RESEARCH MONOGRAPH

The BV–BMS Program for Perturbative Quantum Gravity: Rigorous Results, Analytic Obstructions, and Open Problems

A Systematic Audit of Proven Sectors, Failure Modes, and Completion Criteria

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Abstract

We present a systematic and deliberately conservative synthesis of a 258-gate research archive on four-dimensional gravity, Batalin–Vilkovisky (BV) quantization, Bondi–Metzner–Sachs (BMS) boundary symmetry, infrared domains, and operator-theoretic completion. The archive contains exact finite checkers for each gate, but a finite checker is not identified with a proof of an infinite-dimensional theorem. We therefore separate four epistemic classes: (i) theorem-level statements whose hypotheses and analytic domains are fully stated; (ii) conditional theorems; (iii) finite algebraic or numerical skeletons; and (iv) open or retracted extrapolations.

The strongest audited results are: the two-helicity quotient of linearized Einstein gravity; positive free graviton quantization away from zero momentum; the classical BV master equation and a local, formal causal-renormalization chain; a detailed classical BV–BFV/BMS boundary construction in specified jet and edge categories; a massless radiation Hilbert complex; a sharp collinear Sobolev trace theorem; and several no-go results showing that the standard angular L^2 Fock representation does not support the actual order-zero collinear nonlinear block as a closable operator. For the diagonal trace

$$D_t: H^t(S^2)\widehat{\otimes}_2 H^t(S^2) \longrightarrow H^t(S^2)$$

we prove the sharp trichotomy

$$t \leq \frac{1}{2}\text{:nonclosable, } \frac{1}{2} < t \leq 1\text{:closable but unbounded, } t > 1\text{:bounded.}$$

Pure supertranslation phases intertwine exactly on the intrinsic collinear incidence measure, while a scalar complementary-series norm leaves only the candidate window $1/2 < \tau < 1$; that window is not an actual nonlinear Einstein–BV module.

The audit also finds decisive failures in a later imported chain. In particular, a Lagrangian Weyl subalgebra was incorrectly treated as central; a nonconstant supertranslation multiplier was incorrectly assumed to commute with angular smoothing; an order-minus-two resolvent was incorrectly declared trace class on S^2; and a sharp-cutoff compression proposal, tail-probability bounds, and uncertainty upper bounds were overinterpreted as self-adjoint truncation, dynamical barriers, and operational discreteness. Consequently the archive does not prove a one-loop boundary QME, an interacting BMS charge algebra, infrared-complete scattering, asymptotic completeness, black-hole information recovery, or complete quantum gravity. The paper includes the proof routes, dependency graph, failure modes, and a gate-by-gate evidence atlas needed for independent reconstruction.

Contents

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1 Purpose, scope, and rules of evidence

The long-term target is a complete physical theory of quantum gravity, not a formal Lagrangian and not a collection of successful special cases. A candidate is represented by the package

$$\mathrm{T} = (\mathfrak{D}, \mathfrak{K}, \mathfrak{G}, \mathfrak{S}_{\mathrm{phys}}, \mathfrak{A}_{\mathrm{phys}}, \mathfrak{Z}, \mathfrak{P}, \Theta, \mathfrak{R}, \iota_{\mathrm{IR}}, \mathfrak{O}, \mathfrak{I}), \tag{1}$$

where the symbols respectively encode the domain, kinematics, gauge structure, physical states, observables, dynamics, probabilities, parameters, regularization, low-energy embedding, operational dictionary, and state or sector selection. Completion requires the conjunction of specification, nonperturbative existence, positivity, gauge consistency, causal composition, observables, the controlled GR+QFT limit, matter, strong gravity, cosmology, empirical contact, and global closure. No weighted average is allowed: one missing necessary condition leaves the complete-theory claim open.

1.1 Evidence classes

For every claim C_i we record

$$C_i = (S_i, D_i, A_i, L_i, E_i, F_i, \sigma_i),$$

where S_i is the statement, D_i its domain, A_i its assumptions, L_i its dependencies, E_i the evidence, F_i the failure modes, and σ_i its status. The statuses used in this paper are:

Proved (P) A theorem with fixed objects, quantifiers, domains, and all analytic steps supplied. Independent reconstruction remains a separate sociological requirement for final archive acceptance.

Conditional (C) A valid implication whose hypotheses include an unconstructed physical object or an unproved analytic property.

Finite support (N) Exact finite algebra, truncation, or numerical evidence without a theorem controlling the intended infinite limit.

Unknown (U) A formal, heuristic, or incompletely specified claim.

Refuted (R) A stated quantifier is hit by an explicit counterexample or by an incompatible theorem.

> **Audit warning 1.1**
>
> A program can contain many correct lemmas while its advertised physical completion remains unproved. Throughout, “checker passes” means only that the finite claims encoded by that checker pass. It never silently supplies a wavefront theorem, an operator domain, a continuum limit, or a physical identification absent from the proof.

1.2 Archive and reproducibility boundary

The evidence archive contains 258 proof documents and 258 Python checkers. This manuscript is a semantic audit over that archive. The gate atlas in Appendix A lists every proof file, its checker, its method, and its audited scope. The source archive remains in status U until independent reconstruction; this paper does not change that status by summarizing it.

2 Linearized gravity and the free quantum theory

2.1 The two-helicity quotient

Let η have signature $(-,+,+,+)$ and let $h_{\mu\nu}$ be a complex Fourier mode with nonzero null momentum k. Linearized diffeomorphisms act by

$$h_{\mu\nu} \sim h_{\mu\nu} + k_\mu \xi_\nu + k_\nu \xi_\mu. \tag{2}$$

The trace-reversed field $\bar{h}_{\mu\nu} = h_{\mu\nu} - \frac{1}{2}\eta_{\mu\nu}h$ satisfies the de Donder symbol equation

$$k^\mu \bar{h}_{\mu\nu} = 0,\ k^2 = 0. \tag{3}$$

Theorem 2.1 (Linearized Einstein quotient)

For every nonzero future-null k in four-dimensional Minkowski space, the solution space of (3), modulo (2), has complex dimension two. It is represented by the transverse traceless helicity tensors $e^{+}_{\mu\nu}$ and $e^{\times}_{\mu\nu}$, or equivalently helicity ± 2.

Proof.

Choose a null frame (k, ℓ, e_1, e_2) with $k \cdot \ell = -1$ and $e_A \cdot e_B = \delta_{AB}$. Expanding a symmetric tensor in this frame gives ten coefficients. The four equations $k^\mu \bar{h}_{\mu\nu} = 0$ remove the components with an ℓ index. The four gauge parameters remove the four independent k-longitudinal components. The trace relation removes the remaining scalar trace, leaving the two-dimensional traceless symmetric tensor on span $\{e_1, e_2\}$. Explicit representatives are

$$e^{+} = e_1 \otimes e_1 - e_2 \otimes e_2,\ e^{\times} = e_1 \otimes e_2 + e_2 \otimes e_1.$$

Their classes are nonzero because a pure gauge tensor has at least one k-factor, whereas these tensors are purely transverse. Linear independence is immediate from their transverse 2×2 matrices. The ADM count gives 6 spatial metric components minus four first-class phase-space pairs, hence two configuration degrees of freedom, providing an independent count. □

2.2 Positive free one-particle and Fock spaces

On the future mass shell $\mathcal{N}_+$, write

$$p = \omega(1, n), \omega > 0, n \in S^2, \mathrm{d}\mu(p) = \frac{\omega\, \mathrm{d}\omega\, \mathrm{d}\Omega_n}{2(2\pi)^3}.$$

Let $E_{\mathrm{TT}} \to \mathcal{N}_+$ be the rank-two helicity bundle obtained above. The free one-particle space is

$$\mathcal{H}_1 = L^2(\mathcal{N}_+, E_{\mathrm{TT}}, \mathrm{d}\mu), \tag{4}$$

with positive inner product. Bosonic second quantization gives $\Gamma_s(\mathcal{H}_1)$. The proper Poincaré group acts unitarily through the massless helicity representation, and the free Hamiltonian is multiplication by ω followed by second quantization.

Proposition 2.2 (Exact free scope)

Equation (4) gives a positive free graviton theory on the nonzero-momentum radiative sector. It does not by itself construct the $\omega = 0$ soft sector, an interacting Hilbert space, a BMS-invariant vacuum, or a nonperturbative theory.

Proof.

Positivity follows fiberwise from the TT projector, whose image has rank two and whose restriction to physical polarizations is the identity. The shell measure is invariant under proper Lorentz transformations. The zero-energy endpoint is excluded from the stated domain, so no conclusion about its completion follows. Interaction terms are absent; therefore no interacting operator-domain assertion is part of the theorem. ◻

3 Effective field theory and regulated unitarity

For a connected gravitational diagram with L loops and vertices of derivative order d_i, dimensional analysis and graph topology give the superficial momentum degree

$$D = 2 + 2L + \sum_i N_i(d_i - 2). \tag{5}$$

Proof of (5).

Each loop integral contributes four powers, each internal massless propagator contributes -2, and each vertex contributes d_i. Thus $D = 4L - 2I + \sum_i N_i d_i$. For a connected graph, $L = I - V + 1$ and $V = \sum_i N_i$, hence $D = 4(I - V + 1) - 2I + \sum_i N_i d_i = 2 + 2L + \sum_i N_i(d_i - 2)$. ◻

At any fixed EFT order, only finitely many local operators contribute. With a finite causal regulator and a Hermitian interaction, the perturbative unitarity recursion can be proved coefficient by coefficient. This is not a UV completion: removal of the regulator, summability, and nonperturbative unitarity are separate gates.

4 Classical BV gravity and local cohomological control

4.1 The classical master equation

For the metric g and odd vector ghost c, define

$$sg = \mathcal{L}_c g, qquadsc = \frac{1}{2}[c, c]. \tag{6}$$

The sign in the ghost equation is understood in the graded convention in which s is an odd derivation.

> **Lemma 4.1 (Off-shell nilpotency)**
>
> The differential in (6) satisfies $s^2 g = s^2 c = 0$ without using the Einstein equations.

Proof.

The graded Jacobi identity gives $s^2 c = \frac{1}{2} s[c, c] = 0$. For the metric, graded derivation and the commutator identity for Lie derivatives give

$$s^2 g = s(\mathcal{L}_c g) = \mathcal{L}_{sc} g - \frac{1}{2}[\mathcal{L}_c, \mathcal{L}_c] g = 0.$$

The factor $1/2$ precisely compensates the two identical odd-ghost terms. □

Let Φ denote all fields and ghosts and Φ^* their antifields. The minimal BV action

$$S_{\mathrm{BV}} = S_{\mathrm{EH}}[g] + \int \langle g^*, \mathcal{L}_c g \rangle + \int \langle c^*, \frac{1}{2}[c, c] \rangle \tag{7}$$

satisfies $(S_{\mathrm{BV}}, S_{\mathrm{BV}}) = 0$.

Proof.

The antibracket Hamiltonian vector field generated by S_{BV} restricts on fields to s. The identity $(S, S) = 0$ is equivalent to the square of that Hamiltonian vector field vanishing. The field and ghost components vanish by the preceding lemma. The antifield components vanish by diffeomorphism invariance of S_{EH} and the Noether identity. No gauge fixing is used. □

4.2 Antifield filtration and characteristic cohomology

Filtering local functionals by antifield number decomposes the BV differential as $s = \delta + \gamma + \cdots$, with δ the Koszul–Tate differential and γ the longitudinal gauge differential. The associated spectral sequence separates equations-of-motion exactness from gauge cohomology. The archive proves several finite-jet and symbol-level acyclicity statements using the Einstein symbol complex, Spencer cohomology, curvature jets, and filtered lifting.

The proof template is uniform:

1. identify the principal symbol sequence at nonzero covector;
2. split it into trace, gauge, TT, and Bianchi components;
3. compute exactness at each symbol degree;
4. use a filtered perturbation or jet-isomorphism argument to lift symbol primitives to finite jets;
5. record the characteristic classes that survive the lift.

These results are local and formal. They do not establish global topology, convergence of a jet expansion, or a physical state space.

4.3 One-loop QME as an obstruction problem

Writing $W = S + \hbar M_1 + O(\hbar^2)$, the quantum master equation

$$\frac{1}{2}(W, W) - i\hbar\Delta W = 0 \tag{8}$$

gives at order $\hbar$

$$sM_1 = i\Delta S. \tag{9}$$

Thus ΔS must be s-closed, and its cohomology class is the anomaly obstruction. In an infinite-dimensional theory Δ is not a canonical unregulated operator; equation (9) is meaningful only inside a specified renormalization prescription. The archive's rigorous conclusion is therefore cohomological and conditional: if the regulated local anomaly lies in a vanishing local BRST class, a finite local counterterm restores the QME at that order. This does not prove a regulator-independent boundary QME or convergence of the loop series.

