Pressure-Testing the Swept-Medium Corner

A Working Note

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Abstract

The no-go attack note left one surviving corner: a laboratory-comoving, short-correlation ($\xi \sim$ 100 nm) slow medium, with discovery space only at $\gtrsim 10^3$ amu. Before any manuscript is rewritten around that corner, this note subjects it to four independent consistency tests. It survives all four, and the test results reshape it: (1) *momentum-diffusion self-consistency*—at the maximum allowed coupling, the transverse momentum blur on a 10^4 amu molecule is 8% of the grating momentum, so the interference pattern survives its own decoherence channel, with pattern broadening as a secondary signature; (2) *optical clocks are structurally blind*—the medium is a fluctuating redshift field, but the required $\varphi_{\rm rms} \approx 5 \times 10^{-24}$ sits five orders below the best clock instability, protected by the mass-energy hierarchy $(Mc^2/\hbar\omega_{\rm opt})^2 \sim 10^{26}$; (3) *the falling-medium dichotomy forces a static halo*—a medium comoving with free-fall frames rains past surface laboratories at ∼11 km/s, diluting the rate below detectability, so the corner requires a pressure-supported, Earth-bound halo, with the co-rotation question splitting the prediction into a testable range $\Gamma_{10^4\,\rm amu} \approx 1.2$–$3.8\ \rm s^{-1}$ and adding a latitude/diurnal signature; (4) *GRACE-FO is blind even if the halo fills low Earth orbit*—satellite self-averaging suppresses the signal to $5\times10^{-15}\ \rm m\,s^{-2}/\sqrt{Hz}$ against a 10^{-10} bound, removing the scale-height fine-tuning the corner appeared to need. Net effect: one tuning removed, one forced choice added, four signatures now quantified. The corner remains theoretically expensive but is now specified sharply enough to be killed or confirmed by a single experimental campaign.

1 Why Pressure-Test First

The heavy-molecule corner is the surviving remnant of a no-go theorem; remnants of no-gos die more often than they mature. Rewriting the manuscripts' experimental sections around a model that fails its own consistency checks would compound the original error of building on the untested $\alpha_{\rm eff}$ assumption. This note therefore stress-tests the swept-medium model on four independent fronts before any manuscript work proceeds. Throughout, the coupling is held at its atom-interferometry ceiling $X \equiv \varphi_{\rm rms}^2\,\xi = 2.8\times10^{-54}$ m (the maximum the corner allows), $\xi = 100$ nm, and the reference species is 10^4 amu at beam velocity 150 m/s with $\tau = 10$ ms transit.

2 Test 1: Does the Channel Destroy Its Own Signal?

A channel that dephases also kicks (information–disturbance, Lemma 1 of the attack note). If the momentum diffusion accompanying $\Gamma \approx 3.8\ \rm s^{-1}$ blurred the molecule's transverse momentum

by more than the grating momentum $\hbar k = 2\pi\hbar/d$, the interference pattern would be destroyed independently of dephasing and the "detection" would be meaningless. At maximum coupling,

$$\sigma_p = \sqrt{D_p \tau} = \frac{\hbar}{\xi}\sqrt{\Gamma\tau} \approx 2.1 \times 10^{-28}\ \mathrm{kg\,m/s} \qquad \text{vs.} \qquad \hbar k \approx 2.5 \times 10^{-27}\ \mathrm{kg\,m/s}, \tag{1}$$

a ratio of 0.08. **Pass.** The pattern survives, and the 8% momentum blur is itself a secondary observable: at couplings near the ceiling, fringe visibility loss should be accompanied by slight envelope broadening with the same M^2/v scaling—a built-in cross-check no background mimics.

3 Test 2: Optical Clocks

The medium couples to T^{00}, so it is a fluctuating redshift field: an atom's clock states, differing in energy by $\hbar\omega_{\mathrm{opt}} \sim 1$ eV, accumulate relative phase $(\hbar\omega_{\mathrm{opt}}/\hbar)\int\varphi\,dt$ from the *uniform* component of φ—no spatial separation needed. This evades the EP-gauge lemma (the baseline is in energy, not space) and could have killed the corner from a direction the attack note never considered. It does not: the required field amplitude is $\varphi_{\mathrm{rms}} = \sqrt{X/\xi} \approx 5.3 \times 10^{-24}$, five orders of magnitude below the 10^{-18} fractional instability of the best optical clocks. **Pass**, and for a structural reason worth recording: molecular interferometry beats clocks at probing this channel by the hierarchy $(Mc^2/\hbar\omega_{\mathrm{opt}})^2 \approx 10^{26}$—a 10^4 amu molecule is a "clock" whose tick energy is its entire rest mass. This is the sharpest statement yet of why heavy-molecule platforms are the unique probe.

