

# A Coupled Model of Mind-Motion (ID14) and Field-Charge (ID26) Dynamics: Emergence of Spatial Patterns in 2D Simulations

---

**Author:** David Novak (Conceptual Framework), Cascade AI (Simulation & Analysis)

**Date:** June 6, 2025

**License:** See LICENSE file (Permissive license allowing commercial use and academic study)

## Abstract

---

This paper investigates the coupled dynamics of a hypothetical Mind-Motion system (ID14) and a Field-Charge system (ID26) within a simulated “Toy Universe.” Building upon prior theoretical work and 1D simulations, we extend the model to a 2D spatial domain to explore more complex behaviors. The study focuses on the numerical simulation of a consciousness-related field ( $\Psi_{ID14}$ ) coupled with an electric potential-like field ( $\Phi_{ID26}$ ). Key objectives include achieving stable system dynamics, exploring the impact of nonlinear feedback mechanisms, and investigating the emergence of spatial

patterns in the  $\Phi_{ID26}$  field. We detail the mathematical formulation, the 2D simulation methodology including specific parameters and boundary conditions, and present results demonstrating sustained system activity and the formation of distinct spatial patterns (spots/peaks) under specific parameter regimes, particularly with reduced diffusion. These findings highlight the model's capacity for complex self-organization and provide a richer understanding of the potential emergent phenomena in such interconnected systems.

## 1. Introduction

---

The exploration of consciousness and its potential interplay with physical systems remains a frontier of scientific inquiry. This research is inspired by conceptual frameworks that propose intricate links between mind-like phenomena and fundamental physical fields. We extend previous investigations of ID14 (Mind-Motion dynamics) and ID26 (Field-Charge dynamics), as detailed in prior research (Novak, Prior Works; `paper.md`), by developing a 2D spatial simulation.

Our earlier 1D models established the core mathematical formalisms for ID14—describing internal variables like Imagination ( $I$ ), Realization ( $R$ ), and a Consciousness Field ( $\Psi_{ID14}$ )—and for ID26, which posits a dynamic electric potential-like field ( $\Phi_{ID26}$ ). The central hypothesis is the bidirectional coupling:  $\Psi_{ID14}$  influences  $\Phi_{ID26}$ , which in turn feeds back to  $\Psi_{ID14}$ .

Transitioning to a 2D domain allows for the investigation of spatial dynamics and pattern formation, which are not observable in 1D. This paper details the methodical approach to:

1. Adapt the coupled ODE-PDE system to a 2D Cartesian grid.
2. Implement appropriate boundary conditions for the 2D PDE.
3. Tune parameters, including diffusion coefficients and nonlinear feedback terms, to achieve stable and interesting dynamics.
4. Analyze the simulation output for temporal stability and the

emergence of spatial structures in the  $\phi_{ID26}$  field. 5. Discuss the implications of these 2D findings for the Toy Universe model.

## 2. Theoretical Framework

The fundamental equations governing the ID14 and ID26 systems remain consistent with previous work, with necessary adaptations for 2D spatial considerations.

### 2.1. ID14: Mind-Motion Dynamics (ODEs)

The ID14 system, describing Imagination ( $I$ ), Realization ( $R$ ), and Consciousness Field ( $\psi_{ID14}$ ), is governed by:

$$\begin{aligned} dI/dt &= (U_E / \tau_I) - (U_E / I_{char}) * I * (1 + \cos(\omega_{image} * t)) - k_{I\_phi} * \phi_{avg\_ID14} \\ dR/dt &= (\phi_{E\_val} / I_{char}) * I * \sin(\omega_{image} * t) - (U_E / \tau_R) * R - k_{R\_phi\_prime} * (d\phi_{dt\_ID14\_influence}) \\ d\psi_{ID14}/dt &= \alpha_{Psi} * I - \beta_{Psi} * R - \gamma_{Psi\_ID14} * \psi_{ID14} + k_{Psi\_phi} * \phi_{avg\_ID14} \end{aligned}$$

(Parameters are defined as in `paper.md` and previous documentation.)  $\phi_{avg\_ID14}$  represents the spatially averaged value of  $\phi_{field}$  from the ID26 system, acting as a coupling input to ID14.  $d\phi_{dt\_ID14\_influence}$  is similarly derived from the dynamics of  $\phi_{field}$ .

### 2.2. ID26: Field-Charge Dynamics (PDE in 2D)

The ID26 system describes the evolution of the  $\phi_{field}$  and related fields ( $v_{field}$ ,  $\rho_{electric\_field}$ ,  $\Psi_{c\_field}$ ,  $\Psi_{d\_field}$ ,  $R_{radiative\_field}$ ) over a 2D spatial domain ( $x, y$ ).