5 Causal perturbative renormalization

The causal construction uses time-ordered products T_n satisfying causal factorization. Assuming products through order $n - 1$, the difference between two extensions of the distribution defining T_n is supported on the total diagonal and is therefore local, with degree bounded by scaling degree. The Master Ward defect is likewise local. BRST nilpotency gives the Wess–Zumino condition

$$s\mathcal{A}_n = 0. \tag{10}$$

If the relevant local class vanishes, $\mathcal{A}_n = sC_n$ and the finite renormalization $T_n \mapsto T_n - C_n$ restores the identity.

Theorem 5.1 (Formal causal induction, conditional form)

On a fixed globally hyperbolic background, for a specified field content and renormalization scheme, vanishing of every local anomaly class through order N implies existence of time-ordered products satisfying the Master Ward identity through order N.

Proof.

Induct on n. Causal factorization fixes T_n off the total diagonal. The extension theorem classifies the remaining freedom by local distributions. The lower-order identities imply Wess–Zumino consistency of the defect. Vanishing of its class supplies a local primitive C_n, whose subtraction restores the identity without changing causal factorization. Repeating gives the claim through N. □

Remark 5.2

The theorem is coefficientwise and formal. It gives neither convergence in the coupling nor a nonperturbative measure. It also does not identify the bulk local cohomology with a boundary BMS anomaly class without an explicit bulk–boundary comparison map.

6 Infrared domains, closed range, and zero modes

6.1 The basic closed-range obstruction

Let M_r act on $L^2((0,1), r\,\mathrm{d}r)$ by $(M_r f)(r) = r f(r)$.

Proposition 6.1

M_r is bounded and injective, but its range is dense and not closed.

Proof.

Boundedness and injectivity are immediate. Let $g_n = \mathbf{1}_{[1/n,1]}$. Then $g_n \to 1$ in $L^2((0,1), r\,\mathrm{d}r)$. Each g_n lies in the range, with preimage g_n/r. If 1 lay in the range, its unique preimage would be $1/r$, but

$$\int_0^1 \frac{1}{r^2} r\,\mathrm{d}r = \int_0^1 \frac{\mathrm{d}r}{r} = \infty.$$

Hence the range is not closed. Density follows by truncation away from zero. □

This one-dimensional fact recurs in soft BRST homotopies, Krein pairings, and the attempt to form ordinary cohomology rather than reduced cohomology. Weighted Hilbert scales can close one arrow but generally alter the Lorentz action or exclude local smears. Rigged nuclear spaces accommodate formal finite orders, whereas a single all-order Hilbert/GNS domain is obstructed by unbounded soft order and frame scaling.

6.2 Finite jets and the all-jet obstruction

For each fixed N, finitely many boundary jets can be placed in contractible doublets

$$q\bar{c}_j = b_j, qquadq\phi_j = c_j, qquad0 \le j \le N-2,$$

with a norm-one contracting homotopy. Thus the finite jet complex is acyclic and has closed range. In contrast, frame scaling acts on the j th primal and dual jets with eigenvalues $e^{\pm j\omega}$. Any normed completion containing all jet eigenvectors has operator norm at least $e^{j|\omega|}$ for every j, so no bounded full-frame all-jet Banach/Hilbert representation exists. The strict LF direct limit remains a valid formal test category but is not a normalizable all-order physical Hilbert space.

7 Classical null-boundary BV–BFV and BMS geometry

The boundary chain begins with Bondi data and the distinction between gauge directions and asymptotic symmetries carrying charge. The archive constructs, within explicit finite-jet and edge categories, the following objects:

6. the Bondi ghost map and radiative flux;
7. the cut cotangent extension and improved mass/memory variables;
8. corner and finite-normal-jet obstructions;
9. a moving-cut Stueckelberg edge variable $\ell(n)$;
10. a filtered BV–BFV/AKSZ collar complex and modified master identity;
11. local Noether and constraint towers with their antifield matching.

The essential geometric identity for a supertranslation $T(n)$ is

$$\ell \longmapsto \ell - T, qquadM_{T,\omega} = e^{-i\omega T(n)}. \tag{11}$$

Define

$$\nabla_A^{(\ell,\omega)} = D_A - i\omega D_A\ell. \tag{12}$$

Then

$$\nabla_A^{(\ell-T,\omega)} M_{T,\omega} = M_{T,\omega} \nabla_A^{(\ell,\omega)}, \tag{13}$$

and, when frequencies add,

$$\nabla_A^{(\ell,\omega+\nu)}(fg) = (\nabla_A^{(\ell,\omega)} f)g + f(\nabla_A^{(\ell,\nu)} g). \tag{14}$$

> ***Proof.***
>
> Differentiate $e^{-i\omega T}f$ and use $D_A(\ell - T) = D_A\ell - D_AT$. The two terms proportional to D_AT cancel, proving (13). Expanding both sides of (14) proves the second identity term by term. □

These identities prove an exact pure-supertranslation transport statement. They do not prove that an arbitrary nonlinear coefficient is parallel, nor do they fix the action on every background, Mellin weight, ghost, or antifield.

8 Radiation fields and the first nonlinear boundary gate

The radiation transform realizes the positive-frequency physical TT sector as (4). Its two-point function is positive on TT test data and carries an angular delta distribution. The ambient free BRST complex is a finite-rank complex over each mass-shell point; on a compact positive-frequency core, its cohomology is the TT bundle.

For two future-null momenta

$$p = \omega(1, n), q = \nu(1, m),$$

one has

$$(p + q)^2 = -2\omega\nu(1 - n \cdot m). \tag{15}$$

Thus $p + q$ is null exactly when $n = m$, in which case $p + q = (\omega + \nu)(1, n)$. The leading boundary nonlinear candidate is therefore a same-angle frequency convolution

$$[B_0F](\Omega, n) = \int C(\Omega, \omega, n)F(\omega, n; \Omega - \omega, n)\, \mathrm{d}\omega. \tag{16}$$

The map is well defined on smooth compact-frequency data, but the angular restriction is not continuous on the standard two-particle L^2 space. This is not repaired by merely shrinking the operator domain while retaining the same L^2 graph norm.

9 Massless BMS incidence and the sharp Sobolev trace theorem

9.1 Supertranslation selection and the failed raw pullback

Suppose a distributional bilinear kernel $\mathcal{K}(k; p, q)$ intertwines all smooth supertranslation phases. Differentiating the phase relation at the identity gives

$$[\omega_kT(n_k) - \omega_pT(n_p) - \omega_qT(n_q)]\mathcal{K} = 0 \text{ for all } T \in C^\infty(S^2). \tag{17}$$

Consequently its support lies in

$$\omega_k \delta_{n_k} = \omega_p \delta_{n_p} + \omega_q \delta_{n_q}. \tag{18}$$

For positive frequencies, smooth functions separate distinct points, so

$$n_k = n_p = n_q, qquad \omega_k = \omega_p + \omega_q. \tag{19}$$

> **Audit warning 9.1**
>
> Equation (19) is a necessary support condition. It is sufficient for intrinsic order-zero measures on the incidence manifold, but not for arbitrary normal derivatives of delta distributions: multiplying a normal delta derivative by a function vanishing to first order need not annihilate it.

Let

$$\Phi: \mathcal{N}_+^3 \to \mathbb{R}^{3,1}, \Phi(k, p, q) = k - p - q.$$

At a collinear zero $(\Omega\ell, \omega\ell, \nu\ell)$, $T_{\alpha\ell}\mathcal{N}_+ = \ell^\perp$, hence

$$\operatorname{im} D\Phi = \ell^\perp, qquad \operatorname{rank} D\Phi = 3 < 4. \tag{20}$$

The standard transversality criterion for pulling back δ^4 therefore fails. A radiation or extension prescription is additional data; it is not the ordinary restriction of the ambient delta distribution.

9.2 Nonclosability on angular L^2

In a local two-dimensional angular chart, choose

$$F_\delta(\omega, x; \nu, y) = \psi(\omega, \nu)\phi(x)\chi\,\boxed{\,}\left(\frac{y-x}{\delta}\right), \chi(0) = 1.$$

Then $\| F_\delta\|_{L^2}^2 = O(\delta^2) \to 0$, while its diagonal restriction is independent of δ. On a polarization chart where the actual order-zero coefficient is bounded away from zero, $B_0 F_\delta \to G \neq 0$. Therefore the minimal order-zero block is nonclosable on standard angular L^2.

9.3 Sharp anisotropic row analysis in the equal-index case

On a torus chart, set

$$w_t(k) = (1 + |k|^2)^t, qquad [D_t F]_k = \sum_{p\in\mathbb{Z}^2} F_{p,k-p}.$$

With domain norm $\sum_{p,q} w_t(p)w_t(q)|F_{p,q}|^2$ and output norm $\sum_k w_t(k)|g_k|^2$, the adjoint is

$$[D_t^* g]_{p,q} = \frac{w_t(p+q)}{w_t(p)w_t(q)} g_{p+q}.$$

For the normalized output coordinate, the squared row norm is

$$K_t(k) = w_t(k) \sum_{p\in\mathbb{Z}^2} \frac{1}{w_t(p)w_t(k-p)}. \tag{21}$$

Theorem 9.2 (Sharp order-zero collinear trace)

The diagonal map on the finite Fourier core has the following closures:

$$\begin{array}{ll} t \le \frac{1}{2} & \text{not closable,} \\ \frac{1}{2} < t \le 1 & \text{closable and unbounded,} \\ t > 1 & \text{bounded.} \end{array}$$

If the output is only L^2, boundedness holds exactly for $t > 1/2$. The same thresholds hold on S^2 and finite-rank smooth bundles.

Proof.

For fixed k, the tail of the sum in (21) is $|p|^{-4t}$ in dimension two. Thus each row has finite norm exactly when $t > 1/2$. If $t \le 1/2$, every nonzero output Fourier coordinate produces an infinite adjoint norm; the adjoint domain is $\{0\}$ and the densely defined minimal operator is not closable. If $t > 1/2$, finite output Fourier vectors lie in the adjoint domain, which is therefore dense.

For boundedness one needs $\sup_k K_t(k) < \infty$. Put $N = 2 + |k|$ and split the lattice into the two endpoint regions $|p| \le |k|/2$ and $|k-p| \le |k|/2$, the bulk where both are comparable to N, and the far tail. The endpoint contribution is comparable to

$$A_t(N) = \sum_{|p|\le N} (1 + |p|^2)^{-t},$$

while the bulk and tail, after multiplication by $w_t(k)$, are $O(N^{2-2t})$. Matching lower bounds follow from an endpoint subregion. Hence

$$K_t(k) \asymp \begin{cases} N^{2-2t}, & 1/2 < t < 1, \\ \log N, & t = 1, \\ 1, & t > 1. \end{cases}$$

This proves the equal-index trichotomy. Removing the output weight reduces the uniform estimate to Cauchy–Schwarz for the convolution of $(1 + |p|^2)^{-t}$ with itself, giving $t > 1/2$. Local Bessel-potential norm equivalence, a finite partition of unity, and smooth bundle trivializations transfer both necessity and sufficiency to S^2. □

9.4 Localized Wick lift and its exact scope

Choose compact input and output frequency windows $I \cup (I + I) \subset J \Subset (0, \infty)$. The radial convolution is bounded by Cauchy–Schwarz. For $t > 1/2$, the smooth compact-frequency, finite-harmonic one-particle core lies in the adjoint domain of every fixed-particle component. Finite intersections remain dense, so the localized isolated minimal Wick block is closable. For $t > 1$, the bounded coefficient gives

$$\| Q_{2\to 1}\Psi_n \| \leq C(n-1)\sqrt{n}\ \| \Psi_n \| \leq Cn^{3/2} \| \Psi_n \| . \tag{22}$$

This does not supply a global soft endpoint, a common domain for all species, or nilpotency of the complete interacting charge.

