S^{(5)} \\
W_4 &= -840S''' - 840xS^{(4)} - 252x^2S^{(5)} - 28x^3S^{(6)} - x^4S^{(7)} \\
W_5 &= 15120S^{(4)} + 15120xS^{(5)} + 5040x^2S^{(6)} \\
&\quad + 720x^3S^{(7)} + 45x^4S^{(8)} + x^5S^{(9)} \\
W_6 &= -332640S^{(5)} - 332640xS^{(6)} - 118800x^2S^{(7)} \\
&\quad - 19800x^3S^{(8)} - 1650x^4S^{(9)} - 66x^5S^{(10)} - x^6S^{(11)}
\end{aligned} \tag{12.2}$$

$$\tag{12.2a}$$

Leibniz's rule gives the coefficient of $x^j S^{(k+j-1)}$ as $(-1)^{k-1} (2k-1)! \binom{k}{j} / (k+j-1)!$ for $0 \leq j \leq k$. They are the factorially weighted rows of Figure 14; equation (SW.6) gives the exact conversion and the coefficient form of the recurrence.

Every next row is generated by the same centered odd coefficient:

$$W_{k+1} = -j_k W'_k - x W''_k = -x^{-2k} D_x \left[x^{2k+1} W'_k \right] \quad j_k = 2k+1 \tag{12.3}$$

The repeated $2k+1$ is therefore the rung version of the centered coordinate $j_n = 2n+1$; it is also the odd derivative/factorial index in the confluent Löwner hierarchy. For $k=4$,

$$W_5 = -x^{-8} (x^9 W'_4)' \tag{12.4}$$

Define the folded boundary moments $\mu_r = \sum_{[\rho]} m_\rho q_\rho^{-r-1}$, for $r \geq 0$. Then the exact comparison at every rung is

CLOSED FORM *boundary value of every rung*

$$\frac{W_k(0)}{(2k-1)!} = \mu_{k-1} = Z_k(0) \tag{12.4a}$$

Here $Z_r(x) = \sum_{[\rho]} m_\rho (x + q_\rho)^{-r}$ is the r -th shifted resolvent, defined again with its derivative reading at (SW.2). Li's λ -coefficient expressions are printed in §R15.

Here $F(s) = (s-1)\zeta(s)$ is the regularized source, distinct from the two-index functional $F_{n,k}$ of (13.2).

rungs	exact boundary value	proved positive for every $x > 0$?	route, and the deepest source jet used
W_1	μ_0	PROVED analytic	source, through $F^{(2)}$
$W_2, \dots, W_6$	$(2k-1)!\mu_{k-1}$	CERTIFIED computer-assisted	source, one certificate, through $F^{(12)}$ (Dossier §74A)
$W_k, 7 \leq k \leq K_H$	$(2k-1)!\mu_{k-1}$	CERTIFIED zero-assisted	verified height, §R13
$W_k, K_H < k \leq K_H(c)$	$(2k-1)!\mu_{k-1}$	CERTIFIED zero-assisted	verified height and the zero-free region [125], §R13B
$W_k, k > K_H(c)$	$(2k-1)!\mu_{k-1}$	OPEN	—

This is the position, stated once. The first six rungs are positive for every $x > 0$, proved from the Gamma-prime source alone, with no zero ordinate, no verified height and no use of RH: the first rung analytically, the next five by the certificate of Dossier §74A, which covers $1 \leq s \leq 128$ by a complete rational partition of continuum cells and $s \geq 128$ by an exact analytic tail. That certificate is in the source archive of this volume and was executed on two independent arithmetic backends. The verified-height theorem of §R13 is a different channel — it uses verified zero locations — and it reaches every rung index up to $K_H = 4,712,664,392,502$, fixed exactly at (13.6). With the published zero-free region of §R13B as a second input it reaches $K_H(c) = 4,772,432,051,943$, fixed at (13B.3), and none beyond. From W_7 on, the source channel is open; all rungs at once is the Riemann hypothesis itself.

This table is the reference for rung status throughout the volume; other sections point to it rather than restate what is open.

The boundary column does not need certifying. The second column is $W_k(0) = (2k-1)!\mu_{k-1}$, and those values are governed by one number.

CLOSED FORM *boundary dominance*

Order the folded orbits so that $q_1 < q_2 \leq |q_\rho|$ for every other orbit. Then for every $k \geq 1$

$$\left| q_1^k \mu_{k-1} - 1 \right| \leq C \left(\frac{q_1}{q_2} \right)^k, \quad C = q_2 \sum_{[\rho] \neq [\rho_1]} \frac{m_\rho}{|q_\rho|} < \infty \quad (12.7)$$

With the verified zero data $q_1/q_2 = 0.45240\dots$ of (9.10) and $C = 8.0019\dots$, so the right-hand side falls below 1 at $k = 3$ and

$$\boxed{W_k(0) > 0 \text{ for every } k \geq 3, \text{ with no hypothesis assumed}} \quad (12.8)$$

Proof. Multiply (12.4a) by q_1^k : the first orbit contributes 1 and each other contributes $m_\rho(q_1/q_\rho)^k$. For $k \geq 1$ and $|q_\rho| \geq q_2$, $|q_1/q_\rho|^k \leq (q_1/q_2)^k q_2/|q_\rho|$; summing gives (12.7). The series converges because $|q_\rho| \asymp \gamma^2$ while the zero count is $O(T \log T)$. When the bound is below 1 the left side cannot reach -1 , so $q_1^k \mu_{k-1} > 0$. $\square$

The constant C has an exact bound that needs no zero-counting tail estimate. Every orbit obeys $|\arg q| < \arctan(1/H)$ at the verified height H , so $1/|q| \leq \sqrt{1+H^{-2}} \Re(1/q)$, and absolute convergence gives

$$\boxed{0 \leq C - C_0 \leq q_2 \lambda_1 (\sqrt{1+H^{-2}} - 1) \leq \frac{q_2 \lambda_1}{2H^2}}, \quad C_0 = q_2 \left(\lambda_1 - \frac{1}{q_1} \right) \quad (12.7a)$$

using $\sqrt{1+h} - 1 \leq h/2$. The enclosures of q_1 , q_2 and λ_1 are computed in interval arithmetic by the certificate build (Dossier §96A.5), and with (12.7a) they give, with no hypothesis,

$$8.00193804616020 \leq C \leq 8.00193804616021.$$

What it says, and what it refuses to say. It says the boundary values are asymptotically a single real number, $\mu_{k-1} \sim q_1^{-k}$, with a geometric error fixed by the first two zeros: the constant in (12.7) is $C = q_2(\lambda_1 - 1/q_1)$ up to less than 6×10^{-25} from orbits above the verified height, and $C(q_1/q_2)^3 = 0.741 < 1$ while $C(q_1/q_2)^2 = 1.64$, so $k \geq 3$ in (12.8) is where this argument starts. It also says that **positivity at the boundary is free**: for $k \geq 3$ it follows from the lowest zero being real, and would survive almost any rearrangement of the zeros above the verified height.

So the boundary column of this table is not where the hypothesis lives. The criterion (R.4) quantifies over every k **and every** $x > 0$, and $x = 0$ is the one place where the family is positive for reasons that have nothing to do with the question. **A verification of boundary positivity, finite or infinite, is not evidence for RH.** Positive boundary values do not control interference between all orbits at positive scales. The single-orbit carrier identities do not confine the complete sum to half-gap windows.

The boundary, in the classical literature. The boundary column is the power-sum side of Newton's identities. With τ_n the Taylor coefficients of

$$\frac{\xi(\frac{1}{2} + \sqrt{\frac{1}{4} + x})}{\xi(1)} = \prod_{[\rho]} \left(1 + \frac{x}{q_\rho}\right)^{m_\rho} = \sum_{n \geq 0} \tau_n x^n, \quad n \tau_n = \sum_{i=1}^n (-1)^{i-1} \tau_{n-i} \frac{W_i(0)}{(2i-1)!} \quad (12.9)$$

The ordinary coefficients τ_n in (12.9), normalized at $x = 0$, form a PF_∞ sequence exactly when the completed genus-zero function has only negative real zeros, hence exactly under RH [75]. This criterion concerns every Toeplitz minor of this specified ordinary sequence. The cited Turan and Jensen results [7,76–78] concern their own coefficient normalizations and polynomial families. No transfer to these τ_n and all these minors is proved here, so those finite-minor statuses are not assigned to (12.9). The boundary power sums and the complete PF hierarchy are different sign questions.

The same τ_n are the Taylor coefficients of $F(x)/\xi(1)$, with $F(x) = \xi(\frac{1}{2} + \sqrt{\frac{1}{4} + x})$, in [133]. That paper proves that the Newton coefficients of F , its forward differences at $x = 0, 1, 2, \dots$, are all positive. Like boundary positivity, that positivity does not reach the minors [133, §8]. Thus

The first zero, in the volume's coordinates

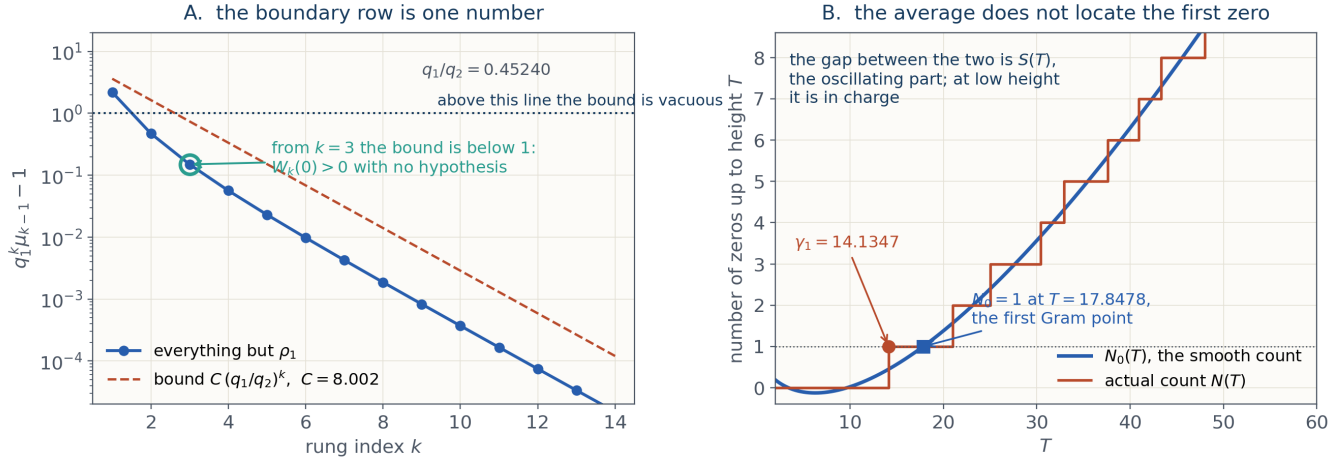


Figure 13: The first zero, in the volume's coordinates. **A:** the deviation $q_1^k \mu_{k-1} - 1$ against the bound of (12.7); from $k = 3$ the bound is below one, which is (12.8). **B:** Riemann's smooth count reaches one at the first Gram point, while the first zero sits well below it; the gap is the oscillating part $S(T)$, and at this height it is in charge.

$$W_1(x), W_2(x), W_3(x), W_4(x), W_5(x), W_6(x) > 0 \quad (x > 0) \quad (12.5)$$

The source certificate now closes the derivative sign

$$(x^9 W_4')' < 0 \iff W_5 > 0 \quad (12.6)$$

without importing zero data, and the same certificate proves $W_6 > 0$. Thus the independent Gamma-prime source prefix is $W_1, \dots, W_6$. The next scalar source task is $W_7 = -x^{-12}(x^{13}W_6')' > 0$, equivalently $(x^{13}W_6')' < 0$, whose source expression reaches $F^{(14)}$. The recurrence remains non-raising: a longer certified prefix does not supply an all-order induction. The zero-assisted theorem in §R13 still extends much farther, to $W_j > 0$ for $1 \leq j \leq K_H$.

One grid, several bases. The coefficient-shape crosswalk in Section R12A distinguishes row k , a segment of row $2k$, reflected positions, the central column and Pascal anti-diagonals. The conversions are exact, but the lists are not literally one row. Section R15 displays the worked W_6 triple.

family	one entry is	how it meets the grid	defined at
$c_{k,j}$	the grid entry itself	$(-1)^j \binom{k}{j}$	(R.1b)
$u_x(q)$	the carrier at one orbit	its k -th power expands using row k	(11.1)
$Z_r(x)$	the r -th shifted resolvent	the objects a row multiplies	(R.1c), (SW.2)
$W_k(x)$	rung k	row k against $Z_k, \dots, Z_{2k}$	(R.3), (SW.4b)
$A_{k,j}$	the coefficient of $x^j S^{(k+j-1)}$	row k , factorially weighted	(SW.6)

family	one entry is	how it meets the grid	defined at
$F_{n,k}(x)$	the full Widder functional	row k , resolvent index shifted by n	(13.2)
μ_r	the boundary moment $W_{r+1}(0)/(2r+1)!$	row k read at $x = 0$	§R12, (12.4a)
$h_n(x_0)$	a Hausdorff entry at one scale	row r is difference order r	(14.1), (14.3a)
λ_n	Li's coefficient	row $2k$ converts λ to μ_{k-1}	(15.1a), (15.3a)
$B_{N,j}(a)$	a completed Bernstein coefficient	row $N - j$	§R17F

Implication lattice: direct arrows only. Pairwise equivalence through RH is mathematically true for the equivalent criteria but does not compare their source difficulty, so those vacuous edges are not drawn. A displayed arrow below is included only when the paper proves it without assuming RH.

target	logical status	direct information retained here
all Widder signs (R.4)	equivalent	implies the necessary W_7 sign immediately
one-scale Hausdorff condition (14.2)	equivalent	no independent arrow to another source target is used
row-variation bound (BR.4)	equivalent	$\Longleftrightarrow$ (BE.3) by $\sqrt{\mathcal{E}_N} \leq \mathcal{V}_N \leq \sqrt{N+1}\sqrt{\mathcal{E}_N}$
Laguerre-energy bound (BE.3)	equivalent	same direct row/energy equivalence as above
all-node Löwner sign (23.1)	equivalent	$\implies$ the Stieltjes/Widder condition (R.4) by the Löwner-Pick/Stieltjes chain of §§R16–R17E
fixed taper $U_N = O_\epsilon(N^\epsilon)$, (155J.5)	equivalent for that specified family	no direct arrow to the matrix/source targets is proved
either curvature/boundary bound in (23.4)	sufficient	each $\implies$ RH; no converse claimed
exact-prefix norm bound (155H.6)	sufficient for the specified family	no converse for arbitrary extensions
$W_7 > 0$ from the independent source	necessary under RH; not sufficient	next scalar source task only

The only nontrivial arrows used by the program are therefore sparse. All other connections either pass through RH itself or remain unknown. Part VIII records ruled-out arrows and shortcuts; blanks are intentional information, not missing editorial work.

R12A. The same rungs in the shifted-zeta basis

The differential coefficients in (12.2) become ordinary Pascal coefficients in a shifted resolvent basis. Define

$$\mathcal{Z}(p; v) = \sum_{[\rho]} m_\rho (\tilde{\gamma}_\rho^2 + v)^{-p} \quad \tilde{\gamma}_\rho = \frac{\rho - 1/2}{i}, \quad q_\rho = \tilde{\gamma}_\rho^2 + \frac{1}{4} \quad (\text{SW.1})$$

Here $\tilde{\gamma}_\rho$ need not be real: this notation does not assume RH. For $v = x + 1/4$, $x \geq 0$, the principal-power series is absolutely convergent when $\Re p > 1/2$. Conjugate folded orbits are retained together. For positive integers r , write

$$Z_r(x) := \mathcal{Z}(r; x + 1/4) = \sum_{[\rho]} \frac{m_\rho}{(x + q_\rho)^r} = \frac{(-1)^{r-1}}{(r-1)!} S_\xi^{(r-1)}(x) \quad (\text{SW.2})$$

For integers $n, k \geq 0$, define the full Widder functional

$$F_{n,k}[S_\xi](x) = (-1)^n D_x^{n+k} [x^k S_\xi(x)] = (n+k)! \sum_{[\rho]} m_\rho \frac{q_\rho^k}{(x + q_\rho)^{n+k+1}} \quad (13.2)$$

Voros's shift identity [56, §6.1] reads $\partial_v \mathcal{Z}(p; v) = -p \mathcal{Z}(p+1; v)$. The elementary expansion $q = (x + q) - x$ now gives the full array:

$$\frac{F_{n,k}(x)}{(n+k)!} = \sum_{j=0}^k (-1)^j \binom{k}{j} x^j Z_{n+j+1}(x) \quad (\text{SW.3})$$

For fixed k , every value of n uses the same signed row k of Figure 14; only the resolvent index shifts. Its seed row is valid in this full array: $F_{n,0}/n! = Z_{n+1}$ for $n \geq 0$, and $F_{0,0} = Z_1 = S_\xi$. The reduced ladder instead selects $n = k-1$, which requires $k \geq 1$.

In particular, with the odd factorial $(2k-1)!$ always in the denominator,

$$\begin{aligned} \frac{W_1}{1!} &= Z_1 - xZ_2, & \frac{W_2}{3!} &= Z_2 - 2xZ_3 + x^2Z_4, & \frac{W_3}{5!} &= Z_3 - 3xZ_4 + 3x^2Z_5 - x^3Z_6, \\ \frac{W_4}{7!} &= Z_4 - 4xZ_5 + 6x^2Z_6 - 4x^3Z_7 + x^4Z_8, \\ \frac{W_5}{9!} &= Z_5 - 5xZ_6 + 10x^2Z_7 - 10x^3Z_8 + 5x^4Z_9 - x^5Z_{10} \end{aligned} \quad (\text{SW.4})$$

$$\frac{W_6}{11!} = Z_6 - 6xZ_7 + 15x^2Z_8 - 20x^3Z_9 + 15x^4Z_{10} - 6x^5Z_{11} + x^6Z_{12} \quad (\text{SW.4a})$$

For all $k \geq 1$, the diagonal $n = k-1$ of (SW.3) is

CLOSED FORM *rung k in $k+1$ terms, for every $k \geq 1$*

$$\frac{W_k}{(2k-1)!} = \sum_{j=0}^k (-1)^j \binom{k}{j} x^j Z_{k+j} = \sum_{j=0}^k c_{k,j} x^j Z_{k+j} \quad (\text{SW.4b})$$

No row of this identity is a truncation, an asymptotic, or a numerical fit. Row k of the grid is the complete answer for rung k , and the grid's own recurrence writes any row directly. What the closed form does **not** supply is the sign: knowing every coefficient of W_k exactly says nothing on its own about whether the sum is nonnegative, and that sign is the whole of the open problem.

At $x = 0$, (SW.4b) reduces to $W_k(0) = (2k-1)!Z_k(0) = (2k-1)!\mu_{k-1}$, joining the Li dictionary in §R15.

One grid, several coefficient chains. With the convention $c_{k,j} = 0$ outside $0 \leq j \leq k$, the signed Pascal array starts at

$$\begin{aligned} c_{k,j} &= (-1)^j \binom{k}{j}, & c_{0,0} &= +1, \\ c_{k+1,j} &= c_{k,j} - c_{k,j-1}, & \sum_{j=0}^k c_{k,j} z^j &= (1-z)^k \quad (k \geq 0). \end{aligned} \tag{SW.5}$$

The row sum is 1 at $k = 0$ and 0 for $k \geq 1$, so the top-left +1 is the algebraic seed of every displayed row.

Raising the carrier to a power is the same act as taking a row. Write $q = (x+q) - x$ and expand:

CLOSED FORM *the carrier and the grid are one object*

$$u_x(q)^k = \frac{q^k}{(x+q)^{2k}} = \sum_{j=0}^k c_{k,j} \frac{x^j}{(x+q)^{k+j}} \tag{SW.5a}$$

Summing (SW.5a) over the folded zeros with multiplicity gives (SW.4b) immediately.

Not every family occupies a whole row. The table in §R12 gave the chains and the identity that defines each; this one gives the shapes the remaining families occupy. All index formulas continue beyond the finite rows printed in Figure 14.

family and location	shape in the grid	reading Figure 14
Li boundary rows, §R15	row segment	Row $2k$, columns $k-1$ down to 0, with common sign $(-1)^{k+1}$.
Half-Gamma, inverse Jacobian and pole ladder, (PR.10b)–(PR.10c), §R17C	centre column	The central entries $c_{2m,m}$, with the displayed sign and scale.
Reciprocal polynomials, Dossier §171	paired rows	Two unsigned rows and the neighbouring-cell difference in (RP.3a).
Bernstein rows and Laguerre, §§R17F–R17G	rescaled rows	Row $N-j$ for each Bernstein entry; row r divided by $j!$ for L_r .
Pascal energy matrix, §R17G	anti-diagonals	Entry (r,s) is $(-1)^r c_{r+s,r}$: its anti-diagonal $r+s=k$ is unsigned row k , and its row $r=2$ is the triangular track $M(2,s) = T_{s+1}$.
Triangular tracks, this section	columns	Column $j=2$ is T_{k-1} ; column $j=3$ is the running sum of triangular numbers.

A shared shape is a shared coefficient list and nothing else. It transports identities, and it transports no inequality: two families can occupy the same row and still have unrelated signs, because the objects the coefficients multiply are different.

