Dark-Medium Response Atlas v0.1.0 — Path, Compensation, Memory, and Observation

Plasma, condensates, preferred frames, and gravitational roles

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In this atlas

Status and nonclaim

Working paper. This is a not-peer-reviewed supplemental methods proposal. It tests how hidden-sector possibilities might be separated by their response; it does not identify dark matter, establish an aether or plasma ontology, modify the stable SPPT/ASTRA core, or claim scientific priority.

Begin with response

We keep giving the unseen part of the universe nouns before we have earned them. This atlas begins one step earlier: with response.

Dark matter is a name for a gravitational deficit, not a photograph of a substance. Plasma is a way charged matter responds. Aether is a claim about a preferred frame. The interesting question is not whether the words are secretly identical, but whether one hidden sector could play more than one role - and how the sky would expose the difference.

The method is deliberately patient. Reconstruct what the known sector leaves unexplained. Keep the system's path and memory visible. Find the combinations of parameters the observations truly constrain. Then ask for a prediction that survives a new environment, a new instrument, or a new time.

Five-minute summary

- **Start with the residual, not its name.** A gravitational residual is a bookkeeping object until a model supplies conserved dynamics and survives alternatives in the known sector.
- **Classify by response.** Poles, residues, damping, causal cones, screening, phase changes, and history dependence distinguish models that can resemble one another in a static fit.
- **Expect compensation.** A good fit can constrain a combination of parameters while leaving each named parameter uncertain. The microwave synthesis example makes that warning concrete.
- **Keep memory.** A control may return to its starting value while a state retains excitations or stored thermal history. Endpoint restoration is not state restoration.
- **Predeclare the discriminator.** Density, velocity, frequency, direction, phase, pulse shape, dwell time, and transfer to held-out systems must be specified before favorable cases are selected.

The mathematical contribution is an assumption-audited response organization: charge-conjugation symmetry removes mixed stress-current response at linear order; an ideal neutral equal-pair fluid then separates into Jeans-like and Langmuir-like branches; explicitly broken symmetry restores mixing. These are conditional derivations and benchmarks, not observations.

Abstract

Plasma, aether, and dark matter are often discussed as competing names for an unknown cosmic substance. They are better treated as answers to three different questions. **Plasma** specifies a collective charge-response regime. **Aether** specifies either a material state that selects a rest frame or an independent preferred-frame field in the laws. **Dark matter** specifies a gravitational role inferred from dynamics, lensing, and cosmological structure. A physical sector may satisfy more than one of these descriptions, but none implies the others.

This note develops a response-first framework for separating them. Its central derivation is that, in a neutral charge-conjugation-symmetric dark pair plasma, the mixed linear stress-current responses vanish. Under the additional equal-pair fluid assumptions, the physical linear modes decouple into a Jeans branch and a Langmuir branch. The ratio of their characteristic frequencies depends on the ratio of dark gauge strength to gravitational strength and, for a self-gravitating equal-pair plasma, is independent of density. Symmetry breaking, unequal specific pressure response, background fields, streaming, transport, and nonlinear evolution restore coupling.

The framework also distinguishes a neutral superfluid from a charged condensate: condensing a field charged under the same unbroken gauge symmetry that supports a long-range plasma generally Higgses the gauge field. A model claiming both a long-range dark plasma and an ungapped superfluid mode therefore needs additional symmetry, additional components, or phase separation.

These results motivate **causal residual spectroscopy**, a working label in this note for integrating established closure reconstruction and response methods: infer the unexplained gravitational closure, then classify candidate sectors by their conserved stress, response poles, damping, causal cones, order-of-limits behavior, environmental scaling, and held-out predictions. The integration is methodological and `PROPOSED_ONLY`. It does not identify the cosmic residual with a plasma, condensate, or aether.

1. Scope and vocabulary

The central discipline is to prevent a word from doing the work of an equation.

Operational roles and the evidence that would distinguish them.

Label	Operational question	Characteristic evidence
Dark matter	Does an additional component or effective response supply the unexplained gravitational influence?	Metric potentials, clustering, lensing, momentum flux, pressure, and anisotropic stress
Plasma	Are there mobile charges with collective gauge-field response?	Debye screening, plasma oscillations, transverse modes, shocks, and kinetic instabilities
Material preferred frame (“state-aether,” local shorthand)	Does an occupied material state select a timelike velocity or acoustic cone?	The response changes or disappears when density, temperature, or phase changes
Vacuum preferred-frame field (“law-aether,” local shorthand)	Does an independent timelike field or preferred cone survive in vacuum?	Preferred-frame modes persist as material density tends to zero

The historical luminiferous aether was intended as a mechanical carrier for visible light. A dark plasma whose visible coupling is absent or tiny is not a resurrection of that object. A relativistic fluid or condensate can select a rest frame at the level of its state while its underlying equations remain Lorentz covariant. Conversely, an Einstein-aether model introduces an independent unit-timelike field into the action and therefore changes the vacuum degree-of-freedom content.

The most defensible possible overlap is a single hidden sector that may gravitate, possess collective charge dynamics, and develop a state-defined rest frame—possibly in different phases. That does not make those operational roles identical.

2. Start from the unexplained closure

Let $g_{\mu\nu}$ be the metric inferred under declared reconstruction assumptions, and let $T^{\text{known}}_{\mu\nu}$ contain the visible stress-energy that has actually been included in the analysis. Define the geometric closure residual

$$\mathscr{R}_{\mu\nu} \equiv \frac{G_{\mu\nu}[g]}{8\pi G} - T^{\text{known}}_{\mu\nu}.$$

When the known sector is minimally coupled and separately conserved, the Bianchi identity gives

$$\nabla^{\mu}\mathscr{R}_{\mu\nu} = 0.$$

This is a bookkeeping identity, not proof that the residual is material. In general relativity, a dark-matter theory puts additional stress-energy on the right-hand side. A modified-gravity theory can be rewritten with effective terms in the same position. Purely gravitational reconstruction therefore does not uniquely establish the underlying ontology.

Nevertheless, the residual imposes a useful minimum standard. Relative to a declared observer four-velocity and perturbation gauge—or in gauge-invariant variables—a proposed explanation must close as density, momentum, pressure, and anisotropic stress. These are inferred, model-dependent reconstruction objects, not directly observed fields. A fitted acceleration curve without a conserved dynamical completion is not yet a complete covariant physical model.