10 Lorentz intertwiners and the scalar candidate window

For scalar density weight w, the boost generator on zonal functions may be written

$$\mathcal{B}_w =-(1-x^2)\partial_x - wx.$$

A rotation-spectral intertwiner $K: E[w] \to E[w']$ with eigenvalues r_j satisfies, on the nontrivial shadow branch $w' =-2-w$,

$$\frac{r_{j+1}}{r_j} = \frac{j+1+\tau}{j+1-\tau}, \tau = w+1, qquad r_j \sim Cj^{2\tau}. \tag{23}$$

The invariant density pairing between $E[w']$ and $E[w]$ turns $(f,g)_\tau = \langle K_\tau f, g\rangle$ into an invariant Hermitian form. It is strictly positive on the full regular scalar module for $-1 < \tau < 1$, degenerates at the endpoints, and changes sign outside. Because its norm is equivalent to H^τ, intersection with the trace closability condition leaves

$$\frac{1}{2} < \tau < 1. \tag{24}$$

> **Audit warning 10.1**
>
> Equation (24) is a norm-level scalar candidate. The actual metric, ghost, nonminimal, and antifield legs need not have equal weights; their nonlinear bilinear Hom space and common domain were not constructed. The window is not a proof of an interacting BMS charge.

11 What the long BV–BMS gate chain establishes

The gates from the first Bondi construction through the collinear theorem can be organized into seven proof mechanisms:

12. **Geometric completion:** cut, corner, cotangent, and edge variables are added until the classical presymplectic and Noether identities close in the stated finite-jet category.
13. **Symbol and support analysis:** principal symbols, generator diagonals, and wavefront conormals identify where products and pullbacks cease to be canonical.
14. **Causal/local cohomology:** local counterterms can move a defect within its cohomology class but cannot cancel a nonlocal or wrong-support component.

15. **Domain no-go arguments:** shrinking tubes, point evaluation, and multiplication operators give explicit nonclosability or nonclosed-range sequences.
16. **Representation transport:** edge dressing can transport a graph unitarily between cut-dependent fibers, but transported and geometric vertices need not coincide.
17. **Rigged/formal repair:** nuclear or LF test spaces support coefficientwise products and filtered homological perturbation, while the corresponding Hilbert/GNS common domain may fail.
18. **Provenance correction:** channel parameters, momenta, sector characters, and Mellin weights are distinct labels; identifying them without a bounded intertwiner is forbidden.

These mechanisms yield many valid conditional constructions and no-go theorems. They do not, in combination, prove a complete quantum BV–BMS boundary chain.

12 Audit of the imported K75Z–K119 extension

The imported extension contains useful finite identities and several valid narrow observations, but its principal physical completion claims do not survive semantic audit. This section records the decisive points so that the paper does not inherit false theorems from passing checkers.

The K75Z–K77 no-go statements remain conditional on their selected induced module, collinear diagonal block, and majorant hypotheses; they do not exclude a differently completed principal-line direct integral or establish the full Einstein vertex. K81–K83 construct, at most, regularized distributional multilinear forms and orderwise classical BRST skeletons on a smooth core. They do not supply a Kato-closed form, a common interacting domain, or a complete classical BV–BMS master equation.

12.1 The K78 shift implementer is strongly continuous

The implementation actually written in K78 is

$$U_g|f\rangle = e^{-i\sigma(g,f)}|f\rangle.$$

The functional $\omega_0(W(f))= \delta_{f,0}$ can nevertheless be positive and symplectically invariant, with a nonseparable GNS carrier. That is a valid abstract nonregular state; it does not imply discontinuity of every supertranslation implementation. For $g = tg_0$ every basis vector therefore acquires the continuous phase $e^{-it\sigma(g_0,f)}$. The orbit is norm-continuous on finite linear combinations, and uniform boundedness of the unitaries extends strong continuity to the whole carrier. Stone's theorem then gives a self-adjoint generator for this one-parameter shift implementation. A different action that moves labels in a discrete basis can be discontinuous, but that argument does not apply to the displayed phase implementation. The blanket K78 claim that supertranslations have no self-adjoint generators is therefore refuted in its stated scope.

12.2 The K80 sector premise fails

Let $\mathcal{W}(\Sigma, \sigma)$ be the Weyl algebra and let $L \subset \Sigma$ be Lagrangian. Although $\sigma|_{L\times L} = 0$, $W(l)$ is not central in the full Weyl algebra: for a conjugate $l^{'}$,

$$W(l)W(l^{'}) = e^{-\frac{i}{2}\sigma(l,l^{'})}W(l+l^{'}), W(l^{'})W(l) = e^{+\frac{i}{2}\sigma(l,l^{'})}W(l+l^{'}).$$

Thus characters of $W(L)$ do not provide a central decomposition of the full algebra. The claimed reduction to a separable TT Fock carrier therefore does not follow. In the corresponding character GNS construction, conjugate directions remain as mutually orthogonal $\ell^2(L^{'})$ labels; they are not removed by fixing a character on L. Thus the carrier is not the advertised TT-only sector, and every later argument depending on that carrier is conditional at best. Moreover, $W(l^{'})$ connects different character fibers, so these characters are not superselection sectors of the full algebra and the later cross-sector selection rule loses its premise.

12.3 Angular smoothing does not commute with supertranslations

For $M_T f = e^{-i\omega T(n)} f$ and nonconstant T,

$$[\Delta_{S^2}, M_T]f = (\Delta m_T)f + 2\nabla m_T \cdot \nabla f \neq 0. \quad (25)$$

Hence $J_\epsilon = (1+\epsilon\Delta)^{-1}$ does not commute with M_T. A checker that diagonalizes both in the same finite basis assumes away the defect and cannot prove the Ward identity. The one-loop boundary QME claimed after this step is consequently not established. Independently, the claimed finite remainder was not derived from the Einstein metric–ghost loop kernel, and finite-dimensional Whitehead-type vanishing does not establish the required local cohomology for the infinite-dimensional boundary module. The all-order induction therefore has no valid one-loop base. A possible moving-cut repair would instead require a separately constructed cut-dependent smoother satisfying $J_{\ell-T}M_T = M_T J_\ell$; that covariance theorem is absent.

12.4 The K85 group law is not an interacting charge algebra

The Weyl relation and a stipulated Lorentz semidirect action define an abstract Heisenberg–semidirect group. They do not derive renormalized charges from the BV action and boundary symplectic form. Charge integrability, flux, field-dependent brackets, a common form domain, BRST descent, and the relevant central-extension classification remain open. K89 cannot promote this definitional group law to an all-order QME because its K84 base case fails.

12.5 The resolvent is not trace class on S^2

The eigenvalue of J_ϵ on angular momentum j is $m_j = (1 + \epsilon j(j + 1))^{-1}$ with multiplicity $2j + 1$. Therefore

$$\sum_{j=0}^{\infty} (2j + 1)m_j \sim \frac{2}{\epsilon} \sum_{j=1}^{\infty} \frac{1}{j} = \infty.$$

Thus

$$J_\epsilon \in \mathfrak{S}_2 \setminus \mathfrak{S}_1$$

for every $\epsilon > 0$: it is Hilbert–Schmidt but not trace class. The trace-class premise used for Kato–Rosenblum scattering and asymptotic completeness fails. The self-adjointness, common-domain, and $C^2(A)$ hypotheses required for the separate Mourre route were not established either.

12.6 Dressing phases do not by themselves cancel soft norms

K79 itself finds that the nonregular Weyl family need not have a Taylor expansion at $\kappa = 0$. K86 nevertheless assumes $\chi(\kappa M) = e^{i\kappa\theta(M)}$ and expands it order by order. For a generic character of the discretely topologized group this continuity is not available. Even if such a continuous character is imposed, replacing a Weyl operator by it produces a modulus-one c-number. Such a phase cannot cancel a positive real logarithmic divergence in the magnitude of an amplitude without an explicit real/virtual factorization theorem and coefficient matching. Defining a second-order amplitude so that the optical identity holds is circular. Consequently the archive does not prove infrared-finite interacting scattering or an optical theorem.

12.7 Cook decay and joint wave operators are absent

A combinatorial identity $\sum_n X^n/n! = e^X$ proves exponentiation only after the relevant diagrammatic factorization has been established; it does not prove gravitational soft factorization itself. A local dispersive estimate for the free evolution does not by itself imply

$$\| Ve^{-itH_0}\psi \| = O(t^{-3/2})$$

for an angular smoothing or momentum-convolution operator V. In particular, a bounded V commuting with H_0 gives a norm that is constant in time. K87 supplies neither the spatial short-range/localization estimate needed by Cook's method nor a self-adjoint interacting Hamiltonian to which a wave operator could refer. Moreover, in the presence of massless–massive cross-interactions the joint wave operator in K95 cannot be inferred as $\Omega_{\mathrm{ml}} \otimes \Omega_{\mathrm{mv}}$. The massive-shell/$\mathcal{H}_3$ measure dictionary and free Lorentz representation are valid, but interacting joint asymptotic completeness is unproved.

12.8 Global anomaly, Higgs sectors, and CPT remain open

For the explicitly selected $C^{\infty}(S^2, \mathbb{R}) \rtimes \mathrm{Diff}(S^2)$ and corresponding boundary conditions, the Smale route can give $\pi_0 \simeq \mathbb{Z}_2$; the ordinary projective component-group question then has $H^2(\mathbb{Z}_2, U(1)) = 0$. These are conditional kinematic facts. They do not compute determinant- or Pfaffian-line holonomy, mapping-torus phases, η-invariants, or the relevant bordism group, so the K90 global-anomaly conclusion remains unproved.

Two standard local checks also survive. For a neutral four-dimensional Weyl fermion, $\widehat{A}$ has no degree-six component that could supply a pure local gravitational anomaly polynomial. The one-generation Standard Model arithmetic cancels $U(1)^3$, mixed gravitational–$U(1)$, $SU(2)^2U(1)$, $SU(3)^2U(1)$, and the nonabelian perturbative anomalies, while an even number of $SU(2)$ doublets passes the Witten mod-two check. These are textbook anomaly calculations, not a construction of matter coupling to the boundary BV–BMS QME.

Likewise a gauge-dependent Higgs vacuum expectation value is not a gauge-invariant central observable and cannot by itself label physical superselection sectors as claimed in K94. Finally, Hermiticity and a finite-dimensional relation $KSK = S^{-1}$ do not establish interacting CPT; locality, covariance, the spectrum condition, and the actual antiunitary implementation are still required. The standard 4D local-anomaly arithmetic and the free massive representation facts survive, but their coupling to the interacting BV–BMS theory has not been constructed.

12.9 The black-hole and cosmology blocks are interfaces, not derivations

Schwarzschild algebraic identities, the Rindler/KMS single-mode algebra, $\int d\omega/\omega$ logarithms, and the elementary de Sitter mode equation are valid within their stated backgrounds. They do not derive collapse, greybody factors, back reaction, information recovery, microstates, decoherence, or a probability measure from the BV–BMS theory. These blocks are conditional interface specifications.

12.10 The oscillator back-reaction chain requires retraction

If H_{int} is self-adjoint and nonnegative and B is bounded self-adjoint, then

$$H_0 = H_{\mathrm{int}} \otimes 1 + 1 \otimes H_{\mathrm{osc}}$$

is self-adjoint on

$$\mathrm{Dom}\,(H_{\mathrm{int}} \otimes 1) \cap \mathrm{Dom}\,(1 \otimes H_{\mathrm{osc}}),$$

and $B \otimes q$ is infinitesimally H_0-bounded. This is a correct conditional abstract theorem. More precisely, if $H_{\mathrm{osc}} = \frac{1}{2}(p^2 + \Omega^2 q^2)$, then for every real κ,

$$H = H_0 + \kappa B \otimes q$$

is self-adjoint on the same intersection domain and

$$H \geq -\frac{\kappa^2 \parallel B \parallel^2}{2\Omega^2}.$$

The actual K81 Einstein boundary block was not shown to be such a fixed bounded self-adjoint B, so this is not yet a derivation of an Einstein back-reaction Hamiltonian. Separately, a decomposable operator with essentially uniformly bounded fibers on an independently imposed compact regular q-domain is bounded; this is only a cutoff direct-integral fact.

The subsequent stronger claims fail:

19. A sharp spectral projection $P_* = \mathbf{1}_{|q|<q_*}$ does not reduce p^2. The compression P_*HP_* is not automatically self-adjoint; a boundary condition and a domain theorem are required.
20. The Chebyshev estimate $\langle \mathbf{1}_{|q|\geq r} \rangle \leq 2\langle H_{osc} \rangle / (\Omega^2 r^2)$ is a tail-probability bound, not a dynamical barrier or an estimate on the norm of $H - P_*HP_*$.
21. A negative smoothing eigenvalue does not by itself imply nonunitarity of a self-adjoint Hamiltonian.
22. An upper bound on ΔA is not a lower bound on measurement resolution. Differences of uncertainty upper bounds at adjacent oscillator energies do not define a discrete operational spectrum.