FULL SIGNED WIDDER-PASCAL GRID

All 171 coefficients: rows $k = 0$ to 17, columns $j = 0$ to 17

k/j	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
0	+1																	
1	+1	-1																
2	+1	-2	+1															
3	+1	-3	+3	-1														
4	+1	-4	+6	-4	+1													
5	+1	-5	+10	-10	+5	-1												
6	+1	-6	+15	-20	+15	-6	+1											
7	+1	-7	+21	-35	+35	-21	+7	-1										
8	+1	-8	+28	-56	+70	-56	+28	-8	+1									
9	+1	-9	+36	-84	+126	-126	+84	-36	+9	-1								
10	+1	-10	+45	-120	+210	-252	+210	-120	+45	-10	+1							
11	+1	-11	+55	-165	+330	-462	+462	-330	+165	-55	+11	-1						
12	+1	-12	+66	-220	+495	-792	+924	-792	+495	-220	+66	-12	+1					
13	+1	-13	+78	-286	+715	-1287	+1716	-1716	+1287	-715	+286	-78	+13	-1				
14	+1	-14	+91	-364	+1001	-2002	+3003	-3432	+3003	-2002	+1001	-364	+91	-14	+1			
15	+1	-15	+105	-455	+1365	-3003	+5005	-6435	+6435	-5005	+3003	-1365	+455	-105	+15	-1		
16	+1	-16	+120	-560	+1820	-4368	+8008	-11440	+12870	-11440	+8008	-4368	+1820	-560	+120	-16	+1	
17	+1	-17	+136	-680	+2380	-6188	+12376	-19448	+24310	-24310	+19448	-12376	+6188	-2380	+680	-136	+17	-1

The shaded row is the coefficient seed. Even rows reverse unchanged; odd rows reverse sign.

Blank cells have $j > k$. Every nonblank cell is printed; no half-row convention is used.

Figure 14: The complete signed coefficient grid beside the W_k arrays (SW.4)–(SW.4a): all 171 entries $c_{k,j} = (-1)^j \binom{k}{j}$ for $0 \leq k \leq 17$, $0 \leq j \leq k$. The shaded seed is $c_{0,0} = +1$; in the full array it gives $F_{0,0} = S_\xi$, without defining a reduced W_0 . For $k \geq 1$, row k multiplies $x^j Z_{k+j}$ in $W_k/(2k-1)!$. Both edges and both halves are printed.

Two external instances, one each way. The arrangement is not peculiar to this volume. In a line running from Cloitre’s tauberian approach of 2011 [67], through the floor-function characterization that introduces *regular arithmetic functions* [68], to the two-volume treatment of 2026 [69], a triangular two-index kernel $G(n, k)$ with $G(n, n) \neq 0$ is solved rank by rank and assigned a *regularity index*: the exponent at which its partial sums change behaviour. The Riemann hypothesis appears there as the statement that Ingham’s kernel $G(n, k) = (k/n)\lfloor n/k \rfloor$ has index $1/2$. The shared triangular shape and the shared rank-by-rank solve carry structure and an equivalence across, and carry no inequality: that index is a growth exponent, not a sign. Read the other way, Xu [70] obtains positivity in every degree for Chenevier’s critical vectors by controlling the sign of every Verblunsky coefficient of an associated circle measure. There the inequality does transport, through a named mechanism rather than through a shared shape. The two together mark the gap in which this volume works. Both are recorded as read and are verified nowhere in this work.

On the k/n coordinate. The reduced rational address $z = a/q$ of Dossier §171 and the ratio k/n inside Ingham’s kernel are the same coordinate, reached by different routes; the constructions raised on it are not the same object, and the two indices are not the same quantity. The present work reached its coordinate independently and without knowledge of [67]–[69], which have priority in the published record.

For the differential basis write $W_k = \sum_{j=0}^k A_{k,j} x^j S^{(k+j-1)}$, with $A_{k,j} = 0$ outside this range. Then

$$\begin{aligned} A_{k,j} &= (-1)^{k+j-1} \frac{(2k-1)!}{(k+j-1)!} c_{k,j}, \\ A_{k+1,j} &= -A_{k,j-1} - (2k+2j+1)A_{k,j} \\ &\quad - (j+1)(2k+j+1)A_{k,j+1}, \quad k \geq 1. \end{aligned} \tag{SW.6}$$

The first line is the substitution (SW.2); the second follows by differentiating each term in (12.3). It generates the displayed arrays from $A_{1,0} = A_{1,1} = 1$. The polynomial source-jet arrays in Dossier §§34–38 add the Jacobian substitution $S = L/R$, $D_x = R^{-1}D_s$ to these same weighted rows; their additional factors are stated there.

The remaining finite arithmetic of the grid itself — how its columns read as tracks, the reflection identity, the interior triangular collisions including the eight positions of 3003, the $k = 0$ seed, and the odd factorial as an accumulated triangular product — is worked in Dossier §173. None of it is used below. The alternating rows encode cancellation, and neither they nor those collisions supply positivity: the proof channels and their current depth are exactly those tabled in §R12. Pearce-Crump [82] gives a recent external example in which Selberg’s single mollifier square is replaced by a positive-semidefinite sum of three squared mollifiers and the resulting arithmetic quadratic form is optimized; this is a methodological analogy only, with no transfer asserted to the completed source here.

Dossier Theorem 32A.1 also represents every $F_{n,k}$ as a Laguerre transform of the heat trace. Its scalar kernel has exactly k simple sign changes for $k \geq 1$; an undifferentiated positive heat trace alone does not supply the required sign.

R13. Height-to-sector theorem and the full finite rectangle

For $q = a + ib$ with $a > 0$,

$$\arg u_x(q) = \arg q - 2 \arg(x + q) \quad (13.1)$$

As x runs from 0 to ∞ , this phase moves continuously from $-\arg q$ to $+\arg q$, crosses zero at $x = |q|$, and remains inside that closed angular band. Consequently a folded zero cannot rotate a fixed power outside the right half-plane once its height reaches the explicit threshold $H \geq \cot(\pi/2M)$ proved below.

The full functional $F_{n,k}$ is defined at (13.2) in §R12A; its reduced diagonal is $W_j = F_{j-1,j}$.

Full zero-assisted sector theorem. Suppose every nontrivial zero with $0 < |\Im \rho| \leq H$ lies on the critical line. Put $M = \max\{k, n + 1\}$. Then

$$H \geq \cot\left(\frac{\pi}{2M}\right) \implies F_{n,k}[S_\xi](x) > 0 \quad (x > 0) \quad (13.3)$$

To see the full two-index phase, put $\theta = \arg q$ and $\phi = \arg(x + q)$. A summand has phase

$$\alpha = k\theta - (n + k + 1)\phi, \quad |\alpha| < \max\{k, n + 1\}|\theta| \quad (\theta \neq 0) \quad (13.3a)$$

For $x > 0$, ϕ lies strictly between 0 and θ when $\theta \neq 0$. If $\theta = 0$, the summand is positive real and the strict angular inequality is not needed. For an unverified zero above height H , $|\theta| < \arctan(1/H)$, since $\Re q = \gamma^2 + \beta(1 - \beta) > \gamma^2$ and $|\Im q| = |\gamma(1 - 2\beta)| < |\gamma|$. Conjugate folded summands have opposite phases, so their real sum is strictly positive under (13.3).

Platt and Trudgian proved the verified height

$$H = 3,000,175,332,800 \quad (13.4)$$

and, in the same theorem, the full integer count: the lowest

$$12,363,153,437,138 \quad (13.5)$$

nontrivial zeros lie on the critical line [42]. The largest integer admitted by the displayed height condition is now certified:

$$K_H = \left\lfloor \frac{\pi}{2 \arctan(1/H)} \right\rfloor = 4,712,664,392,502 \quad (13.6)$$

Exact rational enclosures prove that the number inside the floor lies strictly between 4,712,664,392,502 and 4,712,664,392,503. Thus (13.3) gives

$$\boxed{F_{n,k}[S_\xi](x) > 0 \quad (x > 0, 0 \leq n \leq K_H - 1, 0 \leq k \leq K_H)} \quad (13.7)$$

The exact lineage is

$$\boxed{\begin{aligned} W_j &= F_{j-1,j} \\ G_{n,k}(x) &= \frac{x^n}{(n+k+1)!} F_{n,k+1}[S_\xi](x) \\ G_{r-1,r-1} &= \frac{x^{r-1}}{(2r-1)!} W_r = \frac{x^{r-1}}{j_{r-1}!} W_r \end{aligned}} \quad (13.8)$$

Hence the same theorem gives $G_{n,k}(x) > 0$ for every $x > 0$ and $0 \leq n, k \leq K_H - 1$. The fixed-scale theorem of §R13C instead bounds n by 4,500,262,999,199 and x by $H^2/10^6$, and permits every $k \geq 0$; the two rectangles are incomparable. On the reduced W_j diagonal, the height-to-sector rectangle is stronger.

Differentiating the summands also gives

$$\boxed{F'_{n,k} = -F_{n+1,k}, \quad F_{n,k+1} = (n+k+1)F_{n,k} - xF_{n+1,k}} \quad (13.9)$$

Hence the certified rectangle includes finite strings of alternating derivative signs. In its interior, $0 \leq n \leq K_H - 2$ and $0 \leq k \leq K_H - 1$, one has

$$0 < -\frac{x F'_{n,k}}{F_{n,k}} < n + k + 1 \quad (13.10)$$

This is a finite, zero-assisted, computer-assisted theorem. It does not prove the source-side $F^{(14)}$ inequality, and a finite rectangle—however large—does not replace the all-order quantifier in RH.

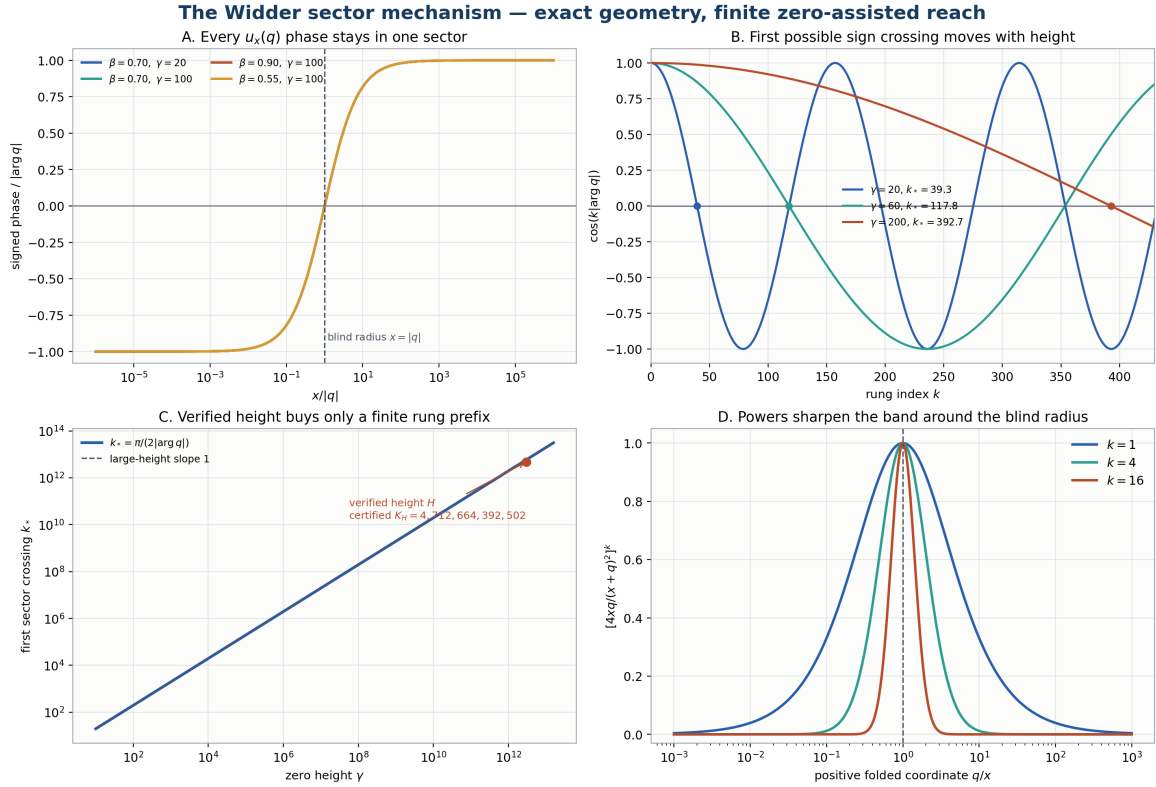


Figure 15: Four views of the sector mechanism: phase band, first cosine crossing, linear height-to-rung scale, and the blind-radius band pass.

R13A. How far the ladder is from the hypothesis, in one number

Dossier §48 writes the ladder at scale x as a power series $\mathcal{G}_x(z) = \sum_{k \geq 1} W_k(x) z^{k-1} / (2k-1)!$ whose poles sit at $z_x(q_\rho) = (x + q_\rho)^2 / q_\rho$, and Dossier §49 proves that its radius R_x satisfies $R_x \geq 4x$ for every x exactly when RH holds. Three facts locate the hypothesis inside that radius.

The deficit identity. For $q = |q|e^{i\theta}$ with $\Re q > 0$ and $x > 0$,

$$\boxed{4x - |z_x(q)| = 4x \sin^2 \frac{\theta}{2} - \frac{(|q| - x)^2}{|q|}}, \quad \max_{x>0} (4x - |z_x(q)|) = \frac{(|q| - \Re q)(3|q| - \Re q)}{|q|} \quad (13A.1)$$

the maximum at $x = 2|q| - \Re q$; at the blind radius $x = |q|$ the deficit is the strictly smaller $2(|q| - \Re q)$, which for a zero at abscissa β and ordinate γ is $(2\beta - 1)^2(1 + O(\gamma^{-2}))$. An off-line zero cuts the radius at its own scale by a **height-free** reading of its distance from the line.

The exact remainder. Write $d = 2\beta - 1$, $v = \gamma^2$, $c = \beta(1 - \beta)$, $A = \Re q = v + c$ and $w = |q| - A \geq 0$, so that $w(2A + w) = vd^2$. The gap between the deficit and the squared

transverse displacement is not an estimate but an identity, every factor positive off the line:

$$d^2 - \max_{x>0} (4x - |z_x(q)|) = \frac{w[w^2 + c(3|q| - A)]}{v|q|} > 0 \quad (13A.1a)$$

together with the two-sided chain

$$\frac{4\gamma^2}{4\gamma^2 + 1} d^2 < 2w < \max_{x>0} (4x - |z_x(q)|) < d^2 \quad (13A.1b)$$

Both are proved at Dossier (48.29)–(48.30); the lower bound reduces to $v < v + \frac{1}{4}$, and no height factor is needed. On-line orbits have deficit $-(q - x)^2/q \leq 0$. Hence

CLOSED FORM *the last unit of radius*

$$4x - 1 < R_x \quad \text{for every fixed } x > 0, \text{ with no hypothesis assumed} \quad (13A.2)$$

Put $\Delta = \sup_{x>0} (4x - R_x)$ and $d_* = \sup_{\rho} |2\Re\rho - 1|$. The minimum defining R_x is attained at each x , so (13A.1a) gives $\Delta \leq d_*^2 \leq 1$. **The displayed theorem is pointwise in x and does not assert $\Delta < 1$.** A uniform restriction $\delta \leq \Re\rho \leq 1 - \delta$ gives $\Delta \leq (1 - 2\delta)^2 < 1$; conversely $d_* = 1$ forces $\Delta = 1$ by (13A.1b). Here $d_* = 1$ is not attained: $\zeta(1 + it) \neq 0$ excludes a zero on $\Re s = 1$, so $d_* = 1$ forces a sequence with $|2\Re\rho_n - 1| \rightarrow 1$. Finiteness of the zero count below any fixed height then forces $|\Im\rho_n| \rightarrow \infty$, and the factor $4\gamma_n^2/(4\gamma_n^2 + 1) \rightarrow 1$ in (13A.1b), giving $\Delta = 1$. Thus $\Delta < 1$ is equivalent to a uniform zero-free strip of positive width along **both** boundaries of the critical strip. The one-sided condition $\Re s < 1 - \delta$ would name the wrong region: read literally, it excludes the line the known zeros are on. The accepted inputs of this edition do not establish such a strip. One was claimed on 6 October 2026, with $\delta = 1/8$; §R13C assumes it and proves what follows. And $\Delta = 0$ is RH (Dossier §49). Proofs: (48.31)–(48.32).

Two consequences. The high-scale statistic is strictly weaker: (48.33) gives $\limsup_{x \rightarrow \infty} (4x - R_x) = \limsup_{|\gamma| \rightarrow \infty} (2\beta - 1)^2$, and a zero value there leaves finitely many off-line exceptions, or displacements tending to zero, untouched. And at the verified height $H = 3,000,175,332,800$,

$$0 \leq d_*^2 - \Delta \leq \frac{1}{4H^2 + 1} = \frac{1}{36,004,208,110,166,363,023,360,001} < 2.8 \times 10^{-26} \quad (13A.2a)$$

Conditional on the carried height input, the displayed amount bounds the gap between the two suprema. It is an error estimate, not a lower bound on computational distinguishability or a numerical-impossibility theorem. A uniform source estimate is still required to force $\Delta = 0$.

So the Euler product, whose absolute convergence stops at the parabola, reaches the deficit 1 and not one digit further — 1 is the width of the critical strip in these units, $(2\beta - 1)^2 \leq 1$ —

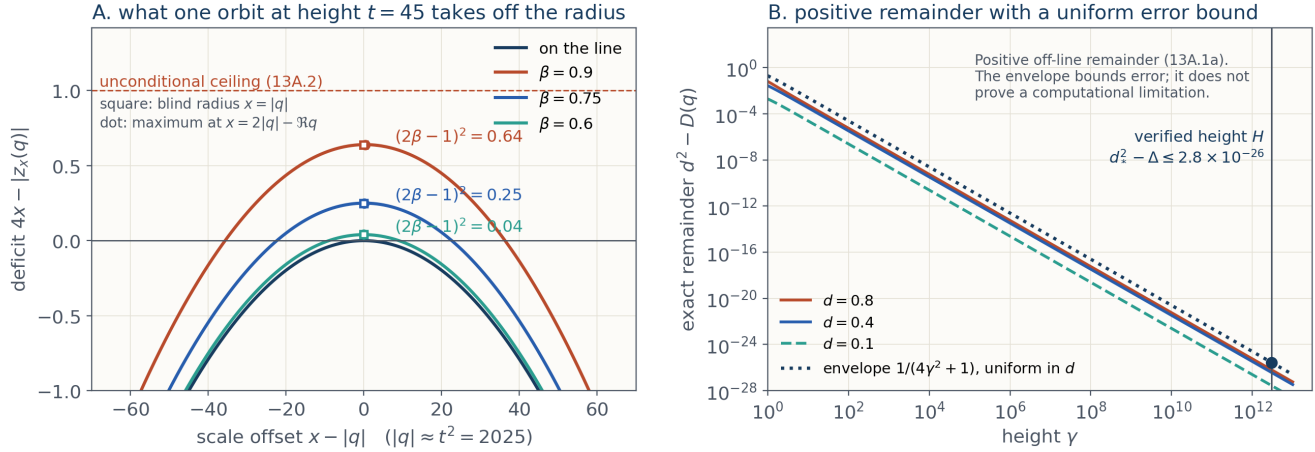


Figure 16: The last unit of radius. **A:** the deficit $4x - |z_x(q)|$ for one on-line orbit and three planted off-line orbits at height 45. The blind-radius value $2(|q| - \Re q)$ and the larger maximum at $x = 2|q| - \Re q$ approach $(2\beta - 1)^2$ as height tends to infinity. **B:** the strictly positive single-orbit remainder $d^2 - D(q)$, with envelope $1/(4\gamma^2 + 1)$ and the carried height marker. The weak global comparison $0 \leq d_*^2 - \Delta \leq (4H^2 + 1)^{-1}$ is an error bound, not a computational-impossibility statement. A uniform boundary strip would imply $\Delta < 1$; no such source estimate is proved.

and **the whole of the hypothesis at scale x is the last unit of R_x** . The deficit records extremal transverse displacement and nothing else; relating it to zero-density estimates or growth hypotheses needs a separate theorem with explicit quantifiers, which the radius identity does not supply. (23.1) is the statement that a source-side argument claims the whole unit.

Where the series comes from. With $a_k = (4x)^k W_k(x)/(2k - 1)! = \sum_{[\rho]} m_\rho t_x(q_\rho)^k$ and $w = \sin^2(\varphi/2)$,

$$\sum_{k \geq 1} a_k(x) w^k = 4xw \frac{h(xe^{-i\varphi}) - h(xe^{i\varphi})}{xe^{-i\varphi} - xe^{i\varphi}} = 2 \tan \frac{\varphi}{2} \Im h(xe^{i\varphi}), \quad h = xS_\xi \quad (13A.3)$$

The factorization $1 - t_x(q)w = (q + xe^{i\varphi})(q + xe^{-i\varphi})/(x + q)^2$ and $\cos \varphi = 1 - 2w$ prove the identity in its Taylor convergence disk, with meromorphic continuation where defined. The rungs are its Taylor coefficients in w . Here h is the function whose Pick property is at issue, not an unconditionally known Pick function. The conjugate-node formula retains the reflection data that Section R20 requires. The Euler-source representation (9.5) applies where $\Re s_{xe^{i\varphi}} > 1$; its domain is not a proof of the full Pick sign.

R13B. A narrower sector from an explicit zero-free region

Section R13 uses one fact about a zero above the verified height: it lies in the open critical strip, so $|1 - 2\beta| < 1$. An explicit zero-free region says more, and the same phase argument then reaches further. The height H of (13.4) is unchanged.

