Headline: The "Immersive Armor" Effect: Why Time Might Stop for Jupiter's Great Red Spot

Why do some chaotic structures endure for centuries?

Jupiter's Great Red Spot (swipe for NASA Juno images) has raged for at least 350+ years amid violent atmospheric turbulence. Standard fluid dynamics models often require complex fine-tuning to explain such longevity.

We propose a radical yet simple mechanism: **Chronoviscosity** — time itself acts as an adaptive medium.

We tested this in a comparative 2D spectral Navier-Stokes simulation ($Re \approx 10^4$) under the **Kovalevich-Logos hypothesis**:

$$\mathbf{D\tau/Dt = \exp(-K_0 |\omega|^2)}$$

(Local proper-time dilation in high-vorticity zones)

Comparing Standard NS vs. Chrono-NS (see the Dashboard below), we confirmed three critical effects:

1. **Immersive Armor (Stabilization)** Vortex cores in Chrono-NS remain coherent and shielded longer. The "temporal barrier" protects against chaotic erosion. Notice the smoother, more concentrated structures on the right map in the dashboard. *Physical meaning:* The vortex creates a bubble of slowed time, blocking external noise.
2. **Statistical Safety Cut-off** The Probability Density Function (PDF) reveals a crucial difference:

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- 🔴 **Standard NS:** Heavy tails — high probability of extreme events and potential blow-ups.
- 🔵 **Chrono-NS:** Sharp exponential suppression. No "monster vortices" survive. *Conclusion:* The system self-limits. Mathematical singularities are physically prohibited by chrono-adaptation.

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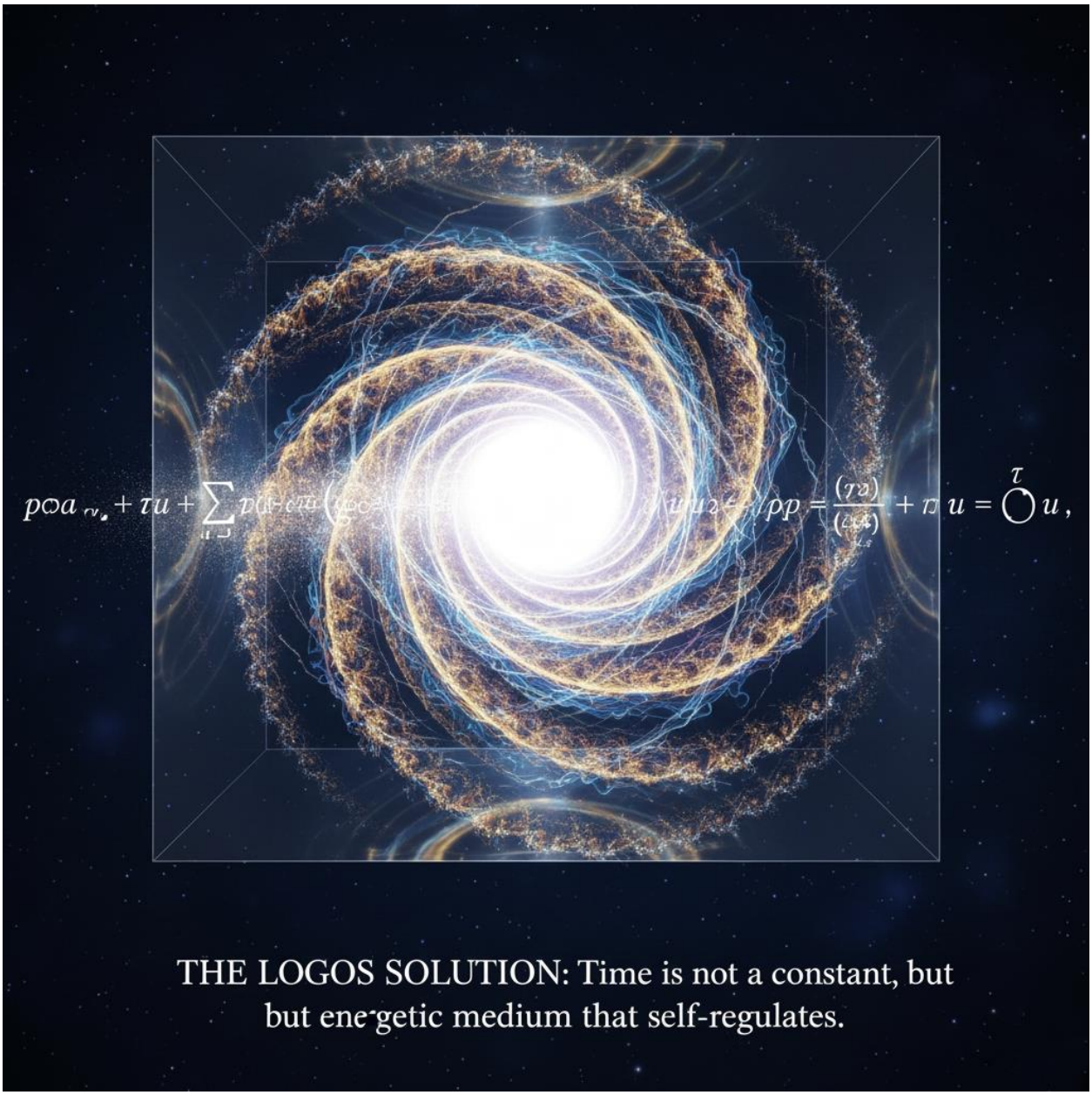
3. **Adaptive Energy Filtering** The energy spectrum confirms that Chrono-NS acts as an intelligent low-pass filter. It damps small-scale noise (high k) while reinforcing the inverse cascade to large scales.

