

Impulsive Axisymmetric Forcing in a Rotating Cylinder, Reversible Swirl Response, and Skymionic Photon Emission: Fluid Benchmarks and Fluid-Inspired Kinematic Hypotheses

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Abstract

We present a one-to-one Swirl–String Theory (SST) translation of a rotating-tank impulse experiment and skymionic-photon framework. All sections/equations from the original are preserved, with SST terms added via Rosetta mapping and mainstream physics glosses inline. Macrodynamics remain standard rotating Euler; SST introduces (i) bookkeeping of swirl energy/mass densities and (ii) the canonical *Swirl Clock* $d\tau/dt = \sqrt{1 - v^2/c^2}$ alongside the legacy $\sqrt{1 - u^2/C_e^2}$ hypothesis (kept as an explicit, testable variant). Dimensional checks and numerics use $\|\mathbf{v}_\odot\| = 1.09384563 \times 10^6 \text{ m s}^{-1}$, $r_c = 1.40897017 \times 10^{-15} \text{ m}$, $\rho_f = 7.0 \times 10^{-7} \text{ kg m}^{-3}$.

Rosetta card (SST \leftrightarrow mainstream)

| | |
|--|--|
| $\rho_E = \frac{1}{2} \rho_f \ \mathbf{v}\ ^2$ | (mainstream: kinetic-energy density), |
| $\rho_m = \rho_E/c^2$ | (mainstream: mass from energy), |
| $\Omega_0 \equiv \ \mathbf{v}_\odot\ /r_c$ | (SST characteristic frequency), |
| $S_t = \sqrt{1 - v^2/c^2}$ | (Swirl Clock; mainstream: Lorentz factor). |

Distinct roles: Ω (lab rotation) controls inertial waves; Ω_0 is an SST material scale derived from \mathbf{v}_\odot and r_c .

1 Set-up and observation

Consider a vertical cylinder of radius R and depth H , rotating at rate Ω about z . A bottom DC motor drives a three-fin impeller that briefly produces a hollow-core vortex of radius $a_v \approx 7.5 \text{ mm}$ and axial jetting. After a delay $\sim H/c_{g,z}$, a two-lobed "push–pull" on-axis surface signal appears at $z = H$.

SST map. Energy in the packet that reaches the surface is tracked as $\rho_E = \frac{1}{2} \rho_f \|\mathbf{u}'\|^2$ and mass-equivalent density $\rho_m = \rho_E/c^2$ (bookkeeping only).

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2 Linear rotating-wave framework

In the bulk, small perturbations admit *inertial waves* with dispersion[?, ?, ?]

$$\omega = 2\Omega \frac{k_z}{k}, \quad k = \sqrt{k_r^2 + k_z^2}. \quad (1)$$

For axisymmetry ($m = 0$) in a cylinder, $k_r \approx \lambda_{0n}/R$ (Bessel eigenvalues)[?]. Group velocities follow from $\partial\omega/\partial k_i$:

$$c_{g,r} = -\frac{2\Omega k_z k_r}{k^3}, \quad c_{g,z} = \frac{2\Omega k_r^2}{k^3}. \quad (2)$$

Beams satisfy $\tan \alpha = |c_{g,r}|/c_{g,z} = k_z/k_r$.

Arrival time. With $c_{g,z}$ as above,

$$t_{\text{arr}} \approx \frac{H}{c_{g,z}} = \frac{H k^3}{2\Omega k_r^2}. \quad (3)$$

Numerics (bench-top). $R = 0.075$ m, $H = 0.30$ m, $\Omega \approx 2$ rad/s, $k_r \approx 3.83/R \approx 51$ m⁻¹, $k_z \approx \pi/H \approx 10.5$ m⁻¹. Then $k \approx 52.1$ m⁻¹, $c_{g,z} \approx 7.4 \times 10^{-2}$ m/s, $t_{\text{arr}} \approx 4.1$ s. Units: $[H/c_{g,z}] =$ s.

Analogy (10-year-old). A tilted line of dominos falls in a slanted path; it reaches the top after a short delay.