Mossinghoff, Trudgian and Yang proved that $\zeta(\sigma + it) \neq 0$ whenever $|t| \geq 2$ and $\sigma \geq 1 - 1/(c \log |t|)$, with $c = 5.558691$ [125]. For a constant $c > 0$ put

$$\theta_H(c) = \arctan\left(\frac{1 - 2/(c \log H)}{H}\right), \quad K_H(c) = \left\lfloor \frac{\pi}{2\theta_H(c)} \right\rfloor \quad (13B.1)$$

Without a region the numerator is 1, and this is the index K_H of (13.6).

Sector theorem with a zero-free region. Suppose every nontrivial zero with $0 < |\Im \rho| \leq H$ lies on the critical line. Suppose ζ has no zero with $|t| \geq H$ and $\sigma \geq 1 - 1/(c \log |t|)$, and that $c(\log H)^2 > 2 \log H + 2$. Then

$$F_{n,k}[S_\xi](x) > 0 \quad (x > 0, 0 \leq n \leq K_H(c) - 1, 0 \leq k \leq K_H(c)) \quad (13B.2)$$

Proof. Let $\rho = \beta + i\gamma$ be a zero with $\gamma > H$. The region and the reflection $\rho \mapsto 1 - \bar{\rho}$ give $1/(c \log \gamma) < \beta < 1 - 1/(c \log \gamma)$, hence $|1 - 2\beta| < 1 - 2/(c \log \gamma)$. As in §R13, $\Re q_\rho = \gamma^2 + \beta(1 - \beta) > \gamma^2$ and $|\Im q_\rho| = \gamma|1 - 2\beta|$, so

$$|\arg q_\rho| < \arctan g(\gamma), \quad g(t) = \frac{1 - 2/(c \log t)}{t} \quad (13B.2a)$$

The derivative of g is given by

$$t^2 g'(t) = -1 + \frac{2}{c \log t} + \frac{2}{c(\log t)^2}$$

The right side is negative exactly when $c(\log t)^2 > 2 \log t + 2$, and that holds for every $t \geq H$ once it holds at H . So g decreases on $t \geq H$, and every unverified folded zero has $|\arg q_\rho| < \theta_H(c)$. Verified zeros have positive real q_ρ . The summand phase obeys (13.3a): with $M = \max\{k, n + 1\} \leq K_H(c)$ it satisfies $|\alpha| < M \theta_H(c) \leq \pi/2$. On-line summands are positive, each conjugate pair has positive real sum, and (13.2) converges absolutely. $\square$

At the height (13.4) and $c = 5.558691$ the condition on c holds with a wide margin, and exact rational enclosures certify the floor:

$$K_H(c) = 4,772,432,051,943 \quad (c = 5.558691) \quad (13B.3)$$

The number inside the floor is 4,772,432,051,943.98..., enclosed strictly between that integer and the next. The gain over (13.6) is 59,767,659,441 indices, about 1.27%. By (60A.6), $K_H(c) - K_H = \pi H/(c \log H - 2) + O(1)$: a region of this shape buys the share $2/(c \log H - 2)$ of the index, which falls as the verified height grows. In particular $W_j = F_{j-1,j} > 0$ for every $x > 0$ and $1 \leq j \leq K_H(c)$, and (13.8)–(13.10) hold on the larger rectangle with $K_H(c)$ in place of K_H . **CERTIFIED**

Three limits keep this result in its place.

- **Inputs.** It is zero-assisted twice over: it uses the verified height [42] and the published region [125]. It is not a source statement and does not touch $W_7 \rightsquigarrow F^{(14)}$.
- **A preprint value, labelled as one.** A March 2026 preprint of Bellotti, Trudgian and Yang states the region with $c = 4.896$ for $t \geq 3$ [126]. If that theorem is invoked, the same proof gives $K_H(c) = 4,780,638,501,492$. That value rests on an unrefereed input. It is recorded here and is not a status row.
- **Priority.** A September 2026 preprint of Rafik already transfers both regions to the diagonal Widder orders at the rounded height $3 \cdot 10^{12}$, and reports 4,772,153,270,068 and 4,780,359,257,170 [127]. That transfer is not claimed here. What is recorded is the exact height (13.4), which adds 278,781,875 and 279,244,322 indices, and the full two-index rectangle that the argument of §R13 already carries.

Neither index is a failing rung, and neither is the largest range another method could reach. Each is the edge of a sufficient angular estimate. The symbol K_H keeps its meaning (13.6) everywhere else in this volume.

R13C. One frontier number, and an assumed half-plane

Write $\beta_* = \sup_\rho \Re \rho$ for the rightmost abscissa of the nontrivial zeros. RH is $\beta_* = 1/2$. This volume reads that one number in several exact ways. This section assumes a bound on it and follows the assumption through all of them at once.

The assumption. Assume that ζ has no zero with $\Re s > 7/8$. Two machine-written manuscripts in a release of 6 October 2026 claim this for every Dirichlet L -function, ζ included [128], and claim $\Re s > 11/12$ by a different argument [129]. A Lean statement of the first is supplied for ζ . The claim is recorded here as read and not built: the proofs were not checked, and no status in this volume rests on them. So the half-plane is an assumption in what follows. Each result that uses it says so, and the one result of this section that does not is marked. Both manuscripts say that the Riemann hypothesis remains open.

The sector index. The proof of (13B.2) uses its region only to bound $|1 - 2\beta|$. If ζ has no zero with $\Re s > \theta_0$, where $1/2 < \theta_0 < 1$, the reflection $\rho \mapsto 1 - \bar{\rho}$ gives $|1 - 2\beta| \leq w = 2\theta_0 - 1$ for every zero. Above the verified height $|\arg q_\rho| < \arctan(w/\gamma) < \arctan(w/H)$, strictly even for a zero on the line $\Re s = \theta_0$, which the hypothesis does not exclude. The same proof then gives the rectangle (13B.2) with $K_H(c)$ replaced by

$$K_H[\theta_0] = \left\lfloor \frac{\pi}{2 \arctan(w/H)} \right\rfloor \quad (13C.1)$$

At the height (13.4), exact rational enclosures give

$$K_H[11/12] = 5,655,197,271,003, \quad K_H[7/8] = 6,283,552,523,337 \quad (13C.2)$$

These are about 18.5% and 31.7% above (13B.3). Each is the strip-only index (13.6) at the verified height H/w , (60A.4a): to this argument the half-plane $\Re s > 7/8$ is worth

1.0000584×10^{12} more of verified height, and no more. The floors are checked arithmetic. The half-plane beneath them is assumed, so the rectangle is conditional there and **(13C.2) is not a status row.**

One number, read seven ways. Each row is an identity or a theorem already in this volume.

reading of the frontier	where	strip alone	assuming $\Re s > 7/8$ zero-free	RH
rightmost abscissa β_* , written Θ_ζ in §R17I	Dossier §60	≤ 1	$\leq 7/8$	$1/2$
transverse reach $d_* = 2\beta_* - 1$	§R13A	≤ 1	$\leq 3/4$	0
radius deficit $\Delta \leq d_*^2$	§R13A, (48.31)	≤ 1	$\leq 9/16$	0
support radius $\beta_* - \frac{1}{2}$	§R21A, Dossier §166	$\leq 1/2$	$\leq 3/8$	0
dilation threshold $2\beta_*$	Dossier §143	≤ 2	$\leq 7/4$	1
first-Riesz exponent $1 + \beta_*$	Dossier §60	≤ 2	$\leq 15/8$	$3/2$
divisor exponent $2\beta_* - 1$	§R17I, (DIV.3a)	≤ 1	$\leq 3/4$	0

Freitas's Li-type criterion [131] is a further reading, from outside this volume. Its coefficients are nonnegative at every order exactly from the parameter $2\beta_*$ on, which is the dilation threshold again (Dossier §60A). A finite range of those coefficients tests only a bounded part of the strip [132]. The sector index is another reading, and it also needs the verified height. The assumption moves every row, and none to its RH value: it gives $\Delta \leq 9/16$, which is the open statement $\Delta < 1$ of §R13A, and it leaves $\Delta = 0$ open. It does not touch the source channel, where $W_7 \rightsquigarrow F^{(14)}$ is open, or the twin, which is not a Dirichlet L -function.

The fixed-scale rectangle, without the assumption and with it. The fixed- $x = 56$ theorem of §R13 holds for every $k \geq 0$ and bounds only the row. A centred saddle argument (Dossier Proposition 60A.6) moves that bound from the 6,901,269,318 of (105.2) to

$$G_{n,k}(56) > 0 \quad \left(k \geq 0, \quad n + 1 \leq \frac{3H}{2w} \right) \quad (13C.3)$$

On the strip alone, $w = 1$, that is every row through $n = 4,500,262,999,199$. This case assumes no half-plane. It uses the verified height [42] and the explicit zero count of [130]. **CERTIFIED** zero-assisted. Assuming the half-plane, $w = 3/4$, the same proof reaches $n = 6,000,350,665,599$, and that row is not a status row. The bound depends on H and w only through H/w , so here too the half-plane is worth a third more verified height, as in (60A.4a). A weaker form of the argument, with the rows of (105.2) under a narrower strip, is (60A.7).

Every scale up to $H^2/10^6$. The scale 56 is not special. The same rows hold on a whole interval of scales, and for every real width $0 < w \leq 1$ (Dossier Proposition 60A.7):

$$G_{n,k}(x) > 0 \quad \left(0 < x \leq \frac{H^2}{10^6}, \quad k \geq 0, \quad n + 1 \leq \frac{3H}{2w} \right) \quad (13C.4)$$

The endpoint is about 9.0×10^{18} . On the strip alone this is every row through $n = 4,500,262,999,199$, in every column, at every one of these scales, with the same two inputs [42] and [130] and no half-plane. **CERTIFIED** zero-assisted. Assuming the half-plane it

is every row through 6,000,350,665,599, and that is not a status row. The criterion of §R14 asks for the whole array $G_{n,k}(x_0) \geq 0$ at one prescribed scale (Dossier (104.12)). Here every column is reached, at all of these scales at once, and what remains finite is the number of rows. The sector rectangle (13.7) is a different region: it holds at every $x > 0$ and bounds both indices. At equal H/w the row bound here is about 95.5% of the sector index; the ratio tends to $3/\pi$, and it reflects the constant $3/2$ of this proof, which is not sharp.

The readings do not improve one another. A reflected quartet at abscissa $7/8$, placed high enough, keeps any finite rectangle positive at every x (Proposition 60A.2). So no finite prefix and no combination of the rows bounds β_* below the input. That takes an independent estimate. The whole columns of (13C.3) do not change this: a model with an accurate zero count and one remote quartet satisfies it as well.

The table and the index are implications. **PROVED** The half-plane is an assumption here and an external claim, and the row $\Delta < 1$ stays **OPEN** in this edition. Dossier §60A has the proofs.

R14. One prescribed scale and the Hausdorff theorem

Fix any $x_0 > 0$ and define

$$h_n(x_0) = (4x_0)^n \frac{W_{n+1}(x_0)}{(2n+1)!} \quad (14.1)$$

Then

$$\boxed{\text{RH} \iff (h_n(x_0))_{n \geq 0} \text{ is a Hausdorff moment sequence on } [0, 1]} \quad (14.2)$$

Equivalently,

$$(-1)^r \Delta^r h_n(x_0) \geq 0 \quad (n, r \geq 0) \quad (14.3)$$

With $\Delta h_n = h_{n+1} - h_n$, Figure 14 supplies the difference weights:

$$(-1)^r \Delta^r h_n(x_0) = \sum_{j=0}^r c_{r,j} h_{n+j}(x_0). \quad (14.3a)$$

Thus row r tests difference order r ; the seed row $r = 0$ simply returns h_n . The weights alone do not determine the sign of the sum.

The theorem holds at any one scale chosen in advance, but it requires all orders at that scale. It is not a finite stopping rule.

Part V. Li data, Löwner matrices, and the source-energy construction

The boundary values $\mu_{k-1} = W_k(0)/(2k-1)!$ connect the rungs to Li's coefficients through (15.2). Section R15 gives that dictionary and the positive reserve with its explicit arithmetic defect. Sections R16–R17E separate the completed Gamma-prime matrix from its comparison models. Sections R17F–R17H construct the fixed-scale energy and its cutoffs. Section R17I connects an exact-divisor error to the same zeta denominator. The source upper bounds remain unproved.

R15. The central-Pascal boundary dictionary

Write ξ for the completed function of §R9 and let ρ run over its zeros with multiplicity, folded as in §R9 so that ρ and $1 - \rho$ share the single point $q_\rho = \rho(1 - \rho)$. **Li's coefficients** are

$$\lambda_n = \sum_{\rho} \left[1 - \left(1 - \frac{1}{\rho} \right)^n \right] = \frac{1}{(n-1)!} \frac{d^n}{ds^n} \left[s^{n-1} \log \xi(s) \right]_{s=1} \quad (15.1a)$$

the symmetrically grouped zero sum agreeing with the derivative definition [5]. The normalization is Li's: λ_n is n times Keiper's coefficient [57–58]. The first is the one this volume uses, because it is a sum over the very orbits that carry the rungs: pairing each zero with its mirror gives $\rho^{-1} + (1 - \rho)^{-1} = q_\rho^{-1}$, so at $n = 1$

$$\lambda_1 = \sum_{[\rho]} \frac{m_\rho}{q_\rho} = S_\xi(0) = \mu_0, \quad (15.1b)$$

which is the value already used in §R10A. The rung chain and the Li chain are therefore two readings of one set of folded data, and (15.2) below is the conversion between them. Section R10C writes the one-orbit form of the same reading: the resolvent pole $-q_\rho$ fixes w_ρ through (10C.2), and the recurrence (10C.4) then generates that orbit's whole column $Q_n(q_\rho^{-1})$, of which the term displayed above is $n = 1$.

Li's coefficients satisfy

$$\text{RH} \iff \lambda_n \geq 0 \quad (n \geq 1) \quad (15.1)$$

The two chains are related by a single alternating transform on a doubled row index. It is an identity, proved from (15.1a) and the folded resolvent, and it is insensitive to where the zeros lie: the folded moments μ_{k-1} satisfy

$$\mu_{k-1} = \sum_{j=1}^k (-1)^{j+1} \binom{2k}{k-j} \lambda_j \quad W_k(0) = (2k-1)! \mu_{k-1} \quad (15.2)$$

The first six rows are printed because the indexing matters:

$$\begin{aligned} \mu_0 &= \lambda_1 \\ \mu_1 &= 4\lambda_1 - \lambda_2 \\ \mu_2 &= 15\lambda_1 - 6\lambda_2 + \lambda_3 \\ \mu_3 &= 56\lambda_1 - 28\lambda_2 + 8\lambda_3 - \lambda_4 \\ \mu_4 &= 210\lambda_1 - 120\lambda_2 + 45\lambda_3 - 10\lambda_4 + \lambda_5 \\ \mu_5 &= 792\lambda_1 - 495\lambda_2 + 220\lambda_3 - 66\lambda_4 + 12\lambda_5 - \lambda_6 \end{aligned} \quad (15.3)$$

These are exact segments of Figure 14, with a doubled row index:

$$\mu_{k-1} = (-1)^{k+1} \sum_{j=1}^k c_{2k,k-j} \lambda_j. \quad (15.3a)$$

Read columns $k-1, k-2, \dots, 0$ of row $2k$, then apply the common sign $(-1)^{k+1}$. For $k=6$, row 12 contributes $(-792, 495, -220, 66, -12, 1)$; reversing the common sign gives $(792, -495, 220, -66, 12, -1)$ in the μ_5 line. The -220 at column 3 equals the reflected entry at column 9 in (SW.4h), Dossier §173, and becomes $+220\lambda_3$ here. The seven-term resolvent row for W_6 is row 6; its six-term Li boundary row is this segment of row 12.

Thus $W_5(0) \leftrightarrow \mu_4$; the row ending $+12\lambda_5 - \lambda_6$ is $\mu_5 = W_6(0)/11!$, not the W_5 row. This alternating transform is exact but increasingly ill-conditioned, so it is a dictionary rather than a stable numerical inversion method.

One row, three readings. At $k=6$, the signed grid Figure 14 gives these linked but distinct expressions:

$$\frac{W_6}{11!} = Z_6 - 6xZ_7 + 15x^2Z_8 - 20x^3Z_9 + 15x^4Z_{10} - 6x^5Z_{11} + x^6Z_{12} \quad (\text{SW.4a})$$

$$W_6 = -332640S^{(5)} - 332640xS^{(6)} - 118800x^2S^{(7)} - \dots - x^6S^{(11)} \quad (12.2a)$$

$$\mu_5 = 792\lambda_1 - 495\lambda_2 + 220\lambda_3 - 66\lambda_4 + 12\lambda_5 - \lambda_6 \quad (15.3)$$

The first two use row 6, 1, $-6, 15, -20, 15, -6, 1$; the last uses row **12**, columns 5 down to 0. In the differential row, the factorial weights $11!/(5+j)!$ are 332640, 55440, 7920, 990, 110, 11, 1. The derivative conversion $Z_{6+j} = (-1)^{5+j} S^{(5+j)}/(5+j)!$ cancels the column alternation and leaves the common negative sign; a global sign alone cannot cancel alternating columns. The first expression is the scalar rung, the second is the source-derivative basis, and the third is their Li boundary dictionary. A coefficient conversion does not introduce an evaluated-source sign.

The same boundary moments occupy the confluent matrix; this is the precise connection between the triangular coefficient image and the matrix image. Locally at the origin,

$$S_\xi(x) = \sum_{r \geq 0} (-1)^r \mu_r x^r, \quad \frac{h^{(i+j+1)}(0)}{(i+j+1)!} = (-1)^{i+j} \mu_{i+j} \quad (15.4)$$

With indices $i, j = 0, \dots, N-1$, set $H_N = [\mu_{i+j}]$ and $D_N = \text{diag}((-1)^i)$. The normalized confluent matrix is $C_N(0) = D_N H_N D_N$, so it has the same inertia as H_N . For example,

$$H_3 = \begin{pmatrix} \mu_0 & \mu_1 & \mu_2 \\ \mu_1 & \mu_2 & \mu_3 \\ \mu_2 & \mu_3 & \mu_4 \end{pmatrix}, \quad (H_3)_{ii} = \frac{W_{2i+1}(0)}{(4i+1)!}, \quad i = 0, 1, 2 \quad (15.5)$$

Thus the first five boundary rungs determine every entry of H_3 . Positive entries alone do not prove its principal minors positive; for example, the first 2×2 condition is $\mu_0 \mu_2 - \mu_1^2 \geq 0$. At positive nodes the corresponding object is the Löwner divided-difference matrix $\mathcal{L}_h$ of (10.3), with diagonal $W_1(x_i)$; its off-diagonal compatibility is the source comparison in §R16. The all-size Hankel condition and the all-node Löwner condition are RH-equivalent, whereas the finite scalar table in §R12 is already proved.

The reflected odd form. Define $\mathcal{P}_0 = 1$, $\mathcal{P}_1 = 3 - y$, and $\mathcal{P}_{m+1} = (2 - y)\mathcal{P}_m - \mathcal{P}_{m-1}$, with $\mathcal{P}_m(y) = \sum_j d_{m,j} y^j$ and $d_{m,j} = (-1)^j (2m+1)(m+j)! / ((m-j)!(2j+1)!)$. Dossier Section 155A proves

$$K_N = C_N H_N C_N^\top, \quad K_{r,s} = \lambda_{r+s+1} - \lambda_{|r-s|}, \quad K_{m,m} = \lambda_{2m+1}, \quad (15.6)$$

where $C_N = [d_{r,j}]$ and $\lambda_0 = 0$. Its determinant is ± 1 , so the two matrices have identical inertia. For example, $\lambda_3 = 9\mu_0 - 6\mu_1 + \mu_2$: an odd Li diagonal already tests original off-diagonal information. For the actual ξ , all odd Li signs, even eventual ones, are RH-equivalent (Theorem 155A.2). They are not the already positive boundary rung values.

Beta filtering $\mu_j \mapsto b_j^k \mu_j$ makes every fixed block with positive diagonal positive at sufficiently large depth. Only one depth fixed before all ranks retains the criterion (Section 104A). Signed recovery uses $2m+1$ observations for λ_{2m+1} ; positive outputs alone need not give a positive value. Section 166E controls common-source error at positive scale, not the regularized boundary of Section 155B.

An explicit positive comparison. Section 155C now constructs

$$K_N = R_N - D_N, \quad R_N \succ 0, \quad c_* = \frac{\pi}{4} + \frac{\log 2}{2} - 1. \quad (15.7)$$

The reserve is a Catalan-density Gram form weighted by a resolvent trace of the even triangular sine modes. Its linear anchor is c_* rather than λ_1 ; the full cost $(c_* - \lambda_1)(2 \min(r, s) + 1)$ stays in the arithmetic defect. The original positive scalar reserve is indefinite as a matrix already

at rank two. All-rank domination $D_N \preceq R_N$ remains unproved. Section 155D proves that any finite, polynomial, or all-rate subexponential upper relative bound would suffice. Under RH the upper extreme tends to one and the absolute norm grows linearly; a nonreal folded point forces both signs at an exponential rate. Only a constant absolute bound is ruled out. Section 155E's cosine basis makes the compensation δI and the remaining matrix explicit in one curvature sequence.

The recurring diagonal pictures now have a precise crosswalk:

construction	diagonal operation	exact value or object
factorial extension (§R3)	identify the two input coordinates	the triangular value $T(x)$
Widder array (§R13)	select $(n, k) = (j - 1, j)$	$F_{j-1,j} = W_j$
boundary Hankel matrix	set $i = j$	$\mu_{2i} = W_{2i+1}(0)/(4i + 1)!$
positive-node Löwner matrix	coalesce the two nodes	$h'(x_i) = W_1(x_i)$

Each picture records its own exact specialization. The derivative and moment identities above supply the links between them; matching diagonal values alone does not settle the off-diagonal source comparison.