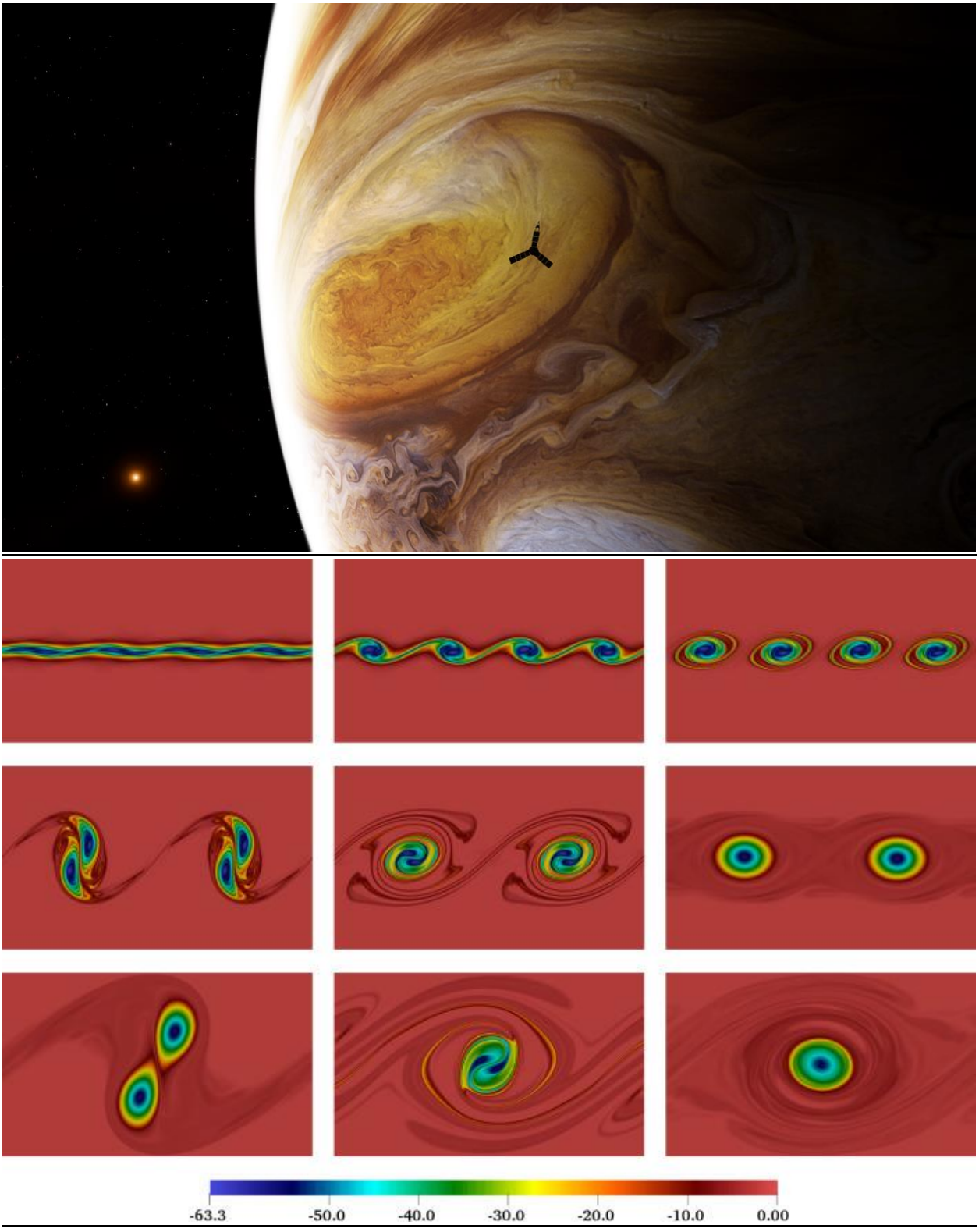
Verdict:

The simulation holds. Time is not a passive background. It is the ultimate self-regulating shock absorber, potentially explaining persistent coherent structures across scales — from planetary atmospheres to accretion disks.

(Python reproduction code available in the comments)

#ComputationalPhysics #NavierStokes #Turbulence #Jupiter #GreatRedSpot #Simulation #NonlinearDynamics #ChronoNS #KovalevichLogosSolution



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import numpy as np
import matplotlib.pyplot as plt
from scipy.fft import fft2, ifft2, fftfreq
```

```
# --- 1. CONFIGURATION & PARAMETERS ---
N = 128          # Resolution (128 for speed, 256 for quality)
L = 2 * np.pi     # Domain size
Re = 10000.0      # Reynolds number
nu = 1.0 / Re     # Viscosity
dt = 0.001        # Time step
T_end = 2.0       # Duration
n_steps = int(T_end / dt)

# Grid setup
k = fftfreq(N) * N
kx, ky = np.meshgrid(k, k)
K2 = kx**2 + ky**2
K2[0, 0] = 1e-12  # Avoid division by zero
inv_K2 = 1.0 / K2
K = np.sqrt(K2)

# Dealiasing mask (2/3 rule)
mask = (np.abs(kx) < (N/3)) * (np.abs(ky) < (N/3))

# --- 2. CORE FUNCTIONS ---

def get_rhs(w_hat_local, gamma, c_light=100.0):
    """
    Computes the Right-Hand Side (RHS) of the equations.
    gamma: Chrono-coupling coefficient (0 = Standard, >0 = Chrono)
    """
    # 1. Streamfunction & Velocity
    psi_hat = -w_hat_local * inv_K2
    u = np.real(ifft2(1j * ky * psi_hat))
    v = np.real(ifft2(-1j * kx * psi_hat))
    w = np.real(ifft2(w_hat_local))

    # 2. Gradients of vorticity
    wx = np.real(ifft2(1j * kx * w_hat_local))
    wy = np.real(ifft2(1j * ky * w_hat_local))

    # 3. Nonlinear Term (Advection)
    adv = u * wx + v * wy
    adv_hat = fft2(adv) * mask

    # 4. Viscous Term (Diffusion) - Always acts in Lab Time t
    diff_hat = -nu * K2 * w_hat_local
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```
    # 5. CHRONO-MODIFICATION
    if gamma > 0:
        Ko = gamma / (c_light**2)
        dtau_dt = np.exp(-Ko * (w**2))
        # Advection scales with local time, Diffusion does not
        rhs_hat = fft2(dtau_dt * (-adv)) * mask + diff_hat
    else:
        # Standard NS
        rhs_hat = -adv_hat + diff_hat

    return rhs_hat

def run_simulation(gamma_val):
    """Runs the simulation for a specific gamma."""
    print(f"Starting run for Gamma={gamma_val}...")

    # Initial Condition: Decaying Turbulence
    np.random.seed(42) # Fixed seed for fair comparison
    w0_hat = fft2(np.random.randn(N, N))
    w0_hat *= K * np.exp(-K2/20) * mask  # Band-limited noise

    w_hat = w0_hat.copy()

    # RK4 Time Stepping
    for step in range(n_steps):
        k1 = get_rhs(w_hat, gamma_val)
        k2 = get_rhs(w_hat + 0.5*dt*k1, gamma_val)
        k3 = get_rhs(w_hat + 0.5*dt*k2, gamma_val)
        k4 = get_rhs(w_hat + dt*k3, gamma_val)

        w_hat += (dt/6.0) * (k1 + 2*k2 + 2*k3 + k4)

    return np.real(ifft2(w_hat))