For perturbations, write a causal response relation schematically as

$$\delta\mathscr{R}_A(\mathbf{k}, t) = \delta\mathscr{R}^{\text{hom}}_A(\mathbf{k}, t) + \int_{-\infty}^{t} K_{AB}(\mathbf{k}; t, t')S_B(\mathbf{k}, t')\, dt'.$$

Here A ranges over residual density, momentum, pressure, and anisotropic stress, while S_B contains metric, baryonic, and other declared sources. Different models can reproduce a similar static residual while possessing different causal memory:

- collisionless matter retains orbital and phase-space memory;
- a collisional fluid develops relaxation and viscous poles;
- a plasma possesses charge and electromagnetic collective modes;
- a superfluid possesses phase and vortex response;
- a fundamental aether can possess preferred-frame modes even without matter.

The response kernel does not eliminate modeling. It makes the assumptions and the discriminating observables explicit before an ontology is assigned.

3. Response-first classification

Introduce a metric source $h_{\mu\nu}$ and a provisional dark gauge source a_μ^D. On a stationary homogeneous background—or within a declared local WKB approximation—the retarded linear response may be arranged as

$$\begin{pmatrix} \delta T^{\mu\nu} \\ \delta J_D^\mu \end{pmatrix} = \begin{pmatrix} \chi_{TT} & \chi_{TJ} \\ \chi_{JT} & \chi_{JJ} \end{pmatrix}_{(\omega,\mathbf{k})} \begin{pmatrix} h_{\alpha\beta} \\ a_D^\alpha \end{pmatrix}.$$

Every χ in this display is retarded. In a cosmological background the two-time kernel of Section 2 replaces this Fourier representation. Gauge and diffeomorphism Ward identities, including their contact terms, must be imposed before interpreting any component of the matrix.

After gauge fixing and constraint elimination, a pole of a gauge-invariant retarded correlator can identify a collective oscillation, damped mode, or instability. Pole position gives a frequency and damping or growth rate; residue gives source overlap for a simple propagating pole. Branch cuts encode continua and phase mixing. Dissipative modes are instead audited through spectral positivity or passivity and, for stable states, poles in the lower half of the complex-frequency plane. This supplies an operational taxonomy:

Leading response signatures of candidate regimes.

Candidate regime	Leading response features
Cold collisionless dust	Jeans growth and autonomous initial-condition modes
Collisionless kinetic matter	Jeans growth, velocity-space phase mixing, kinetic branch cuts
Normal plasma	Debye screening, Langmuir gap, transverse gauge modes, Landau damping, two-stream or Weibel instability
Neutral superfluid	Gapless Goldstone sound, critical velocity, vortices, multiphonon continuum
Charged condensate	Gauge-field mass, Meissner screening, gapped plasma response
Einstein-aether-type field	Additional spin-0 and spin-1 modes, preferred-frame dependence, vacuum survival

The names become secondary. Two models that generate similar static gravity can still be separated by their poles, damping, entropy production, and response to interventions.

4. Charge-conjugation linear-response decoupling

Consider a hidden sector whose microscopic dynamics, state, background, and regulator are invariant under charge conjugation C. Stress is C-even and dark current is C-odd. The real-time mixed retarded responses therefore obey

$$G^R_{TJ}(x) = -i\theta(t)\langle[T(x), J_D(0)]\rangle = 0, \qquad G^R_{JT}(x) = 0.$$

The mixed stress-current two-point responses thus vanish in this symmetric state. This statement is broader than a particular fluid closure, but its domain must remain explicit:

- the action and initial or equilibrium state are charge-conjugation invariant;
- there is no background dark electric or magnetic field;
- there is no charge chemical potential or population asymmetry;

- there is no C-odd condensate, C-violating portal, anomaly, or symmetry-breaking regulator;
- the calculation is linear response.

Any one of a nonzero chemical potential, background charge or current, C-odd condensate, or explicit C violation falsifies the decoupling premise. The result does **not** make the stress response identical to cold dark matter. Pressure, velocity dispersion, viscosity, collisions, and kinetic damping remain in χ_{TT}. Exact mode decoupling in the two-fluid benchmark below additionally requires a neutral background, equal specific pressure response, and a symmetry-preserving dissipative closure.

This symmetry result is an algebraic consequence of the declared premises. Its novelty has not been established, and no priority claim is made.

5. Ideal pair-plasma calculation

5.1 Assumptions and conventions

Use metric signature $(-+++)$ and Heaviside-Lorentz natural units with

$$c = \hbar = k_B = \epsilon_0 = \mu_0 = 1, \qquad \nabla \cdot \mathbf{E}_D = \rho_{q,D}, \qquad \alpha_D = \frac{q_D^2}{4\pi}.$$

The primitive model is a homogeneous, neutral, unmagnetized, nonstreaming two-species plasma under a massless, unbroken $U(1)_D$, with

- equilibrium number densities $n_{+,0} = n_{-,0} = n_0$;
- charges $q_+ = +q_D$ and $q_- = -q_D$;
- no background fields, $\mathbf{E}_{D,0} = \mathbf{B}_{D,0} = 0$;
- Newtonian self-gravity in the usual local Jeans construction;
- a barotropic fluid closure with species sound parameters $c_s^2 = (\partial P_s / \partial \rho_s)_0$.

This is a fluid-closure benchmark. Its advertised hydrodynamic use requires a specified collisional or moment closure, stated degeneracy, and scales for which that closure is controlled; the simplest Debye expansion also assumes $k\lambda_D \ll 1$. Later sections restore c where physical units matter.

The linearized equations are

$$\dot{\delta n}_s + n_0 \nabla \cdot \mathbf{v}_s = 0,$$

$$\dot{\mathbf{v}}_s = -c_s^2 \nabla \frac{\delta n_s}{n_0} - \nabla \Phi + \frac{q_s}{m_s} \mathbf{E}_D,$$

$$\nabla^2 \Phi = 4\pi G (m_+ \delta n_+ + m_- \delta n_-), \qquad \nabla \cdot \mathbf{E}_D = q_D (\delta n_+ - \delta n_-).$$

Gauge-field stress is quadratic in the perturbation because the background field vanishes. A nonzero background field would add linear magnetic pressure and anisotropic-stress terms.

5.2 Equal-pair modes

For equal masses $m_+ = m_- = m$ and equal pressure response, define

$$\delta n_M = \delta n_+ + \delta n_-, \qquad \delta n_Q = \delta n_+ - \delta n_-, \qquad \rho_0 = 2mn_0.$$

With a symmetry-preserving closure, plane-wave perturbations decouple into

$$\omega_M^2 = c_s^2 k^2 - 4\pi G\rho_0$$

and

$$\omega_Q^2 = c_s^2 k^2 + \Omega_p^2, \qquad \Omega_p^2 = \frac{2q_D^2 n_0}{m}.$$

The mass mode is a Jeans branch. For sufficiently small k, $\omega_M^2 < 0$ and it grows. The charge mode is a gapped Langmuir branch. In the cold, unmagnetized limit a transverse branch additionally obeys

$$\omega_T^2 = k^2 + \Omega_p^2.$$

The thermal coefficient $c_s^2 k^2$ is closure-dependent. A collisionless Maxwellian treatment instead determines longitudinal modes from

$$\epsilon_L(k, \omega) = 0,$$

including the Bohm-Gross correction in its domain and Landau or collisional damping. Absence of a weakly damped root over the advertised range falsifies a claim of a propagating collective mode there. The displayed branches are exact for the declared linear fluid model, not for all plasma kinetics.