R16. What L_Γ and L_P actually mean

Split the safe-axis formula (9.5) as

$$S_\xi(x) = \frac{1}{x} + G(x) - P(x) \quad (16.1)$$

where

$$G(x) = \frac{\psi((1+R)/4) - \log \pi}{2R} \quad P(x) = \frac{1}{R} \sum_{n \geq 2} \frac{\Lambda_{\text{vM}}(n)}{n^{s_x}} \quad R = \sqrt{1+4x} \quad (16.2)$$

Define the scalar channel functions

$$h_\Gamma(x) = xG(x) \quad h_P(x) = xP(x) \quad h(x) = 1 + h_\Gamma(x) - h_P(x) \quad (16.3)$$

L_Γ and L_P are the ordinary Löwner divided-difference matrices of the Gamma channel and the prime channel. Explicitly,

$$[L_\Gamma]_{ij} = \begin{cases} \frac{h_\Gamma(x_i) - h_\Gamma(x_j)}{x_i - x_j}, & i \neq j \\ h'_\Gamma(x_i), & i = j \end{cases} \quad (16.4)$$

and the same formula with h_P gives L_P . Since the constant 1 drops out of divided differences,

$$\boxed{\mathcal{L}_h = L_\Gamma - L_P} \quad (16.5)$$

The open statement is therefore a comparison:

$$\boxed{c^*(L_\Gamma - L_P)c \geq 0 \quad \text{for every finite positive node set and every } c} \quad (16.6)$$

Neither channel is asserted positive separately. In fact L_Γ already has a negative 1×1 value near $x = 0$:

$$\lim_{x \downarrow 0} h'_\Gamma(x) = -\frac{\gamma_E + \log(4\pi)}{2} < 0 \quad (16.7)$$

Completion is therefore cancellation-first. The theorem, if proved, must control the difference rather than dominate a negative prime matrix by an independently positive Gamma matrix.

R17. The Gamma triangular scaffold—and why it is not L_Γ

Antisymmetrize the Gamma logarithmic derivative across the two reflection sheets. The result is the exact Cauchy transform

$$\mathfrak{G}_\Delta(q) = \frac{1}{2} \sum_{m=0}^{\infty} \frac{1}{q + 2T_{2m}} \quad (17.1)$$

Its poles are

$$q = -2T_{2m} = 0, -6, -20, -42, -72, \dots \quad (17.2)$$

and its normalized form has an all-order positive Löwner Gram representation. This is a genuine triangular theorem. It is nevertheless a different object from the one-sheet safe-axis h_Γ in (16.3). In the completed function, the elementary and zeta terms cancel every pole of (17.1). Substituting the positive scaffold for L_Γ would therefore discard the very completion coupling that the source problem requires.

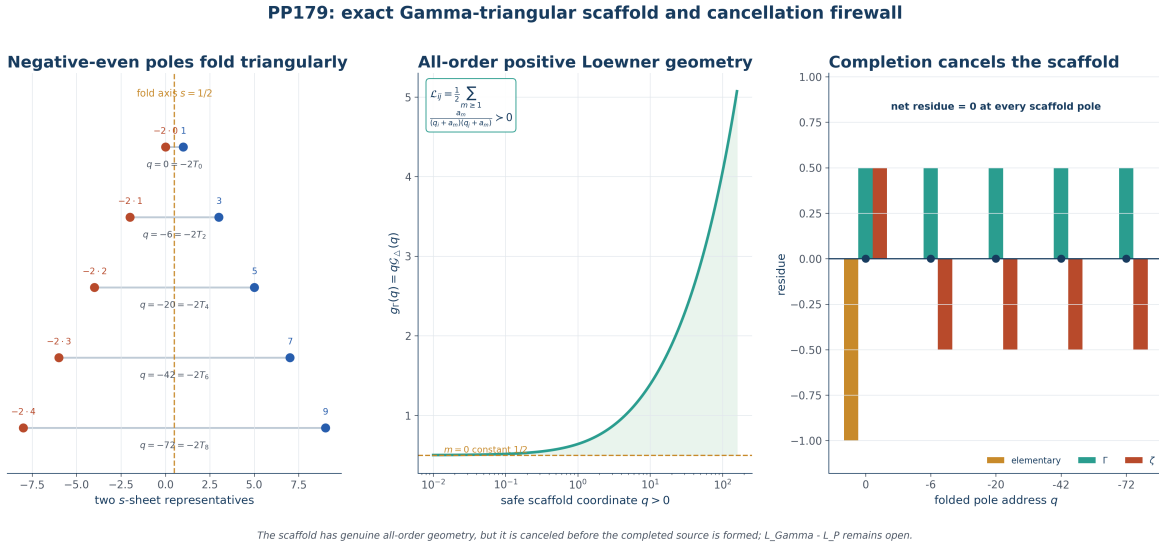


Figure 18: The Gamma triangular scaffold is positive before completion; completion cancels its apparent triangular poles.

The quarter shift makes this normalization explicit: $C(q) = \Gamma(s/2)\Gamma((1-s)/2)$, $q = s(1-s)$, satisfies $-(\log C)' = 2G_\Delta$. Dossier Section 133A derives its even-triangular product and a positive Li comparison model; neither replaces the completed source.

R17A. The completed spectral zeta and its source signature

The sequence $A_n = 1/(2T_{2n})$ of (TR.2) and the folded Riemann sequence define two different spectral zeta functions:

$$Z_A(p) = \sum_{n \geq 1} (2T_{2n})^{-p}, \quad \mathfrak{Z}_\xi(p) = \sum_{[\rho]} m_\rho q_\rho^{-p} = \mathcal{Z}(p; 1/4) \quad (\text{VZ.1})$$

Both series converge absolutely for $\Re p > 1/2$. The first is built from positive triangular numbers. The second uses the principal powers of possibly complex, conjugate-paired q_ρ ; positivity of those locations is exactly the RH question. Their common critical exponent does not identify their spectra.

For $1/2 < \Re p < 1$, the scalar Mellin resolvent identity gives

$$\mathfrak{Z}_\xi(p) = \frac{\sin \pi p}{\pi} \int_0^\infty x^{-p} S_\xi(x) dx = \frac{\sin \pi p}{\pi} \int_1^\infty [s(s-1)]^{-p} \frac{\xi'(s)}{\xi(s)} ds \quad (\text{VZ.2})$$

In the second integral $x = s(s-1) = 2T(s-1)$ and $dx = (2s-1)ds$: the source Jacobian cancels exactly. Completion must be combined before integration near $s = 1$; its separate elementary and prime poles cancel there.

Subtracting the large- x terms of (OP.1) continues this expression across the critical exponent. With $p = 1/2 + \varepsilon$,

$$\mathfrak{Z}_\xi(1/2 + \varepsilon) = \frac{1}{8\pi\varepsilon^2} - \frac{\log(2\pi)}{4\pi\varepsilon} + O(1), \quad \mathfrak{Z}_\xi(0) = \frac{7}{8} \quad (\text{VZ.3})$$

These are classical formulas of Voros [56, equations (40)–(41)], recovered here from the completed source. The value at zero is an analytic continuation value, not the ordinary trace of an infinite identity operator. The two Laurent coefficients test more than the exponent $1/2$ alone.

Voros normalizes his completed function as $\Xi_V = 2\xi$, so $\Xi_V(0) = \Xi_V(1) = 1$. This normalization leaves logarithmic derivatives unchanged but matters when comparing determinants.

R17B. Regularized triangular values: the fraction sequence

The continuation of (VZ.1) has a particularly simple triangular relation at nonpositive integers. Let the signed Euler numbers be defined by

$$\operatorname{sech} t = \sum_{j \geq 0} E_{2j} \frac{t^{2j}}{(2j)!} \quad E_0, E_2, E_4, E_6, E_8 = 1, -1, 5, -61, 1385 \quad (\text{TV.1})$$

Triangular trace identity. For every integer $m \geq 0$, the analytic continuations satisfy

$$\mathfrak{Z}_\xi(-m) = \frac{1}{2}\delta_{m0} + \frac{(-1)^{m+1}}{2}Z_A(-m) \quad (\text{TV.2})$$

The first values make both the sign pattern and the factor of two visible:

m	completed value $\mathfrak{Z}_\xi(-m)$	triangular value $Z_A(-m)$
0	7/8	-3/4
1	-1/16	-1/8
2	-1/16	1/8
3	-5/32	-5/16
4	-13/16	13/8
5	-227/32	-227/16

These are finite regularized values of divergent power sums. The negative signs do not contradict positivity of an ordinary positive spectrum: analytic continuation is not a positive summation operation.

Proof. The centered triangular identity gives

$$2T_{2n} = 4 \left[\left(n + \frac{1}{4} \right)^2 - \frac{1}{16} \right] \quad (\text{TV.3})$$

Expanding in the constant shift and continuing by the Hurwitz zeta function yields, at $p = -m$,

$$Z_A(-m) = 4^m \sum_{j=0}^m \binom{m}{j} \left(-\frac{1}{16} \right)^j \zeta \left(-2(m-j), \frac{5}{4} \right) \quad (\text{TV.4})$$

Here the Hurwitz series is being continued as a family before the integer is substituted. The Bernoulli-polynomial and Hurwitz identities [2, §25.11]

$$\begin{aligned} \zeta(-2r, a) &= -\frac{B_{2r+1}(a)}{2r+1} \\ B_{2r+1}(1/4) &= -\frac{(2r+1)E_{2r}}{4^{2r+1}} \\ \zeta(-2r, 5/4) &= \frac{E_{2r}-4}{4^{2r+1}} \end{aligned} \quad (\text{TV.5})$$

reduce (TV.4) to a finite rational sum. Independently, the completed Stirling expansion in (VZ.2), or Voros's trace formula [56, §6.1 and Table 1], gives

$$\mathfrak{Z}_\xi(-m) = \delta_{m0} - \frac{1}{2 \cdot 4^{m+1}} \sum_{j=0}^m (-1)^j \binom{m}{j} E_{2j} \quad (\text{TV.6})$$

Substitution proves (TV.2), including the separate constant term at $m = 0$. Thus the result is an exact cross-identification of classical continuation formulas with our triangular scaffold, with no claim of literature priority.

Replacing p by -1 before continuing would suggest $4\zeta(-2) + 2\zeta(-1) = -1/6$. The continuation of $Z_A(p)$ instead gives $Z_A(-1) = -1/8$. In an uncentered binomial continuation a coefficient vanishing at $p = -1$ multiplies a zeta pole and leaves $+1/24$. Equation (TV.4) keeps this contribution correctly. Formal linearity between different regularization families would lose it.

The value $\zeta(-1) = -1/12$ of Dossier §172 reappears in that tempting calculation; it does not by itself define the continuation of a quadratic triangular family.

The identity at integers does not assert $\mathfrak{Z}_\xi(p) = \frac{1}{2}(-1)^{p+1}Z_A(p)$ as a function of p . In fact their poles at $p = 1/2$ have different orders. It also does not assert that a completed zero equals a triangular scaffold pole.

R17C. The odd-coordinate pole ladder and the determinant

The shifted family makes another coefficient sequence visible. At $p = 1/2 - m$, the coefficient of the double pole of $\mathcal{Z}(p; v)$ is

$$C_m(v) = \frac{1}{8\pi} \frac{\Gamma(m+1/2)}{m!\Gamma(1/2)} v^m = \frac{1}{8\pi} \binom{2m}{m} \left(\frac{v}{4}\right)^m \quad (\text{PC.1})$$

This follows by shifting the leading double pole of the centered family [56, equations (91)–(94)]. At $v = 1/4$, write $C_m(1/4) = c_m/(8\pi)$. Then

$$c_m = \frac{\binom{2m}{m}}{16^m}, \quad c_0, c_1, c_2, c_3, c_4 = 1, \frac{1}{8}, \frac{3}{128}, \frac{5}{1024}, \frac{35}{32768} \quad (\text{PC.2})$$

Figure 14 makes this pole chain explicit: $c_m = (-1)^m c_{2m,m}/16^m$, and $C_m(v) = (-1)^m c_{2m,m}(v/4)^m/(8\pi)$. Here the one-index c_m denotes the scaled pole coefficient, while the two-index $c_{k,j}$ denotes a signed grid entry. In particular, the value $c_0 = 1$ uses the newly printed grid seed $c_{0,0} = +1$.

The recurring odd index has a direct coefficient role:

$$\frac{c_{m+1}}{c_m} = \frac{2m+1}{8(m+1)} = \frac{j_m}{8(m+1)} \quad (\text{PC.3})$$

Compare the two recurrences horizontally, with $m \geq 1$ in the Widder row:

$$\underbrace{W_{m+1} = -j_m W'_m - x W''_m}_{\text{Widder differential ladder}} \quad \underbrace{c_{m+1} = \frac{j_m}{8(m+1)} c_m}_{\text{central-binomial pole ladder}} \quad (\text{PC.4})$$

They expose the same odd integer $2m + 1$, through different operations. One recurrence does not prove positivity of the other. A related determinant count is exact rather than heuristic: a Vandermonde on n nodes scales with degree T_{n-1} , and for confluent multiplicities m_i the surviving degree is $T_{n-1} - \sum_i T_{m_i-1} = \sum_{i < j} m_i m_j$. Raw derivative columns also carry $\prod_i \prod_{j=0}^{m_i-1} j!$; Taylor-normalized jets remove that factor. This is a bookkeeping check for confluent determinants, not a source sign. At the first lower pole, for example,

$$3_\xi(-1/2 + \varepsilon) = \frac{1}{64\pi\varepsilon^2} - \frac{3\log(2\pi) + 4}{96\pi\varepsilon} + O(1) \quad (\text{PC.5})$$

There is also a logarithmic companion to (TV.2):

$$\boxed{Z'_A(0) = -\frac{1}{2}\log(2\pi), \quad 3'_\xi(0) = \frac{1}{4}\log(8\pi) = \frac{1}{2}\log 2 - \frac{1}{2}Z'_A(0)} \quad (\text{PC.6})$$

For completeness, differentiating the centered Hurwitz expansion of Z_A at zero gives

$$\begin{aligned} Z'_A(0) &= \frac{3}{4}\log 4 + 2\zeta'(0, 5/4) + \sum_{r \geq 1} \frac{\zeta(2r, 5/4)}{r16^r} \\ &= \frac{3}{4}\log 4 - \log(2\pi) + \log \Gamma(3/2) + \log \Gamma(1) \\ &= -\frac{1}{2}\log(2\pi) \end{aligned} \quad (\text{PC.7})$$

The Gamma product identity sums the absolutely convergent series in the first line, using $\zeta'(0, a) = \log \Gamma(a) - \frac{1}{2}\log(2\pi)$ [2, equation 25.11.18]. Voros gives the completed value in (PC.6) [56, equation (41)]. Both statements concern specified regularized determinants, not ordinary products of infinitely many positive numbers.

More strongly, the full shifted derivative is

$$\boxed{\partial_p \mathcal{Z}(p; x + 1/4)|_{p=0} = \frac{1}{4}\log(8\pi) - \log \frac{\xi(s_x)}{\xi(1)}} \quad (\text{PC.8})$$

Indeed, differentiating the left side in x gives $-S_\xi(x)$; its value at $x = 0$ is (PC.6). Thus a proposed positive model must match the full x -dependent function on the safe axis, or its logarithmic derivative together with the normalization at $x = 0$. The determinant $\xi(s_x)/\xi(1)$ is entire in x ; its logarithm is not entire. Matching a finite list of regularized constants does not establish this identity.

R17D. What the triangular–Volterra benchmark establishes

The scaffold can be enlarged to have the correct critical pole order. Let A be the diagonal with entries $A_n = 1/(2T_{2n})$ from (TR.2), and let B_a have eigenvalues $[\pi^2(n+a)^2]^{-1}$, $n \geq 0$, $a > 0$. Then

$$Z_{A \otimes B_a}(p) = Z_A(p) \pi^{-2p} \zeta(2p, a) \quad (\text{BM.1})$$

Keep the auxiliary model and completed source distinct

TRIANGULAR-VOLTERRA BENCHMARK	COMPLETED RIEMANN SOURCE
Positive model	$S_\xi(x)$ for every $x > 0$
Specified scalar calibrations	Gamma-prime compensation
Its own measure and spectral zeta	Exact equality still required

A matching coefficient or scalar is a calibration, not a function identity.

Figure 19: Two spectral objects: the triangular–Volterra benchmark can match specified scalar data, whereas an exact realization of S_ξ must match the whole function and its completed source. Calibration does not supply that equality.

Define the convergent constant

$$C_\Delta = \frac{\gamma_E - \log 2}{2} + \sum_{n \geq 1} \left(\frac{1}{\sqrt{2T_{2n}}} - \frac{1}{2n} \right) \quad (\text{BM.2})$$

The double-pole coefficient of (BM.1) agrees with (VZ.3). Its simple-pole coefficient agrees exactly when

$$\boxed{\psi(a_*) = \log 2 + 2C_\Delta, \quad \frac{7}{4} < a_* < 2} \quad (\text{BM.3})$$

Strict monotonicity of ψ gives uniqueness. The bracket is supported by an exact rational interval certificate; $a_* \approx 1.75164355$ is only a numerical orientation. It is not the exact quarter-step $7/4$.

At zero, however,

$$Z_{A \otimes B_{a_*}}(0) = \frac{3}{4}(a_* - 1/2), \quad Z_{A \otimes B_{a_*}}(0) - \frac{7}{8} = \delta := \frac{3a_* - 5}{4} \in (1/16, 1/4) \quad (\text{BM.4})$$

An exact infinite-row adjustment matches this coefficient: replace the first row $A_1 B_{a_*}$ by $A_1 B_b$, where $b = a_* + \delta = (7a_* - 5)/4$. Its zeta correction is

$$A_1^p \pi^{-2p} [\zeta(2p, b) - \zeta(2p, a_*)] \quad (\text{BM.5})$$

The correction is regular at $p = 1/2$ and equals $-\delta$ at $p = 0$. The row perturbation has entries $O(n^{-3})$ and belongs to $\mathcal{S}_p$ for $p > 1/3$; it is infinite rank. Replacing a finite list of positive

entries by another list of the same length leaves all three regularized data unchanged. By choosing a sufficiently long list, its sum can also be adjusted to λ_1 while the untouched tail stays fixed.

Consequently positive models can match the two critical Laurent coefficients, the value $7/8$, and the trace λ_1 . The benchmark is exact; it does not select the source: redistributing two positive replacement entries at fixed sum changes $\text{Tr } D^2$ and therefore changes the resolvent. The derivative (PC.6), lower poles such as (PC.5), and the exact fractions in (TV.2) are additional tests. The decisive target remains (PC.8) for every x , together with an independent proof of positivity.

The raw triangular–Volterra tensor is still easier to exclude. For $(Vf)(u) = \int_0^u f(t)dt$ on $L^2[0, 1]$, V^*V has kernel $1 - \max(u, v)$ and trace $1/2$. Thus

$$\text{Tr}(A \otimes V^*V) = \frac{1 - \log 2}{2} \neq \lambda_1 \quad (\text{BM.6})$$

Its positivity is exact; its scalar source is different. No inference here requires the particular tensor architecture to be unique.

R17E. What the continuation retains about primes

The regularized fractions and polar coefficients are unusually explicit because $\log \zeta(s)$ is exponentially small as real $s \rightarrow +\infty$. It contributes no term to the algebraic Stirling expansion used in (TV.6). Therefore even an entire ladder of those asymptotic coefficients does not determine the prime-dependent remainder of the source.

Voros supplies a complementary integral that retains that remainder. Let $\mathcal{Z}_c(p) = \mathcal{Z}(p; 0)$ and distinguish the linear half-step zeta function

$$\mathcal{S}_{1/2}(z) = \sum_{n \geq 1} (2n + 1/2)^{-z} = 2^{-z} \zeta(z, 5/4) \quad (\text{VP.1})$$

For $0 < \Re p < 1/2$, his regular-integrand continuation is

$$\begin{aligned} \mathcal{Z}_c(p) = & -\frac{\mathcal{S}_{1/2}(2p)}{2 \cos \pi p} \\ & + \frac{\sin \pi p}{\pi} \int_0^\infty t^{-2p} \left[\frac{\zeta'}{\zeta}(1/2 + t) + \frac{1}{t - 1/2} \right] dt \end{aligned} \quad (\text{VP.2})$$

The apparent singularity of the bracket at $t = 1/2$ is removable: the zeta logarithmic derivative has residue -1 at its pole. Keep the two terms inside the bracket combined. This is an unconditional continuation formula [56, equation (74)], with a different centered parameter from $\mathfrak{Z}_\xi(p) = \mathcal{Z}(p; 1/4)$.

Equation (VP.2) is useful for deriving a completed source remainder before seeking a sign. It does not display a positive kernel. The prime series for $\zeta'/\zeta(1/2 + t)$ converges only when $t > 1/2$, so termwise use of that series throughout the integral is invalid. Voros's separate

raw prime-cutoff resummation in equation (79) explicitly invokes RH; it cannot serve as an unconditional forcing step here.

The same center gives another odd-index sequence [56, equation (81)]:

$$\boxed{(\log |\zeta|)^{(2m+1)}(1/2) = \frac{(2m)!}{2}(2^{2m+1} - 1)\zeta(2m+1) + \frac{\pi^{2m+1}}{4}|E_{2m}|, \quad m \geq 1} \quad (\text{VP.3})$$

For example, the third and fifth derivatives are $7\zeta(3) + \pi^3/4$ and $372\zeta(5) + 5\pi^5/4$. These are derivatives in the real s direction at $1/2$. They express the vanishing odd derivatives of $\log \xi$ at its reflection center. They do not fix the even derivatives or the all-node Löwner sign.