3 Impulse sign and the observed "push-pull"

Start impulse: axial upwelling and centrifugal low p' in the hollow core yield a *surface depression* on arrival. Stop impulse reverses the sign and gives a *surface rise*. Hydrostatic surface coupling[?, ?]:

$$p'(z=0) + \rho g \eta = 0 \Rightarrow \eta = -\frac{p'(0)}{\rho g}. \quad (4)$$

4 Relation to vortex rings and jet starting vortices

A short burst sheds a starting ring with translational speed in quiescent fluid[?]

$$U_{\text{ring}} \approx \frac{\Gamma}{4\pi R_v} \left[\ln\left(\frac{8R_v}{a_v}\right) - \frac{1}{4} \right]. \quad (5)$$

In rotation, the on-axis *delayed* packet at the surface is dominated by the inertial-wave field, not by ring ballistic motion.

5 What this *is* and *is not* an analogy to

Photon analogy (limited)

Localized impulse \Rightarrow localized packet with clear parity. Inertial waves are anisotropic and dispersive ((1)–(2)); free photons in vacuum are isotropic and nondispersive. Analogy is qualitative.

Gravitational-wave analogy (limited)

GR waves are transverse, quadrupolar, nondispersive (in vacuum). Axisymmetric inertial-wave response is neither quadrupolar nor nondispersive; c_g depends on (k_r, k_z) and Ω .

6 A proposed microscopic interpretation inspired by fluid analogs (VAM)

Legacy rule (kept as testable hypothesis). Let $u(\mathbf{r}, t)$ be local swirl speed. Postulate

$$\frac{d\tau}{dt} = \sqrt{1 - \frac{u^2}{C_e^2}}, \quad (6)$$

with C_e a characteristic speed. (Rosetta: $C_e \mapsto \|\mathbf{v}_\odot\|$.)

Canonical SST (Swirl Clock). SST uses

$$\frac{d\tau}{dt} = S_t = \sqrt{1 - \frac{v^2}{c^2}} \quad (v = |u_\theta| \text{ locally}), \quad (7)$$

recovering Lorentz kinematics.

Parity prediction. Two opposite-sign swirl impulses flip surface angle, but any time-rate effect even in speed ((6) or (7) expansion) does not reverse.

7 Falsifiable checks

- **Travel-time scaling:** $t_{\text{arr}} \propto \Omega^{-1}$; infer (k_r, k_z) from beam angle or cylinder modes[?].
- **Bipolarity:** Start/stop impulses give opposite η via (4).
- **Anisotropy:** Off-axis probes detect beams at angle $\tan \alpha = k_z/k_r$; axis receives vertical arrival.
- **Time-rate parity:** Two "clock tracers" at the surface (on-axis vs off-axis reference); bound even-in-speed time drift.

Conclusion (Part I)

An impulsive rotor in a rotating cylinder launches an axisymmetric inertial-wave packet whose $c_{g,z}$ yields a delayed on-axis surface response of the observed magnitude. The two-lobed signal follows the impulse signs. A speed-based time-rate rule, whether legacy (6) or canonical (7), produces even-in-speed effects that do not reverse.

8 Why the Surface "Push–Pull" Requires Background Rotation

Observation. The delayed bipolar surface signal occurs only for nonzero Ω ; for $\Omega = 0$ there is no reproducible delayed response.

8.1 Mechanism: Coriolis restoring force and inertial-wave beams

Linear rotating Euler equations[?]:

$$\partial_t \mathbf{u} + 2\mathbf{\Omega} \times \mathbf{u} = -\nabla \pi, \quad \nabla \cdot \mathbf{u} = 0. \quad (8)$$

They admit inertial waves with dispersion and group velocity ((1)–(2)). Arrival time (3). Hydrostatic coupling (4).

8.2 Scaling explaining the "off" state at $\Omega = 0$

As $\Omega \rightarrow 0$: $\omega \rightarrow 0$, $c_{g,z} \propto \Omega \rightarrow 0$, $t_{\text{arr}} \rightarrow \infty$. Geostrophic scaling yields $\eta \propto \Omega$; viscous damping also grows (Ekman). Hence the delayed bipolar signature vanishes.

8.3 Testable predictions vs Ω

$$t_{\text{arr}}(\Omega) \propto \Omega^{-1}, \quad (9)$$

$$\eta_{\text{max}}(\Omega) \propto \Omega. \quad (10)$$

Dimensional checks: $[H/c_{g,z}] = \text{s}$; $[p'/\rho g] = \text{m}$.