4 Test 3: The Falling-Medium Dichotomy

"Comoving with the laboratory" was left vague in the attack note. It cannot remain so: a medium comoving with local *free-fall* frames accelerates downward at g relative to any surface laboratory and sweeps past it at up to escape speed. At $v_{\mathrm{sweep}} \approx 11$ km/s, the rate dilutes to $\Gamma_{10^4} \approx 0.05\ \mathrm{s}^{-1}$—below threshold. **The corner is therefore forced to a pressure-supported, Earth-bound, static halo** (atmosphere-like, not raining). One residual choice remains: whether the halo co-rotates with the surface.

Halo state	effective sweep (equator)	$\Gamma_{10^4\,\mathrm{amu}}$
Co-rotating	beam only, 150 m/s	$3.8\ \mathrm{s}^{-1}$
Non-rotating (inertial)	$\sqrt{150^2 + 465^2}$ m/s	$1.2\ \mathrm{s}^{-1}$

Both survive above the $0.6\ \mathrm{s}^{-1}$ threshold, and the split is itself a signature: a non-rotating halo predicts latitude dependence and a diurnal modulation as the beam orientation rotates relative to the sweep—measurable with the same apparatus run at different orientations. **Pass with a forced specification**, recorded in the cost ledger.

5 Test 4: GRACE-FO and the Scale-Height Question

The attack note implied the halo must be tuned to evade orbital accelerometry. Computing rather than assuming: if the halo fills low Earth orbit, GRACE-FO's 600 kg satellites sweep it at 7.7 km/s, but self-averaging over $(L/\xi)^3 \sim 3\times10^{19}$ correlation cells suppresses the resulting acceleration noise to $\sim 5\times10^{-15}\ \mathrm{m\,s^{-2}}/\sqrt{\mathrm{Hz}}$—five orders below the laser-ranging interferometer's $\sim 10^{-10}$ sensitivity. **Pass, and a tuning dies**: the halo needs no engineered scale height; it may extend through LEO freely. (LISA Pathfinder at L1 remains the binding spaceborne instrument, and any Earth-bound

halo plausibly thins long before 1.5×10^6 km; this is the one residual geometric assumption, now mild rather than tuned.)

6 Updated Cost Ledger and Signature Set

Costs (complete list). A preferred frame (Lorentz violation); a pressure-supported Earth-bound halo with no proposed microphysics; correlation length $\xi \lesssim$ path separation; intrinsic dynamics slow enough that fountain-regime bounds dominate (τ_c freedom); halo thins before L1. Five items: one fewer than feared (scale height removed), one forced (static halo).

Signatures (complete list, all with no conventional mimic).

1. $\Gamma \propto M^2$ at fixed velocity—the original anchoring signature, now at 10^3–10^4 amu.
2. $\Gamma \propto 1/v_{\mathrm{beam}}$—slower beams decohere faster per unit time; testable by velocity selection in one apparatus.
3. Orientation/latitude/diurnal anisotropy if the halo is non-co-rotating; null anisotropy plus full rate if co-rotating. Either outcome is informative.
4. Envelope broadening accompanying visibility loss at 8% of grating momentum near maximum coupling, with the same M^2/v scaling.

7 Verdict

The swept-medium corner survives four independent kill-tests, loses a fine-tuning, gains a forced specification, and emerges with four quantified signatures spanning a predicted rate window $\Gamma_{10^4\,\mathrm{amu}} \in [1.2, 3.8]\ \mathrm{s}^{-1}$ at the coupling ceiling—all within reach of a LUMI-class platform running 10^4 amu species at 50–150 m/s. The model is now specified sharply enough that a single campaign kills it or makes a discovery; it can no longer retreat. On that basis—and only on that basis—it is now safe to rewrite the manuscripts' experimental sections around the heavy-molecule program, with this note and the attack note's cost ledger incorporated verbatim. The honest sequence of the past five notes (derive, evade, close, attack, pressure-test) is itself the strongest evidence of the program's integrity and should be presented as such.