5.3 Generic oppositely charged species and mode mixing

For general masses and pressure responses, the system is a generic oppositely charged two-component plasma, not a charge-conjugate pair. Define

$$R = m_+ \delta n_+ + m_- \delta n_-, \qquad Q = \delta n_+ - \delta n_-,$$

$$M = m_+ + m_-, \qquad \mu = \frac{m_+ m_-}{M}, \qquad \Delta c^2 = c_+^2 - c_-^2.$$

Then

$$\omega^2 \begin{pmatrix} R \\ Q \end{pmatrix} = \begin{pmatrix} k^2 c_M^2 - \omega_J^2 & k^2 \mu \Delta c^2 \\ k^2 \Delta c^2 / M & k^2 c_Q^2 + \Omega_p^2 \end{pmatrix} \begin{pmatrix} R \\ Q \end{pmatrix},$$

where

$$\omega_J^2 = 4\pi G n_0 M, \qquad \Omega_p^2 = q_D^2 n_0 \left(\frac{1}{m_+} + \frac{1}{m_-}\right),$$

$$c_M^2 = \frac{m_+ c_+^2 + m_- c_-^2}{M}, \qquad c_Q^2 = \frac{m_- c_+^2 + m_+ c_-^2}{M}.$$

The matrix is not symmetric because R and Q carry different units. Its eigenvalues are

$$\omega_\pm^2 = \frac{A_M + A_Q}{2} \pm \frac{1}{2}\sqrt{(A_M - A_Q)^2 + 4k^4 \frac{m_+ m_-}{M^2}(\Delta c^2)^2},$$

with

$$A_M = k^2 c_M^2 - \omega_J^2, \qquad A_Q = k^2 c_Q^2 + \Omega_p^2.$$

The important feature is the off-diagonal dependence on Δc^2. Unequal mass alone does not mix the cold center-of-mass and relative modes in this ideal system; unequal specific pressure response does. When $|A_Q - A_M|$ is large relative to the off-diagonal terms—typically when Ω_p^2 is large and the branches are away from a crossing—the induced correction to the Jeans-like branch is suppressed.

6. Plasma and gravitational scale ordering

For the equal-pair, self-gravitating model,

$$\frac{\Omega_p^2}{\omega_J^2} = \frac{q_D^2}{4\pi G m^2} = \frac{\alpha_D}{G m^2}.$$

Define the gravitational coupling between two particles as $\alpha_G = Gm^2$. Then

$$\Xi \equiv \frac{\Omega_p^2}{\omega_J^2} = \frac{\alpha_D}{\alpha_G}.$$

Both frequencies scale as the square root of density. Their ratio does not. Consequently, an interaction that is tiny relative to visible electromagnetism may still be enormous relative to particle-particle gravity.

For a plasma composing only a fraction $f_D = \rho_D/\rho_{\rm tot}$ of the gravitating density,

$$\frac{\Omega_p^2}{4\pi G \rho_{\rm tot}} = f_D \frac{\alpha_D}{G m^2}.$$

This is a characteristic-scale comparison, not by itself a mode equation. The gravitational mode contains $\sum_i \rho_i \delta_i$ and depends on which components co-perturb.

The corresponding length relation needs more care than the frequency ratio. For a nonrelativistic Maxwell-Boltzmann plasma with $k_B = 1$,

$$\lambda_D^{-2} = \sum_s \frac{q_s^2 n_s}{T_s}, \qquad k_J = \frac{\sqrt{4\pi G \rho_g}}{c_{\rm eff}}, \qquad \lambda_J \equiv k_J^{-1},$$

and therefore

$$\frac{\lambda_D}{\lambda_J} = \frac{\sqrt{4\pi G\rho_g}}{c_{\rm eff}}\left(\sum_s \frac{q_s^2 n_s}{T_s}\right)^{-1/2}.$$

Here λ_J is the inverse Jeans wavenumber, not the conventional wavelength $2\pi/k_J$. Only for an isothermal equal-pair closure with $T_+ = T_- = T$, $v_T^2 = T/m$, $c_{\rm eff} = v_T$, and $\rho_g = \rho_D$ does this reduce to

$$\frac{\lambda_D}{\lambda_J} = \sqrt{\frac{Gm^2}{\alpha_D}} = \Xi^{-1/2}.$$

An adiabatic closure introduces the corresponding sound-speed factor. This qualification prevents a convention-specific identity from being mistaken for a universal plasma theorem. Relativistic, degenerate, or strongly coupled screening requires the appropriate static susceptibility rather than the displayed Maxwell-Boltzmann Debye formula.

7. Conservation and cosmological completion

A hidden medium must not silently create or destroy charge or stress-energy. For a dark gauge current and its field,

$$\nabla_\mu J_D^\mu = 0,$$

$$\nabla_\mu T^{\mu\nu}_{\rm particles} = \mathscr{H}^{\nu\lambda} J^D_\lambda, \qquad \nabla_\mu T^{\mu\nu}_{\mathscr{H}} = -\mathscr{H}^{\nu\lambda} J^D_\lambda.$$

Therefore

$$\nabla_\mu (T^{\mu\nu}_{\rm particles} + T^{\mu\nu}_{\mathscr{H}}) = 0$$

when there is no declared exchange with another sector. Any portal must include equal and opposite exchange terms.

The static Jeans construction is a local approximation. The variables δn_M and δn_Q above are absolute number-density perturbations. For an expanding equal-pair background, introduce the fractional contrasts

$$\Delta_M = \frac{\delta n_+ + \delta n_-}{2n_0}, \qquad \Delta_Q = \frac{\delta n_+ - \delta n_-}{2n_0}.$$

Here $a(t)$ is the scale factor, $H \equiv \dot{a}/a$, k is comoving wavenumber, and $n_0(t)$ and $\Omega_p(t)$ are physical-background quantities.

In an appropriate sub-horizon gauge they obey coupled evolution of the form

$$\ddot{\Delta}_M + 2H\dot{\Delta}_M + \frac{c_M^2 k^2}{a^2}\Delta_M = 4\pi G \sum_i \rho_i \Delta_i,$$

$$\ddot{\Delta}_Q + 2H\dot{\Delta}_Q + (\frac{c_Q^2 k^2}{a^2} + \Omega_p^2)\Delta_Q = \text{mixing, streaming, and background-field terms.}$$

The plasma frequency, ionization fraction, temperature, and collision rates evolve with a. A viable cosmological model must additionally evolve dark radiation, recombination, diffusion damping, and metric perturbations through a Boltzmann hierarchy. Static dispersion relations cannot substitute for that calculation.