9 Hypothesized Compressional Signaling Branch (Fluid-Inspired, Microscopic)

Summary. Add a longitudinal compressional channel with speed $c_P \gg c$ that couples (ultra-weakly) to isotropic stress. Macrodynamics unchanged.

9.1 Minimal linear model

Relax strict incompressibility and let $p' = B_* \rho' / \rho_*$; linearization gives[?, ?]

$$\partial_t^2 \rho' - c_P^2 \nabla^2 \rho' = 0, \quad c_P = \sqrt{\frac{B_*}{\rho_*}}. \quad (11)$$

Dimension: $[c_P] = \text{m s}^{-1}$.

9.2 Field-theoretic sketch (source coupling)

Introduce scalar Φ with action

$$S_\Phi = \int dt d^3x \frac{1}{2} [\kappa_\Phi^{-1} (\partial_t \Phi)^2 - \Lambda_\Phi^2 (\nabla \Phi)^2] + \int dt d^3x \varepsilon \Phi \mathcal{T}, \quad (12)$$

where \mathcal{T} is isotropic stress trace. Euler–Lagrange equation

$$\partial_t^2 \Phi - C_*^2 \nabla^2 \Phi = \varepsilon \kappa_\Phi \mathcal{T}, \quad C_* \equiv \Lambda_\Phi \sqrt{\kappa_\Phi}. \quad (13)$$

Identifying $\rho' \propto \partial_t \Phi$ maps $C_* \rightarrow c_P$ and (11).

9.3 Numerical checks with supplied parameters

Using $\rho_* = 7.0 \times 10^{-7} \text{ kg m}^{-3}$, $B_* \approx 3.49924562 \times 10^{35} \text{ J m}^{-3}$:

$$c_P = \sqrt{B_*/\rho_*} = 7.0703057319 \times 10^{20} \text{ m s}^{-1}. \quad (14)$$

Ratios: $c_P/c \approx 2.36 \times 10^{12}$; for $L = 10 \text{ m}$, $t = L/c_P \approx 1.4 \times 10^{-20} \text{ s}$. Compatibility: GW170817 constrains $v_{\text{GW}} \approx c$ [?, ?]; a distinct, trace-coupled channel can evade provided coupling is tiny.

9.4 Falsifiable protocol

Two baselines $L_1 < L_2$; earliest correlated arrivals t_1, t_2 (after excluding EM/acoustic paths) obey

$$c_P \gtrsim \frac{L_2 - L_1}{t_2 - t_1}. \quad (15)$$

Null at resolution δt yields $c_P \gtrsim (L_2 - L_1)/\delta t$.

10 Replacing the Working Fluid by a VAM-Like Superfluid Medium

Aim. Consider a hypothetical inviscid superfluid with microscopic swirl. Macroscopically, keep rotating Euler; microscopically, two branches: transverse (inertial-like) and longitudinal (compressional).

10.1 Transverse inertial-like branch with effective background rate

Define $\Omega_* \equiv C_e/\ell_*$. Then

$$\omega = 2\Omega_* \frac{k_z}{k}, \quad c_{g,z} = \frac{2\Omega_* k_r^2}{k^3} \sim 2C_e \frac{R}{\ell_*}. \quad (16)$$

Arrival:

$$t_{\text{arr}} \sim \frac{H \ell_*}{2C_e R}. \quad (17)$$

Numbers. $R = 7.5 \text{ cm}$, $H = 30 \text{ cm}$, $C_e = 1.09384563 \times 10^6 \text{ m s}^{-1}$: (i) $\ell_* = R$: $t \sim H/(2C_e) \approx 1.37 \times 10^{-7} \text{ s}$; (ii) $\ell_* = r_c$: $t \sim 2.6 \times 10^{-21} \text{ s}$. Units: $[H\ell_*/(C_e R)] = \text{s}$.

10.2 Longitudinal compressional branch

As in (11), $c_P = \sqrt{B_*/\rho_*}$ is kinematic front speed; detection requires ultra-weak coupling to avoid conflicts with known tests[?, ?].

Part II: Reversible Azimuthal Response to Axisymmetric Vertical Forcing

Setting. Cylinder radius R , height H , fluid density ρ . Container rotates at Ω ; base state at rest in rotating frame; absolute vorticity $\omega_a^{(0)} = 2\Omega$ [?, ?].