Therefore the claimed low-energy singularity isolation, effective area discreteness, and K120 barrier-stability handoff are not proved.

One further narrow fact survives. If one independently postulates the carrier $L^2((-q_*, q_*), \mathrm{d}q)$ and the multiplication observable $A = A_0 + \kappa q$ with $\kappa \neq 0$, then its spectrum is the continuous interval $A_0 + \kappa[-q_*, q_*]$ and it has no point spectrum. This conditional spectral statement is neither a derivation of the physical 4D area observable nor a spacing or dynamical-cutoff theorem.

13 Current theorem boundary and open obligations

The audited status is summarized in Table 1.

Audited status of the main research layers.

Layer	Status	Strongest justified statement
Linearized Einstein gravity	P	Two physical helicities at every nonzero null momentum.
Free graviton Fock sector	P, narrow	Positive TT Fock space away from $\omega = 0$.

Layer	Status	Strongest justified statement
Gravity EFT	P, orderwise	Power counting and regulated coefficientwise unitarity; no UV completion.
Classical BV gravity	P, local	Off-shell BRST nilpotency and CME for the stated field content.
Local causal QME restoration	C/formal	Valid when the specified local anomaly class vanishes; no convergence.
Classical null-boundary BV–BFV	P/C by gate	Explicit finite-jet and edge constructions plus no-go theorems.
Massless collinear nonlinear block	P	Nonclosable on angular L^2; sharp equal-index Sobolev thresholds.
Scalar complementary repair	C	Norm-level window $1/2 < \tau < 1$; not an actual nonlinear BV module.
One-loop boundary QME after K84	R/U	Claimed proof uses the false commutator $[J_c, M_T] = 0$.
Interacting charge algebra and IR scattering	U	Sector premise, dressing cancellation, and scattering domains are not established.
Global anomaly, Higgs sectors, and CPT	C/U	Narrow kinematic and anomaly arithmetic survives; physical coupling and global reconstruction are open.
Black-hole/cosmology blocks	C/N	Background identities and interface specifications only.
Abstract oscillator coupling / Einstein identification	P abstract/U physical	Self-adjoint and lower-bounded for postulated fixed bounded B; no 4D Einstein derivation.
Complete quantum gravity	U	PO-0–PO-11 are not jointly satisfied.

The next legitimate research gate is a correction and reconstruction gate, not the imported K120. It must first fix the representation premise, construct the actual boundary reduced phase space and gauge-invariant geometric observables, derive the nonlinear operator or closed form with its domain, and only then revisit quantum Ward identities, scattering, horizons, or dynamical geometry.

14 Conclusion

The program has produced a substantial body of precise local, perturbative, boundary-geometric, and operator-domain mathematics. Its strongest internally audited analytic result is the sharp massless collinear trace theorem and its application to the actual order-zero Einstein–ghost boundary component. The same audit that validates this theorem also blocks premature completion claims: formal BV identities do not create an interacting Hilbert domain; finite skeletons do not prove infinite-dimensional spectral statements; and background thermodynamic identities do not solve black-hole dynamics.

Accordingly, the present work is best described as an audited BV–BMS research program with rigorous sector theorems and explicit obstruction maps. It is not a proof of complete quantum gravity. This distinction is not rhetorical; it is the main mathematical output of enforcing theorem-level scope at every gate.

Appendix A Gate-by-gate proof and evidence atlas

The supplementary atlas is part of this manuscript. It lists every proof document, the associated checker, the proof mechanism, and the audited scope. For space and auditability, line-by-line source derivations remain in the frozen proof files, while every proof route is represented in the atlas and in the thematic derivations above.

Complete 258-gate evidence atlas. "Checker" identifies the finite executable skeleton; the final column gives the semantic audit and proof mechanism.

Gate	Archived proof route	Checker	Audited status and mechanism
IR-BV-ALLJET-12	arbitrary order symbol exactness	verify_alljet_symbol.py	Scoped local/formal BV theorem or conditional analytic gate; method: symbol-rank/jet exactness and filtered lifting
IR-BV-BMSCHARGE-28	bondi ghost map and charge gate	verify_bondi_bms_ghost_map.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: boundary symmetry, Ward identity, or representation calculation
IR-BV-BMSCHARGE-28E	radiative flux and corner obstruction	verify_bms_radiative_flux.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: explicit witness, incompatibility, or domain no-go
IR-BV-BMSCHARGE-28F	shear jet no go and edge embedding	verify_bms_edge_embedding.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: explicit witness, incompatibility, or domain no-go
IR-BV-BMSCHARGE-28G	cut cotangent bfv algebra	verify_bms_cut_bfv.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: direct algebraic, geometric, or functional-analytic proof route
IR-BV-BMSCHARGE-28H	supertranslation mass constraint matching	verify_bms_mass_matching.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: boundary symmetry, Ward identity, or representation calculation
IR-BV-BMSCHARGE-28I	improved mass and memory split	verify_bms_improved_mass.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: soft asymptotics, weighted-domain, or zero-mode analysis
IR-BV-BMSCHARGE-28J2	angular shift constraint	verify_bondi_angular_shift.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: direct algebraic, geometric, or functional-analytic proof route
IR-BV-BMSCHARGE-28J3	mass loss reconstruction	verify_bondi_mass_loss.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: direct algebraic, geometric, or functional-analytic proof route
IR-BV-BMSCHARGE-28J4	raw angular momentum constraint	verify_bondi_angular_momentum.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: direct algebraic, geometric, or functional-analytic proof route
IR-BV-BMSCHARGE-28J	radial constraint and beta	verify_bondi_radial_constraint.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: soft asymptotics, weighted-domain, or zero-mode analysis
IR-BV-BMSCHARGE-28K100	ratio lemma greybody and hawking flux gate	verify_bms_k100_ratio_lemma_greybody_and_hawking_flux_gate.py	Conditional Hawking/greybody scaling interface; not an exact lifetime theorem; method: background thermodynamic or horizon-interface calculation
IR-BV-BMSCHARGE-28K101	entropy bookkeeping page time and information tension gate	verify_bms_k101_entropy_bookkeeping_page_time_and_information_tension_gate.py	Thermodynamic bookkeeping/interface; information recovery unproved; method: background thermodynamic or horizon-interface calculation
IR-BV-BMSCHARGE-28K102	microstate interface and hair entropy gate	verify_bms_k102_microstate_interface_and_hair_entropy_gate.py	Microstate-interface counting only; no microstate construction; method: operator-domain, representation, or spectral argument

Gate	Archived proof route	Checker	Audited status and mechanism
IR-BV-BMSCHARGE-28K103	horizon row criticality and route selection gate	verify_bms_k103_horizon_row_criticality_and_route_selection_gate.py	Unproved horizon-row physical identification and no-go extrapolation; method: background thermodynamic or horizon-interface calculation
IR-BV-BMSCHARGE-28K104	uv interface specification gate	verify_bms_k104_uv_interface_specification_gate.py	Specification/audit gate only; no UV candidate accepted; method: direct algebraic, geometric, or functional-analytic proof route
IR-BV-BMSCHARGE-28K105	cosmological entry gate	verify_bms_k105_cosmological_entry_gate.py	Cosmological entry specification/background identities only; method: model/interface or continuum-limit calculation
IR-BV-BMSCHARGE-28K106	static patch algebra thermal reduction and horizon ward gate	verify_bms_k106_static_patch_algebra_thermal_reduction_and_horizon_ward_gate.py	Static-patch finite algebra/interface; no global de Sitter theory; method: background thermodynamic or horizon-interface calculation
IR-BV-BMSCHARGE-28K107	perturbation spectrum and quantum classical gate	verify_bms_k107_perturbation_spectrum_and_quantum_classical_gate.py	Standard mode-equation skeleton; decoherence and data interface open; method: operator-domain, representation, or spectral argument
IR-BV-BMSCHARGE-28K108	empirical interface specification gate	verify_bms_k108_empirical_interface_specification_gate.py	Empirical protocol specification only; no data analysis; method: direct algebraic, geometric, or functional-analytic proof route
IR-BV-BMSCHARGE-28K109	ledger checkpoint and obligation graph gate	verify_bms_k109_ledger_checkpoint_and_obligation_graph_gate.py	Historical ledger/checkpoint hygiene gate; method: direct algebraic, geometric, or functional-analytic proof route
IR-BV-BMSCHARGE-28K10	constraint bracket cokernel obstruction	verify_bms_constraint_cokernel.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: explicit witness, incompatibility, or domain no-go
IR-BV-BMSCHARGE-28K110	nonperturbative entry candidates constraints and subproblem gate	verify_bms_k110_nonperturbative_entry_candidates_constraints_and_subproblem_gate.py	Nonperturbative-program specification; no existence theorem; method: direct algebraic, geometric, or functional-analytic proof route
IR-BV-BMSCHARGE-28K111	truncated interface theory specification and existence gate	verify_bms_k111_truncated_interface_theory_specification_and_existence_gate.py	Finite truncation model only; method: direct algebraic, geometric, or functional-analytic proof route
IR-BV-BMSCHARGE-28K112	uniform estimates and continuum limit gate	verify_bms_k112_uniform_estimates_and_continuum_limit_gate.py	Conditional fixed-regulator bounded-operator model; physical Hamiltonian unconstructed; method: direct algebraic, geometric, or functional-analytic proof route
IR-BV-BMSCHARGE-28K113	interface verdict handoff and next layer gate	verify_bms_k113_interface_verdict_handoff_and_next_layer_gate.py	Interface handoff/specification only; method: direct algebraic, geometric, or functional-analytic proof route
IR-BV-BMSCHARGE-28K114	generator decompactification and s5 continuum gate	verify_bms_k114_generator_decompactification_and_s5_continuum_gate.py	Riemann/logarithm facts plus conditional fixed-regulator model; method: model/interface or continuum-limit calculation
IR-BV-BMSCHARGE-28K115	angular lorentz recovery and covariance verdict gate	verify_bms_k115_angular_lorentz_recovery_and_covariance_verdict_gate.py	Conditional representation estimate; no complete BMS dynamics; method: boundary symmetry, Ward identity, or representation calculation
IR-BV-BMSCHARGE-28K116	background dynamics entry gate	verify_bms_k116_background_dynamics_entry_gate.py	Background-dynamics program specification; method: direct algebraic, geometric, or functional-analytic proof route
IR-BV-BMSCHARGE-28K117	single mode coupling specification and selfadjointness gate	verify_bms_k117_single_mode_coupling_specification_and_selfadjointness_gate.py	Conditional abstract oscillator coupling; domain correction required; method: operator-domain, representation, or spectral argument
IR-BV-BMSCHARGE-28K118	back reaction form verdict gate	verify_bms_k118_back_reaction_form_verdict_gate.py	Refuted truncation/barrier inference; only Chebyshev tail bound survives; method: direct algebraic, geometric, or functional-analytic proof route
IR-BV-BMSCHARGE-28K119	area spectrum interface and single mode closure gate	verify_bms_k119_area_spectrum_interface_and_single_mode_closure_gate.py	Continuous multiplication spectrum conditional; effective-discreteness claim refuted; method: operator-domain, representation, or spectral argument
IR-BV-BMSCHARGE-28K11	coulombic news symplectic extension	verify_bms_coulombic_news_extension.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: direct algebraic, geometric, or functional-analytic proof route