The core PDE for `phi_field` is:

```
dphi_field/dt = alpha_Phi_PDE * (P0_s_alpha_epsilon *  
tanh(phi_field / P0_s_alpha_epsilon)) *  
tanh(Psi_c_field)  
                - beta_Phi_PDE * R_radiative_field  
                + gamma_Phi_PDE * (d^2phi_field/dx^2 +  
d^2phi_field/dy^2) // 2D Laplacian  
                + epsilon_Phi_PDE * (P0_s_alpha_epsilon *  
tanh(phi_field / P0_s_alpha_epsilon)) *  
tanh(Psi_d_field) * rho_electric_field  
                - delta_Phi_PDE * phi_field // Linear  
damping term
```

Key modifications and considerations for 2D: - The Laplacian term `laplacian(phi_field)` is now the 2D Laplacian  $(\partial^2\phi_{\text{field}}/\partial x^2 + \partial^2\phi_{\text{field}}/\partial y^2)$ . - Self-saturation of `phi_field`'s contribution to its own growth is modeled as `P0 * tanh(phi_field / P0)` where `P0 = P0_s_alpha_epsilon` (Memory `1dd92966...`). - The coupling term `phi_avg_ID14` (input to ID14) is saturated: `phi_for_ID14_scalar = Phi_coupling_saturation_limit * tanh(mean(phi_field) / Phi_coupling_saturation_limit)` (Memory `44c9edfe...`).

The definitions for `v_field`, `rho_electric_field`, `Psi_c_field`, `Psi_d_field`, and `R_radiative_field` are as per `paper.md`, now applied pointwise in the 2D domain.

## 3. Simulation Methodology

### 3.1. Numerical Scheme

The coupled system is solved numerically. The ID14 ODEs are solved using a standard ODE solver (e.g., `scipy.integrate.solve_ivp` with RK45 method). The ID26 PDE is discretized on a 2D Cartesian grid and advanced in time using

a finite difference method (e.g., forward Euler for time, central differences for space).

## 3.2. 2D Simulation Parameters (CPU Version)

Based on successful 2D CPU simulations (Memory 19201ceb..., d0c6b52e...): - **Spatial Grid:** -  $N_x = 50$ ,  $N_y = 50$  (grid points in x and y) -  $L_x = 10.0$ ,  $L_y = 10.0$  (physical domain size) -  $dx = L_x / N_x$ ,  $dy = L_y / N_y$  - **Temporal Discretization:** -  $T_{\text{final}} = 200.0$  (total simulation time) -  $dt = 0.001$  (time step) - **Initial Conditions:** -  $\Phi_{\text{field}}(x, y, t=0) = (\text{random\_values\_uniform}[-0.01, 0.01])$  (e.g.,  $(\text{np.random.rand}(N_y, N_x) - 0.5) * 0.02$ ) - ID14 variables ( $I_0$ ,  $R_0$ ,  $\text{Psi\_ID14}_0 = 0.5$ ) initialized as per previous studies. - **Boundary Conditions for  $\Phi_{\text{field}}$ :** - Neumann zero-flux boundary conditions:  $\partial\Phi/\partial n = 0$  on all boundaries. This is implemented by padding the array appropriately when calculating the Laplacian. - **Key ID14 Parameters:** -  $\text{beta\_psi}_p = 2.0$  -  $k_{R\_phi\_prime\_p} = 0.01$  - **Key ID26 Parameters for Pattern Formation:** -  $\text{kappa}_{R\_p} = 1.0$  -  $\text{gamma}_{\Phi\_p} = 0.01$  (Reduced diffusion coefficient, crucial for pattern emergence) -  $\text{alpha}_{\Phi\_PDE}$  and  $\text{epsilon}_{\Phi\_PDE}$  set to values promoting growth (e.g., 2.1, as in Memory b3fb7fca...) -  $\text{Phi0\_saturation\_alpha\_epsilon} = 0.2$  (Saturation limit for  $\Phi_{\text{field}}$  self-interaction, Memory b3fb7fca...) -  $\text{Phi\_coupling\_saturation\_limit} = 0.5$  (Saturation for  $\Phi_{\text{field}}$  average coupling to ID14, Memory 44c9edfe..., b3fb7fca...) - **Stability Measures:** - The sign of the diffusion term was corrected to  $+ \gamma_{\Phi\_PDE} * \text{laplacian}(\Phi_{\text{field}})$  for stability (Memory 339fd7c7...). - Careful implementation of saturation mechanisms as described in the theoretical framework.

### 3.3. Data Storage and Analysis

- Due to potentially large data output in 2D, a data downsampling strategy might be employed for storage ( `storage_skip_factor` , Memory `b96ebca4...` ), though for `T_final=200` and `Nx,Ny=50` full storage might be feasible.
- Outputs include time series of spatially averaged `phi_field` , ID14 variables, and snapshots of the 2D `phi_field` at various times, especially the final state.

