Rotating–Frame Unification in Swirl–String Theory: Swirl–EMF Coupling, Flux Compression, and Quantized Impulses

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Abstract

We present a unified rotating–frame formulation in the Swirl–String Theory (SST) Canon in which time–varying vortex–line areal density $\varrho_{\circlearrowleft}$ acts as a *source* of electromotive curl in Faraday's law,

$$\nabla \times \mathbf{E} = -\partial_t \mathbf{B} - \mathbf{b}_{\circlearrowleft}, \qquad \mathbf{b}_{\circlearrowleft} = \mathcal{G}_{\circlearrowleft}\, \partial_t \varrho_{\circlearrowleft}.$$

Topology fixes the time–integrated EMF impulse per net vortex event to be quantized:

$$\int dt \oint \mathbf{E} \cdot d\boldsymbol{\ell} = -\, \mathcal{G}_{\circlearrowleft}\, \Delta N, \quad \Delta N \in \mathbb{Z},$$

and canonical normalization yields $\mathcal{G}_{\circlearrowleft} = \Phi_\star \in \{h/e,\ h/2e\}$ [?, ?]. With frozen line count, flux compression (shrinking area A) increases $\varrho_{\circlearrowleft} \propto 1/A$; when the mean spacing $a \sim r_c$ vortex nucleation bursts occur, producing EMF spikes consistent with the impulse law. We organize the manuscript by: (i) conceptual novelty and units, (ii) concise derivation and field diagram, (iii) predictions and falsifiers, with detailed derivations in Appendices ??–??, and a coil engineering appendix (Addendum Q). Non–original elements draw on [?, ?, ?, ?, ?, ?, ?, ?, ?].

1 Introduction: Conceptual novelty

On SST leaves Σ_t (absolute time t), particles are knotted vortex loops; circulation obeys the chronos–Kelvin invariant

$$\Gamma = \oint \mathbf{v}_{\circlearrowleft} \cdot d\boldsymbol{\ell} = N\kappa, \qquad N \in \mathbb{Z}, \tag{1}$$

mirroring Onsager–Feynman quantization [?, ?]. The rotating–frame decomposition merges centrifugal and (swirl) gravity channels and motivates a long–range source $\mathbf{b}_{\circlearrowleft}$ for $\nabla \times \mathbf{E}$. We show the unique linear, unit–consistent law

$$\boxed{\mathbf{b}_{\circlearrowleft} = \mathcal{G}_{\circlearrowleft}\, \partial_t \varrho_{\circlearrowleft}} \tag{2}$$

and fix $\mathcal{G}_{\circlearrowleft}$ by a flux–pumping pillbox argument to a flux quantum $\Phi_\star$ [?,?]. The prediction is falsifiable: EMF–time impulses are integer multiples of $\Phi_\star$ and tied to topological changes ΔN.

2 Framework, dimensions, and constitutive mirrors

Define the coarse–grained areal density (units m^{-2})

$$\boldsymbol{\varrho}_{\circlearrowleft}(\mathbf{x},t) \coloneqq n_v(\mathbf{x},t)\,\hat{\mathbf{n}}, \qquad \Phi_{\circlearrowleft}(A,t) = \int_A \boldsymbol{\varrho}_{\circlearrowleft} \cdot d\mathbf{A} = N(A,t). \tag{3}$$

Local linear maps (laboratory tier) mirror standard electrodynamics [?]:

$$\mathbf{D} = \varepsilon\,\mathbf{E}, \quad \mathbf{B} = \mu\,\mathbf{H}, \qquad \boldsymbol{\varrho}_{\circlearrowleft} = \chi_H\,\mathbf{H}, \quad [\chi_H] = \mathrm{m}^{-1}\mathrm{A}^{-1}. \tag{4}$$

Dimensional check: $[\partial_t \boldsymbol{\varrho}_{\circlearrowleft}] = \mathrm{m}^{-2}\mathrm{s}^{-1}$; since $[\nabla \times \mathbf{E}] = \mathrm{V\,m}^{-2}$, one needs $[\mathcal{G}_{\circlearrowleft}] = \mathrm{V\,s} = \mathrm{Wb}$ in (??). This sets the stage for a topological coupling normalized by a flux quantum.