Gate	Archived proof route	Checker	Audited status and mechanism
IR-BV-BMSCHARGE-28K12	hard flux endpoint value obstruction	verify_bms_hard_flux_endpoint_obstruction.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: explicit witness, incompatibility, or domain no-go
IR-BV-BMSCHARGE-28K13	shear value edge dynamical completion	verify_bms_shear_value_edge_completion.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: direct algebraic, geometric, or functional-analytic proof route
IR-BV-BMSCHARGE-28K14	finite normal jet dynamical no go	verify_bms_normal_jet_dynamical_no_go.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: explicit witness, incompatibility, or domain no-go
IR-BV-BMSCHARGE-28K15	projet cotangent topology no go	verify_bms_projet_cotangent.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: explicit witness, incompatibility, or domain no-go
IR-BV-BMSCHARGE-28K16	collar history cotangent obstruction	verify_bms_collar_history_cotangent.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: explicit witness, incompatibility, or domain no-go
IR-BV-BMSCHARGE-28K17	finite conormal edge no go	verify_bms_finite_conormal_edge.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: explicit witness, incompatibility, or domain no-go
IR-BV-BMSCHARGE-28K18	sobolev scale hamiltonian domain	verify_bms_sobolev_scale_domain.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: direct algebraic, geometric, or functional-analytic proof route
IR-BV-BMSCHARGE-28K19	scale poisson and lorentz core	verify_bms_scale_poisson_lorentz.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: boundary symmetry, Ward identity, or representation calculation
IR-BV-BMSCHARGE-28K20	mass constraint scale brackets	verify_bms_mass_constraint_scale_brackets.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: direct algebraic, geometric, or functional-analytic proof route
IR-BV-BMSCHARGE-28K21	angular matching underdetermination	verify_bms_angular_matching_gate.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: direct algebraic, geometric, or functional-analytic proof route
IR-BV-BMSCHARGE-28K22	global angular equivariance gate	verify_bms_global_angular_equivariance_gate.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: direct algebraic, geometric, or functional-analytic proof route
IR-BV-BMSCHARGE-28K23	angular metric order and E gate	verify_bms_angular_metric_order_gate.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: direct algebraic, geometric, or functional-analytic proof route
IR-BV-BMSCHARGE-28K24	E stratum global BMS invariance	verify_bms_E_stratum_invariance.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: boundary symmetry, Ward identity, or representation calculation
IR-BV-BMSCHARGE-28K25	coulombic pair equivariance no go	verify_bms_coulombic_equivariance_no_go.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: explicit witness, incompatibility, or domain no-go
IR-BV-BMSCHARGE-28K26	lorentz coulombic hamiltonian completion	verify_bms_lorentz_coulombic_completion.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: boundary symmetry, Ward identity, or representation calculation
IR-BV-BMSCHARGE-28K27	global BMS classical boundary BFV	verify_bms_global_boundary_bfv.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: boundary symmetry, Ward identity, or representation calculation
IR-BV-BMSCHARGE-28K28	EH corner provenance gate	verify_bms_EH_corner_provenance_gate.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: direct algebraic, geometric, or functional-analytic proof route
IR-BV-BMSCHARGE-28K29	extended EH edge action transgression	verify_bms_extended_edge_action.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: direct algebraic, geometric, or functional-analytic proof route
IR-BV-BMSCHARGE-28K2	boost balance and corner obstruction	verify_bms_boost_balance.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: explicit witness, incompatibility, or domain no-go

Gate	Archived proof route	Checker	Audited status and mechanism
IR-BV-BMSCHARGE-28K30	collar AKSZ modified master	verify_bms_collar_aksz_bvbfv.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: direct algebraic, geometric, or functional-analytic proof route
IR-BV-BMSCHARGE-28K31	standard EH BV restriction gate	verify_bms_standard_EH_BV_restriction_gate.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: direct algebraic, geometric, or functional-analytic proof route
IR-BV-BMSCHARGE-28K32	EH collar antifield matching gate	verify_bms_EH_collar_antifield_matching.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: direct algebraic, geometric, or functional-analytic proof route
IR-BV-BMSCHARGE-28K33	cotangent graph and EH Noether split	verify_bms_cotangent_graph_noether_split.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: direct algebraic, geometric, or functional-analytic proof route
IR-BV-BMSCHARGE-28K34	bare Komar mass projection gate	verify_bms_bare_Komar_mass_gate.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: direct algebraic, geometric, or functional-analytic proof route
IR-BV-BMSCHARGE-28K35	linear shear supertranslation IW gate	verify_bms_linear_shear_IW_gate.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: boundary symmetry, Ward identity, or representation calculation
IR-BV-BMSCHARGE-28K36	Bondi counterterm WZ flux	verify_bms_Bondi_counterterm_WZ_flux.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: local cohomology, causal induction, or subtraction analysis
IR-BV-BMSCHARGE-28K37	Lorentz counterterm cocycle	verify_bms_Lorentz_counterterm_cocycle.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: local cohomology, causal induction, or subtraction analysis
IR-BV-BMSCHARGE-28K38	moving frame counterterm completion	verify_bms_moving_frame_counterterm.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: local cohomology, causal induction, or subtraction analysis
IR-BV-BMSCHARGE-28K39	metric antifield basicness gate	verify_bms_metric_antifield_basicness.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: direct algebraic, geometric, or functional-analytic proof route
IR-BV-BMSCHARGE-28K3	finite corner tower no go	verify_bms_corner_tower_no_go.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: explicit witness, incompatibility, or domain no-go
IR-BV-BMSCHARGE-28K40	formal jet tower Q matching	verify_bms_jet_tower_q_matching.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: symbol-rank/jet exactness and filtered lifting
IR-BV-BMSCHARGE-28K41	Noether Delta2 closure	verify_bms_noether_delta2_closure.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: direct algebraic, geometric, or functional-analytic proof route
IR-BV-BMSCHARGE-28K42	full Noether constraint BFV	verify_bms_full_noether_bfv.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: direct algebraic, geometric, or functional-analytic proof route
IR-BV-BMSCHARGE-28K43	full modified master tower	verify_bms_full_modified_master_tower.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: direct algebraic, geometric, or functional-analytic proof route
IR-BV-BMSCHARGE-28K44	unrestricted locally convex no go	verify_bms_unrestricted_lcs_no_go.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: explicit witness, incompatibility, or domain no-go
IR-BV-BMSCHARGE-28K45	filtered scale BVBFV	verify_bms_filtered_scale_bvbfv.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: direct algebraic, geometric, or functional-analytic proof route
IR-BV-BMSCHARGE-28K46	boundary QME regulator gate	verify_bms_boundary_qme_regulator_gate.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: local cohomology, causal induction, or subtraction analysis
IR-BV-BMSCHARGE-28K47	boundary microlocal generator diagonal gate	verify_bms_boundary_generator_diagonal_gate.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: direct algebraic, geometric, or functional-analytic proof route

Gate	Archived proof route	Checker	Audited status and mechanism
IR-BV-BMSCHARGE-28K48	null pullback and inflow quotient gate	verify_bms_null_pullback_inflow_quotient_gate.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: direct algebraic, geometric, or functional-analytic proof route
IR-BV-BMSCHARGE-28K49	physical TT radiation field gate	verify_bms_physical_tt_radiation_field_gate.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: direct algebraic, geometric, or functional-analytic proof route
IR-BV-BMSCHARGE-28K4	moving cut supertranslation completion	verify_bms_moving_cut_supertranslations.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: boundary symmetry, Ward identity, or representation calculation
IR-BV-BMSCHARGE-28K50	ambient BRST radiation gate	verify_bms_ambient_brst_radiation_gate.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: direct algebraic, geometric, or functional-analytic proof route
IR-BV-BMSCHARGE-28K51	nonlinear radiation regulator gate	verify_bms_nonlinear_radiation_regulator_gate.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: direct algebraic, geometric, or functional-analytic proof route
IR-BV-BMSCHARGE-28K52	sobolev stratified renormalization	verify_bms_sobolev_stratified_renormalization.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: local cohomology, causal induction, or subtraction analysis
IR-BV-BMSCHARGE-28K53	intersecting forest relative coefficient gate	verify_bms_intersecting_forest_relative_coefficient.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: local cohomology, causal induction, or subtraction analysis
IR-BV-BMSCHARGE-28K54	bulk collar boundary condition identifiability	verify_bms_bulk_collar_boundary_condition_identifiability.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: direct algebraic, geometric, or functional-analytic proof route
IR-BV-BMSCHARGE-28K55	conformal calderon supertranslation gate	verify_bms_conformal_calderon_supertranslation_gate.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: boundary symmetry, Ward identity, or representation calculation
IR-BV-BMSCHARGE-28K56	edge connected mixed calderon gate	verify_bms_edge_connected_mixed_calderon_gate.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: direct algebraic, geometric, or functional-analytic proof route
IR-BV-BMSCHARGE-28K57	full graded calderon curvature gate	verify_bms_full_graded_calderon_curvature_gate.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: direct algebraic, geometric, or functional-analytic proof route
IR-BV-BMSCHARGE-28K58	nonsplit cosymbol transgression gate	verify_bms_nonsplit_cosymbol_transgression_gate.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: symbol-rank/jet exactness and filtered lifting
IR-BV-BMSCHARGE-28K59	all order chain strictification lorentz class gate	verify_bms_all_order_chain_strictification_gate.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: boundary symmetry, Ward identity, or representation calculation
IR-BV-BMSCHARGE-28K5	lorentz covariant moving slab	verify_bms_lorentz_moving_slab.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: boundary symmetry, Ward identity, or representation calculation
IR-BV-BMSCHARGE-28K60	knapp stein strict lorentz graded calderon gate	verify_bms_knapp_stein_strict_lorentz_graded_calderon_gate.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: boundary symmetry, Ward identity, or representation calculation
IR-BV-BMSCHARGE-28K61	first interacting forest inflow identifiability gate	verify_bms_first_interacting_forest_inflow_identifiability.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: local cohomology, causal induction, or subtraction analysis
IR-BV-BMSCHARGE-28K62	gauge fixed EH pushforward counterterm nonuniqueness gate	verify_bms_gauge_fixed_EH_pushforward_counterterm_nonuniqueness.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: local cohomology, causal induction, or subtraction analysis
IR-BV-BMSCHARGE-28K63	strict BMS nuclear regulator pushforward no go	verify_bms_strict_BMS_nuclear_regulator_pushforward_no_go.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: explicit witness, incompatibility, or domain no-go
IR-BV-BMSCHARGE-28K64	heat regulator relative restoration obstruction	verify_bms_heat_regulator_relative_restoration_obstruction.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: explicit witness, incompatibility, or domain no-go

Gate	Archived proof route	Checker	Audited status and mechanism
IR-BV-BMSCHARGE-28K65	generator counterterm causal QAP no go	verify_bms_generator_counterterm_causal_QAP_no_go.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: explicit witness, incompatibility, or domain no-go
IR-BV-BMSCHARGE-28K66	bulk induced nonlocal cancellation and null timeslice gate	verify_bms_bulk_induced_nonlocal_cancellation_and_null_timeslice.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: direct algebraic, geometric, or functional-analytic proof route
IR-BV-BMSCHARGE-28K67	finite edge determinant and global holonomy gate	verify_bms_finite_edge_determinant_and_global_holonomy.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: direct algebraic, geometric, or functional-analytic proof route
IR-BV-BMSCHARGE-28K68	finite full target truncation no go and hessian gate	verify_bms_finite_full_target_truncation_no_go_and_hessian_gate.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: explicit witness, incompatibility, or domain no-go
IR-BV-BMSCHARGE-28K69	scale fredholm hessian and relative determinant gate	verify_bms_scale_fredholm_hessian_and_relative_determinant_gate.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: symbol-rank/jet exactness and filtered lifting
IR-BV-BMSCHARGE-28K6	mass constraint tangency obstruction	verify_bms_mass_constraint_tangency.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: explicit witness, incompatibility, or domain no-go
IR-BV-BMSCHARGE-28K70	modified trace qap and endpoint gluing gate	verify_bms_modified_trace_qap_and_endpoint_gluing_gate.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: direct algebraic, geometric, or functional-analytic proof route
IR-BV-BMSCHARGE-28K71A	calculus choice and naive residue rejection	verify_bms_k71a_calculus_choice_and_naive_residue_rejection.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: direct algebraic, geometric, or functional-analytic proof route
IR-BV-BMSCHARGE-28K71AA	finite history transfer supertrace index gate	verify_bms_k71aa_finite_history_transfer_supertrace_index_gate.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: direct algebraic, geometric, or functional-analytic proof route
IR-BV-BMSCHARGE-28K71AB	KS endpoint determinant line metaplectic QME gate	verify_bms_k71ab_KS_endpoint_determinant_line_metaplectic_QME_gate.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: local cohomology, causal induction, or subtraction analysis
IR-BV-BMSCHARGE-28K71AC	strict Volterra QME cohomology gate	verify_bms_k71ac_strict_Volterra_QME_cohomology_gate.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: local cohomology, causal induction, or subtraction analysis
IR-BV-BMSCHARGE-28K71AD	actual TT composite memory lift gate	verify_bms_k71ad_actual_TT_composite_memory_lift_gate.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: soft asymptotics, weighted-domain, or zero-mode analysis
IR-BV-BMSCHARGE-28K71AE	full minimal BV Volterra spectral sequence gate	verify_bms_k71ae_full_minimal_BV_Volterra_spectral_sequence_gate.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: direct algebraic, geometric, or functional-analytic proof route
IR-BV-BMSCHARGE-28K71AF	two vertex order provenance gate	verify_bms_k71af_two_vertex_order_provenance_gate.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: direct algebraic, geometric, or functional-analytic proof route
IR-BV-BMSCHARGE-28K71AG	relative BV Hom lifting obstruction gate	verify_bms_k71ag_relative_BV_Hom_lifting_obstruction_gate.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: explicit witness, incompatibility, or domain no-go
IR-BV-BMSCHARGE-28K71AH	finite edge relative class detector image gate	verify_bms_k71ah_finite_edge_relative_class_detector_image_gate.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: direct algebraic, geometric, or functional-analytic proof route
IR-BV-BMSCHARGE-28K71AI	sobolev frechet grouped completion no go	verify_bms_k71ai_sobolev_frechet_grouped_completion_no_go.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: explicit witness, incompatibility, or domain no-go
IR-BV-BMSCHARGE-28K71AJ	distributional polynomial forest variation gate	verify_bms_k71aj_distributional_polynomial_forest_variation_gate.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: local cohomology, causal induction, or subtraction analysis
IR-BV-BMSCHARGE-28K71AK	external source WZ extension dynamicalization gate	verify_bms_k71ak_external_source_WZ_extension_dynamicalization_gate.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: direct algebraic, geometric, or functional-analytic proof route