The first Stieltjes cumulant is $\gamma_1^c = \gamma_1 + \gamma_E^2/2 \approx 0.093773116$ [56–57]. The normalization is Li's. These conventions govern the sequence tables.

R17F. The completed Bernstein row

Fix one prescribed scale $a > 0$ and define the completed derivative row

$$\boxed{B_{N,j}(a) = \frac{a^j}{j!(N-j)!} F_{j,N-j}(a), \quad 0 \leq j \leq N.} \quad (\text{BR.1})$$

With $\theta = a/(a+q)$, each folded zero contributes a Bernstein row,

$$B_{N,j}(a) = \sum_{[\rho]} \frac{m_\rho}{a+q_\rho} \binom{N}{j} \theta_\rho^j (1-\theta_\rho)^{N-j}. \quad (\text{BR.2})$$

The scalar Widder carrier is the fold $t_a(q) = 4\theta(1-\theta)$; the full row retains θ and $1-\theta$ separately. Its signed mass is exactly conserved,

$$\sum_{j=0}^N B_{N,j}(a) = S_\xi(a), \quad \mathcal{V}_N(a) = \sum_j |B_{N,j}(a)| \geq S_\xi(a). \quad (\text{BR.3})$$

The existing scalar ladder sits on the central entries: $B_{2k-1,k-1} = a^{k-1}W_k/[(k-1)!k!]$. Thus the source-certified $W_1, \dots, W_6$ are visible inside the row, but no finite set of central entries controls its total variation.

Section 164 proves the ordinary root-growth limit. Consequently RH is equivalent, at one fixed $a > 0$, to the still-open source estimate

$$\boxed{\forall \varepsilon > 0 \exists C_{a,\varepsilon} < \infty \forall N : \quad \mathcal{V}_N(a) \leq C_{a,\varepsilon}(1+\varepsilon)^N.} \quad (\text{BR.4})$$

The verified-height theorem makes the row positive over an enormous finite prefix; (BR.4) is an all-degree statement and is not supplied by that prefix.

R17G. The same row as a positive energy

The Bernstein coefficients have an exact Laguerre realization

$$\mathcal{Q}_N(t; a) = \sum_{j=0}^N B_{N,j}(a) L_j^{(0)}(t), \quad \mathcal{E}_N(a) = \int_0^\infty e^{-t} |\mathcal{Q}_N(t; a)|^2 dt = \sum_{j=0}^N B_{N,j}(a)^2. \quad (\text{BE.2})$$

Hence $\sqrt{\mathcal{E}_N} \leq \mathcal{V}_N \leq \sqrt{N+1} \sqrt{\mathcal{E}_N}$. Theorem 164.2 gives $\mathcal{E}_N(a) \sim \mathcal{K}(a) \mathcal{R}(a)^{2N} / \sqrt{N}$, where $\mathcal{R}(a) = \sup_q (a + |q|) / |a + q|$. Under RH the energy decays like $N^{-1/2}$; any off-line folded pair forces exponential growth. The source obligation is therefore equivalently

$$\boxed{\forall \varepsilon > 0 \exists C_{a,\varepsilon} < \infty \forall N : \quad \mathcal{E}_N(a) \leq C_{a,\varepsilon} (1 + \varepsilon)^{2N}.} \quad (\text{BE.3})$$

The Gamma channel has a finite signed Stieltjes variation, so §166B isolates the same open condition in the full prime source. At the concrete scale $a = 2$ it becomes

$$\boxed{\forall N \geq 0 : \quad \mathcal{E}_N[P](2) \leq \left(1 + \log 2 + \frac{\pi}{6}\right)^2.} \quad (\text{BE.5})$$

Theorem 166B.1 proves that this all-degree cap is RH-equivalent; it does not prove the cap. The full derivations of the Bernstein involution, Pascal Gram matrix and energy asymptotics are archived in the version chain of this record; this Reader keeps the objects and the exact unsupported line.

R17H. What the prime-cutoff attack proves

The cap in (BE.5) is a statement about the full prime source at every degree. Dossier §166C examines the natural attempt to pass to it from finite Euler sums P_X . The sums include prime powers $n \leq X$. For each fixed degree their derivatives converge to those of P . That convergence is not uniform over all degrees.

The sharp distinction appears in the last Bernstein coefficient:

$$\boxed{B_{N,N}[P](a) \rightarrow \frac{1}{a}, \quad B_{N,N}[P_X](a) \rightarrow 0 \quad (X \text{ fixed})} \quad (\text{CUT.1})$$

Both statements are unconditional. The full endpoint comes from the pole $1/x$ after completion; the finite sum has only its signed continuous cut measure. Their energy-norm distance therefore has lower limit at least $1/a$. A fixed cutoff cannot approximate all degrees, even if RH is true. The positive contributions to this endpoint define an exact probability distribution on prime powers. Theorem 166C.3 proves that their logarithms have center $(N+1)/a$, variance $(N+1)(2/a + 1/a^2)$, and a normal limit. At $a = 2$, half the endpoint mass is asymptotically captured near $X = \exp((N+1)/2)$; fixed normal quantiles occur at

$$\boxed{\log X_N = \frac{N+1}{2} + v\sqrt{\frac{5(N+1)}{4}}, \quad B_{N,N}[P_{X_N}](2) \rightarrow \frac{\Phi(v)}{2}} \quad (\text{CUT.2})$$

Here Φ is the standard normal distribution function. This theorem comes from the moving pole at $x = \omega(1 + \omega) = 2T(\omega)$ of the shifted source $-\zeta'/\zeta(s_x - \omega)/R_x$. It needs neither RH nor the prime number theorem. The triangular coordinate is part of the residue calculation.

There is a second, stronger restriction on the cutoff strategy:

$$\boxed{\sup_{X \geq 2, N \geq 0} \frac{\mathcal{E}_N[P_X](2)}{(1.01)^{2N}} = \infty} \quad (\text{CUT.3})$$

Theorem 166C.4 proves this by the exact row generating function and the pole of zeta at one. A uniform bound over all raw cutoffs would force bounded Euler partial sums at $s = 3/4 + i/4$, contradicting that pole by Abel summation. The obstruction is independent of zero locations.

Theorem 166D.1 now proves the full-row error bound for the prescribed schedule $X_N = 20^{N+1}$ at $a = 2$, with an explicit remainder tending to zero. Endpoint recovery alone is insufficient, but this entire-row approximation is proved. What remains open is the RH-equivalent bound $\sup_N \|\mathcal{Q}_N[P_{20^{N+1}}](\cdot; 2)\|_{L^2(e^{-t}dt)} < \infty$ of (166D.2). Section 166E transfers the same error to fixed-degree filtered outputs at a positive scale, not to unregularized boundary data.

Growing approximations at one fixed scale. Section 166D also proves whole-row convergence for $X_N = 13^{N+1}$. Direct Cauchy estimates in Section 166E control every recovered degree $2m \leq N$ at 5^{N+1} . These are different bounds. For the full degree-below- d mixed jet block, Section 166F uses the sharper constant $\Sigma_d = 9(9^d - 9^{-d})/128 + 3d/8$ and cutoff $X_d = 5^{2d-1}$. Its reserve-normalized common error tends to zero. The target there is a separately defined completed matrix at $a = 2$, not a boundary Li matrix. A polynomial upper bound on its largest normalized cutoff-defect eigenvalue would imply RH; that bound remains unproved. Neither convergence nor a finite computed prefix supplies it.

A separate route to the actual boundary. Section 166G forms the finite Taylor polynomial

$$\hat{S}_d(z) = \sum_{\ell=0}^{15d-1} \frac{S_{8^{15d}}^{(\ell)}(2)}{\ell!} (z-2)^\ell. \quad (\text{CUT.4})$$

It evaluates this polynomial at zero, never the raw cutoff. Both the completed Taylor remainder and the finite prime-tail error are controlled; the full boundary rank- d error, normalized by the same reserve, is $O(d\Theta^d)$ with $\Theta = 36(18/23)^{15} < 1$. The boundary defect's polynomial upper bound remains unproved. Independent coefficient rounding has an additional error budget.

R17I. Exact divisors and one denominator residual

Accurate boundary reconstruction leaves an arithmetic question: why should the actual signed source remain bounded? Sections 155F–155G test what information a proof must use. The regularized direct curvature formula keeps a polynomial counterterm and a finite endpoint. A PNT-size envelope alone, even with nonnegative integer weights, admits a fixed countermodel with superexponential positive even curvature. A second model retains actual prime-power support, any fixed exact prime prefix, positive Euler coefficients and the same envelope, yet has exponentially growing curvature on every fixed progression. Neither model retains the actual completed source or all its divisor identities.

The actual denominator is $\mathcal{B}(z) = z\zeta(1/(1-z))$, with its removable value $\mathcal{B}(0) = 1$. Its Taylor coefficients b_n^{den} obey the signed convolution (155G.3); they are not the Beta weights of Section 104A. They are not all positive: already $b_1^{\text{den}} = \gamma_E - 1 < 0$, and after the numerically positive run $b_2^{\text{den}}, \dots, b_{16}^{\text{den}}$ the directed enclosure $b_{17}^{\text{den}} < 0$ shows the sign changing again. Their square sum $\log(2\pi) - \gamma_E$, the constant of (GA.3) and (GA.6), does not supply a lower bound for the denominator. Section 155I connects this denominator to a different use of the exact arithmetic, rather than inferring positivity from its coefficients.

Write $\mu(d)$ for the Möbius function. The actual laws $\Lambda * 1 = \log$ and $\mu * 1 = \delta_1$ imply, for $N = \lfloor X \rfloor$,

$$\sum_{k=1}^N M\left(\log \frac{X}{k}\right) = \log(N!) - XH_N + N, \quad H_N = \sum_{k=1}^N \frac{1}{k}. \quad (\text{DIV.1})$$

Now take finitely supported real coefficients c_d with $\sum c_d/d = 0$ and set $D_c(s) = \sum c_d d^{-s}$, $h_c(x) = 1 - \sum c_d \lfloor x/d \rfloor$. Balance cancels the linear term in the floors. The resulting squared error is

$$\mathcal{N}(c) = \int_1^\infty h_c(x)^2 \frac{dx}{x^2} = \sum_{n \geq 1} \frac{h_c(n)^2}{n(n+1)}. \quad (\text{DIV.2})$$

Here $1/[n(n+1)] = 1/(2T_n)$ is the integral over one unit interval. The square follows the signed arithmetic sum; it does not replace each term by an independent absolute budget. If $c_d = \mu(d)$ for $d \leq K$, then $h_c = 0$ on $[1, K+1)$. Every zero $\rho = \sigma + i\gamma$ with $\sigma > 1/2$ would force

$$\mathcal{N}(c) \geq \frac{2\sigma - 1}{|\rho|^2} (K+1)^{2\sigma-1}. \quad (\text{DIV.3})$$

Section 155H proves this by Mellin evaluation at the zero and Cauchy–Schwarz on the remaining tail. Section 155J now fixes one explicit linear-taper family $V_N(s) = \sum_{d \leq N} \mu(d)(1 - d/N)d^{-s}$ and proves

$$\lim_{N \rightarrow \infty} \frac{\log(1 + U_N)}{\log N} = 2\Theta_\zeta - 1, \quad \Theta_\zeta = \sup_{\rho} \Re \rho. \quad (\text{DIV.3a})$$

Its balanced dyadic plateau has the same exponent. Hence RH is equivalent, for this specified family, to $U_N = O_\epsilon(N^\epsilon)$ for every $\epsilon > 0$; one fixed unbounded index set is enough. The proof uses the classical estimate for $1/\zeta$ in a zero-free half-plane [3] and the exact-prefix lower bound above. It does not prove boundedness or convergence under RH. A zero-free half-plane $\Re s > \theta_0$ caps the exponent at $2\theta_0 - 1$; for the half-plane assumed in §R13C that is $3/4$.

The same section also records a distinct scalar target $B_{\log}(x) = 1 - \sum_{d \leq x} (\mu(d)/d) \log(x/d)$. RH is equivalent to $B_{\log}(n) \leq C_\epsilon n^{-1/2+\epsilon}$ on the eventual integer tail. Section 155J now proves a logarithmic-chord interpolation theorem: it is enough to verify the corresponding bound at all sufficiently large fourth powers k^4 , or at the squared triangular samples T_k^2 . This is structured sampling, not permission to use an arbitrary sparse set. The canonical prefix family is also shown to have exact power exponent $2\Theta_\zeta - 1$, while the fixed taper has the unconditional bound $U_N \ll N \exp(-c\sqrt{\log N})$ for some $c > 0$. None is yet subpower unconditionally.

The two approaches meet in one exact identity. Put $\mathcal{C}_c(z) = D_c(1/(1-z))/z$, filling its removable value. Then

$$\begin{aligned} 1 - \mathcal{B}(z)\mathcal{C}_c(z) &= \sum_{n \geq 0} r_n(c)z^n, \\ r_n(c) &= \int_0^\infty e^{-u} h_c(e^u) L_n^{(0)}(u) du, \\ \mathcal{N}(c) &= \sum_{n \geq 0} |r_n(c)|^2. \end{aligned} \tag{DIV.4}$$

This is the normalized Hardy coefficient norm, proved by the complete Laguerre expansion in Section 155I. It is not the finite row energy $\mathcal{E}_N$ or the curvature sequence I_n . Section 155J further writes the same norm as a weighted sine integral and isolates the signed mixed Möbius sum $\mathcal{X}_N$, with $U_N - \mathcal{X}_N = \omega \log N + \omega_0 + o(1)$. Thus the closing arithmetic task may be stated as a one-sided subpower bound for $\mathcal{X}_N$, or as the scalar $B_{\log}$ decay above. Neither bound is established. A finite coefficient prefix still gives only a lower bound on the full norm.

Part VI. Translation defects and reflection contours

The defects record what an off-line zero would leave behind. Sections R18–R18B compare the translation, Beta and varying-endpoint forms; R19 gives stationary-symbol blindness; R20 gives the reflection contour and the missing conjugation. Sections R21–R21B connect strict one-node defects, heat and signed-row growth. The completed detectors vanish under RH, but none has been forced to vanish from the source.

R18. Positive defects with a negative scalar anchor

On the resolvent test span, the archimedean channel admits the exact translation-defect form

$$Q_{\Gamma}(F) = a_{\Gamma} \|F\|_2^2 + \frac{1}{2} \int_0^{\infty} \|(I - U_v)F\|_2^2 \frac{e^{v/2}}{2 \sinh v} dv \quad (18.1)$$

with

$$a_{\Gamma} = \frac{1}{2} \left(\psi\left(\frac{1}{4}\right) - \log \pi \right) = -\frac{\zeta'}{\zeta}\left(\frac{1}{2}\right) < 0 \quad (18.2)$$

The identity is exact; the right side is not manifestly nonnegative because the scalar anchor is negative. The equality in (18.2) uses analytic continuation at the functional-equation center. It is not the divergent prime mass $\sum \Lambda(n)/\sqrt{n}$.

The compact Beta measure $2(1-u) du$ of (4.5) and the Gamma defect density in (18.1) are different measures with different supports, total masses, and moment growth. Their shared triangular language does not make them interchangeable.

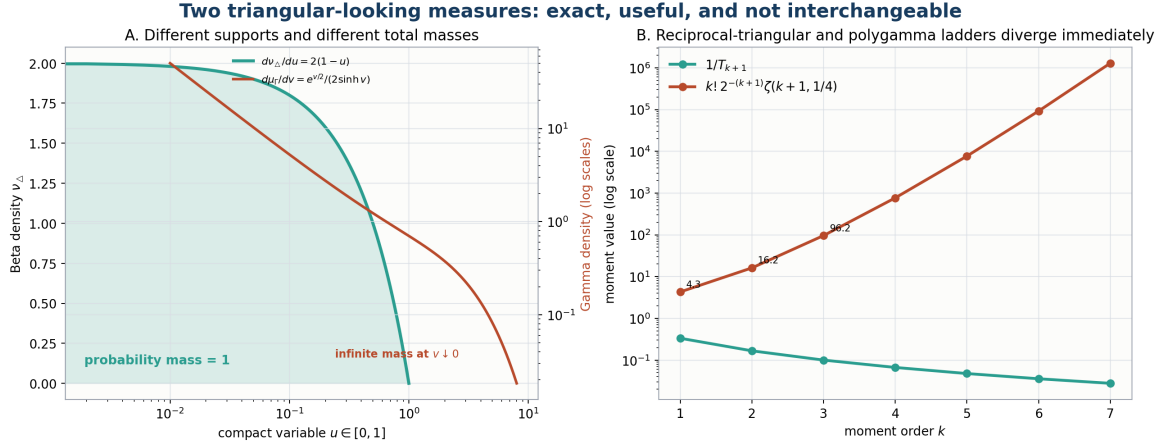


Figure 20: Compact Beta moments and the infinite Gamma translation-defect measure must remain separate.

R18A. Beta and Volterra forms side by side

The compact triangular moment measure and the Volterra operator are both positive, but they produce different quadratic forms. For $F \in L^2[0, 1]$, put

$$\mathcal{B}[F] = 2 \int_0^1 (1-u) |F(u)|^2 du \quad \mathcal{Q}[F] = 2 \|VF\|_2^2 \quad (\text{VG.1})$$

With $K(u, v) = 1 - \max(u, v)$, their exact difference is

$$\boxed{\begin{aligned} \mathcal{B}[F] - \mathcal{Q}[F] &= \int_0^1 (1-u)^2 |F(u)|^2 du \\ &\quad + \int_0^1 \int_0^1 K(u, v) |F(u) - F(v)|^2 du dv > 0 \end{aligned}} \quad (\text{VG.2})$$

for nonzero F . To check the coefficients, use $\int_0^1 K(u, v) dv = (1-u^2)/2$ and expand the square. The strict difference supplies an exact comparison, not an equality with the completed Gamma-prime form.

For logarithmic characters $e_L(u) = e^{2\pi i L u}$, use the inner product conjugate-linear in its first slot, and set $E(t) = \int_0^1 e^{2\pi i t u} du$. The Volterra Gram entries are

$$\boxed{Q(L, M) := 2 \langle V e_L, V e_M \rangle = \frac{E(M-L) - E(-L) - E(M) + 1}{2\pi^2 L M}} \quad (\text{VG.3})$$

The values at $L = 0$ or $M = 0$ are defined by continuous extension. In particular,

$$Q(L, L) = \frac{1 - \sin(2\pi L)/(2\pi L)}{\pi^2 L^2} \quad Q(0, 0) = \frac{2}{3} \quad (\text{VG.4})$$

The negative phases in (VG.3) are the conjugates of the positive phases; $Q(M, L) = \overline{Q(L, M)}$. Positivity follows from its Gram definition. Nevertheless, normalized adjacent entries satisfy

$$\frac{Q(\log n, \log(n+1))}{\sqrt{Q(\log n, \log n)Q(\log(n+1), \log(n+1))}} \rightarrow 1 \quad (\text{VG.5})$$

The fixed interval therefore leaves neighboring logarithmic frequencies strongly coherent. Positivity alone does not give the cancellation required by the completed source.

R18B. A varying-endpoint Gram candidate

One way to change that coherence is to let the interval length vary with the integer label. Define

$$\phi_n(u) = n^{-1/2} \mathbf{1}_{[0, n]}(u) e^{2\pi i (\log n) u} \quad J_L(a) = \int_0^L e^{2\pi i a u} du \quad (\text{EG.1})$$

Its exact Gram matrix is

$$K_{mn} = \langle \phi_m, \phi_n \rangle = \frac{J_{\min(m, n)}(\log(n/m))}{\sqrt{mn}} \quad K_{nn} = 1, \quad K_{nm} = \overline{K_{mn}} \quad (\text{EG.2})$$

For every fixed positive integer k ,

$$K_{n+k, n} = -\frac{k}{2n} + O_k(n^{-2}) \quad (\text{EG.3})$$

Indeed, $n \log(1 + k/n) = k - k^2/(2n) + O_k(n^{-2})$; the leading phase is an integer multiple of 2π . This gives a contrasting pair of adjacent limits: fixed-interval Volterra coherence tends to 1, whereas the varying-endpoint Gram entry tends to 0.

The estimate is for fixed k and is not a uniform bound on growing matrices. For any fixed signed nonzero integer k , its leading term is $-|k|/(2n)$; (EG.3) uses $k > 0$. Also, the 2π frequency scale and endpoint length must be transported together: removing 2π while leaving the endpoints unchanged destroys the integer-phase cancellation.

Candidate boundary. The Gram positivity in (EG.2) is proved. Section 161 now excludes its fixed ordinary tensor-norm translation lift as the completed realization, for finite sums and strongly convergent series. Singular form limits or a different source-defined realization remain open and must match the complete source, with a specified domain and topology.

For example, expanding a candidate norm involving $\phi_n \otimes (I - U_{\log n})F$ introduces mixed translations $\log(n/m)$. Equal reduced ratios must be grouped before a coefficient is declared noncancellable. The stronger obstruction in §161 uses the absolutely continuous Fourier density of the regular lift; mixed shifts alone do not prove a no-go theorem.

R19. Why stationary symbols are blind

Put

$$\Phi(s) = \frac{\xi'(s)}{\xi(s)}, \quad s = \sigma + it \quad (19.1)$$

Away from zero ordinates, $\xi(1/2 + it)$ is real, so

$$\Re \Phi\left(\frac{1}{2} + it\right) = 0 \quad (19.2)$$

In the distributional boundary value, a functional-equation pair at $\beta = 1/2 \pm \delta$ cancels exactly. The surviving stationary symbol is

$$\Omega(t) = \pi \sum_{\rho: \Re \rho = 1/2} m_\rho \delta_{\Im \rho}(t) \geq 0 \quad (19.3)$$

unconditionally. Thus a construction that collapses internally to this scalar multiplier has erased the off-line information. The no-go is scoped: it rejects premature stationary compression, not the translation covariance of the final Weil form.