3 Rotating–frame unification and the swirl–EMF law

Starting from Faraday in differential form and appending the long–range source yields

$$\boxed{\nabla \times \mathbf{E} = -\partial_t \mathbf{B} - \mathbf{b}_{\circlearrowleft}, \quad \mathbf{b}_{\circlearrowleft} = \mathcal{G}_{\circlearrowleft}\,\partial_t \boldsymbol{\varrho}_{\circlearrowleft}}\,. \tag{5}$$

Integrating over a surface S with boundary ∂S and time window $[t_i, t_f]$ gives the impulse law

$$\boxed{\int_{t_i}^{t_f} \oint_{\partial S} \mathbf{E} \cdot d\boldsymbol{\ell}\,dt = -\,\mathcal{G}_{\circlearrowleft}\,\Delta N(S)}\,, \qquad \Delta N \in \mathbb{Z}. \tag{6}$$

A single topological event ($\Delta N = \pm 1$) generates a quantized EMF–time impulse of size $|\mathcal{G}_{\circlearrowleft}|$ regardless of geometry. Canonical normalization (Appendix ??) fixes $\mathcal{G}_{\circlearrowleft} = \Phi_\star \in \{h/e, h/2e\}$ [?, ?].

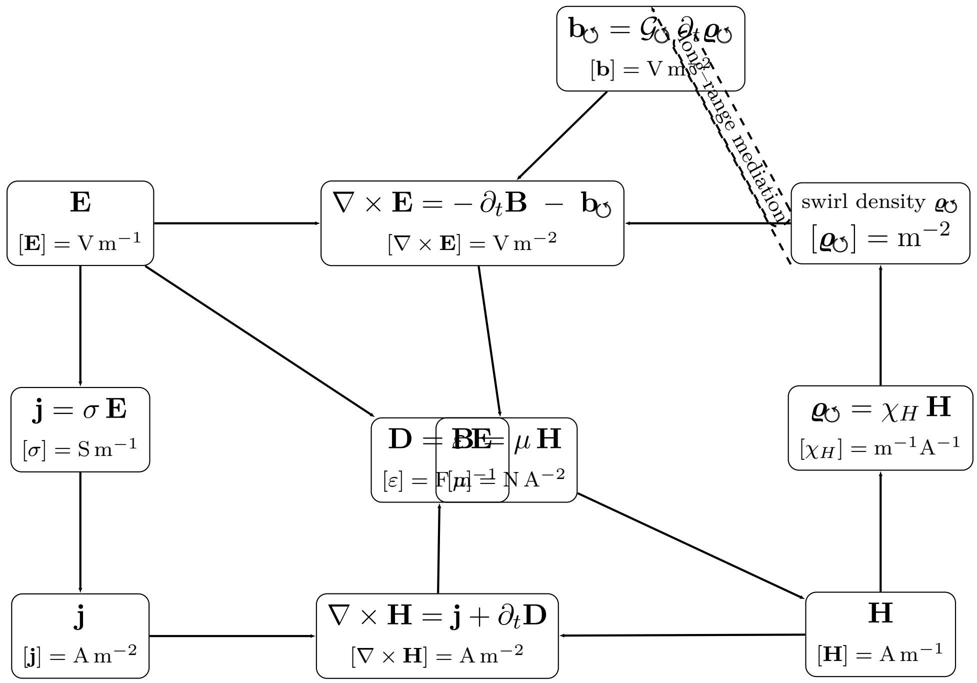

Figure 1: Constitutive mirrors and the added long–range swirl source in Faraday's law.

4 Flux compression and nucleation (kept; empirical VAM table dropped)

With total line count N frozen,

$$\boldsymbol{\varrho}_\circlearrowleft(A) = \frac{N}{A}\,\hat{\mathbf{n}}, \qquad n_v = \frac{N}{A}, \qquad a \sim n_v^{-1/2} = \sqrt{\frac{A}{N}}. \tag{7}$$

Nucleation occurs when $a \lesssim \alpha\, r_c$:

$$n_v \gtrsim (\alpha\, r_c)^{-2}. \tag{8}$$

In a rotating bucket, $n_v \simeq 2\Omega/\kappa$ [?], providing a rotation–dependent threshold. During nucleation bursts, $\partial_t \boldsymbol{\varrho}_\circlearrowleft \neq 0$, so $\mathbf{b}_\circlearrowleft \neq 0$ and EMF impulses follow (??).