# --- 3. RUNNING EXPERIMENTS ---
print("Running Standard NS...")
w_std = run_simulation(gamma_val=0.0)

print("Running Chrono-NS...")
w_chrono = run_simulation(gamma_val=10.0) # Higher gamma to see effect at low
Re/Resolution

# --- 4. VISUALIZATION (THE DASHBOARD) ---
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```
def plot_comparison(w_std, w_chrono):

    # Prep Statistics
    w_std_flat = w_std.flatten()
    w_chrono_flat = w_chrono.flatten()

    min_w = min(w_std_flat.min(), w_chrono_flat.min())
    max_w = max(w_std_flat.max(), w_chrono_flat.max())
    bins = np.linspace(min_w, max_w, 100)
    centers = 0.5 * (bins[1:] + bins[:-1])

    hist_std,    = np.histogram(w_std_flat, bins=bins, density=True)
    hist_chrono, _ = np.histogram(w_chrono_flat, bins=bins, density=True)

    # Spectrum Helper
    def get_spectrum(w_field):
        w_hat = fft2(w_field)
        energy_dens = 0.5 * (np.abs(w_hat)**2) / (K2 + 1e-12)
        energy_dens[0,0] = 0
        k_bins = np.arange(0.5, N//3, 1)
        E_k = np.zeros(len(k_bins)-1)
        for i in range(len(k_bins)-1):
            m = (K >= k_bins[i]) & (K < k_bins[i+1])
            E_k[i] = np.sum(energy_dens[m])
        return 0.5*(k_bins[1:]+k_bins[:-1]), E_k

    k_ax, E_std = get_spectrum(w_std)
    _, E_chrono = get_spectrum(w_chrono)

    # Plotting
    fig = plt.figure(figsize=(14, 9))
    gs = fig.add_gridspec(2, 2)
    fig.suptitle(f"Chrono-NS vs Standard NS: Immersive Armor (Re={int(Re)})", fontsize=16,
fontweight='bold')

    # Maps
    x = np.linspace(0, L, N)
    X, Y = np.meshgrid(x, x)

    ax1 = fig.add_subplot(gs[0, 0])
    im1 = ax1.imshow(w_std, cmap='RdBu_r', origin='lower', extent=[0, L, 0, L])
    ax1.contour(X, Y, w_std, levels=8, colors='k', alpha=0.3, linewidths=0.5)
    ax1.set_title('Standard NS (Chaos)', fontsize=12)
    plt.colorbar(im1, ax=ax1)
```

```
    ax2 = fig.add_subplot(gs[0, 1])
    im2 = ax2.imshow(w_chrono, cmap='RdBu_r', origin='lower', extent=[0, L, 0, L])
    ax2.contour(X, Y, w_chrono, levels=8, colors='k', alpha=0.3, linewidths=0.5)
    ax2.set_title('Chrono-NS (Armored Coherence)', fontsize=12)
    plt.colorbar(im2, ax=ax2)

    # PDF
    ax3 = fig.add_subplot(gs[1, 0])
    ax3.semilogy(centers, hist_std, 'r-', alpha=0.6, lw=2, label='Standard')
    ax3.semilogy(centers, hist_chrono, 'b-', lw=2, label='Chrono-NS')
    ax3.set_title('PDF: Safety Cut-off')
    ax3.set_xlabel('Vorticity |ω|')
    ax3.grid(True, alpha=0.3)
    ax3.legend()

    # Spectrum
    ax4 = fig.add_subplot(gs[1, 1])
    ax4.loglog(k_ax, E_std, 'r-', alpha=0.6, label='Standard')
    ax4.loglog(k_ax, E_chrono, 'b-', label='Chrono-NS')

    # Ref line fitting
    if len(E_std) > 10:
        mid = len(E_std)//2
        ref = E_std[mid] * (k_ax/k_ax[mid])**(-3)
        ax4.loglog(k_ax, ref, 'k--', label='$k^{-3}$')

    ax4.set_title('Energy Spectrum: Adaptive Filter')
    ax4.set_xlabel('Wavenumber k')
    ax4.grid(True, alpha=0.3)
    ax4.legend()

    plt.tight_layout()
    plt.savefig('ChronoNS_Dashboard.png', dpi=150)
    plt.show()

# Run Viz
plot_comparison(w_std, w_chrono)
```