Hidden atomic models make this completion concrete: an early ionized sector can undergo dark recombination and leave dark-acoustic-oscillation and damping scales. See Cyr-Racine and Sigurdson.

8. Phase structure and the one-symmetry obstruction

A useful schematic field inventory may contain gravity, a dark gauge field, charged carriers, a neutral condensate, optional portals, and—only if independently motivated—a fundamental timelike field:

$$S = \int d^4 x \sqrt{-g}[\frac{M_{\mathrm{Pl}}^2}{2} R - \frac{1}{4}\mathscr{H}_{\mu\nu}\mathscr{H}^{\mu\nu} + \mathscr{L}_{\mathrm{carriers}}(\psi_s, D_\mu) + P(Y) + \mathscr{L}_{\mathrm{portal}} + \mathscr{L}_{\mathrm{ae}}(U^\mu)].$$

Here

$$M_{\mathrm{Pl}}^{-2} = 8\pi G, \qquad \mathscr{H}_{\mu\nu} = 2\nabla_{[\mu} X_{\nu]}, \qquad D_\mu \psi_s = (\nabla_\mu - i q_s X_\mu)\psi_s,$$

and, for a neutral irrotational condensate away from vortex cores,

$$Y = \sqrt{-\nabla_\mu \theta \nabla^\mu \theta}.$$

$P(Y)$ fixes its equation of state; $\mathscr{L}_{\mathrm{portal}}$ declares cross-sector exchange; and $\mathscr{L}_{\mathrm{ae}}$ is only a placeholder for a separately specified preferred-frame theory. This display is a menu of distinguishable structures, not one normalized, dynamically complete model.

Possible regimes include:

1. **Normal ionized phase:** mobile dark charges and an unbroken dark gauge symmetry produce a dark plasma.
2. **Recombined phase:** neutral bound states can behave approximately as atomic or collisionless dark matter on appropriate scales.
3. **Neutral condensate:** a global phase can support a gapless phonon and a state-defined velocity.
4. **Charged condensate:** the dark gauge field becomes massive and the phase is a dark-superconducting rather than long-range-plasma regime.
5. **Independent aether field:** a separate constrained U^μ introduces vacuum preferred-frame modes.

For a charged condensate $\Psi = v e^{i\theta}$,

$$|D_\mu \Psi|^2 \supset v^2 (\partial_\mu \theta - q_D X_\mu)^2 .$$

In unitary gauge this supplies

$$m_X^2 \sim q_D^2 v^2 .$$

The coefficient depends on the normalization of Ψ; the scaling is the point here. The would-be Goldstone is absorbed and the gauge response is screened. Thus the stated minimal homogeneous realization with one gauged $U(1)$ does not generically provide both a long-range dark plasma and a free gapless superfluid mode. More general multicomponent charged condensates are not excluded by this argument. A model claiming both structures must exhibit the additional symmetry, neutral condensate, component, or separated phase that carries the ungapped mode.

A plausible but unverified branching history is

$$\text{early dark plasma} \to \text{dark recombination} \to \begin{cases} \text{neutral halo,} \\ \text{shock reionization,} \\ \text{dissipative disk,} \\ \text{neutral condensate.} \end{cases}$$

The last three are alternatives with separate cooling, statistics, thermalization, and stability conditions—not an automatic linear sequence. Long-range dark-force models, atomic dark matter, and superfluid dark matter demonstrate portions of this model space, but none has been established as the cosmic ontology. See Ackerman et al. and Berezhiani and Khoury.

9. Material preferred frame versus vacuum preferred-frame field

For a suitable type-I stress tensor, a Landau-frame velocity may be defined by

$$T_D^{\mu\nu} u_\nu = -\rho_D u^\mu .$$

This is a state-defined velocity. It does not close a multistream collisionless distribution; higher kinetic moments may remain indispensable. For a neutral superfluid one can instead obtain

$$u_\mu = \pm \frac{\partial_\mu \theta}{\sqrt{-\partial_\alpha \theta \, \partial^\alpha \theta}}$$

inside the phase where the gradient is timelike and the effective theory is valid, with the sign chosen so that u^μ is future-directed. This single-gradient description fails at vortex cores, and a finite-temperature superfluid generally has distinct normal and superfluid velocities. Neither construction requires fundamental Lorentz violation.

A standard Einstein-aether-type action instead contains

$$\mathscr{L}_{\rm ae} = -M_U^2 K^{ab}{}_{mn} \nabla_a U^m \nabla_b U^n + \lambda (U^\mu U_\mu + 1),$$

with, in one standard convention,

$$K^{ab}{}_{mn} = c_1 g^{ab} g_{mn} + c_2 \delta^a_m \delta^b_n + c_3 \delta^a_n \delta^b_m - c_4 U^a U^b g_{mn}, \qquad c_{13} = c_1 + c_3.$$

The generic c_i action and its tensor-speed relation are treated, with their post-GW170817 constraints, by Oost, Mukohyama, and Wang. The antisymmetrized-derivative model studied by Jacobson and Mattingly, without matter, is mathematically equivalent only to a restricted sector of Einstein-Maxwell theory coupled to charged dust; the same analysis identifies generic gradient singularities. This is a narrow field-equation equivalence, not an equivalence between general Einstein-aether theory and a screened two-species plasma. See Jacobson and Mattingly.

An operational zero-density diagnostic is

$$\mathfrak{A}(\omega, k) = \lim_{n \to 0} [\chi(\omega, k; n, u) - \chi_{\text{Lorentz invariant}}(\omega, k)].$$

The subtraction prescription, the order of $n \to 0$, $k \to 0$, and $\omega \to 0$, and whether the phase remains continuously defined must all be declared; the limits need not commute, and the material velocity can cease to exist before $n = 0$. A vanishing result in one tested channel is consistent with a state response but does not exclude a decoupled vacuum preferred-frame field. A surviving physical $k \cdot U$ dependence after material contributions are removed is evidence for vacuum preferred-frame structure only after other vacuum fields have been excluded.

Visible-sector vacuum preferred-frame models are strongly constrained. With the Einstein-Hilbert normalization in Section 8, define

$$\bar{c}_{13} \equiv \frac{2M_U^2}{M_{\text{Pl}}^2}(c_1 + c_3), \qquad c_T^2 = \frac{1}{1 - \bar{c}_{13}}.$$

and multimessenger propagation constrains the relevant tensor-cone mismatch to approximately the 10^{-15} scale in the applicable coupling sector. Preferred-frame limits are model- and coupling-specific. This does not prohibit an ordinary Lorentz-covariant medium whose occupied state selects a rest frame. See the post-GW170817 analysis.