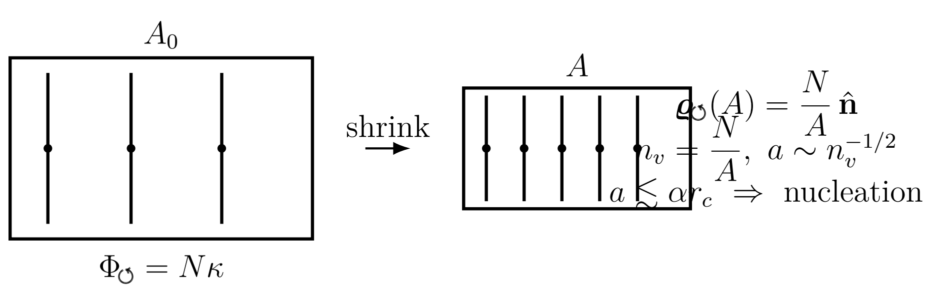

Figure 2: Fixed swirl flux, shrinking area $\Rightarrow$ increased $\boldsymbol{\varrho}_\circlearrowleft$ and nucleation at $a \sim r_c$.

5 Predictive power: experimental outlook

Quantized impulse (primary observable).

$$\int dt\,\mathrm{EMF}(t) = \Phi_\star\,\Delta N, \qquad \Phi_\star \in \{h/e,\ h/2e\}. \tag{9}$$

Platforms. (i) Type–II superconducting films with controlled single–vortex entry/exit and SQUID pickup [?, ?]; (ii) superfluid vortex nucleation/annihilation [?]; (iii) magnetic topological textures (skyrmion nucleation/erasure) as analogs.

Falsifiers. (a) Histogram of $\Delta\Phi = \int V(t)dt$ exhibits integer peaks at $\Phi_\star$ (no fractional plateaus); (b) sign flips with chirality; (c) topology dependent, geometry independent; (d) unlinking eliminates the signal.

6 Conclusion & discussion

Equations (??)–(??) provide a minimal, unit–consistent bridge from rotating–frame vortex dynamics to EM induction. The integrated impulse $\Phi_\star\,\Delta N$ is a sharp, falsifiable signature already compatible with existing single–vortex control. Determining whether $\Phi_\star = h/2e$ or h/e is a material/topology discriminator. Full derivations are in Appendices.

Appendix A: Modified Faraday law from swirl flux pumping

Start with integral Faraday:

$$\oint_{\partial S} \mathbf{E}\cdot d\boldsymbol{\ell} = -\frac{d}{dt}\int_S \mathbf{B}\cdot d\mathbf{A}. \tag{10}$$

Define $N(t) = \int_S \boldsymbol{\varrho}_{\circlearrowleft}\cdot d\mathbf{A}$ and a swirl–flux term $\Phi_{\circlearrowleft} = \mathcal{G}_{\circlearrowleft}\,N$. Then

$$\begin{aligned}\oint_{\partial S} \mathbf{E}\cdot d\boldsymbol{\ell} &= -\frac{d\Phi_B}{dt} - \frac{d\Phi_{\circlearrowleft}}{dt}\\ &= -\int_S \partial_t\mathbf{B}\cdot d\mathbf{A} \;-\; \mathcal{G}_{\circlearrowleft}\int_S \partial_t\boldsymbol{\varrho}_{\circlearrowleft}\cdot d\mathbf{A}.\end{aligned} \tag{11}$$

By Stokes, $\int_S[\nabla\times\mathbf{E} + \partial_t\mathbf{B} + \mathcal{G}_{\circlearrowleft}\,\partial_t\boldsymbol{\varrho}_{\circlearrowleft}]\cdot d\mathbf{A} = 0$ for arbitrary S, giving (??). Choosing $\mathcal{G}_{\circlearrowleft} = \Phi_\star$ aligns one net event with one flux quantum [?, ?].