The scalar-weight class is closed too, and by an inequality rather than a cancellation. For real $\alpha \neq 0$, $-\alpha g_F(v) = \frac{1}{2} \|(I - \alpha U_v)F\|_2^2 - \frac{1+\alpha^2}{2} \|F\|_2^2$, so rewriting the prime channel with per-frequency scalar weights $\alpha_m > 0$ forces a coefficient of $\|F\|^2$ equal to $\sum_m \lambda_m (\alpha_m + \alpha_m^{-1})/2 \geq \sum_m \lambda_m = +\infty$, with $\lambda_m = \Lambda(m)/\sqrt{m}$, because $\alpha + \alpha^{-1} \geq 2$. The divergence of the scalar defect is therefore not an artifact of the unit weight; it is forced by the arithmetic-geometric mean. The surviving class is the *operator*-weighted one, and it is open.

R20. Reflection contour and the missing conjugation

For a finite positive node set and real coefficients define

$$\Psi_X(q) = \sum_{i=1}^N \frac{c_i}{x_i + q} \quad \mathcal{L}_F(s) = q(s) \Psi_X(q(s))^2 \quad (20.1)$$

Use the explicitly meromorphic carrier $\mathcal{F}_X(s) = (1-s)\Psi_X(q(s))$, so $\mathcal{L}_F(s) = \mathcal{F}_X(s)\mathcal{F}_X(1-s)$. The real-frequency symbol is its boundary restriction $\widehat{F}(t) = \mathcal{F}_X(1/2+it)$. Here the convention is $\widehat{F}(t) = \int_{\mathbb{R}} F(u) e^{-itu} du$ for the real resolvent combination $F = \sum_i c_i f_{x_i}$ defined in (153.5). The positive-sign transform is $\overline{\widehat{F}(t)}$ and has numerator $1/2 + it$ in each summand. Only the meromorphic carrier is evaluated at complex zeros; a real-frequency Fourier formula is not silently continued there.

The test symbol is reflection-even, while Φ is reflection-odd:

$$\mathcal{L}_F(1-s) = \mathcal{L}_F(s) \quad \Phi(1-s) = -\Phi(s) \quad (20.2)$$

For

$$1 < \sigma_0 < \min_i \frac{1 + \sqrt{1 + 4x_i}}{2} \quad (20.3)$$

the exact folded zero form is

$$Q_X(c) = \sum_{[\rho]} m_\rho \mathcal{L}_F(\rho) = \frac{1}{2\pi i} \int_{(\sigma_0)} \mathcal{L}_F(s) \Phi(s) ds \quad (20.4)$$

At $s = 1/2 + it$,

$$\mathcal{L}_F\left(\frac{1}{2} + it\right) = |\hat{F}(t)|^2 \geq 0 \quad \Phi\left(\frac{1}{2} + it\right) \in i\mathbb{R} \quad (20.5)$$

The positive terminal object and the pairing are orthogonal. The critical-line integral is zero only as a symmetrically indented principal value; the integrand is not zero. The RH content lies in shifting the contour and collecting residues.

The type mismatch can now be stated without shorthand:

$$\underbrace{\mathcal{F}_X(\rho)\mathcal{F}_X(1-\rho)}_{\text{reflection; bilinear}} \quad \text{versus} \quad \underbrace{\mathcal{F}_X(\rho)\overline{\mathcal{F}_X(\rho)}}_{\text{conjugation; Hermitian}} \quad (20.6)$$

For a fixed real-coefficient test and $0 < \Re s < 1$, away from the test poles, their pointwise agreement is exactly

$$\mathcal{F}_X(s)\mathcal{F}_X(1-s) = |\mathcal{F}_X(s)|^2 \iff \sigma = 1/2 \text{ or } \Psi_X(q(s)) = 0 \quad (20.6a)$$

For example, nodes (1, 2, 3) and coefficients (1289, −5330, 4553) give

$$\Psi_X(q) = \frac{512[(q - 19/16)^2 + 1/4]}{(q+1)(q+2)(q+3)} \quad (20.6b)$$

which annihilates the synthetic off-line point $s = 1/4 + i$. This point is not asserted to be a zeta zero. A single multinode test can therefore hide an off-line orbit. The RH equivalence requires a separating family; a nonzero one-node carrier has no such accidental zero. A successful source construction must create the identification

$$\boxed{s \mapsto 1-s \quad \text{with} \quad s \mapsto \bar{s}} \quad (20.7)$$

without assuming RH.

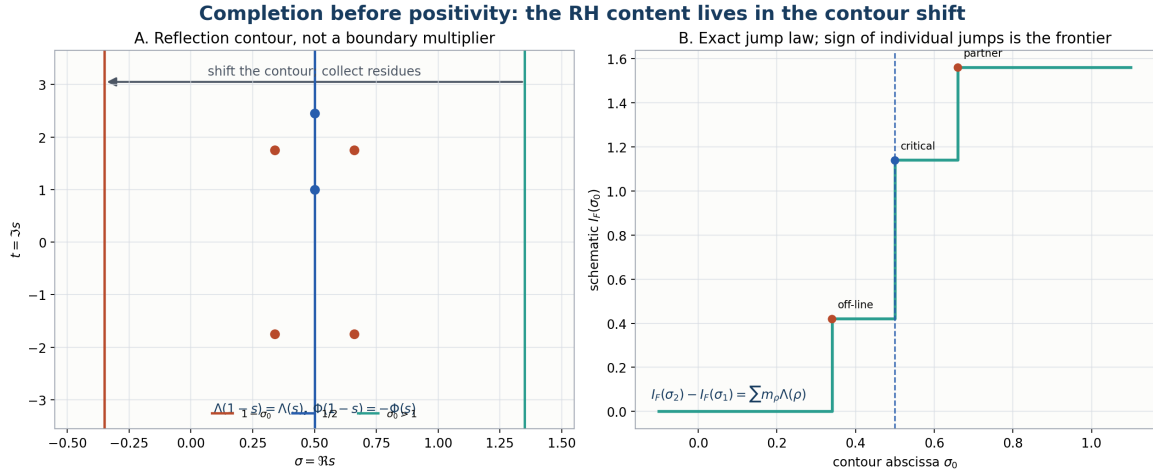


Figure 21: The reflection contour, principal-value center, and jump law. The plotted jump profile is schematic; the identity is exact.

R21. The one-node strict defect

For the one-node carrier $u_x(q) = q/(x + q)^2$ of (11.1), define the Hermitian comparison

$$\mathcal{H}_x = \frac{1}{2} \sum_{\rho \text{ all}} m_\rho |\mathcal{F}_x(\rho)|^2 \quad (21.1)$$

Pairing every zero with its reflected-conjugate partner gives the exact global square

$$\boxed{\mathcal{H}_x - W_1(x) = \frac{1}{4} \sum_{\rho \text{ all}} m_\rho \left| \mathcal{F}_x(\rho) - \overline{\mathcal{F}_x(1 - \rho)} \right|^2 \geq 0} \quad (21.2)$$

For this carrier the defect is individually strict for every off-line quartet, so equality is equivalent to RH. For a general multinode test, accidental agreement is possible (§R20).

The same one-node carrier produces a positive measure on zero abscissae. Put

$$w_x(s) = \frac{q(s)}{[x + q(s)]^2} \quad (21.3)$$

and group conjugate ordinates at each real part:

$$d\nu_x(\sigma) = \sum_{\beta} \left(\sum_{\Re \rho = \beta} m_\rho w_x(\rho) \right) \delta_\beta(d\sigma) \quad (21.4)$$

Then

$$d\nu_x \geq 0, \quad \nu_x(\mathbb{R}) = 2W_1(x) \quad (21.5)$$

The positivity is termwise after conjugate pairing. If $q = a + ib$, $a > 0$,

$$2\Re \frac{q}{(x+q)^2} = \frac{2[a(x+a)^2 + (a+2x)b^2]}{[(x+a)^2 + b^2]^2} > 0 \quad (21.5a)$$

The weights are absolutely summable: they are $O(\gamma^{-2})$ at large height and the zero-counting function is $O(T \log T)$. Thus grouping conjugate ordinates does not depend on a conditional ordering.

The topology must be stated with its closure:

$$\boxed{\text{Atoms}(\nu_x) = \{\Re \rho\} \quad \text{supp } \nu_x = \overline{\{\Re \rho : \xi(\rho) = 0\}}} \quad (21.6)$$

Reflection centers this measure at $1/2$. Its unnormalized centered second moment is

$$\boxed{M_{2,x} := \int \left(\sigma - \frac{1}{2}\right)^2 d\nu_x(\sigma) \geq 0 \quad M_{2,x} = 0 \iff \text{RH}} \quad (21.7)$$

The probability measure $\nu_x/[2W_1(x)]$ has variance $M_{2,x}/[2W_1(x)]$. Nonnegativity is automatic on the zero side; forcing this moment to vanish from the source is the hard direction.

Exact regularized Riesz/Green representations are available. With

$$U = \log |\xi| \quad d_x(s) = \left| \mathcal{F}_x(s) - \overline{\mathcal{F}_x(1-s)} \right|^2 \quad (21.8)$$

one has, as improper distributional pairings over admissibly truncated strips,

$$\boxed{\mathcal{H}_x = \frac{1}{4\pi} \langle \Delta U, |\mathcal{F}_x|^2 \rangle \quad \mathcal{H}_x - W_1(x) = \frac{1}{8\pi} \langle \Delta U, d_x \rangle} \quad (21.9)$$

Also, for

$$h_x^\perp(s) = \left(\Re s - \frac{1}{2} \right)^2 \Re \left(\frac{s(1-s)}{[x + s(1-s)]^2} \right) \quad (21.10)$$

$$\boxed{M_{2,x} = \frac{1}{2\pi} \langle \Delta U, h_x^\perp \rangle} \quad (21.11)$$

These are source representations; they do not provide the missing reverse sign. No one-variable meromorphic function can equal $|\mathcal{F}_x(s)|^2$ on an open set, since $\partial_{\bar{s}}|\mathcal{F}_x|^2$ is generically nonzero. The surviving source representation must therefore remain two-variable, nonlocal, distributional, or discrete.

For the one-dimensional source contour, begin with the meromorphic weight w_x in (21.3) and define, on zero-free vertical lines,

$$I_x(\sigma) = \frac{1}{2\pi} \lim_{T_j \rightarrow \infty} \int_{-T_j}^{T_j} w_x(\sigma + it) \Phi(\sigma + it) dt \quad (21.12a)$$

The heights T_j avoid zero ordinates and make the horizontal contour remainders vanish. On lines through zeros, symmetric indentation and midpoint boundary values specify the principal-value representative. The residue theorem then identifies that source contour with

$$I_x(\sigma) = -W_1(x) + \nu_x((0, \sigma)) + \frac{1}{2} \nu_x(\{\sigma\}) \quad (21.12)$$

Then

$$M_{2,x} = \frac{W_1(x)}{2} - 4 \int_{1/2}^1 \left(\sigma - \frac{1}{2} \right) I_x(\sigma) d\sigma \quad (21.13)$$

The first unsupported reverse forcing line is

$$\int_{1/2}^1 \left(\sigma - \frac{1}{2} \right) I_x(\sigma) d\sigma \geq \frac{W_1(x)}{8} \quad (21.14)$$

The positive zero measure gives the opposite inequality. An independent source proof of (21.14) would force equality and RH.

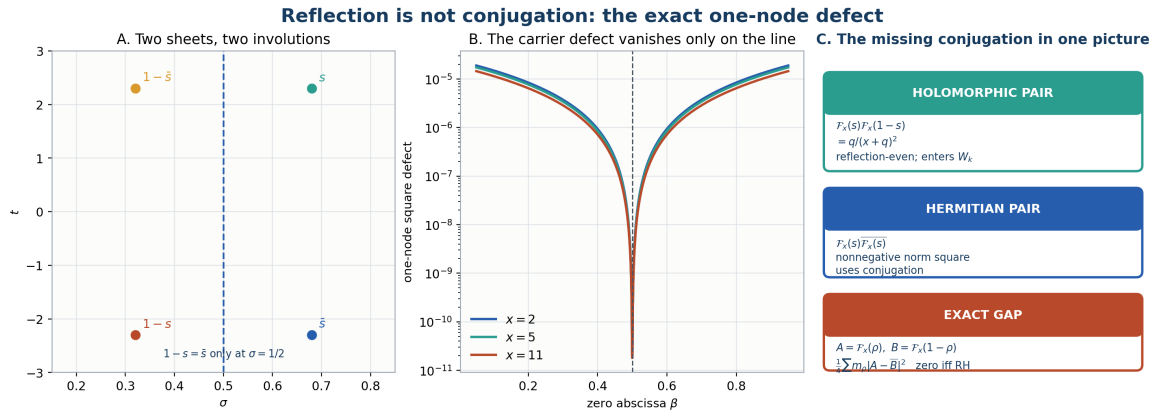


Figure 22: The two reflection sheets, the strict one-node defect, and the bilinear versus Hermitian pairings.

R21A. Strict defects and the Green boundary

The one-node reflection defect factors exactly:

$$s = \sigma + it$$

$$d_x(s) = |f(s) - \overline{g(s)}|^2 = (1 - 2\sigma)^2 \frac{|x + (1-s)\bar{s}|^2}{|x + q(s)|^4} \geq 0, \quad (\text{GM.1})$$

and vanishes precisely on $\sigma = 1/2$. Its Laplacian is strictly positive away from carrier poles. Therefore the Green identity for $U = \log |\xi|$ necessarily contains both bulk and boundary terms; adding a constant to U transfers mass between them while leaving the zero sum unchanged. A bulk sign alone cannot force the defect to vanish.

The heat-resolvent version is even shorter. For $q = A + ib$,

$$r_x = \frac{1}{x + A} - \Re \frac{1}{x + q} = \frac{b^2}{(x + A)|x + q|^2} \geq 0. \quad (\text{GM.3a})$$

The same transverse coordinate controls the higher moment sequence. If $M_{2m,x}$ is the $2m$ th centered abscissa moment, then $[M_{2m,x}/(2W_1(x))]^{1/(2m)}$ tends to the support radius $\sup_\rho |\Re \rho - 1/2|$. This is an exact support diagnostic, not a source-side upper bound.

R21B. Heat, transverse distance, and source-energy growth

For a nontrivial zero $\rho = \beta + i\gamma$ write $q = A + ib$. Then

$$b = \gamma(1 - 2\beta), \quad b^2 = 4\gamma^2(\beta - 1/2)^2. \quad (\text{HG.1})$$

The off-line heat defect $\mathcal{E}_H(h) = \sum m_\rho b_\rho^2 e^{-hA_\rho}$ vanishes for one (hence every) $h > 0$ exactly under RH. At fixed source scale $a > 0$, the Bernstein row sees the same transverse quantity through

$$\boxed{R_q(a)^2 - 1 = \frac{2ab^2}{(|q| + A)|a + q|^2} = \frac{2a(a + A)}{|q| + A} d_a(q).} \quad (\text{HG.4})$$

Thus the heat defect, the row-growth factor and the distance from the critical line are three readings of the same b^2 . Theorem 164.2 converts that geometry into the ordinary energy-growth limit. None of these exact detectors supplies the remaining source estimate; they identify what an off-line zero would force if it existed.

Part VII. Results and the research boundary

Section R22 records results with their quantifiers; R23 states the first unsupported source inequality; R24 maps the reading routes. Comparison positivity and finite certificates remain distinct from the all-order completed-source assertion.

R22. Results and their quantifiers

mathematical layer	established result	status, and what is still required
Triangular arithmetic	primitive, factorial, reciprocal, cyclic and Pell identities	PROVED Reader §§R1–R5E and the Dossier arithmetic chapters. EVIDENCE empirical spacing comparisons remain separate (§168).
Euler’s constant on the triangular coordinate	the mirror parity of Ramanujan’s expansion; $\sum_{k \geq 2} \zeta(k)/T_k = \log 2\pi - \gamma_E$ and its four readings; the simplex ladder; the pairing (GA.8) with λ_1	PROVED §R4A and Dossier §96A; classical in substance [95–109]. It carries no sign information about the zeros.
Completion and exact criteria	heat, Stieltjes, Widder, Hausdorff, Li and Loewner criteria; scalar curvature and admissible progressions	RH-EQUIVALENT Each retains its stated full quantifier; Sections 155D–155E and 166F–166G add growth targets, not their source bounds.
Source rungs	$W_1 - W_6 > 0$ globally from the source	PROVED analytic W_1 ; CERTIFIED computer-assisted $W_2 - W_6$, one certificate on two independent arithmetic backends (§R12, Dossier §74A). OPEN the independent $W_7 \rightsquigarrow F^{(14)}$ proof.
Verified-height rectangle	$F_{n,k} > 0$ for all $x > 0$, $n \leq K_H - 1$, $k \leq K_H$	CERTIFIED $K_H = 4,712,664,392,502$; includes $W_5, W_6 > 0$ with zero-assisted input (§R13).
Verified-height rectangle with a zero-free region	$F_{n,k} > 0$ for all $x > 0$, $n \leq K_H(c) - 1$, $k \leq K_H(c)$	CERTIFIED $K_H(c) = 4,772,432,051,943$ at $c = 5.558691$, with the published region [125] as a second input (§R13B).
Fixed-scale rectangle	$G_{n,k}(x) > 0$ for all $k \geq 0$, $0 < x \leq H^2/10^6$, $n + 1 \leq 3H/2$	CERTIFIED $n \leq 4,500,262,999,199$, zero-assisted, with the published zero count [130] as a second input (§R13C, Dossier Propositions 60A.6 and 60A.7).
Finite matrices	global order eight; rank twelve at $x = 56$	CERTIFIED with different quantifiers. OPEN global order nine and the all-node sign (§§92–93, 138).

mathematical layer	established result	status, and what is still required
Positive comparison and reserve growth	triangular sine projection, compensated Catalan reserve, exact linear/exponential defect alternatives	PROVED Sections 12A–12B, 61A, 95A, 155C–155D. OPEN the one-sided arithmetic upper bound.
Reflection and heat defects	exact nonnegative detectors; vanishing is RH-equivalent	RH-EQUIVALENT OPEN contour and Green representations exist; the reverse forcing signs do not (§§R20–R21B).
Completed and prime energy	exact rows, Pascal/Laguerre norm, boundedness equivalence and prime plateau	PROVED signed Gamma measure. RH-EQUIVALENT OPEN the full-prime all-degree cap (BE.5), §§163–166B.
Prime cutoffs and boundary reconstruction	whole rows at 20^{N+1} and 13^{N+1} ; shifted block at 5^{2d-1} ; actual boundary from degree $15d - 1$ and cutoff 8^{15d}	PROVED Sections 166C–166G. OPEN the uniform or polynomial source bounds; convergence alone supplies no sign.
Exact-divisor residual	Mellin/Hardy/Laguerre/sine norm, plateau/canonical exponents, scalar transfer and structured sampling	PROVED Sections 155H–155J. The fixed taper and canonical family have exponent $2\Theta_\zeta - 1$; fourth powers and T_k^2 suffice for the scalar criterion. OPEN the subpower mixed-sum bound or the required scalar upper decay.
Radius deficit	exact single-orbit remainder, two-sided chain, and the separation of Δ from its high-scale limsup	PROVED §§R13A, 48A. OPEN $\Delta < 1$, equivalently a uniform zero-free boundary strip.
Horizontal frontier	seven exact readings of $\beta_* = \sup_\rho \Re \rho$, and the sector index a zero-free half-plane would give	PROVED the readings and the implications (§R13C, Dossier §60A). OPEN every bound $\beta_* < 1$; a half-plane is claimed externally [128], is not verified here, and is used only as an assumption.
NO-GO theorems	scalar-Fourier, Gamma-sublattice, tensor-lift, large-sieve, cutoff-envelope and finite-prefix shortcuts	PROVED unconditional limitations collected once in §R25; the proofs are in the Dossier.

One entry in the second row now has a machine-checkable statement of record: the Li criterion has been formalized in Lean against the ambient library’s own Riemann-hypothesis predicate, stated without hypothesis binders and reporting only the three standard axioms [71]. It is recorded here as read and not built: the project was not compiled in the course of this work, so this is a report of someone else’s certificate and not a certificate of this volume. It formalizes the equivalence, and it asserts nothing about the sign of the coefficients.

A finite certificate proves its stated finite region. None replaces the all-order quantifier in an RH criterion. The table separates an open statement from an open independent proof of an already established sign.

R23. The first unsupported lines, by route

There is no proved reduction of all surviving routes to one source inequality. The matrix route begins with:

$$s = \sigma + it$$

OPEN *equivalent to RH; not proved here or anywhere in the Dossier*

$$\boxed{\begin{array}{c} \text{No source-side argument presently proves} \\ L_\Gamma - L_P \succeq 0 \\ \text{for every finite positive node set} \end{array}} \quad (23.1)$$

Equivalently, no source-side argument proves

$$\sum_{[\rho]} m_\rho \mathcal{L}_F(\rho) \geq 0 \quad (23.2)$$

for every rational-resolvent test. The surviving design target is a positive two-sheet form before compression that preserves reflection information, whose final compression recovers the reflection contour and the translation covariance of the Weil functional.

A distinct compact-window problem. Zhu [72] reports half-width 0.8; Liu [81] reports 1 and 17/16 plus a localization NO-GO beyond $\log 8/2$. Liu's manuscript is submitted, not peer-reviewed or on arXiv, and not yet externally reproduced. These are comparison results only: the rung transforms here are noncompact, so the fixed-window bounds do not transfer as stated.