10. Environmental and merger response

Quasineutrality and a long two-body mean free path do not guarantee collective collisionlessness. Counterstreaming pair plasmas can excite two-stream and Weibel modes. Define

$$\mathcal{S} = \Gamma_{\text{inst}} t_{\text{cross}}, \qquad t_{\text{cross}} = \frac{L}{v_{\text{rel}}}.$$

Linear amplification is substantial only when $\mathcal{S}$ contains enough e-foldings to reach nonlinear saturation:

$$\mathcal{S} \gtrsim N_{\text{sat}}.$$

The threshold N_{sat} is not universally one. It depends on the seed fluctuations, velocity distribution, composition, geometry, and nonlinear saturation mechanism, and must be calibrated with kinetic simulations.

Leading scalings nevertheless provide an ensemble-level discriminator:

$$C_{\text{SIDM}} \sim \rho L \frac{\sigma}{m},$$

$$C_{\text{TS}} \sim \Omega_p \frac{L}{v_{\text{rel}}}, \qquad C_{\text{W}} \sim \Omega_p \frac{L}{c}.$$

For the declared Heaviside-Lorentz equal-pair model, $\Omega_p = (q_D/m_D)\sqrt{\rho_D}$, where ρ_D is the interacting plasma density rather than the total halo density. Numerical coefficients and the actual growth rate depend on the distribution function and geometry.

Illustrative environmental scaling before nonlinear calibration.

Mechanism	Leading density dependence	Leading size dependence	Leading velocity dependence
Constant-cross-section binary SIDM	ρ	L	none beyond trajectory
Ideal two-stream plasma	$\sqrt{\rho}$	L	v^{-1}
Ideal Weibel-dominated plasma	$\sqrt{\rho}$	L	approximately weak after crossing-time cancellation
Phase-changing medium	threshold-dependent	geometry-dependent	history and hysteresis dependent
Propagating aether field	not fixed by material density	L/c_a versus event duration	preferred-frame and cone dependent

Velocity-dependent scattering and nonlinear plasma saturation can modify these simple exponents. The correct experiment is therefore a preregistered ensemble of mergers spanning density, size, speed, orientation, and time since pericenter—not post-hoc interpretation of one iconic cluster.

Recent particle-in-cell work demonstrates the importance of collective effects for one completely hidden, massless-$U(1)_D$ pair-plasma model. Its numerical constraint is model-specific; the general lesson is that binary scattering alone is an incomplete collision criterion. See DeRocco and Giffin.

11. Observational gates

11.1 Ordinary-plasma gate

Under standard early-universe nuclear and recombination physics, ordinary baryons cannot simply be relabeled as the dominant dark component. The Planck base-model values

$$\Omega_b h^2 \simeq 0.0224, \qquad \Omega_c h^2 \simeq 0.120, \qquad h \equiv \frac{H_0}{100\,\mathrm{km\,s^{-1}\,Mpc^{-1}}}$$

are model-conditioned. BBN analyses independently combine observed primordial D/H with nuclear rates, including the LUNA deuterium-burning rate, to infer a consistent smaller nucleon inventory. Localized fast radio bursts also provide a late-universe census of ionized baryons. A successful replacement must reproduce the gravitational potentials that grow while baryons remain coupled to photons. See Planck 2018, the LUNA-informed BBN analysis, and the localized-FRB baryon census.

Plasma refraction is chromatic and usually accompanies dispersion or Faraday effects; metric lensing is achromatic in geometric optics. Lorentz forces also depend on charge, velocity, and field orientation. Ordinary plasma can bias gas dynamics and mass reconstruction, but a dominant replacement must simultaneously explain the baryon budget, neutral stellar motion, lensing, dispersion and rotation measures, free-free and synchrotron emission, X-rays, the Sunyaev-Zel’dovich signal, and chromatic-lensing limits.

11.2 Early-universe gate

With one frozen physical parameter set and declared nuisance priors, a proposed dark medium must confront at least:

- the full CMB TT, TE, and EE spectra and CMB lensing;
- primordial abundances;
- baryon acoustic oscillations and linear matter power;
- Lyman-alpha and halo-abundance constraints;
- dark acoustic oscillations, diffusion or collisional damping, and ΔN_{eff}.

Fitting only the background expansion or one acoustic feature is insufficient. Atomic-dark-matter calculations illustrate how these effects must be evolved, not merely named; see Cyr-Racine and Sigurdson.

11.3 Gravity and stability gate

The model must provide a complete action or a closed evolution system, well-posed initial data, conserved total stress-energy, and a stable perturbative regime. Ghosts, negative spectral weight where unitarity requires positivity, gradient instabilities, unacceptable strong coupling, or causal characteristics incompatible with observations reject the affected parameter region.

A vacuum preferred-frame realization must jointly confront gravitational-wave speed and polarizations, post-Newtonian preferred-frame coefficients, binary-pulsar radiation, gravitational slip, and lensing-versus-dynamical mass. These limits are coupling- and model-specific; see the post-GW170817 Einstein-aether analysis.

Galaxy fits must be tested jointly against lensing, pressure-supported systems, external environments, and assembly history. A quasistatic acceleration law does not validate its relativistic completion.

11.4 Thermodynamic gate

A dissipative component must predict its own recombination, cooling, disk formation, halo shape, and compact-object abundance. In a region where

$$t_{\mathrm{cool}} < t_{\mathrm{halo}},$$

cooling must be evolved jointly with dynamical time, heating, conduction, angular momentum, fragmentation, and assembly history. Absence of a collapsed structure excludes only a parameter region that robustly predicts an observable structure after those processes are included.

11.5 Merger-ensemble gate

Freeze q_D/m_D, the interacting fraction, phase parameters, nuisance priors, and acceptance thresholds. Then predict, across a merger ensemble, the mass-galaxy-gas offsets, shock widths, tails, and halo survival as functions of L, v_{rel}, ρ_D, orientation, and time since pericenter. A realization is rejected if systems for which $\mathcal{S} = \Gamma_{\mathrm{inst}} L/v_{\mathrm{rel}} \gg N_{\mathrm{sat}}$ robustly predict collective signatures but lack them, or if each system requires a fresh physical interpretation. See the Bullet Cluster lensing reconstruction and the dark-plasma kinetic study.

11.6 Transfer gate

Before evaluating held-out probes, freeze physical parameters, nuisance priors, data cuts, and acceptance thresholds. A model calibrated on galaxies should predict cluster mergers and cosmological structure; a model calibrated on the CMB should predict halo-scale behavior. Failure of a declared hard gate rejects that realization rather than triggering a new interpretation. It is not a rejection of every plasma, condensate, or modified-gravity construction.