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IR-BV-BMSCHARGE-28K71AL	retarded WZ causal factorization cutoff gate	verify_bms_k71al_retarded_WZ_causal_factorization_cutoff_gate.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: direct algebraic, geometric, or functional-analytic proof route
IR-BV-BMSCHARGE-28K71AM	stateful Weyl unitarity cutoff limit gate	verify_bms_k71am_stateful_Weyl_unitarity_cutoff_limit_gate.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: operator-domain, representation, or spectral argument
IR-BV-BMSCHARGE-28K71AN	nonregular contact cutoff algebra gate	verify_bms_k71an_nonregular_contact_cutoff_algebra_gate.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: direct algebraic, geometric, or functional-analytic proof route
IR-BV-BMSCHARGE-28K71AO	one loop exhaustiveness scheme universality gate	verify_bms_k71ao_one_loop_exhaustiveness_scheme_universality_gate.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: direct algebraic, geometric, or functional-analytic proof route
IR-BV-BMSCHARGE-28K71B	product trace and orientation gluing gate	verify_bms_k71b_product_trace_and_gluing_gate.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: direct algebraic, geometric, or functional-analytic proof route
IR-BV-BMSCHARGE-28K71C	principal symbol packet compatibility gate	verify_bms_k71c_principal_symbol_packet_compatibility_gate.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: symbol-rank/jet exactness and filtered lifting
IR-BV-BMSCHARGE-28K71D	bulk edge schur complement gate	verify_bms_k71d_bulk_edge_schur_complement_gate.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: direct algebraic, geometric, or functional-analytic proof route
IR-BV-BMSCHARGE-28K71E	regulated boundary green dtn gate	verify_bms_k71e_regulated_boundary_green_dtn_gate.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: direct algebraic, geometric, or functional-analytic proof route
IR-BV-BMSCHARGE-28K71F	cotangent cross berezinian gate	verify_bms_k71f_cotangent_cross_berezinian_gate.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: direct algebraic, geometric, or functional-analytic proof route
IR-BV-BMSCHARGE-28K71G	dynamical mixed forest subprincipal gate	verify_bms_k71g_dynamical_mixed_forest_subprincipal_gate.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: local cohomology, causal induction, or subtraction analysis
IR-BV-BMSCHARGE-28K71H	global lorentz partial diagonal determinant gate	verify_bms_k71h_global_lorentz_partial_diagonal_gate.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: boundary symmetry, Ward identity, or representation calculation
IR-BV-BMSCHARGE-28K71I	supertranslation hard flux volterra forest gate	verify_bms_k71i_supertranslation_hard_flux_volterra_gate.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: local cohomology, causal induction, or subtraction analysis
IR-BV-BMSCHARGE-28K71J	fixed frequency tt heat tadpole gate	verify_bms_k71j_fixed_frequency_tt_heat_tadpole_gate.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: direct algebraic, geometric, or functional-analytic proof route
IR-BV-BMSCHARGE-28K71K	positive frequency normal ordering gate	verify_bms_k71k_positive_frequency_normal_ordering_gate.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: direct algebraic, geometric, or functional-analytic proof route
IR-BV-BMSCHARGE-28K71L	bulk edge first nonlinear order gate	verify_bms_k71l_bulk_edge_first_nonlinear_order_gate.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: direct algebraic, geometric, or functional-analytic proof route
IR-BV-BMSCHARGE-28K71M	shear supertranslation heat defect gate	verify_bms_k71m_shear_supertranslation_heat_defect_gate.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: boundary symmetry, Ward identity, or representation calculation
IR-BV-BMSCHARGE-28K71N	matched cotangent heat supertrace gate	verify_bms_k71n_matched_cotangent_heat_supertrace_gate.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: direct algebraic, geometric, or functional-analytic proof route
IR-BV-BMSCHARGE-28K71O	independent edge polarization identifiability gate	verify_bms_k71o_independent_edge_polarization_identifiability_gate.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: direct algebraic, geometric, or functional-analytic proof route
IR-BV-BMSCHARGE-28K71P	endpoint projector state transport gate	verify_bms_k71p_endpoint_projector_state_transport_gate.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: operator-domain, representation, or spectral argument

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IR-BV-BMSCHARGE-28K71Q	KS endpoint quasifree state gate	verify_bms_k71q_KS_endpoint_quasifree_state_gate.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: operator-domain, representation, or spectral argument
IR-BV-BMSCHARGE-28K71R	KS mixed AKSZ inverse cross gate	verify_bms_k71r_KS_mixed_AKSZ_inverse_cross_gate.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: direct algebraic, geometric, or functional-analytic proof route
IR-BV-BMSCHARGE-28K71S	KS companion supertrace identifiability gate	verify_bms_k71s_KS_companion_supertrace_identifiability_gate.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: direct algebraic, geometric, or functional-analytic proof route
IR-BV-BMSCHARGE-28K71T	mass history BV pushforward unit Berezinian gate	verify_bms_k71t_mass_history_BV_pushforward_unit_Berezinian_gate.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: direct algebraic, geometric, or functional-analytic proof route
IR-BV-BMSCHARGE-28K71U	dynamical inflow cutoff rigidity minimal packet no go	verify_bms_k71u_dynamical_inflow_cutoff_rigidity_minimal_packet_no_go.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: explicit witness, incompatibility, or domain no-go
IR-BV-BMSCHARGE-28K71V	metric antifield direct vertex support gate	verify_bms_k71v_metric_antifield_direct_vertex_support_gate.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: direct algebraic, geometric, or functional-analytic proof route
IR-BV-BMSCHARGE-28K71W	EH boundary covariance provenance no go	verify_bms_k71w_EH_boundary_covariance_provenance_no_go.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: explicit witness, incompatibility, or domain no-go
IR-BV-BMSCHARGE-28K71X	AKSZ cross map dynamical quotient gate	verify_bms_k71x_AKSZ_cross_map_dynamical_quotient_gate.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: direct algebraic, geometric, or functional-analytic proof route
IR-BV-BMSCHARGE-28K71Y	proper BMS Volterra intertwiner gluing gate	verify_bms_k71y_proper_BMS_Volterra_intertwiner_gluing_gate.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: boundary symmetry, Ward identity, or representation calculation
IR-BV-BMSCHARGE-28K71Z	minimal history multiplet order sign no go	verify_bms_k71z_minimal_history_multiplet_order_sign_no_go.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: explicit witness, incompatibility, or domain no-go
IR-BV-BMSCHARGE-28K72	contact finite part locality and input gate	verify_bms_k72_contact_finite_part_locality_and_input_gate.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: direct algebraic, geometric, or functional-analytic proof route
IR-BV-BMSCHARGE-28K72A	zero doublet ghost sheaf finite basis gate	verify_bms_k72a_zero_doublet_ghost_sheaf_finite_basis_gate.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: direct algebraic, geometric, or functional-analytic proof route
IR-BV-BMSCHARGE-28K72B	frame doublet relative restriction gate	verify_bms_k72b_frame_doublet_relative_restriction_gate.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: direct algebraic, geometric, or functional-analytic proof route
IR-BV-BMSCHARGE-28K72C	normal bundle radial order and projet reduction gate	verify_bms_k72c_normal_bundle_radial_order_projet_gate.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: symbol-rank/jet exactness and filtered lifting
IR-BV-BMSCHARGE-28K72D	uv contact ir soft three normal category gate	verify_bms_k72d_uv_contact_ir_soft_three_normal_category_gate.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: soft asymptotics, weighted-domain, or zero-mode analysis
IR-BV-BMSCHARGE-28K72E	actual shear highest symbol order reduction no go	verify_bms_k72e_actual_shear_highest_symbol_order_reduction_no_go.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: explicit witness, incompatibility, or domain no-go
IR-BV-BMSCHARGE-28K72F	positive weight radial KT later page gate	verify_bms_k72f_positive_weight_physical_KT_finite_seed_gate.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: soft asymptotics, weighted-domain, or zero-mode analysis
IR-BV-BMSCHARGE-28K72G	vandermonde4 all degree physical KT quotient gate	verify_bms_k72g_vandermonde4_all_degree_physical_KT_quotient_gate.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: direct algebraic, geometric, or functional-analytic proof route
IR-BV-BMSCHARGE-28K72H	lorentz spin weight lift and coefficient sheaf gate	verify_bms_k72h_lorentz_spin_weight_lift_and_coefficient_sheaf_gate.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: boundary symmetry, Ward identity, or representation calculation

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IR-BV-BMSCHARGE-28K72I	fixed EH angular Hessian symbol and local splitting no go	verify_bms_k72i_fixed_EH_angular_Hessian_symbol_and_local_splitting_no_go.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: explicit witness, incompatibility, or domain no-go
IR-BV-BMSCHARGE-28K72J	local Spencer Hessian compatibility and contact obstruction gate	verify_bms_k72j_local_Spencer_Hessian_compatibility_and_contact_obstruction_gate.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: explicit witness, incompatibility, or domain no-go
IR-BV-BMSCHARGE-28K72K	orientation even scalar source exactness and magnetic origin gate	verify_bms_k72k_orientation_even_scalar_source_exactness_and_magnetic_origin_gate.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: direct algebraic, geometric, or functional-analytic proof route
IR-BV-BMSCHARGE-28K72L	field linear transport AKSZ magnetic transgression gate	verify_bms_k72l_field_linear_transport_AKSZ_magnetic_transgression_gate.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: direct algebraic, geometric, or functional-analytic proof route
IR-BV-BMSCHARGE-28K72M	order two one STF and typed QAP identifiability gate	verify_bms_k72m_order_two_one_STF_and_typed_QAP_identifiability_gate.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: direct algebraic, geometric, or functional-analytic proof route
IR-BV-BMSCHARGE-28K72N	homogeneous supertranslation one field symbol acyclicity gate	verify_bms_k72n_homogeneous_supertranslation_one_field_symbol_acyclicity_gate.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: symbol-rank/jet exactness and filtered lifting
IR-BV-BMSCHARGE-28K72O	oriented source mismatch and P4 lorentz descent gate	verify_bms_k72o_oriented_source_mismatch_and_P4_lorentz_descent_gate.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: boundary symmetry, Ward identity, or representation calculation
IR-BV-BMSCHARGE-28K72P	absolute cut primitive and fixed cut mapping cone gate	verify_bms_k72p_absolute_cut_primitive_and_fixed_cut_mapping_cone_gate.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: direct algebraic, geometric, or functional-analytic proof route
IR-BV-BMSCHARGE-28K72Q	cut doublet retract and fixed label chain map trichotomy gate	verify_bms_k72q_cut_doublet_retract_and_fixed_label_chain_map_trichotomy_gate.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: direct algebraic, geometric, or functional-analytic proof route
IR-BV-BMSCHARGE-28K72R	constant cut nonminimal gauge and physical T cost gate	verify_bms_k72r_constant_cut_nonminimal_gauge_and_physical_T_cost_gate.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: direct algebraic, geometric, or functional-analytic proof route
IR-BV-BMSCHARGE-28K72S	external T compensator and mass constraint first class gate	verify_bms_k72s_external_T_compensator_and_mass_constraint_first_class_gate.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: direct algebraic, geometric, or functional-analytic proof route
IR-BV-BMSCHARGE-28K72T	fixed label relative Ward cone curvature and KT gate	verify_bms_k72t_fixed_label_relative_Ward_cone_curvature_and_KT_gate.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: direct algebraic, geometric, or functional-analytic proof route
IR-BV-BMSCHARGE-28K72U	rank one new edge curvature conversion and finite BFV gate	verify_bms_k72u_rank_one_new_edge_curvature_conversion_and_finite_BFV_gate.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: direct algebraic, geometric, or functional-analytic proof route
IR-BV-BMSCHARGE-28K72V	new edge AKSZ provenance fixed cut gauge and QAP sheaf gate	verify_bms_k72v_new_edge_AKSZ_provenance_fixed_cut_gauge_and_QAP_sheaf_gate.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: direct algebraic, geometric, or functional-analytic proof route
IR-BV-BMSCHARGE-28K72W	mixed polarization determinant and one loop category dichotomy gate	verify_bms_k72w_mixed_polarization_determinant_and_one_loop_category_dichotomy_gate.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: direct algebraic, geometric, or functional-analytic proof route
IR-BV-BMSCHARGE-28K72X	wavefunction renormalization no go and contact doublet exactness gate	verify_bms_k72x_wavefunction_renormalization_no_go_and_contact_doublet_exactness_gate.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: explicit witness, incompatibility, or domain no-go
IR-BV-BMSCHARGE-28K72Y	renormalized label continuum and zero doublet reduction gate	verify_bms_k72y_renormalized_label_continuum_and_zero_doublet_reduction_gate.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: local cohomology, causal induction, or subtraction analysis
IR-BV-BMSCHARGE-28K72Z	graded quartet leakage and curved Lorentz QAP gate	verify_bms_k72z_graded_quartet_leakage_and_curved_Lorentz_QAP_gate.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: boundary symmetry, Ward identity, or representation calculation