Appendix B: Flux compression ⇒ nucleation threshold

With N frozen, (??) gives $a = \sqrt{A/N}$; the onset condition $a \lesssim \alpha r_c$ implies

$$\frac{N}{A} \gtrsim \frac{1}{\alpha^2 r_c^2}. \tag{12}$$

In a rotating frame, the Feynman relation $n_v \simeq 2\Omega/\kappa$ [?] yields a rotation–dependent threshold $A_\star(\Omega) \simeq N\,\kappa/(2\Omega)$.

Appendix C: Impulse quantization and choice of $\Phi_\star$

Integrate (??) over S and $[t_i, t_f]$:

$$\int_{t_i}^{t_f}\oint_{\partial S} \mathbf{E}\cdot d\boldsymbol{\ell}\,dt = -\int_{t_i}^{t_f}\int_S \partial_t \mathbf{B}\cdot d\mathbf{A}\,dt \;-\; \mathcal{G}_{\circlearrowleft}\int_{t_i}^{t_f}\int_S \partial_t \boldsymbol{\varrho}_{\circlearrowleft}\cdot d\mathbf{A}\,dt. \tag{13}$$

Holding Φ_B fixed gives $\int dt \oint \mathbf{E}\cdot d\boldsymbol{\ell} = -\mathcal{G}_{\circlearrowleft}\,\Delta N$. Thus impulses are quantized in units of $|\mathcal{G}_{\circlearrowleft}|$, and canonical choices are $\Phi_\star = h/2e$ (superconducting flux quantum) or h/e [?, ?].

Appendix D (Addendum Q): Double–Saw–Shaped Coil Stack Realization

Q.1 Definition (Double–Saw–Shaped Coil)

On a stator with $S = 40$ slots and $p = 4$ poles, consider a short–pitched 3–phase winding with pitch $y = 2$ (step rule $+11/-9$). The chording angle

$$\gamma = y\,\alpha_e = 36^\circ, \qquad \alpha_e = \frac{180^\circ p}{S} = 18^\circ,$$

implies $k_p^{(5)} = \cos\!\left(\frac{5\gamma}{2}\right) = 0$. Implement two interleaved 3–phase saw–shaped coils ("Double–Saw–Shaped"), with electrical displacement $\Delta_e = 30^\circ$,

$$\mathcal{A}_\nu \propto 2\cos\!\left(\frac{\nu\Delta_e}{2}\right) k_w^{(\nu)},$$

hence $\mathcal{A}_1 \approx 1.93\,k_w^{(1)}$, $\mathcal{A}_5 = 0$, $\mathcal{A}_6 = 0$, $\mathcal{A}_7 \simeq -0.05$.

Q.2 Stacking (Two Double–Saw–Shapeds)

Place two identical Double–Saw–Shaped coils axially stacked (gap h), on–axis contributions $B_T(z)$, $B_B(z)$. Canonical modes:

$$\begin{aligned}
\text{Mode A (additive):}\quad & B_{\text{tot}} \simeq B_T + B_B \Rightarrow \text{max fundamental},\\
\text{Mode B (gradient):}\quad & \Delta p = \eta\,\tfrac{B_B^2 - B_T^2}{2\mu_0} \Rightarrow \text{effective gravity blocking},\\
\text{Mode C (counter–rot.):}\quad & B_{\text{rot}} \to 0,\ \nabla B^2 \neq 0 \Rightarrow \text{standing pressure pattern},\\
\text{Mode D (beat):}\quad & \varphi \neq 0 \Rightarrow \text{axially traveling envelope}.
\end{aligned}$$

Q.3 Canonical Equation (Swirl Pressure)

Within the SST Canon,

$$p_{\rm sw}(z) = \eta\,\frac{\langle B^2(z)\rangle}{2\mu_0},$$

so a stacked asymmetry yields

$$F_z = \int_A \Delta p(z)\,dA = \eta\,\frac{B_B^2 - B_T^2}{2\mu_0}\,A.$$

Q.4 Experimental Pathway

1. Verify harmonic hygiene: $5^{th} = 0$, $6^{th} = 0$, $7^{th} \ll 1$.
2. Map $B(z)$ with Hall sensors for both stacks.
3. Tune B_B/B_T to measure Δp on a plate of area A.
4. Switch to Mode C (counter–rotate top stack) to confirm ∇B^2 persists with vanishing torque.

Q.5 Canonical Status

This configuration satisfies Canon hygiene and realizes swirl pressure modulation for gravity–blocking tests.

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