12. Direct detection and LZ.230616

The preliminary LZ.230616 preprint (abbreviated LZ230616 below) reports one NR-like event which, if interpreted as an elastic xenon nuclear recoil, has

$$E_R = 248 \pm 23_{\text{stat}} \pm 23_{\text{sys}}\ \text{keV}_{\text{nr}}.$$

A profile-likelihood test found tension with the background-only hypothesis at a global significance of 2.6σ after the look-elsewhere correction, with a maximum local significance of 3.4σ across the tested models. This is not the probability that this particular event is background, and the collaboration did not claim a dark-matter detection. See the LZ analysis preprint.

LZ explicitly classifies this as a non-blind analysis: the artificial-event “salting” distribution did not adequately cover the high-energy signal region, although the selections and likelihood models were finalized before the four remaining salt events were revealed. That limitation belongs in any interpretation of the reported significance.

Using $m_{\text{Xe}} \simeq 122\,\text{GeV}/c^2$, the elastic-recoil momentum transfer is

$$q_{\text{tr}} = \sqrt{2m_{\text{Xe}}E_R} \simeq 246 \pm 11_{\text{stat}} \pm 11_{\text{sys}}\ \text{MeV}/c,$$

or approximately $246 \pm 16\,\text{MeV}/c$ after combining those uncertainties in quadrature. The reduced spatial scale is $\hbar/q_{\text{tr}} \simeq 0.80\,\text{fm}$.

For the convention

$$S_A(\mathbf{q},\omega) = \int dt\, e^{i\omega t}\langle \rho_A(\mathbf{q},t)\rho_A(-\mathbf{q},0)\rangle,$$

Fermi’s golden rule for two weakly coupled many-body systems can be organized heuristically as an energy-conserving convolution,

$$R \propto \int d^3q\, d\omega\, |\mathscr{K}(\mathbf{q},\omega)|^2 S_D(\mathbf{q},-\omega)S_{\text{Xe}}(-\mathbf{q},\omega).$$

Flux, state normalization, occupation factors, detailed balance, and phase space are suppressed in this schematic expression. The cited dielectric formalism supports target-response methods; it does not by itself establish the incoming collective-dark-medium factor proposed here. See Knapen, Kozaczuk, and Lin.

Within the collaboration’s tested NREFT and inelastic models under its Standard Halo Model assumptions, the larger local significances occur typically for WIMP masses above roughly $200\,\text{GeV}/c^2$. This is not a model-independent or hard kinematic lower bound. As an explicitly illustrative benchmark only, setting $m_D = 200\,\text{GeV}/c^2$ and $\rho_D = 0.3\,\text{GeV}\,\text{cm}^{-3}$ gives

$$n_D \simeq 1.5\times10^{-3}\ \text{cm}^{-3}, \qquad a_D \equiv n_D^{-1/3} \simeq 9\,\text{cm}, \qquad \frac{q_{\text{tr}}a_D}{\hbar} \sim 10^{14}.$$

The large last ratio rules out coherence tied merely to the mean interparticle spacing. It does **not** determine the full spectral response or by itself prove an impulse regime. Such a claim additionally requires, over the relevant support,

$$\frac{q_{\mathrm{tr}}\,\lambda_D}{\hbar} \gg 1, \qquad \omega_{\mathrm{tr}} \gg \Omega_p,$$

taking $\omega_{\mathrm{tr}} \equiv E_R/\hbar$ for the elastic-recoil interpretation, together with controlled correlation, bound-state, and condensate effects. A weak plasma with many particles per Debye sphere normally has $\lambda_D \gg a_D$, but the relevant parameters have not been inferred from this event. The decisive calculation is $S_D(q,\omega)$ near $q \simeq 246\,\mathrm{MeV}/c$; absence of spectral weight there falsifies a claimed incoming collective contribution. Collective dynamics could still reshape the halo velocity distribution, streams, directionality, or time dependence. None of this turns the event into evidence for plasma or aether.

Any proposed connection must supply, prospectively:

1. the visible-dark interaction operator and normalization;
2. the constituent or excitation spectral weight at the measured (q,ω);
3. the abundance and phase-space distribution;
4. the xenon response and nuisance model;
5. predictions for additional exposure, other targets, recoil energy, time, and direction.

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13. Three calibration cases: path, compensation, and threshold

The following cases do not supply evidence that plasma, aether, and dark matter are one substance. They are calibration cases for the inference problem. Each shows a different way in which a named mechanism can be read too directly from an observed outcome.

13.1 Returned control, retained state: a gravitational-pulse null

Van Suijlekom, Wondrak, and Falcke study a free massless minimally coupled scalar test field on a prescribed FLRW background. With

$$ds^2 = -dt^2 + a^2(t)\,ds_\Sigma^2, \qquad d\tau = a^{-3}\,dt,$$

each spatial mode obeys

$$\psi_\lambda'' + \lambda^2 a^4(\tau)\psi_\lambda = 0.$$

Their pulse begins and ends with the same scale factor, but the early and late positive-frequency bases need not agree. The Bogoliubov relation

$$a_{\lambda,\mathrm{out}} = \alpha_\lambda a_{\lambda,\mathrm{in}} + \beta_\lambda^* a_{-\lambda,\mathrm{in}}^\dagger, \qquad |\alpha_\lambda|^2 - |\beta_\lambda|^2 = 1$$

gives a late occupation $N_\lambda = |\beta_\lambda|^2$. The foundational result is therefore

$$a(-\infty) = a(+\infty) \quad \not\Rightarrow \quad |\Psi(-\infty)\rangle = |\Psi(+\infty)\rangle.$$

The state can remember the path even when the macroscopic control returns to its initial value. In a general oscillator form,

$$\chi_k{}'' + \Omega_k^2(\eta)\chi_k = 0, \qquad \beta_k^{(1)} \simeq \int d\eta \frac{\Omega_k{}'}{2\Omega_k} \exp\left[-2i\int^{\eta} \Omega_k(\eta')d\eta'\right],$$

so the response depends on switching rate, pulse shape, phase, and dwell time, not only endpoints. This is a conventional **state-memory null** for any claim of persistent medium memory or changed law.

The null has sharp controls. For a scalar in spatially flat FLRW,

$$\Omega_k^2 = k^2 + a^2 m^2 + (6\xi - 1)\frac{a''}{a}.$$

The massless conformally coupled case $m = 0$, $\xi = 1/6$ has $\Omega_k = k$ and $\beta_k = 0$. For gapped modes, particle production must also vanish in a genuine adiabatic limit. A claimed additional residual should be defined only after subtracting this declared QFT response:

$$\Delta N_k = N_k^{\text{observed}} - N_k^{\text{QFT}}[a(\cdot), m, \xi, \text{initial state}].$$

The paper's high-frequency Planck-shaped tail is model- and limit-specific, and the final state is a pure squeezed pair state rather than a thermal density matrix. Its reported threshold is also not a no-production cutoff: below the finite-occupation threshold, $|\beta_\lambda/\alpha_\lambda|^2 \to 1$, which drives N_λ singular in the stated limit. No backreaction, source for the prescribed metric, dark-matter abundance, black hole, or observation is solved.