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IR-BV-BMSCHARGE-28K73	bulk causal retract and independent edge extension gate	verify_bms_k73_bulk_causal_retract_and_independent_edge_extension_gate.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: direct algebraic, geometric, or functional-analytic proof route
IR-BV-BMSCHARGE-28K73A	minimal causal edge packet and one loop QME gate	verify_bms_k73a_minimal_causal_edge_packet_and_one_loop_QME_gate.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: local cohomology, causal induction, or subtraction analysis
IR-BV-BMSCHARGE-28K73B	all order causal boundary QME induction gate	verify_bms_k73b_all_order_causal_boundary_QME_induction_gate.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: local cohomology, causal induction, or subtraction analysis
IR-BV-BMSCHARGE-28K74	physical supertranslation canonical conversion trilemma gate	verify_bms_k74_physical_supertranslation_canonical_conversion_trilemma_gate.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: explicit witness, incompatibility, or domain no-go
IR-BV-BMSCHARGE-28K74A	external BMS charge outer derivation and quantum lift gate	verify_bms_k74a_external_BMS_charge_outer_derivation_and_quantum_lift_gate.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: boundary symmetry, Ward identity, or representation calculation
IR-BV-BMSCHARGE-28K74B	external source causal stability and tree outer lift dichotomy gate	verify_bms_k74b_external_source_causal_stability_and_tree_outer_lift_dichotomy_gate.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: direct algebraic, geometric, or functional-analytic proof route
IR-BV-BMSCHARGE-28K74C	invertible inflow rejection and relative small gauge external edge tree gate	verify_bms_k74c_invertible_inflow_rejection_and_relative_small_gauge_external_edge_tree_gate.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: direct algebraic, geometric, or functional-analytic proof route
IR-BV-BMSCHARGE-28K74D	relative external CE one loop equivariant QME gate	verify_bms_k74d_relative_external_CE_one_loop_equivariant_QME_gate.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: local cohomology, causal induction, or subtraction analysis
IR-BV-BMSCHARGE-28K74E	one loop quantum charge and local central H2 gate	verify_bms_k74e_one_loop_quantum_charge_and_local_central_H2_gate.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: boundary symmetry, Ward identity, or representation calculation
IR-BV-BMSCHARGE-28K74F	all order relative external QME and quantum charge induction gate	verify_bms_k74f_all_order_relative_external_QME_and_quantum_charge_induction_gate.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: local cohomology, causal induction, or subtraction analysis
IR-BV-BMSCHARGE-28K75	regular vacuum no go and nonregular zero mode gns gate	verify_bms_k75_regular_vacuum_no_go_and_nonregular_zero_mode_gns_gate.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: explicit witness, incompatibility, or domain no-go
IR-BV-BMSCHARGE-28K75A	induced bms sector representation and hard range separation gate	verify_bms_k75a_induced_bms_sector_representation_and_hard_range_separation_gate.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: boundary symmetry, Ward identity, or representation calculation
IR-BV-BMSCHARGE-28K75B	coherent dressing closed range and centered covariance no go gate	verify_bms_k75b_coherent_dressing_closed_range_and_centered_covariance_no_go_gate.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: explicit witness, incompatibility, or domain no-go
IR-BV-BMSCHARGE-28K75C	general radial covariance and boundary atom necessity gate	verify_bms_k75c_general_radial_covariance_and_boundary_atom_necessity_gate.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: soft asymptotics, weighted-domain, or zero-mode analysis
IR-BV-BMSCHARGE-28K75D	finite jet boundary quartet and all jet hilbert no go gate	verify_bms_k75d_finite_jet_boundary_quartet_and_all_jet_hilbert_no_go_gate.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: explicit witness, incompatibility, or domain no-go
IR-BV-BMSCHARGE-28K75E	actual soft order unbounded tree homotopy gate	verify_bms_k75e_actual_soft_order_unbounded_tree_homotopy_gate.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: soft asymptotics, weighted-domain, or zero-mode analysis
IR-BV-BMSCHARGE-28K75F	reduced physical projector soft TT nondecoupling gate	verify_bms_k75f_reduced_physical_projector_soft_TT_nondecoupling_gate.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: soft asymptotics, weighted-domain, or zero-mode analysis
IR-BV-BMSCHARGE-28K75G	resummed schur strata and inequivalent norm gate	verify_bms_k75g_resummed_schur_strata_and_inequivalent_norm_gate.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: direct algebraic, geometric, or functional-analytic proof route

Gate	Archived proof route	Checker	Audited status and mechanism
IR-BV-BMSCHARGE-28K75H	boundary atom direct integral positivity and all jet gate	verify_bms_k75h_boundary_atom_direct_integral_positivity_and_all_jet_gate.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: symbol-rank/jet exactness and filtered lifting
IR-BV-BMSCHARGE-28K75I	filtered quartet SDR and hard positivity separation gate	verify_bms_k75i_filtered_quartet_SDR_and_hard_positivity_separation_gate.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: direct algebraic, geometric, or functional-analytic proof route
IR-BV-BMSCHARGE-28K75J	nuclear soft order triple and resummed common domain no go	verify_bms_k75j_nuclear_soft_order_triple_and_resummed_common_domain_no_go.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: explicit witness, incompatibility, or domain no-go
IR-BV-BMSCHARGE-28K75K	graph domain groupoid and common core no go	verify_bms_k75k_graph_domain_groupoid_and_common_core_no_go.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: explicit witness, incompatibility, or domain no-go
IR-BV-BMSCHARGE-28K75L	direct integral graph Fock and constant smear no go	verify_bms_k75l_direct_integral_graph_Fock_and_constant_smear_no_go.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: explicit witness, incompatibility, or domain no-go
IR-BV-BMSCHARGE-28K75M	dressing connection contact and unitary no go	verify_bms_k75m_dressing_connection_contact_and_unitary_no_go.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: explicit witness, incompatibility, or domain no-go
IR-BV-BMSCHARGE-28K75N	flat singular superconnection and contractible cancellation no go	verify_bms_k75n_flat_singular_superconnection_and_contractible_cancellation_no_go.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: explicit witness, incompatibility, or domain no-go
IR-BV-BMSCHARGE-28K75O	noncontractible dual edge sector and local smear no go	verify_bms_k75o_noncontractible_dual_edge_sector_and_local_smear_no_go.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: explicit witness, incompatibility, or domain no-go
IR-BV-BMSCHARGE-28K75P	actual edge vertex weight selection and QAP domain gate	verify_bms_k75p_actual_edge_vertex_weight_selection_and_QAP_domain_gate.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: direct algebraic, geometric, or functional-analytic proof route
IR-BV-BMSCHARGE-28K75Q	singular vertex dense core and cubic pole extension gate	verify_bms_k75q_singular_vertex_dense_core_and_cubic_pole_extension_gate.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: direct algebraic, geometric, or functional-analytic proof route
IR-BV-BMSCHARGE-28K75R	actual minimal BV typing and Koszul Tate reciprocal Hilbert no go	verify_bms_k75r_actual_minimal_BV_typing_and_Koszul_Tate_reciprocal_Hilbert_no_go.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: explicit witness, incompatibility, or domain no-go
IR-BV-BMSCHARGE-28K75S	hybrid rigged classical BV and canonical Laplacian no go	verify_bms_k75s_hybrid_rigged_classical_BV_and_canonical_Laplacian_no_go.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: explicit witness, incompatibility, or domain no-go
IR-BV-BMSCHARGE-28K75T	spectral finite part star and formal QME base change gate	verify_bms_k75t_spectral_finite_part_star_and_formal_QME_base_change_gate.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: local cohomology, causal induction, or subtraction analysis
IR-BV-BMSCHARGE-28K75U	grouped pole cancellation and diagonal Fock block no go	verify_bms_k75u_grouped_pole_cancellation_and_diagonal_Fock_block_no_go.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: explicit witness, incompatibility, or domain no-go
IR-BV-BMSCHARGE-28K75V	fiberwise Fock and Sobolev trace repair inequivalence gate	verify_bms_k75v_fiberwise_Fock_and_Sobolev_trace_repair_inequivalence_gate.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: operator-domain, representation, or spectral argument
IR-BV-BMSCHARGE-28K75W	transported Sobolev BMS vertex and fiberwise label recovery trilemma gate	verify_bms_k75w_transported_Sobolev_BMS_vertex_and_fiberwise_label_recovery_trilemma_gate.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: explicit witness, incompatibility, or domain no-go
IR-BV-BMSCHARGE-28K75X	actual label provenance mixed background Fock and BMS intertwiner identifiability gate	verify_bms_k75x_actual_label_provenance_mixed_background_Fock_and_BMS_intertwiner_identifiability_gate.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: operator-domain, representation, or spectral argument
IR-BV-BMSCHARGE-28K75Y	massless collinear Sobolev trace and edge supertranslation Lorentz gate	verify_bms_k75y_massless_collinear_Sobolev_trace_and_edge_supertranslation_Lorentz_gate.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: boundary symmetry, Ward identity, or representation calculation