At one node the same boundary is (21.14), or equivalently the missing independent upper sign in the Green identity for d_x . The source-rung prefix now reaches W_6 independently. The first scalar rung not yet proved directly from the Gamma-prime source is $W_7 = -x^{-12}(x^{13}W'_6)' > 0$, whose source expression reaches $F^{(14)}$. These are different compressions of the frontier; no finite source prefix replaces the all-order condition.

For a positive trace-class model D , the corresponding concrete target is

$$\boxed{\det(I + xD) = \frac{\xi(s_x)}{\xi(1)} \quad (x \geq 0)} \quad (23.3)$$

Differentiation would identify its resolvent with S_ξ and yield the positive Gram form in §R10A. The continued zeta identities and the triangular-Volterra benchmark constrain this target; they do not establish it. The ordinary strongly convergent tensor lift is ruled out in §161 and listed with the other finished limitations in §R25; singular-form and source-defined discrete realizations remain candidates.

Section R17F now supplies a specific source-defined discrete sequence. Its next source target is (BR.4): for one fixed $a > 0$, bound the completed row variation by $C_{a,\varepsilon}(1+\varepsilon)^N$ for every $\varepsilon > 0$ and every N . By the growth criterion of §164, quoted above, that bound at one prescribed $a > 0$ is not merely sufficient for RH but equivalent to it. Equivalently one may bound the exact Laguerre energy in (BE.3). Lemma 166A.1 supplies the elementary/Gamma growth estimate. The signed measure in §166B further reduces the question to the explicit bounded full-prime criterion (BE.5). That all-degree source inequality remains open. The heat identity

(HG.4) shows that the excess growth detects the same squared imaginary folded coordinate as the off-line heat defect. This gives a common coordinate for two distinct source obligations.

A proposed transfer, not an identified theorem. The growth exponent of Theorem 164.1 invites comparison with the regular-arithmetic-function framework [67–69] and its Tauberian/Volterra methods [73]. The differential rung recurrence $W_{k+1} = -j_k W'_k - x W''_k$ does not by itself verify the hypotheses of a rank-by-rank arithmetic transfer theorem. Applicability to (BR.4) is open. It is not claimed here in either direction; these external statements were read, not verified.

Two concrete source targets. The curvature already defined in Section 155B is $I_n = \int_0^\infty e^{-u} M(u) L_{n+1}^{(0)}(u) du$, with $M(u) = \Psi(e^u) - e^u + 1$. Section 155E proves that a one-sided polynomial upper bound on either parity separately would suffice. Its progression argument uses an explicit pole-angle condition to prevent cancellation; it does not license arbitrary sparse scalar sampling. Independently, Section 166F defines the cutoff defect at fixed scale $a = 2$ and proves its growing-block error tends to zero. The remaining alternatives are

$$\boxed{\begin{array}{ll} I_{2m} \leq C(m+1)^A & (m \text{ sufficiently large}), \\ \text{or } \hat{\beta}_{2,d}^+ \leq C'(1+d)^{A'} & (d \geq 1). \end{array}} \quad (23.4)$$

Each alternative requires fixed finite constants; each would imply RH. Neither is established. The odd-curvature alternative uses I_{2m+1} . Section 166G now gives a separate controlled boundary reconstruction; a polynomial upper bound on $\hat{\beta}_d^{\partial,+}$ would also suffice. Section R17I gives a fixed exact-divisor alternative: for the linear taper V_N , RH is equivalent to $U_N = O_\epsilon(N^\epsilon)$ for every $\epsilon > 0$ (even on one fixed unbounded index set). Equivalently one may attack the signed mixed sum $\mathcal{X}_N$. For the scalar $B_{\log}$ route, Section 155J proves that the eventual-integer premise may be replaced by all sufficiently large fourth powers, or by the squared triangular mesh T_k^2 , with the stated endpoint decay. Neither required arithmetic estimate is proved. The original full-row cap (BE.5), the bounded cutoff norms in (166D.2)/(166D.4), and the one-sided reserve growth theorem remain valid routes to the same obligation. The compensation, complete prime-error kernel and its regularization stay present throughout. A smaller cutoff, a positive comparison model, or a finite sign list does not supply the missing uniform source estimate.

R24. Proof map and reading routes

The Dossier chapters follow mathematical dependencies: triangular arithmetic and geometry, completion, flux and source rungs, moment and matrix criteria, arithmetic cancellation, and the completed discrete energy. Reader sections carry an **R** prefix and Dossier sections keep their existing identifiers, so section numbers need not increase at every chapter boundary; the convention is stated in full in the notation table of the study spine.

question	reader entry	full proof or comparison
What does the triangular primitive generate?	§§R1–R1A, R3–R5E	Dossier §§5–14, 76–78, 94–98 (including 95A and 96A), 156, 162, 167–168
How does Euler’s constant enter?	§R4A, (9.8)	§96A; compare §§155G–155I
How do reflection and the complex fold connect?	§§R6–R10	§§12A, 16–18, 20–31, 61A, 152–153
Which scalar signs are proved from the source?	§§R11–R13	§§32–38, 74–75, 55; §49 supplies the general negative-rung converse
Why do moments become matrices?	§§R14–R16	§§48–54, 104, 136, 145; finite determinant inequalities in §§85–93 and 138
Which positive Gamma models match the source?	§§R17–R17E	§§131–133; compare the source split in §54 and the reserve/defect in §155C
What remains in prime oscillation?	§R13 and the source split	§§56–61, 105–113, 118, 129; each route states its own limit and uniformity
What do finite Weil models establish?	§§R10A, R18–R18B	§§19, 44, 123–125; cutoff, band and prime limits remain separate
Where does conjugation enter?	§§R18–R21B	§§103, 137, 148–149, 154, 157–161
What is the fixed-scale source-energy task?	§§R17F–R17H, R21B	§§163–166E; the all-degree full-prime cap (166B.11) is open
What degree growth would force the source sign?	Sections R15, R23	Sections 155D–155E: reserve growth, curvature and progression proofs
Which cutoff approximates its own matrix target?	Sections R17H, R23	Sections 166D–166G: whole row, shifted block, and actual boundary reconstruction

THE COMPLETED OBJECT AND ITS RH CRITERIA

$$q_\rho = \rho(1 - \rho), \quad S_\xi(x), \quad h(x) = xS_\xi(x)$$

RH OPEN · Each criterion below retains its full quantifiers

FOLDED SUPPORT $q_\rho > 0$ for every folded zero Technical §§16–18	LI SEQUENCE $\lambda_n \geq 0$ for every $n \geq 1$ Reader §R15; technical §155
MOMENT MATRICES $[\mu_{i+j}] \geq 0$ for every size Technical §17	STIELTJES / HEAT S_ξ Stieltjes; heat completely monotone Every derivative and every heat time
WIDDER SIGNS $W_k(x) \geq 0$ for every $k \geq 1, x > 0$ Technical §33	ONE PRESCRIBED SCALE Complete Hausdorff sequence at fixed scale All finite-difference orders; §§50–51
CBF / LOEWNER h CBF; $\mathcal{L}_h(X) \geq 0$ Every finite positive node set	DILATION ENDPOINT $T_{\lambda_j} h$ CBF along $\lambda_j \downarrow 1$ Technical §§143–145
BERNSTEIN-LAGUERRE ENERGY At $a = 2$: $\mathcal{E}_N[P](2) \leq (1 + \log 2 + \pi/6)^2$ for every $N \geq 0$ Full-prime cap open; new cutoff theorems in §166C	
EXACT SOURCE IDENTITY; OPEN ALL-NODE SIGN $\mathcal{L}_h(X) = L_\Gamma(X) - L_\rho(X)$ Gamma energy estimate proved; the full fixed-scale prime estimate remains open	

Figure 23: The proof map for this volume. Each criterion retains its full quantifiers. The source identities are exact; the surviving all-order source bounds are listed by route in §R23.

For the new boundary reconstruction, read R17H with Dossier Section 166G. For exact-divisor cancellation and its denominator residual, read R17I with Sections 155H–155J; Sections 155F–155G explain the countermodels that motivate this use of actual arithmetic.

The map uses the same completed object S_ξ , with $h = xS_\xi$. Auxiliary Gamma and triangular models retain their own measures. Reproducibility details and the section review are in the source archive.

Part VIII. What this approach cannot do

The proofs are in the Dossier; this Part collects the NO-GO theorems in one table. Each row names the shortcut that fails and what remains open.

R25. No-go theorems and what they leave open

exact limitation	what it rules out	what survives
Theorem 22A.1: every scalar rung test has at least k Fourier sign changes and is not positive definite	scalar Fourier positivity as a rung proof	completed/two-variable Weil forms and the arithmetic source
§48C: centered Gamma-pole terms have a universal rank-two negative direction, and neither pole-index sublattice absorbs the prime channel with a finite baseline	“unused Gamma poles” as a positive Löwner reserve	the repaired reserve and the full signed prime-error estimate
§49 and §69: a fixed positive rung/Li/Hankel prefix can coexist with later failure	any finite certificate as an infinite stopping rule	the full quantifiers in §§R12, R14, R23
§161: ordinary strongly convergent tensor/vector-multiplier realizations cannot represent the completed meromorphic Stieltjes target	the regular translation-energy tensor lift	singular-form, atomic/discrete, or different source-norm representations
Theorems 107.1 and 112.1: the loose diagonal is exponent-self-limiting, and the classical blockwise large sieve misses the short-shift target by at least $X^{1/2+o(1)}$	those two coarse analytic closures	the exact-diagonal/interior-saddle route or a stronger arithmetic mechanism
§§155F–155G and (H07): PNT-quality envelopes, positive prime-power support, sparse support counts, long prefixes and meromorphic Euler products do not force the needed curvature/source sign	replacing the actual signed arithmetic remainder by support or envelope domination	exact divisor arithmetic and the weighted completed prime error
§69C: a conjugation-symmetric linear zero functional erases the orientation bit, and compact Euler-ray data cannot continuously recover the zero defect	first-order detection by symmetric real-axis tests; extraction from finite-order ray data	half-plane projections and one-sided routes such as §R17I; identities using zeta’s complete prime and Gamma data
§§69A–69B: a Dirichlet series with the reflection of ξ (different Gamma factor) and no Euler product fails some rung (computed: first at W_{16589} on the ranges scanned; certified negative there on an interval of x , Dossier §69D), and (TW.1)	functional-equation-only proofs of all rungs; a finite rung prefix read as progress	arguments using the Euler product together with the functional equation

These are unconditional theorems about what this approach cannot do. They are finished and explain what remains open; none is evidence for RH or against it.

Summary: the object, the results, and the remaining line

The starting object is the triangular primitive, not a conjectured zero pattern. Its half-step symmetry continues to the exact fold $q = s(1 - s) = -2T(s - 1)$. The completed function factors as $\xi(s) = X(q)$, and one reflection orbit $[\rho] = \{\rho, 1 - \rho\}$ gives one folded node q_ρ , one resolvent pole $-q_\rho$, and one reciprocal seed $y_\rho = 1/q_\rho$. An off-line quartet remains two conjugate folded nodes, each carrying its original multiplicity. The branch label is folded away; critical-line membership is not.

From these nodes the volume constructs the absolutely convergent resolvent S_ξ , the Widder rungs, the moment and Li dictionaries, the source matrices, and the completed energies. The signed Pascal identity is exact at every rung. Its existence does not decide the sign of every rung. The proved source prefix reaches W_6 on the interval certificates; the verified-height channel reaches a much longer but still finite range. Those are different proof channels with different inputs. The next independent source proof is $W_7 \rightsquigarrow F^{(14)}$.

The full statement remains the one printed near the beginning: $\text{RH} \iff W_k(x) \geq 0$ for every $k \geq 1$ and every $x > 0$. The all-node Gamma-minus-prime matrix inequality is a second equivalent form. Sections R17F–R17I and R23 give additional exact energy and divisor routes with their own unproved uniform bounds; no unproved reduction among those routes is used. A positive comparison model, a real-part scalar, or a finite certificate cannot supply a missing full quantifier.

The twin of Dossier §§69A–69D measures one side of that boundary. A twin with the reflection of ξ , a different Gamma factor and no Euler product passes thousands of computed rungs, and a hundred Löwner nodes at the tested centres, before failing. What must be proved therefore has to use the Euler product and the functional equation together. The arithmetic identities and finite certificates stand on their stated domains. The uniform completed-source positivity required by RH remains open.

The zero-assisted ranges are long and finite. A published zero-free region lengthens the sector prefix (§R13B). The fixed-scale array is positive in every column, at every scale up to $H^2/10^6$, through row 4,500,262,999,199 (§R13C). Neither is evidence for RH.

An externally claimed zero-free half-plane [128] is used only as an assumption (§R13C). If it is confirmed, $\Delta < 1$ closes; $\Delta = 0$ does not.

References

1. E. Bombieri, *The Riemann Hypothesis - official problem description*, Clay Mathematics Institute, Millennium Prize Problems, Clay problem description.
2. NIST Digital Library of Mathematical Functions, Sections 5.5, 5.7–5.9, 5.11, 24.4, 25.4, 25.10, 25.11, 25.16, and 26.8; in particular Hurwitz special values and derivatives, zero counting, and Gamma and digamma asymptotics.
3. E. C. Titchmarsh, revised by D. R. Heath-Brown, *The Theory of the Riemann Zeta-Function*, 2nd ed., Oxford University Press, 1986.
4. X.-J. Li, “The positivity of a sequence of numbers and the Riemann hypothesis,” *Journal of Number Theory* 65 (1997), no. 2, 325–333, DOI 10.1006/jnth.1997.2137.
5. E. Bombieri and J. C. Lagarias, “Complements to Li’s criterion for the Riemann hypothesis,” *Journal of Number Theory* 77 (1999), no. 2, 274–287, DOI 10.1006/jnth.1999.2392.
6. L. de Branges, *Hilbert Spaces of Entire Functions*, Prentice-Hall, 1968.
7. G. Csordas, T. S. Norfolk, and R. S. Varga, “The Riemann hypothesis and the Turan inequalities,” *Transactions of the American Mathematical Society* 296 (1986), 521–541.
8. J. Huckstead, *Divisor-Band Bijections and Totient Shells in the Triangular-Fractional Grid*, version 5, Zenodo (2026), DOI 10.5281/zenodo.21440877.
9. J. Huckstead, *Triangular Addressing, Null Coordinates, and Reciprocal-Metallic Locks in a Scale-Covariant Plane Geometry*, Working Draft III, Zenodo (2026), DOI 10.5281/zenodo.21444929.
10. J. Huckstead, *From Measure to Flux: Energy-Conjugate Bookkeeping and Exact Semidiscrete Scattering in Finite Radial Wave Models*, publication layer v0.6.13, Zenodo (2026), DOI 10.5281/zenodo.21444339.
11. J. Huckstead, *Two-Term Asymptotics for the Total Variation of Exponentially Weighted Laguerre Polynomials*, v0.1, Zenodo (2026), DOI 10.5281/zenodo.21861619.
12. J. Sondow and C. Dumitrescu, “A monotonicity property of Riemann’s xi function and a reformulation of the Riemann hypothesis,” *Periodica Mathematica Hungarica* 60 (2010), 37–40, DOI 10.1007/s10998-010-1037-3; arXiv:1005.1104.
13. Y. Matiyasevich, F. Saidak, and P. Zvengrowski, “Horizontal monotonicity of the modulus of the Riemann zeta function and related functions,” arXiv:1205.2773 (2012).
14. J. C. Lagarias, “On a positivity property of the Riemann xi-function,” *Acta Arithmetica* 89 (1999), 217–234.
15. A. D. Sokal, “Real-variables characterization of generalized Stieltjes functions,” *Expositiones Mathematicae* 28 (2010), 179–185; arXiv:0902.0065.
16. D. V. Widder, “The Stieltjes transform,” *Transactions of the American Mathematical Society* 43 (1938), 7–60.
17. F. Johansson, “Rigorous high-precision computation of the Hurwitz zeta function and its derivatives,” arXiv:1309.2877 (2013).
18. GNU MPFR Project, *GNU MPFR 4.2.2 Manual*, <https://www.mpfr.org/mpfr-current/mpfr.html>.
19. F. Hausdorff, “Summationsmethoden und Momentfolgen. I,” *Mathematische Zeitschrift* 9 (1921), 74–109, DOI 10.1007/BF01378337.
20. F. Hausdorff, “Summationsmethoden und Momentfolgen. II,” *Mathematische Zeitschrift* 9 (1921), 280–299, DOI 10.1007/BF01279032.
21. A. Pringsheim, “Ueber Functionen, welche in gewissen Punkten endliche Differentialquotienten jeder endlichen Ordnung, aber keine Taylor’sche Reihenentwicklung besitzen,” *Mathematische Annalen* 44 (1894), 41–56, EuDML 157700.
22. K. Löwner, “Über monotone Matrixfunktionen,” *Mathematische Zeitschrift* 38 (1934), 177–216, DOI 10.1007/BF01170633.
23. R. L. Schilling, R. Song, and Z. Vondraček, *Bernstein Functions: Theory and Applications*, 2nd ed., De Gruyter, 2012, DOI 10.1515/9783110270000

- 10.1515/9783110269338.
24. M. Riesz, “Sur l’hypothèse de Riemann,” *Acta Mathematica* 40 (1916), 185–190, DOI 10.1007/BF02418544.
 25. L. Báez-Duarte, “A sequential Riesz-like criterion for the Riemann hypothesis,” *International Journal of Mathematics and Mathematical Sciences* 2005, 3527–3537, DOI 10.1155/IJMMS.2005.3527.
 26. A. Agarwal, M. Garg, and B. Maji, “Riesz-type criteria for the Riemann hypothesis,” *Proceedings of the American Mathematical Society* 150 (2022), DOI 10.1090/proc/16064.
 27. H. L. Montgomery and R. C. Vaughan, “Hilbert’s inequality,” *Journal of the London Mathematical Society* (2) 8 (1974), 73–82.
 28. H. L. Montgomery, *Ten Lectures on the Interface Between Analytic Number Theory and Harmonic Analysis*, CBMS Regional Conference Series in Mathematics 84, American Mathematical Society, 1994.
 29. H. Iwaniec and E. Kowalski, *Analytic Number Theory*, American Mathematical Society Colloquium Publications 53, 2004.
 30. J. B. Conrey and A. Gamburd, “Pseudomoments of the Riemann zeta-function and pseudomagic squares,” arXiv:math/0307213v2; *Journal of Number Theory* 117 (2006).
 31. M. Wahl, “On the mod-Gaussian convergence of a sum over primes,” arXiv:1201.5295v3 (2013), especially equation (1.4).
 32. M. Gerspach and Y. Lamzouri, “Low pseudomoments of Euler products,” arXiv:2103.03870 (2021).
 33. A. Connes, “The Riemann Hypothesis: Past, Present and a Letter Through Time,” arXiv:2602.04022v1 (2026).
 34. D. S. P. Salazar, “Order-Moment Transport and Hankel Determinants in Special-Function Inequalities,” arXiv:2606.31647v2 (2026).
 35. M. Bhowmik, A. Chatterjee, and M. Putinar, “Holomorphic Interpolation of Multivariate Completely Monotone Functions,” arXiv:2606.12102 (2026).
 36. L. Guth and J. Maynard, “New large value estimates for Dirichlet polynomials,” *Annals of Mathematics* 203 (2026), no. 2, 623–675, DOI 10.4007/annals.2026.203.2.6; arXiv:2405.20552v2.
 37. B. Chen, V. Gupta, and Y. C. Li, “Large Value Estimates for Dirichlet Polynomials with Characters and Zero Density of Dirichlet L -Functions,” arXiv:2507.08296v2 (2026).
 38. A. Bondarenko, O. F. Brevig, E. Saksman, K. Seip, and J. Zhao, “Pseudomoments of the Riemann zeta function,” *Bulletin of the London Mathematical Society* 50 (2018), no. 4, 709–724, DOI 10.1112/blms.12183; arXiv:1701.06842v3.
 39. E. Lill, “Résolution graphique des équations numériques de tous les degrés à une seule inconnue, et description d’un instrument inventé dans ce but,” *Nouvelles Annales de Mathématiques*, 2e série, 6 (1867), 359–362.
 40. E. Lill, “Résolution graphique des équations algébriques qui ont des racines imaginaires,” *Nouvelles Annales de Mathématiques*, 2e série, 7 (1868), 363–367.
 41. B. Bellotti and P.-J. Wong, “Improved estimates for the argument and zero-counting function of the Riemann zeta-function,” arXiv:2412.15470v2 (2025), accepted by *Mathematics of Computation*.
 42. D. J. Platt and T. S. Trudgian, “The Riemann hypothesis is true up to $3 \cdot 10^{12}$,” *Bulletin of the London Mathematical Society* 53 (2021), 792–797; arXiv:2004.09765.
 43. O. Dobsch, “Matrixfunktionen beschränkter Schwankung,” *Mathematische Zeitschrift* 43 (1938), 353–388.
 44. W. F. Donoghue, Jr., *Monotone Matrix Functions and Analytic Continuation*, Grundlehren der mathematischen Wissenschaften 207, Springer, 1974.
 45. Euclid, *The Thirteen Books of The Elements*, translated with introduction and commentary by T. L. Heath, 2nd ed., Dover, 1956, Book VII, Definition 22, and Book IX, Proposition 36.
 46. L. E. Dickson, *History of the Theory of Numbers*, Volume I: Divisibility and Primality, Carnegie Institution of Washington, 1919, Chapter I.
 47. A. Groskin, “A finite Guinand–Weil dictionary and archimedean tail order for the truncated Weil quadratic form,” arXiv:2607.02828v3 (2026), archival DOI 10.5281/zenodo.21124802.
 48. A. Connes, C. Consani, and H. Moscovici, “Zeta Spectral Triples,” arXiv:2511.22755v1 (2025), forthcoming in the EMS Lecture Notes in Mathematics volume *Applications of Noncommutative Geometry to Gauge Theories, Field Theories, and Quantum Space-Time*.
 49. A. Connes and W. D. van Suijlekom, “Quadratic Forms, Real Zeros and Echoes of the Spectral Action,” arXiv:2511.23257v1 (2025).
 50. A. Connes, C. Consani, and H. Moscovici,