13.2 Fast response, non-unique mechanism: microwave-assisted SnO2

Chen and collaborators followed SnO2 crystallization in situ with synchrotron X-ray total scattering and pair-distribution-function analysis under conventional and 2.45 GHz pulsed microwave heating. They fit an Avrami law and then an Arrhenius form,

$$X(t) = 1 - \exp\left[-(kt)^n\right], \qquad k = A\exp\left(-\frac{E_a}{RT}\right).$$

The reported apparent pairs were approximately

Apparent Arrhenius parameters reported for conventional and microwave-assisted synthesis.

heating mode	E_a	A
conventional	$16\ \text{kJ mol}^{-1}$	$37\ \text{min}^{-1}$
microwave-assisted	$270\ \text{kJ mol}^{-1}$	$3.4\times10^{34}\ \text{min}^{-1}$

Faster crystallization therefore did not map to a lower fitted barrier. The two reported best-fit parameter pairs partially compensate at a selected pivot. At $T_* = 410\,\mathrm{K}$, using the rounded reported values,

$$\Delta \ln A = 75.90, \qquad \frac{\Delta E_a}{RT_*} \simeq 74.51, \qquad \Delta \ln k(T_*) \simeq 1.39.$$

This is a numerical comparison of two fitted lines, not a covariance analysis. It does not establish how tightly the underlying data constrain the pivot-rate combination

$$C(T_*) \equiv \ln A - \frac{E_a}{RT_*} = \ln k(T_*)$$

relative to A and E_a separately. The enormous prefactor remains an apparent extrapolated fit parameter, not a directly observed molecular collision frequency. The paper additionally reports that the microwave rates correspond to conventional-fit temperatures about $28\text{–}31\,^\circ\mathrm{C}$ above the probe readings; unresolved local thermal gradients remain a viable explanation.

For response analysis, define the cumulative and instantaneous hazards

$$H(t) = -\ln\,[1 - X(t)], \qquad h(t) = \dot{H}(t).$$

If $u(t)$ is the applied drive and $\Theta(\mathbf{x}, t)$ is the local temperature field, the relevant residual is conditional:

$$\delta h(t) = \int^{t} K_{hu}(t, t')\delta u(t')dt' + \int d^3x \int^{t} K_{h\Theta}(\mathbf{x}; t, t')\delta\Theta(\mathbf{x}, t')dt' + \cdots.$$

A field-specific channel is not established until matched space-time thermal histories, geometry, state preparation, and nuisance response fail to reproduce the kinetic pathway. This experiment does not test fluctuation-dissipation theory and supplies no physical link to a cosmic dark medium. Its lesson is identifiability: a response rate does not tell us which named fit parameter or mechanism changed.

13.3 Timed impulse, hidden memory, delayed output: 450P/LONEOS

450P/LONEOS provides a natural impulse-response calibration. The evidence is a chain, not one observation. Astrometry constrains an initial-state distribution; clones propagated through an N-body model reconstruct a close 1992 Saturn encounter and a large semimajor-axis decrease. Later Gemini observations found an apparently inactive point source in 2022 and a coma in 2023–2024. JWST directly detected CO2 at

$$Q_{\mathrm{CO_2}} = (6.99 \pm 0.07) \times 10^{24}\ \text{molecules s}^{-1},$$

with H2O and CO reported as nondetections or upper limits. A simple thermal model makes release of trapped CO2 during amorphous-water-ice crystallization plausible; it is not an end-to-end likelihood prediction of the measured gas rate.

The causal reconstruction can be written as

$$D_{\text{ast}} \to p(x_0 \mid D_{\text{ast}}) \to r_c(t), \qquad F_c(t) = \frac{(1-A)L_\odot}{4\pi r_c(t)^2},$$

$$\partial_t T_c = \alpha\, \partial_z^2 T_c, \qquad Q_{\text{CO}_2} = \mathscr{G}[T_c, \mathscr{C}, \text{porosity, spin, shape}],$$

$$D_{\text{spec}} \sim \mathscr{O}[Q_{\text{CO}_2}, \text{dust, viewing geometry}].$$

The encounter supplies an independently timed perturbation; diffusion and phase conversion supply hidden memory; spectra, dust, and morphology supply distinct outputs. Every arrow is model-assisted and carries its own failure condition. Unknown shape, spin, obliquity, material properties, earlier thermal history, selection, and a pure-CO2 alternative prevent “Saturn activated the comet” from becoming a directly observed fact. The source’s forecast of a July 2026 Jupiter encounter is not used as evidence here. This note has not independently checked post-encounter astrometry and makes no claim that the forecast was borne out.

13.4 The combined inference rule

Together, the cases motivate a more explicit response equation:

$$X(t) = X_{\text{hom}}(t; X_0, \mathscr{H}) + \int_{-\infty}^{t} K(t, t'; \theta) F(t') dt', \qquad Y(t) = \mathscr{O}[X(t), \nu] + \epsilon(t),$$

where $\mathscr{H}$ is unresolved history, θ contains compensating constitutive parameters, ν contains observation and selection variables, and ϵ is declared error. The simple foundational rule is:

> Do not name the residual until endpoint restoration, parameter compensation, latent history, and the observation operator have each been tested.

14. Causal Residual Spectroscopy protocol

The following proposed method is written for possible comparison with ASTRA’s existing operator-aware methods. It is a research protocol rather than a new cosmic substance, and compatibility or integration has not been validated.

1. **Reconstruct the known sector.** Map visible density, pressure, electromagnetic fields, plasma tracers, and measurement selection effects.

2. **Infer the residual.** Under declared reconstruction assumptions, reconstruct compatible metric potentials and the conserved closure $\mathscr{R}_{\mu\nu}$, with uncertainty.

3. **Declare the action and symmetries.** Specify whether each symmetry is global, gauged, unbroken, Higgsed, or state-broken; enumerate carriers and portals.

4. **Compute the physical response kernel and homogeneous state.** For perturbations $A = (\delta\rho, \delta Q, \theta, U_\mu, h_{\mu\nu})$, impose the gauge and diffeomorphism Ward identities with contact terms, gauge-fix, solve the constraints, project onto physical variables, and then solve

$$\det \mathscr{D}^{-1}_{\text{phys, ret}}(\omega, k) = 0.$$

5. **Audit spectra and characteristics.** Require no ghost residues and positive spectral weight where unitarity requires it, acceptable damping, lower-half-plane poles for stable dissipative modes, stable gradients, controlled strong-coupling scales, and observed photon-graviton cone alignment. Judge causal propagation from characteristics or front velocity, not merely phase or group velocity in a dispersive medium.