Gate	Archived proof route	Checker	Audited status and mechanism
IR-BV-BMSCHARGE-28K75Z	actual weight census spin rigidity and complementary window closure gate	verify_bms_k75z_actual_weight_census_spin_rigidity_and_complementary_window_closure_gate.py	Conditional fixed-module/collinear theorem; no full Einstein-module extrapolation; method: explicit witness, incompatibility, or domain no-go
IR-BV-BMSCHARGE-28K76	bv krein cotangent quartet and mirror rigidity gate	verify_bms_k76_bv_krein_cotangent_quartet_and_mirror_rigidity_gate.py	Conditional fixed-module/collinear theorem; no full Einstein-module extrapolation; method: explicit witness, incompatibility, or domain no-go
IR-BV-BMSCHARGE-28K77	soft boundary coupling dichotomy and nonregular forcing gate	verify_bms_k77_soft_boundary_coupling_dichotomy_and_nonregular_forcing_gate.py	Conditional fixed-module/collinear theorem; no full Einstein-module extrapolation; method: soft asymptotics, weighted-domain, or zero-mode analysis
IR-BV-BMSCHARGE-28K78	hybrid bms covariant state and continuity cost gate	verify_bms_k78_hybrid_bms_covariant_state_and_continuity_cost_gate.py	Mixed: positive abstract Weyl example; blanket noncontinuity claim refuted; method: operator-domain, representation, or spectral argument
IR-BV-BMSCHARGE-28K79	exponentiated bms ward and weyl dressed tower gate	verify_bms_k79_exponentiated_bms_ward_and_weyl_dressed_tower_gate.py	Finite/definitional Weyl-covariance skeleton; no dynamical Ward theorem; method: operator-domain, representation, or spectral argument
IR-BV-BMSCHARGE-28K7	minimal news compensator no go	verify_bms_news_compensator_closure.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: explicit witness, incompatibility, or domain no-go
IR-BV-BMSCHARGE-28K80	fixed memory central decomposition and sector regularity gate	verify_bms_k80_fixed_memory_central_decomposition_and_sector_regularity_gate.py	Refuted in full-Weyl scope: Lagrangian subalgebra is not central; method: soft asymptotics, weighted-domain, or zero-mode analysis
IR-BV-BMSCHARGE-28K81	sector smoothing and form category gate	verify_bms_k81_sector_smoothing_and_form_category_gate.py	Conditional smooth-core regularized multilinear form only; method: direct algebraic, geometric, or functional-analytic proof route
IR-BV-BMSCHARGE-28K82	form level master equation gate	verify_bms_k82_form_level_master_equation_gate.py	Conditional formal classical BRST skeleton; method: direct algebraic, geometric, or functional-analytic proof route
IR-BV-BMSCHARGE-28K83	composition identification and classical form cme gate	verify_bms_k83_composition_identification_and_classical_form_cme_gate.py	Conditional formal classical composition skeleton; method: direct algebraic, geometric, or functional-analytic proof route
IR-BV-BMSCHARGE-28K84	one loop form qme and boundary anomaly descent gate	verify_bms_k84_one_loop_form_qme_and_boundary_anomaly_descent_gate.py	Refuted proof step: nonconstant phase does not commute with angular resolvent; method: local cohomology, causal induction, or subtraction analysis
IR-BV-BMSCHARGE-28K85	form charge algebra central extension and soft layer gate	verify_bms_k85_form_charge_algebra_central_extension_and_soft_layer_gate.py	Abstract Weyl semidirect group law; not an interacting charge algebra; method: boundary symmetry, Ward identity, or representation calculation
IR-BV-BMSCHARGE-28K86	adiabatic ir finite dressed amplitudes and form optical gate	verify_bms_k86_adiabatic_ir_finite_dressed_amplitudes_and_form_optical_gate.py	Unproved: sector phase cannot supply FK cancellation; optical check circular; method: direct algebraic, geometric, or functional-analytic proof route
IR-BV-BMSCHARGE-28K87	all order ir exponentiation wave operators and cross sector gate	verify_bms_k87_all_order_ir_exponentiation_wave_operators_and_cross_sector_gate.py	Unproved: Cook norm decay and self-adjoint interacting Hamiltonian absent; method: direct algebraic, geometric, or functional-analytic proof route
IR-BV-BMSCHARGE-28K88	sector spectral and asymptotic completeness gate	verify_bms_k88_sector_spectral_and_asymptotic_completeness_gate.py	Refuted trace-class premise; asymptotic completeness unproved; method: direct algebraic, geometric, or functional-analytic proof route
IR-BV-BMSCHARGE-28K89	all order form qme induction gate	verify_bms_k89_all_order_form_qme_induction_gate.py	Unproved: all-order induction lacks a valid one-loop base; method: local cohomology, causal induction, or subtraction analysis
IR-BV-BMSCHARGE-28K8	cut stueckelberg momentum improvement	verify_bms_cut_stueckelberg_improvement.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: direct algebraic, geometric, or functional-analytic proof route
IR-BV-BMSCHARGE-28K90	boundary mapping class and global anomaly gate	verify_bms_k90_boundary_mapping_class_and_global_anomaly_gate.py	Unproved global-anomaly conclusion; determinant-line/bordism analysis absent; method: local cohomology, causal induction, or subtraction analysis
IR-BV-BMSCHARGE-28K91	minimal scalar matter coupling gate	verify_bms_k91_minimal_scalar_matter_coupling_gate.py	Mixed: standard anomaly/representation arithmetic; interacting BV–BMS coupling unproved; method: direct algebraic, geometric, or functional-analytic proof route

Gate	Archived proof route	Checker	Audited status and mechanism
IR-BV-BMSCHARGE-28K92	spinor coupling half integer rigidity and gravitational anomaly gate	verify_bms_k92_spinor_coupling_half_integer_rigidity_and_gravitational_anomaly_gate.py	Mixed: standard anomaly/representation arithmetic; interacting BV–BMS coupling unproved; method: explicit witness, incompatibility, or domain no-go
IR-BV-BMSCHARGE-28K93	gauge field coupling and chiral anomaly gate	verify_bms_k93_gauge_field_coupling_and_chiral_anomaly_gate.py	Mixed: standard anomaly/representation arithmetic; interacting BV–BMS coupling unproved; method: local cohomology, causal induction, or subtraction analysis
IR-BV-BMSCHARGE-28K94	electroweak yukawa and vacuum superselection gate	verify_bms_k94_electroweak_yukawa_and_vacuum_superselection_gate.py	Refuted physical identification: gauge-dependent Higgs VEV is not a central observable; method: direct algebraic, geometric, or functional-analytic proof route
IR-BV-BMSCHARGE-28K95	timelike infinity massive asymptotics and joint completeness gate	verify_bms_k95_timelike_infinity_massive_asymptotics_and_joint_completeness_gate.py	Free massive representation facts only; interacting joint completeness unproved; method: direct algebraic, geometric, or functional-analytic proof route
IR-BV-BMSCHARGE-28K96	cpt reconstruction and spin statistics interface gate	verify_bms_k96_cpt_reconstruction_and_spin_statistics_interface_gate.py	Kinematic census only; interacting CPT reconstruction unproved; method: direct algebraic, geometric, or functional-analytic proof route
IR-BV-BMSCHARGE-28K97	sector model consolidation and freeze gate	verify_bms_k97_sector_model_consolidation_and_freeze_gate.py	Version/catalogue artifact; not a theory-completion theorem; method: direct algebraic, geometric, or functional-analytic proof route
IR-BV-BMSCHARGE-28K98	black hole entry horizon kinematics and thermality gate	verify_bms_k98_black_hole_entry_horizon_kinematics_and_thermality_gate.py	Conditional background identities; formation and symmetry extrapolations unproved; method: background thermodynamic or horizon-interface calculation
IR-BV-BMSCHARGE-28K99	horizon kms bogoliubov and soft hair gate	verify_bms_k99_horizon_kms_bogoliubov_and_soft_hair_gate.py	Single-mode thermal algebra/interface; not a full Hawking derivation; method: soft asymptotics, weighted-domain, or zero-mode analysis
IR-BV-BMSCHARGE-28K9	lorentz mass transformation and tangency	verify_bms_lorentz_mass_improvement.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: boundary symmetry, Ward identity, or representation calculation
IR-BV-BMSCHARGE-28K	rotation aspect and flux	verify_bms_rotation_aspect.py	Scoped classical/analytic proof or conditional gate; no complete-chain upgrade; method: direct algebraic, geometric, or functional-analytic proof route
IR-BV-BRST-3	classical master equation	verify_bv_brst.py	Scoped local/formal BV theorem or conditional analytic gate; method: direct algebraic, geometric, or functional-analytic proof route
IR-BV-CHAR-6	reducibility and characteristic cohomology	verify_gravity_characteristic.py	Scoped local/formal BV theorem or conditional analytic gate; method: direct algebraic, geometric, or functional-analytic proof route
IR-BV-COH-5	antifield spectral sequence	verify_bv_cohomology.py	Scoped local/formal BV theorem or conditional analytic gate; method: direct algebraic, geometric, or functional-analytic proof route
IR-BV-COMPAT-14	low order nonlinear compatibility	verify_compatibility_low_orders.py	Scoped local/formal BV theorem or conditional analytic gate; method: direct algebraic, geometric, or functional-analytic proof route
IR-BV-FILTER-13	filtered lifting gate	verify_filtered_lifting.py	Scoped local/formal BV theorem or conditional analytic gate; method: direct algebraic, geometric, or functional-analytic proof route
IR-BV-FULLCHAR-7	full nonlinear local sector	verify_fullchar.py	Scoped local/formal BV theorem or conditional analytic gate; method: direct algebraic, geometric, or functional-analytic proof route
IR-BV-GAMMA-20	longitudinal anomaly descent	verify_gamma_descent.py	Scoped local/formal BV theorem or conditional analytic gate; method: local cohomology, causal induction, or subtraction analysis
IR-BV-HIGHCHAR-17	bulk afn2 characteristic	verify_bulk_afn2_characteristic.py	Scoped local/formal BV theorem or conditional analytic gate; method: direct algebraic, geometric, or functional-analytic proof route
IR-BV-HIGHJET-8	symbol order reduction	verify_highjet_symbol.py	Scoped local/formal BV theorem or conditional analytic gate; method: symbol-rank/jet exactness and filtered lifting

Gate	Archived proof route	Checker	Audited status and mechanism
IR-BV-HIGHKT-18	higher afn and symmetry gate	verify_higher_kt.py	Scoped local/formal BV theorem or conditional analytic gate; method: direct algebraic, geometric, or functional-analytic proof route
IR-BV-IDEAL-16	symbol to differential ideal	verify_differential_ideal_lifting.py	Scoped local/formal BV theorem or conditional analytic gate; method: symbol-rank/jet exactness and filtered lifting
IR-BV-JETISO-15	normal metric curvature jets	verify_normal_jet_isomorphism.py	Scoped local/formal BV theorem or conditional analytic gate; method: symbol-rank/jet exactness and filtered lifting
IR-BV-PROLONG-11	third prolongation	verify_prolong3.py	Scoped local/formal BV theorem or conditional analytic gate; method: symbol-rank/jet exactness and filtered lifting
IR-BV-QME-4	one loop consistency and anomaly gate	verify_qme_anomaly.py	Scoped local/formal BV theorem or conditional analytic gate; method: local cohomology, causal induction, or subtraction analysis
IR-BV-RENORM-21	causal bv renormalization	verify_causal_bv_renormalization.py	Scoped local/formal BV theorem or conditional analytic gate; method: local cohomology, causal induction, or subtraction analysis
IR-BV-RIGGED-25	lorentz rigging and loss tame gate	verify_rigged_soft_scale.py	Scoped local/formal BV theorem or conditional analytic gate; method: boundary symmetry, Ward identity, or representation calculation
IR-BV-RIGWICK-26	wick composition and zero mode obstruction	verify_rigged_wick_obstruction.py	Scoped local/formal BV theorem or conditional analytic gate; method: explicit witness, incompatibility, or domain no-go
IR-BV-SOFTDOM-23	weighted brst scale and tame gate	verify_soft_domain_scale.py	Scoped local/formal BV theorem or conditional analytic gate; method: direct algebraic, geometric, or functional-analytic proof route
IR-BV-SOFTINT-24	tree soft no go and anisotropic domain	verify_soft_interaction_domain.py	Scoped local/formal BV theorem or conditional analytic gate; method: explicit witness, incompatibility, or domain no-go
IR-BV-SPENCER-9	einstein symbol complex	verify_einstein_symbol_complex.py	Scoped local/formal BV theorem or conditional analytic gate; method: symbol-rank/jet exactness and filtered lifting
IR-BV-STATE-22	formal brst states and soft domain gate	verify_formal_brst_states.py	Scoped local/formal BV theorem or conditional analytic gate; method: operator-domain, representation, or spectral argument
IR-BV-SYM-19	natural variational symmetries	verify_natural_symmetry.py	Scoped local/formal BV theorem or conditional analytic gate; method: direct algebraic, geometric, or functional-analytic proof route
IR-BV-WEYLJET-10	first prolongations	verify_weyl_jet_modules.py	Scoped local/formal BV theorem or conditional analytic gate; method: symbol-rank/jet exactness and filtered lifting
IR-BV-ZEROMODE-27	boundary brst cocycle and vacuum gate	verify_zero_mode_boundary.py	Scoped local/formal BV theorem or conditional analytic gate; method: direct algebraic, geometric, or functional-analytic proof route
IR-EFT-POWER-1	gravity eft power counting	verify_eft_power_counting.py	Orderwise EFT theorem; no UV/nonperturbative completion; method: direct algebraic, geometric, or functional-analytic proof route
IR-EFT-UNIT-2	regulated unitarity and soft sector	verify_eft_unitarity.py	Orderwise EFT theorem; no UV/nonperturbative completion; method: soft asymptotics, weighted-domain, or zero-mode analysis
IR-FP-QUANT-1	free graviton quantization	verify_fp_quant1.py	Proved in the stated nonzero-momentum free sector; method: direct algebraic, geometric, or functional-analytic proof route
LGR-1	linearized gravity proof	verify_lgr1.py	Proved in the stated nonzero-momentum free sector; method: direct algebraic, geometric, or functional-analytic proof route

Appendix B Independent reconstruction checklist

For each theorem selected for external reconstruction, an auditor should:

23. freeze the exact proof and checker hashes;
24. restate the domain, quantifiers, and external lemmas independently;
25. reproduce the analytic proof without using checker output as a lemma;
26. run the checker and confirm that it tests only its declared skeleton;
27. vary the regulator, chart, basis, and finite cutoff where applicable;
28. test whether the physical identification is invariant under field, gauge, and representation changes;
29. register a downgrade immediately if any necessary infinite-dimensional step is absent.

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