10.3 Governing equations and vorticity production

Inviscid rotating-frame equations:

$$\partial_t \mathbf{u} + (\mathbf{u} \cdot \nabla) \mathbf{u} + 2\mathbf{\Omega} \times \mathbf{u} = -\nabla \Pi, \quad (18)$$

$$\nabla \cdot \mathbf{u} = 0. \quad (19)$$

Curl gives absolute-vorticity equation[?, ?]

$$\partial_t \boldsymbol{\omega} = \nabla \times (\mathbf{u} \times \boldsymbol{\omega}_a), \quad \boldsymbol{\omega}_a = \boldsymbol{\omega} + 2\mathbf{\Omega}. \quad (20)$$

Linearizing about $\boldsymbol{\omega}_a^{(0)}$ yields

$$\partial_t \boldsymbol{\omega} \approx 2(\mathbf{\Omega} \cdot \nabla) \mathbf{u}. \quad (21)$$

Axisymmetry \Rightarrow vertical component

$$\boxed{\partial_t \omega_z = 2\Omega \partial_z w.} \quad (22)$$

Introduce displacement ξ with $w = \partial_t \xi$; integrate from rest:

$$\boxed{\omega_z(r, z, t) = 2\Omega \partial_z \xi(r, z, t).} \quad (23)$$

10.4 From vertical vorticity to azimuthal velocity

Kinematic relation

$$\omega_z = \frac{1}{r} \partial_r (r u_\theta) \Rightarrow u_\theta(r, z, t) = \frac{1}{r} \int_0^r \omega_z(r', z, t) r' dr'. \quad (24)$$

Gaussian kernel. For $\xi = Z(t) \exp(-(r^2 + z^2)/a^2)$,

$$u_\theta(r, z, t) = -\frac{2\Omega Z(t) z}{a^2} e^{-z^2/a^2} \frac{1 - e^{-r^2/a^2}}{r}. \quad (25)$$

Sign: cyclonic below ($z < 0$), anticyclonic above ($z > 0$). Near-axis regularity: $1 - e^{-r^2/a^2} \sim r^2/a^2$.

10.5 Angle reversal and reversibility

Relative angular rate $\dot{\theta}_{\text{rel}} = u_\theta/r$. Over a stroke $[t_1, t_2]$,

$$\Delta\theta_{\text{rel}}(r, z) = \int_{t_1}^{t_2} \frac{u_\theta}{r} dt. \quad (26)$$

Because $\dot{\theta}_{\text{rel}}$ is linear in $Z(t)$, a symmetric up-down cycle with zero mean displacement yields

$$\boxed{\Delta\theta_{\text{rel}}(r, z; \text{one period}) = 0 \quad (\text{to leading order}).} \quad (27)$$

Deviations arise from viscosity (Ekman), quadratic advection (streaming), or near-resonant inertial waves[?].

10.6 A fluid-inspired kinematic time hypothesis (legacy variant)

Define $L \equiv \frac{1}{2} r_e$ with classical electron radius $r_e = e^2/(4\pi\epsilon_0 m_e c^2) \approx 2.82 \times 10^{-15} \text{ m}$. With $\omega = 2u_\theta/C_e$, define

$$\alpha_f \equiv \frac{\omega L}{c} = \frac{r_e}{c C_e} u_\theta, \quad \frac{d\tau}{dt} = \sqrt{1 - \alpha_f^2}. \quad (28)$$

For $\alpha_f \ll 1$, $d\tau/dt \approx 1 - \frac{1}{2}\alpha_f^2$. Quadratic parity: angle reverses; time deficit does not.

Part III: Skymionic Photon Emission from Knotted Swirl Sources

10.7 From optical skyrmions to VAM/SST topology

Optical skyrmions built from LG modes with opposite circular polarizations carry integer topological charge via Stokes field[?, ?, ?]:

$$N_{\text{sk}}^{(\text{ph})} = \frac{1}{4\pi} \int d^2 k_\perp \hat{S} \cdot (\partial_{k_x} \hat{S} \times \partial_{k_y} \hat{S}) \in \mathbb{Z}. \quad (29)$$

Let $\hat{\omega} = \omega/\|\omega\|$; define vortex charge on Σ by

$$H_{\text{vortex}}[\hat{\omega}|\Sigma] \equiv \frac{1}{4\pi} \int_\Sigma \hat{\omega} \cdot (\partial_x \hat{\omega} \times \partial_y \hat{\omega}) dx dy. \quad (30)$$

Topological inheritance. $N_{\text{sk}}^{(\text{ph})} = H_{\text{vortex}}[\hat{\omega}|\Sigma]$.