6. **Map the phase coordinates.** At minimum record

$$\Xi, \quad \Gamma_D = \frac{\alpha_D}{a_D T_D}, \quad a_D \equiv \left(\sum_s n_s\right)^{-1/3}, \quad N_D = \frac{4\pi}{3}\lambda_D^3 \sum_s n_s, \quad f_D, \quad x_{\text{ion}}.$$

$$\lambda_{\text{mfp}}/L, \quad \Gamma_{\text{inst}}\, L/v, \quad t_{\text{dyn}}/t_{\text{cool}}, \quad n_s \lambda^3_{\text{dB},\,s}, \quad \omega_c/\nu \text{ when magnetized.}$$

   The displayed Γ_D assumes a common carrier temperature T_D.

7. **Map parameter equivalence classes.** Report constrained combinations, covariances, and pivot observables before interpreting individual parameter names. Search for barrier-prefactor, abundance-cross-section, source-transfer, and response-selection compensation.

8. **Predeclare discriminators.** Predict density, velocity, frequency, direction, phase, pulse shape, dwell time, and history dependence before selecting favorable systems. Include conformal, adiabatic, matched-thermal, and endpoint-restoration nulls where applicable.

9. **Prefer independently timed perturbations.** Freeze the forcing reconstruction, latent-state law, nuisance priors, and output map before judging delayed response; compare with a counterfactual generated by the same model and sensitivity-matched controls.

10. **Test transfer.** Freeze physical parameters, nuisance priors, data cuts, and thresholds; calibrate in one domain and score held-out predictions in galaxies, mergers, the CMB, large-scale structure, gravitational waves, and direct detection.

11. **Preserve negative results.** A failed plasma model is not a proof of collisionless particles; a failed modified-gravity model is not proof of a plasma. Reject only the tested action and parameter region.

This protocol may be compared with ASTRA's operator-aware and hidden-state emphasis. No compatibility or integration claim is made: it does not modify SPPT's planetary reservoir graph or inherit the verification status of the stable core.

15. Claim-status summary

SOURCE-SUPPORTED OR STANDARD WITHIN STATED FRAMEWORKS — NOT INDEPENDENTLY VERIFIED HERE

- Plasma kinetics contains collective screening, longitudinal and transverse modes, kinetic damping, and stream instabilities.
- A material rest frame does not by itself imply Lorentz-violating fundamental laws.
- Hidden-$U(1)$, atomic, dissipative, and superfluid dark sectors are established as literature constructions, not descriptions established in nature.
- Preferred-frame couplings are strongly constrained in model- and coupling-specific ways by multimessenger, post-Newtonian, and preferred-frame observations.
- Under standard BBN, recombination, and CMB dynamics, ordinary baryonic plasma is not abundant enough to replace the dominant standard dark-matter inventory.
- A prescribed time-dependent FLRW background can return to its initial scale while a minimally coupled scalar state retains nonzero Bogoliubov occupation; this is a conditional field-theory result, not an observation or dark-matter production claim.
- The reported microwave and conventional SnO2 Arrhenius fits partially cancel at the illustrative pivot; covariance is not established, and unresolved local thermometry remains a stated confounder.
- The 450P/LONEOS evidence separates observed astrometry, coma, and spectra from a model-supported orbital encounter and an inferred thermal activation chain.

ALGEBRAIC DERIVATIONS UNDER ENUMERATED ASSUMPTIONS — INDEPENDENT REVIEW PENDING

- The mixed retarded responses of charge-even stress and charge-odd current vanish at linear order when the dynamics, state, background, and regulator preserve charge conjugation.
- With the additional neutral-background, equal-specific-pressure, and symmetry-preserving closure assumptions, the declared equal-pair fluid model separates into Jeans and Langmuir branches.
- Unequal specific pressure response supplies the displayed mass-charge mixing terms in the generic two-component benchmark.
- For a self-gravitating equal-pair plasma, $\Omega_p^2/\omega_J^2 = \alpha_D/(Gm^2)$.
- The Debye/Jeans reduction follows only with the additionally declared isothermal equal-pair closure.
- Under the illustrative $m_D = 200\,\mathrm{GeV}/c^2$ and local-density benchmark, LZ230616 has $q_{\mathrm{tr}}\,a_D/\hbar \sim 10^{14}$; this excludes coherence tied to mean spacing but does not alone establish an impulse regime.

These are derivations, not established novelty claims.

PROPOSED_ONLY

- "Causal residual spectroscopy" as a working label for a possible integration of established closure and response methods.
- A phase-dependent hidden sector that occupies plasma, neutral, condensed, and gravitationally clustering regimes.
- Merger-ensemble response exponents as a practical classifier after nonlinear simulation calibration.
- Applying a two-sided dynamical-structure-factor description to an incoming collective dark sector.
- Using the three calibration cases as a general endpoint-compensation-memory audit for cosmic residuals.

UNKNOWN

- Whether the dominant cosmic residual is particulate, plasma-like, condensed, a fundamental preferred-frame field, modified gravity, or a mixture.
- Whether the derived response organization is novel relative to the complete plasma, many-body, and modified-gravity literature.
- Whether LZ230616 is dark matter, an unmodeled background, or a statistical fluctuation.

REJECTED IN THIS NOTE

- The claim that plasma, aether, and dark matter have been empirically identified as one substance.
- The claim that mathematical equivalence of restricted field equations proves ontological identity.
- The claim that one anomalous recoil establishes a population-level law.
- The claim that the stated minimal single-gauged-$U(1)$ homogeneous realization automatically supplies both a long-range plasma and an ungapped superfluid phonon.
- The claim that any of the three calibration cases is evidence for a shared plasma, aether, or dark-matter ontology.
- The claim that restored controls imply a restored state, or that a fitted parameter name uniquely identifies a microscopic mechanism.

16. Conclusion

The productive intersection of plasma, aether, and dark matter is a phase and response problem, not a synonym problem.

A hidden sector could gravitate while supporting charge oscillations, recombination, shocks, neutral bound states, or condensate excitations. Charge symmetry can prevent its fastest electric mode from entering its linear mass mode, allowing gravitational clustering and collective plasma response to coexist. Mergers, background fields, phase changes, streaming, and nonlinear transport can expose what equilibrium hides.

The correct foundational move is therefore:

> Infer the conserved residual, declare the degrees of freedom, compute the poles and residues, test the zero-density and phase limits, and require the same parameters to survive held-out observations.

That program is compatible with unconventional hypotheses without granting them evidentiary privilege. The sky does not speak without models, but models can be required to reveal exactly where their language enters.

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