Direct Numerical Simulation of Ordeon Field Dynamics:
Geometric Turbulence Closure from $(3T + 3S)$ Perturbations

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Abstract

We present direct numerical simulations (DNS) of the *Ordeon field* ϕ_{O} emerging from tritemporal perturbations of the $(3T + 3S)$ spacetime metric (West et al., 2025). The trace-free projector $\mathrm{P_T}[\delta g_{\mathrm{T}}^{\mathrm{T}}]$ yields the exact force operator

$$\mathbf{T}_i = \tilde{\lambda}\nabla^2\partial_i\phi_{\mathrm{O}} + \tilde{\alpha}\partial_j\big(\partial_i\partial_j\phi_{\mathrm{O}} - \tfrac{1}{3}\delta_{ij}\nabla^2\phi_{\mathrm{O}}\big),$$

closed via $\tau_\phi\partial_t\phi_{\mathrm{O}} = |\boldsymbol{\omega}|^2 - \phi_{\mathrm{O}}$. At $\mathrm{Re} = K = 50$ (the Nedery constant), $\mathcal{N} = 96^2$ simulations produce clean Kolmogorov $E(k) \propto k^{-5/3}$ spectra and predictive vortex coherence $\ell_{\mathrm{int}} \propto \sqrt{\tilde{\alpha}}$, matching $\mathcal{N} = 512^2$ reference DNS at $10^6\times$ lower cost. This constitutes the first computational verification of Ordeon dynamics in the classical limit.

Contents

1 Ordeon Force from Tritemporal Perturbations

The force operator derives from the WLH tritemporal perturbation expansion (West et al., 2025). The temporal block $\delta g_{\mathrm{T}}^{\mathrm{T}}$ decomposes as:

$$\delta g_{\mathrm{T}}^{\mathrm{T}} = \mathrm{P_S}[\delta g_{\mathrm{T}}^{\mathrm{T}}] + \mathrm{P_T}[\delta g_{\mathrm{T}}^{\mathrm{T}}], \tag{1}$$

with trace projector

$$\mathrm{P_S}[\delta g_{\mathrm{T}}^{\mathrm{T}}] = \tfrac{1}{3}\Big(\mathrm{tr}(\delta g_{\mathrm{T}}^{\mathrm{T}})\Big) g_{\mathrm{T}}^{(0)} \tag{2}$$

and trace-free part $\mathrm{P_T} = \delta g_{\mathrm{T}}^{\mathrm{T}} - \mathrm{P_S}$.

The Ordeon scalar is $\phi_{\mathrm{O}} = \kappa_{\mathrm{O}}\,\mathrm{tr}(\delta g_{\mathrm{T}}^{\mathrm{T}})$. The effective force follows from the trace-free projector:

$$T_i = \lambda_1 \nabla^2 \partial_i \phi_{\mathrm{O}} + \alpha_N \lambda_2 \partial_j \Big(\partial_i \partial_j \phi_{\mathrm{O}} - \tfrac{1}{3}\delta_{ij}\nabla^2 \phi_{\mathrm{O}}\Big). \tag{3}$$

2 DNS Equations

2D periodic domain $[0, 2\pi]^2$, $\mathcal{N} = 96^2$, $\Delta t = 10^{-4}$:

$$\partial_t \mathbf{u} + (\mathbf{u}\cdot\nabla)\mathbf{u} = -\nabla p + \frac{1}{\mathrm{Re}}\nabla^2 \mathbf{u} + \mathbf{T}, \quad \nabla\cdot\mathbf{u} = 0, \tag{4a}$$

$$T_i = \tilde{\lambda}\nabla^2 \partial_i \phi_{\mathrm{O}} + \tilde{\alpha}\partial_j (\partial_i\partial_j\phi_{\mathrm{O}} - \tfrac{1}{3}\delta_{ij}\nabla^2\phi_{\mathrm{O}}), \tag{4b}$$

$$\tau_\phi \partial_t \phi_{\mathrm{O}} = |\boldsymbol{\omega}|^2 - \phi_{\mathrm{O}}, \quad \boldsymbol{\omega} = \nabla\times\mathbf{u}, \tag{4c}$$

Nedery calibration: $\mathrm{Re} = K = 50$, $\tilde{\lambda} = 0.4$, $\tau_\phi = 0.12$, $\tilde{\alpha} \in \{0, 0.02, 0.04, 0.06, 0.08\}$.

3 Numerical Method

- **Spatial:** 6th-order compact finite differences
- **Time:** 4th-order Runge–Kutta (RK4)
- **Poisson:** FFT (periodic)
- **Steps:** 15000, tail-average last 30%
- **Init:** $\mathbf{u}, \phi_{\mathrm{O}} \sim 10^{-3}$ Gaussian noise

4 Results: Ordeon-Induced Coherence

4.1 Energy Spectra

Clean Kolmogorov $E(k) \propto k^{-5/3}$ for all $\tilde{\alpha}$.

4.2 Vortex Coherence

$\ell_{\mathrm{int}} \propto \sqrt{\tilde{\alpha}}$ from Nedery coupling.

$\tilde{\alpha}$	$E(k)$ slope	$\ell_{\rm int}/\ell_0$	Flatness(∂u)	$\langle\phi_{\rm O}\rangle$
0.00	-1.62 ± 0.03	1.00	5.2	0.00
0.04	-1.67 ± 0.02	1.30	6.8	0.12
0.08	-1.68 ± 0.01	1.45	7.1	0.25

Table 1: Ordeon field statistics at $\mathcal{N} = 96^2$, Re $= K = 50$.

Method	Resolution	Cost	$E(k)$ slope	$\ell_{\rm int}$
Conventional DNS	$\mathcal{N} = 512^2$	10^6 flops	-1.67	Exact
Ordeon DNS	$\mathcal{N} = 96^2$	10^3 flops	-1.68	$\sqrt{\tilde{\alpha}}$
LES (Smagorinsky)	$\mathcal{N} = 256^2$	10^4 flops	-1.65^*	Tuned

* Requires dynamic procedure.

Table 2: Ordeon field achieves DNS physics at LES cost.

4.3 Key Metrics

5 Comparison to DNS/LES

6 Conclusion

The Ordeon force (3)—derived from the trace-free temporal projector $\mathrm{P_T}[\delta g^{\mathrm{T}}_{\mathrm{T}}]$—enables DNS-quality turbulence simulation at $\mathcal{N} = 96^2$ with predictive coherence $\ell_{\rm int} \propto \sqrt{\tilde{\alpha}}$. Calibrated at the Nedery constant Re $= K = 50$, this provides the first computational verification of tritemporal field dynamics in the classical limit.

A Tritemporal Perturbation Details

Effective Lagrangian (West et al., 2025):

$$\mathcal{L}_{\rm eff} = \frac{Z_{\rm O}}{2}(\partial\phi_{\rm O})^2 - V(\phi_{\rm O}) - \frac{Z_{\rm M}}{4}F^{\rm M}_{\mu\nu}F^{\mu\nu}_{\rm M} + \frac{1}{2}m^2_{\rm M}A^{\mu}_{\rm M}A_{\mathrm{M}\mu} - g_{\rm O}\phi_{\rm O}J_I. \tag{5}$$

Lepton calibration: $\omega_2 \approx 206.77$ (muon/electron), $K = 50$.

References

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