- “Zeta zeros and prolate wave operators,” arXiv:2310.18423v2 (2024).
51. M. Suzuki, “Weil’s quadratic form via the screw function,” arXiv:2606.09096v2 (2026).
 52. A. Groskin, “High-Precision Approximation of Riemann Zeros via the Truncated Weil Form,” arXiv:2605.20224v4 (2026), archival DOI 10.5281/zenodo.19546514.
 53. E. W. Weisstein, “Gamma Function,” *MathWorld—A Wolfram Web Resource*, MathWorld entry, page captured 27 August 2026.
 54. *Hermitian Spaces*, Chapter 12 lecture slides, CIS 5150, University of Pennsylvania, Sections 12.1–12.2, especially the definitions of sesquilinear/Hermitian forms and the complex polarization identities, <https://www.cis.upenn.edu/~cis5150/cis515-20-sl9.pdf>.
 55. J. Huckstead, *The Polar Shell Renderer: A Lens, Not a Law*, revised 9 July 2026, Zenodo, DOI 10.5281/zenodo.21280464.
 56. A. Voros, “Zeta functions for the Riemann zeros,” *Annales de l’Institut Fourier* 53 (2003), no. 3, 665–699; first preprint 2001, arXiv:math/0104051v4. Equations (40)–(41), (59), (74), (81), and (91)–(95), and Table 1 supply the classical spectral-zeta formulas used here.
 57. A. Voros, “Erratum - Zeta functions for the Riemann zeros,” *Annales de l’Institut Fourier* 54 (2004), no. 4, 1139, DOI 10.5802/aif.2046.
 58. J. B. Keiper, “Power series expansions of Riemann’s ξ function,” *Mathematics of Computation* 58 (1992), no. 198, 765–773, DOI 10.2307/2153215.
 59. NIST, *Digital Library of Mathematical Functions*, §§5.4–5.5, Gamma special values, recurrence, reflection, and duplication. Official formulas.
 60. S. M. Eisenberg, “Moment Sequences and the Bernstein Polynomials,” *Canadian Mathematical Bulletin* 12 (1969), no. 4, 401–411. DOI 10.4153/CMB-1969-050-8. Classical background; the source-specific growth argument is printed independently in §164, without a claim of literature novelty.
 61. *A Search-Adjusted Audit of Row-Sector Modulus Signals in Terminal Zeta-Zero Spacing Residuals*, unpublished historical report (2026), 10 pages. Only its reported tables are used; its raw arrays and permutation runs are not part of this work.
 62. *A Finite-Count Search for Localized Enrichment Near 2.75 in Unfolded Riemann Zeta-Zero Gap Coordinates*, unpublished historical report, May 2026, 24 pages. Its reported counts and stated design are compared in §168.
 63. NIST, *Digital Library of Mathematical Functions*, sine Maclaurin series and Euler infinite product, and the fourth-kind Chebyshev representation. The triangular factorization in (PR.6) is a direct regrouping of the factorial coefficients; Gamma reflection is covered by [59].
 64. L. Euler, *De formulis exponentialibus replicatis*, E489 (1778), original paper in the Euler Archive. The fixed-point differentiation and stability calculation used here are displayed in §R5E.
 65. A. Edelman and G. Strang, *Pascal Matrices*, MIT course essay. Classical symmetric Pascal matrix, Vandermonde factorization, and determinant one. Section 163A identifies this matrix inside the completed-source energy.
 66. Y. Lamzouri, *A new proof that more than 2/3 of the zeros of the Riemann zeta function are simple and on the critical line*, arXiv:2609.02882v2, 17 pages. Proposition 2.1, Lemma 3.1 and Theorem 1.1 are the statements compared in §159. Its notation is local to that paper; in particular its critical-line counting symbol is not the smooth approximation N_0 of §168.
- Entries 67–73 are external work consulted in preparing this volume. Each was read at the level its entry states and **none is verified anywhere in this work**; they are cited for what they say, not as support for anything claimed here.
67. B. Cloitre, *A tauberian approach to RH*, arXiv:1107.0812, submitted 5 July 2011. Introduces functions of good variation and the family approaching $x \mapsto x^{-1}[x]$, by the author’s account inspired by the Ingham summation process. Cited in §R12A for the shared coordinate and in §R23 for the exponent route.
 68. B. Cloitre, *A tauberian characterization of the Riemann hypothesis through the floor function*, arXiv:2407.18859, submitted 26 July 2024. The term *regular arithmetic function* and the floor-function characterization appear here.
 69. B. Cloitre, *Regular arithmetic functions, Volume I: theory, applications, examples*, arXiv:2609.09366, submitted 8 September 2026, 374 pages. The kernel $G(n, k)$, the regularity

- index, and the statement that the hypothesis holds exactly when Ingham's kernel has index $1/2$. Abstract read; the body is not read.
70. S. Xu, *Positivity and asymptotics for Chenevier's orthogonal polynomials*, arXiv:2609.10328, submitted 9 September 2026. Positivity in every degree from strict negativity of all Verblunsky coefficients of an associated circle measure. Cited in §R12A as the transporting case. Abstract read.
 71. Lean formalization of the Li criterion against the ambient library's own Riemann-hypothesis predicate, public repository `li-criterion-rh-equivalence-lean`, registry entry PALOMAR-2026-09-05-000005. Statement and sources read at file level; the project was not compiled in the course of this work, and the axiom report quoted in §R22 is the one the sources declare.
 72. X. Zhu, *Weil positivity in compact windows: a finite reduction, certified two-sided bounds, and a Landau–Widom decay law*, arXiv:2608.24827, submitted 25 August 2026, revised 2 September 2026, 34 pages. The certified window bound and the two-sided decay law quoted in §R23. Abstract, discussion and failed-route sections read; the body is not read.
 73. B. Cloitre, *On the orthorecursive expansion of unity*, arXiv:2505.09645, submitted 11 May 2025. The tauberian transfer from a discrete recurrence to a Volterra integral equation referred to in §R23. Abstract read.
 74. B. Riemann, *Ueber die Anzahl der Primzahlen unter einer gegebenen Grösse*, Monatsberichte der Königlich Preussischen Akademie der Wissenschaften zu Berlin, November 1859. The source of the hypothesis, of the explicit formula whose oscillation periods are quoted in §R9A, and of the counting statement completed by von Mangoldt.
 75. M. Aissen, I. J. Schoenberg, and A. Whitney, “On the generating functions of totally positive sequences I,” *Journal d'Analyse Mathématique* 2 (1952), 93–103; A. Edrei, “On the generating functions of totally positive sequences II,” *ibid.*, 104–109. Announced in M. Aissen, A. Edrei, I. J. Schoenberg and A. Whitney, “On the generating functions of totally positive sequences,” *Proceedings of the National Academy of Sciences* 37 (1951), 303–307, which carries all four names on one note; the 1952 sequel is the two-part paper cited first. The characterization of Pólya frequency sequences used at (12.9).
 76. D. K. Dimitrov and F. R. Lucas, “Higher order Turán inequalities for the Riemann ξ -function,” *Proceedings of the American Mathematical Society* 139 (2011), 1013–1022.
 77. M. Griffin, K. Ono, L. Rolén, and D. Zagier, “Jensen polynomials for the Riemann zeta function and other sequences,” *Proceedings of the National Academy of Sciences* 116 (2019), 11103–11110. Hyperbolicity of every fixed degree for all large n ; all degrees for all n is the hypothesis.
 78. J. Holland, *A new hyperbolicity wedge and a joint semicircle limit for Jensen polynomials of Riemann's ξ -function*, arXiv:2608.08682, submitted 9 August 2026. Reports the threshold $n^3 \log^2(n+2) \geq Kd^5$ for its own Jensen family; no transfer to the ordinary-coefficient minors in (12.9) is asserted. Abstract and statement of the wedge read; the body is not read.
 79. H. L. Montgomery, “The pair correlation of zeros of the zeta function,” in *Analytic Number Theory*, Proceedings of Symposia in Pure Mathematics 24, American Mathematical Society, 1973, 181–193. The historical theorem and conjectured density are distinguished in Section 61A; the comparison does not import the conjecture as an actual-source estimate.
 80. L. Elaissaoui and Z. E.-A. Guennoun, “Fourier expansion of the Riemann zeta function and applications,” *Journal of Number Theory* 211 (2020), 113–138, DOI 10.1016/j.jnt.2019.09.025; preprint arXiv:1809.02829. Theorem 1.1 and Corollary 2.4 of the preprint (v2): the zeta Fourier-coefficient and Parseval identities. Section 155G re-derives the Mellin normalization independently.
 81. V. Liu, *Certified Weil Positivity Beyond the Unit Window*, manuscript submitted to *Mathematics of Computation*, 14 September 2026; reproducible source repository `luciferyu666/certified-weil-positivity`. Fixed-window claims only; not peer-reviewed, not on arXiv, and the repository states that external reproduction has not yet been completed. Cited in §R23 only as an external comparison and NO-GO for a specified localization.
 82. A. Pearce-Crump, *Optimising Selberg's method for critical zeros*, arXiv:2609.15329v1, 14

- September 2026. Theorem 1.1 proves $\omega_0 > 0.0700162$ by a positive-semidefinite sum of three squared mollifiers; cited in §R12 only as a methodological comparison.
- Entries 83–120 are the classical primary sources, and the modern accounts, for results that this volume uses or re-derives. Each is cited for the statement named where it is used.
83. Nicomachus of Gerasa, *Introduction to Arithmetic* (c. 100 CE), end of Chapter 20; used at (2.3).
 84. J. Faulhaber, *Academia Algebrae*, Augsburg, 1631; used at (2.1).
 85. C. G. J. Jacobi, “De usu legitimo formulae summatoriae Maclauriniana,” *Journal für die reine und angewandte Mathematik* 12 (1834), 263–272, DOI 10.1515/crll.1834.12.263. The first general proof of Faulhaber’s assertion.
 86. D. E. Knuth, “Johann Faulhaber and sums of powers,” *Mathematics of Computation* 61 (1993), no. 203, 277–294, DOI 10.2307/2152953. The inverse form and derivative rule of §R2.
 87. R. Wituła, K. Kaczmarek, P. Lorenc, E. Hetmaniok, and M. Pleszczyński, “Jordan numbers, Stirling numbers and sums of powers,” *Discussiones Mathematicae – General Algebra and Applications* 34 (2014), 155–166, DOI 10.7151/dmgaa.1225. The case $r = 1$ of their product decomposition (13) is $3S_2 = j_n T_n$, the summed form of (2.2a).
 88. N. Derby, “A search for sums of powers,” *The Mathematical Gazette* 99 (2015), no. 546, 416–421, DOI 10.1017/mag.2015.77. Used in §§R2 and R5C; the printed quadratic should read $(p - T_{2n})(p + n) = 0$.
 89. D. Singmaster, “How often does an integer occur as a binomial coefficient?” (Research Problems), *American Mathematical Monthly* 78 (1971), no. 4, 385–386, DOI 10.2307/2316907.
 90. B. Pascal, *Traité du triangle arithmétique*, Paris, 1665 (written 1654).
 91. P. Mengoli, *Novae quadraturae arithmeticae, seu de additione fractionum*, Bologna, 1650; the telescope (4.1).
 92. L. Euler, “De summis serierum reciprocarum,” *Commentarii academiae scientiarum Petropolitanae* 7 (1740), 123–134; Euler Archive E41, scholarlycommons.pacific.edu/euler-works/41.
 93. L. Euler, “De progressionibus harmonicis observationes,” *Commentarii academiae scientiarum Petropolitanae* 7 (1740), 150–161; Euler Archive E43, scholarlycommons.pacific.edu/euler-works/43.
 - The paper that introduces Euler’s constant.
 94. J. Stirling, *Methodus Differentialis: sive Tractatus de Summatione et Interpolatione Serierum Infinitarum*, London, 1730.
 95. J. L. Raabe, “Angenäherte Bestimmung der Factorenfolge $1 \cdot 2 \cdot 3 \cdot 4 \cdot 5 \cdots n = \Gamma(1+n) = \int x^n e^{-x} dx$, wenn n eine sehr grosse Zahl ist,” *Journal für die reine und angewandte Mathematik* 25 (1843), 146–159, DOI 10.1515/crll.1843.25.146. The source of Raabe’s integral $\int_0^1 \log \Gamma = \frac{1}{2} \log 2\pi$.
 96. E. Cesàro, “Sur la série harmonique,” *Nouvelles Annales de Mathématiques* (3) 4 (1885), 295–296.
 97. M. B. Villarino, “Ramanujan’s harmonic number expansion into negative powers of a triangular number,” preprint (2007), arXiv:0707.3950; see also “Ramanujan’s harmonic number expansion,” preprint (2005), arXiv:math/0511335. Derives (GA.2), with an error estimate, from [120].
 98. C. Mortici and M. B. Villarino, “On the Ramanujan–Lodge harmonic number expansion,” *Applied Mathematics and Computation* 251 (2015), 423–430, DOI 10.1016/j.amc.2014.11.088.
 99. C.-P. Chen, “On the coefficients of asymptotic expansion for the harmonic number by Ramanujan,” *The Ramanujan Journal* 40 (2016), 279–290, DOI 10.1007/s11139-015-9670-3; and “Ramanujan’s formula for the harmonic number,” *Applied Mathematics and Computation* 317 (2018), 121–128, DOI 10.1016/j.amc.2017.08.053.
 100. D. W. DeTemple, “A quicker convergence to Euler’s constant,” *American Mathematical Monthly* 100 (1993), no. 5, 468–470, DOI 10.2307/2324300.
 101. L. J. Boya, “Another relation between π , e , γ and $\zeta(n)$,” *RACSAM* 102 (2008), no. 2, 199–202, DOI 10.1007/BF03191819. The reciprocal-triangular series (GA.3), obtained from Stirling’s formula.
 102. E. T. Whittaker and G. N. Watson, *A Course of Modern Analysis*, 5th ed., Cambridge University Press, 2021, Chapter 12 (the Gamma function), DOI 10.1017/9781009004091.
 103. J. C. Lagarias, “Euler’s constant: Euler’s work and modern developments,” *Bulletin of the American Mathematical Society* 50 (2013), no. 4, 527–628, DOI 10.1090/S0273-0979-2013-01423-X.
 104. O. Espinosa and V. H. Moll, “On some

- integrals involving the Hurwitz zeta function: Part 1,” *The Ramanujan Journal* 6 (2002), 159–188, DOI 10.1023/A:1015706300169.
105. H. Kinkelin, “Ueber eine mit der Gammafunction verwandte Transcendente und deren Anwendung auf die Integralrechnung,” *Journal für die reine und angewandte Mathematik* 57 (1860), 122–138, DOI 10.1515/crll.1860.57.122; J. W. L. Glaisher, “On the product $1^1 \cdot 2^2 \cdot 3^3 \cdots n^n$,” *Messenger of Mathematics* 7 (1878), 43–47.
 106. B. Nyman, *On Some Groups and Semigroups of Translations*, thesis, Uppsala, 1950.
 107. A. Beurling, “A closure problem related to the Riemann zeta-function,” *Proceedings of the National Academy of Sciences* 41 (1955), no. 5, 312–314, DOI 10.1073/pnas.41.5.312.
 108. L. Báez-Duarte, M. Balazard, B. Landreau, and E. Saias, “Notes sur la fonction ζ de Riemann, 3,” *Advances in Mathematics* 149 (2000), 130–144, DOI 10.1006/aima.1999.1861.
 109. L. Báez-Duarte, M. Balazard, B. Landreau, and E. Saias, “Étude de l’autocorrélation multiplicative de la fonction « partie fractionnaire »,” *The Ramanujan Journal* 9 (2005), 215–240, DOI 10.1007/s11139-005-0834-4.
 110. J. Hadamard, “Étude sur les propriétés des fonctions entières et en particulier d’une fonction considérée par Riemann,” *Journal de Mathématiques Pures et Appliquées* (4) 9 (1893), 171–215, Numdam.
 111. H. von Mangoldt, “Zur Verteilung der Nullstellen der Riemannschen Funktion $\xi(t)$,” *Mathematische Annalen* 60 (1905), 1–19, DOI 10.1007/BF01447494.
 112. H. Davenport, *Multiplicative Number Theory*, 3rd ed., revised by H. L. Montgomery, Graduate Texts in Mathematics 74, Springer, 2000, Chapter 12, DOI 10.1007/978-1-4757-5927-3. The Hadamard constant $B = -\frac{1}{2}\gamma_E - 1 + \frac{1}{2}\log 4\pi$ and $\sum_{\rho} \Re \rho^{-1} = -B$.
 113. T.-J. Stieltjes, “Recherches sur les fractions continues,” *Annales de la Faculté des Sciences de Toulouse* (1) 8 (1894), no. 4, J1–J122, Numdam.
 114. S. Bernstein, “Sur les fonctions absolument monotones,” *Acta Mathematica* 52 (1929), 1–66, DOI 10.1007/BF02592679.
 115. D. V. Widder, *The Laplace Transform*, Princeton University Press, 1941.
 116. A. Weil, “Sur les « formules explicites » de la théorie des nombres premiers,” *Communications du Séminaire Mathématique de l’Université de Lund*, tome supplémentaire (1952), 252–265.
 117. E. C. Titchmarsh, *Introduction to the Theory of Fourier Integrals*, 2nd ed., Oxford University Press, 1948. Mellin inversion and the Mellin–Plancherel theorem used at (GA.6).
 118. H. M. Edwards, *Riemann’s Zeta Function*, Academic Press, 1974.
 119. B. C. Berndt, *Ramanujan’s Notebooks, Part V*, Springer-Verlag, New York, 1998, Chapter 38, Entry 9, p. 521; the expansion (GA.2).
 120. D. W. DeTemple and S.-H. Wang, “Half-integer approximations for the partial sums of the harmonic series,” *Journal of Mathematical Analysis and Applications* 160 (1991), no. 1, 149–156, DOI 10.1016/0022-247X(91)90296-C.
- Entries 121–124 are in the Dossier only. Entries 126–129 are not peer reviewed. The journal details of 125 were checked against the publisher’s record, and the two indices quoted from 127 against (A78) and (A79) of its version 2.
125. M. J. Mossinghoff, T. S. Trudgian, and A. Yang, “Explicit zero-free regions for the Riemann zeta-function,” *Research in Number Theory* 10 (2024), article 11, DOI 10.1007/s40993-023-00498-y; arXiv:2212.06867.
 126. C. Bellotti, T. Trudgian, and A. Yang, “Zero-free regions inspired by work of Heath-Brown,” arXiv:2603.21490v1, 23 March 2026. A preprint with no journal reference at the date of this edition.
 127. Zeraoulia Rafik, “Uniform Beta Smoothing of Widder Sums for the Riemann ξ -Function and a Schur–Triple Application to Simple Critical Zeros,” Preprints.org manuscript 202609.1018, version 2, September 2026. A preprint, not peer reviewed. Its Appendix B transfers explicit zero-free regions to diagonal Widder orders.
 128. OpenAI, “The Quasi-Riemann Hypothesis: A Zero-Free Half-Plane $\Re s > 7/8$,” manuscript of 30 September 2026 in the OpenAI mathematics release of 6 October 2026, commit adc7f124. Machine-written and not peer reviewed. A Lean 4 statement for ζ is supplied as `OAI.riemannZeta_ne_zero_of_seven_eighths_lt_re`. Read for this edition; the proof was not checked and the Lean development was not built.
 129. OpenAI, “The Quasi-Riemann Hypothesis,” an alternate proof of the half-plane $\Re s > 11/12$, manuscript of 5 October 2026 in the same release. Written with human assistance by its own note, and not peer reviewed. Read for this edition; the proof was not checked.

-
130. E. Hasanalizade, Q. Shen, and P.-J. Wong, “Counting zeros of the Riemann zeta function,” *Journal of Number Theory* 235 (2022), 219–241, DOI 10.1016/j.jnt.2021.06.032; arXiv:2107.06506. The explicit zero count used in Dossier §60A.
 131. P. Freitas, “A Li-type criterion for zero-free half-planes of Riemann’s zeta function,” arXiv:math/0507368, 18 July 2005. The ninth reading of the frontier in Dossier §60A.
 132. N. Palojärvi, “Explicit zero-free regions and a τ -Li-type criterion,” arXiv:1807.01506v3, 29 April 2020. The finite index ranges quoted in Dossier §60A.
 133. J. Huckstead, *Reading the Fold: A Global Newton Series for the Riemann Xi Function*, version 1.3, Zenodo, 20 October 2026, DOI 10.5281/zenodo.23511096. The companion paper on the fold and its Newton series.
 134. W. Bosma, K. Dajani, and C. Kraaikamp, “Entropy quotients and correct digits in number-theoretic expansions,” in *Dynamics & Stochastics*, IMS Lecture Notes–Monograph Series 48 (2006), 176–188, DOI 10.1214/074921706000000202. The entropy of the Lüroth map.
 135. The On-Line Encyclopedia of Integer Sequences, A090585 and A090586: the numerator and the denominator of $T_n/n!$ in lowest terms.