10.8 Projection law: from swirl to Stokes

Let $\mathbf{p}(\mathbf{r}) = p_0(\mathbf{r}) \hat{\omega}_\perp(\mathbf{r})$ on Σ . Far-field Jones amplitude in mode space (LG basis $u_{p,\ell}$, helicity $\sigma = \pm 1$):

$$A_{p\ell\sigma} = \int_\Sigma (\hat{e}_\sigma^* \cdot \mathbf{P}_\perp \hat{\omega}_\perp) u_{p,\ell}(\mathbf{r}) e^{i\Phi(\mathbf{r})} d^2 r, \quad (31)$$

with $\mathbf{P}_\perp = \mathbf{I} - \hat{\mathbf{k}}\hat{\mathbf{k}}^\top$ and a phase Φ . Stokes field computed from \mathbf{E} yields (29).

10.9 VAM/SST radiative vertex: OAM additivity and chirality

Per-photon OAM in SPDC conserves ℓ additively[?, ?]; adopt

$$\ell_{\text{src}} = \sum_{j=1}^n \ell_j \quad (n\text{-photon channel}). \quad (32)$$

Swirl chirality sets photon helicity: ccw $\Rightarrow \sigma = +1$, cw $\Rightarrow \sigma = -1$.

10.10 Frequency and energy scale

$$\Omega_0 \equiv \frac{C_e}{r_c}, \quad E_0 = \hbar \Omega_0. \quad (33)$$

Numerically (given values): $\Omega_0 \simeq 7.77 \times 10^{20} \text{ s}^{-1}$, $E_0 \simeq 0.511 \text{ MeV}$.

Quantized line set. Let

$$\omega_{m\ell} = m \Omega_0 + \delta\omega_\ell, \quad E_{m\ell} = \hbar \omega_{m\ell} = m E_0 + \delta E_\ell. \quad (34)$$

10.11 Predictions

- **P1 (topological spectroscopy):** $N_{\text{sk}}^{(\text{ph})} = H_{\text{vortex}}$ within a fixed mode family.
- **P2 (chirality–helicity):** flip swirl chirality \Rightarrow flip photon helicity; OAM additivity (32) intact.
- **P3 (robustness):** $N_{\text{sk}}^{(\text{ph})}$ invariant under smooth, linear propagation.
- **P4 (Purcell tuning):** LDOS changes reshape texture without changing integer charge.
- **P5 (line assignments):** $m = 1$ near $m_e c^2$; absence of a strong ladder at $n \times 0.511 \text{ MeV}$ constrains δE_ℓ and higher- m couplings.

11 Minimal experimental roadmap

11.1 E1: Re-analyze single-photon skyrmion data

Express measured Stokes fields via a reconstructed $\hat{\omega}_\perp$; test $N_{\text{sk}}^{(\text{ph})} = H_{\text{vortex}}$, and OAM/helicity control.

11.2 E2: Swirl-based emitters at non-optical frequencies

Macroscopic swirl sources coupled via electro-/magneto-/piezo-optic effects should reproduce topological mapping independent of absolute energy scale.

11.3 E3: High-energy cross-checks

Consistency with electron mass/QED precision and absence of extra stable lines near multiples of 0.511 MeV .

Global Conclusion

Part I. Inertial-wave packet with $c_{g,z}$ explains delayed axial "push–pull"; $t_{\text{arr}} \propto \Omega^{-1}$ and $\eta_{\text{max}} \propto \Omega$. Time-rate hypotheses are even in speed.

Part II. Vertical forcing produces opposite-sign vorticity above/below; linear reversibility gives zero net angle over a symmetric cycle.

Part III. Skyrmionic photon textures inherit vortex topology; OAM additivity and chirality–helicity mapping follow; $\Omega_0 = C_e/r_c$ sets a kinematic scale with numerical validation.

Analogy (10-year-old). Knots in a river can flick patterns into light; how they’re tied (knot type) decides the pattern, not how loudly you splash.

Acknowledgments. Fluid/wave results: [?, ?, ?, ?, ?, ?]. Topological/OAM optics: [?, ?, ?, ?, ?]. Relativistic/causality constraints: [?, ?, ?, ?].