## 4. Results

---

### 4.1. System Stability and Sustained Activity in 2D

Simulations with the parameters outlined above successfully ran to completion ( `T_final = 200.0` ), demonstrating overall system stability. The ID14 variables ( `psi_ID14` , `I` , `R` ) exhibited sustained oscillations, and the spatially averaged `phi_field` showed consistent growth, similar to behavior observed in stable 1D high-activity states. This confirms that the coupled system can maintain dynamic activity in a 2D spatial context.

Key time-series results are captured in `plots/id14_id26_2D_timeseries.png`.

### 4.2. Emergence of Spatial Patterns in $\Phi_{\text{field}}$

A significant finding of the 2D simulations is the emergence of distinct spatial patterns in the `phi_field`. Under conditions of relatively strong local growth (driven by `alpha_Phi_PDE` , `epsilon_Phi_PDE` ) and, crucially, a low diffusion coefficient

( `gamma_Phi_PDE = 0.01` ), the initially near-uniform `phi_field` evolved to form localized spots or peaks of high intensity.

These patterns are indicative of a self-organization process driven by the nonlinear dynamics of the PDE. The reduced diffusion allows local activations to grow and persist without being immediately smoothed out over the domain.

The final state of the `phi_field`, showcasing these spatial patterns, is visualized in `plots/id14_id26_2D_phi_final_heatmap.png`.

*(Placeholder for Figure 1: id14\_id26\_2D\_timeseries.png - showing temporal evolution of key variables)*

```
![Temporal Dynamics in 2D Simulation](plots/
id14_id26_2D_timeseries.png "Time series of Psi_ID14
and avg(Phi_field) in 2D CPU simulation")
```

*(Placeholder for Figure 2: id14\_id26\_2D\_phi\_final\_heatmap.png - showing final spatial pattern of Phi\_field)*

```
![Spatial Pattern in Phi_field at T_final](plots/
id14_id26_2D_phi_final_heatmap.png "Heatmap of
Phi_field at T_final showing spatial patterns")
```

## 5. Discussion

---

The successful extension of the ID14-ID26 coupled model to a 2D spatial domain and the subsequent observation of emergent spatial patterns represent a significant advancement in the exploration of this Toy Universe.

The stability of the 2D system, achieved through careful parameter tuning and the implementation of saturation mechanisms (Memories `b3fb7fca...`, `1dd92966...`, `44c9edfe...`), underscores the robustness of the underlying

theoretical model. The parameters leading to pattern formation, particularly the low diffusion rate (  $\gamma_{\Phi\_PDE} = 0.01$  ), suggest a Turing-like mechanism where local autocatalytic processes (positive feedback in  $\Phi\_field$  growth) dominate over long-range inhibition or smoothing (diffusion).

The observed spots/peaks in  $\Phi\_field$  can be interpreted as regions of high “field-charge” activity. Their formation and persistence imply that the system can spontaneously break spatial symmetry and develop complex structures from near-uniform initial conditions. This is a hallmark of many nonlinear dynamical systems found in nature, such as reaction-diffusion systems in chemistry and biology.

These findings open up new avenues for interpreting the behavior of  $\Phi\_field$  as not just a global average but as a spatially varying entity capable of supporting localized phenomena. The interaction of these spatial patterns with the globally coupled ID14 system warrants further investigation.

## 6. Conclusion and Future Work

---

**Conclusion:** This study has successfully demonstrated that the coupled ID14-ID26 model, when simulated in a 2D spatial domain, can produce stable, sustained dynamics and, critically, lead to the emergence of non-trivial spatial patterns in the  $\Phi\_ID26$  field. The formation of these patterns is sensitive to parameters like the diffusion coefficient, highlighting the rich nonlinear dynamics inherent in the model. These results provide a more complex and spatially nuanced view of the Toy Universe, moving beyond the spatially averaged considerations of 1D models.

**Future Work:** The emergence of spatial patterns in 2D invites several directions for future research: 1. **Detailed Characterization of Patterns:** Analyze the properties of the observed patterns (e.g., characteristic wavelength, size,



distribution, temporal evolution of individual spots). 2.

**Parameter Space Exploration for Patterns:** Systematically map the parameter regimes (especially `gamma_Phi_PDE`, `alpha_Phi_PDE`, `epsilon_Phi_PDE`, and saturation parameters) that lead to different types of patterns or instability. 3. **Long-Term Evolution of Patterns:** Extend simulation times to observe the long-term stability and evolution of these spatial structures. Do they remain static, oscillate, or undergo further transformations? 4. **Impact of Boundary Conditions:** Investigate the influence of different boundary conditions (e.g., Dirichlet, periodic) on pattern formation. 5. **GPU Acceleration:** Adapt the 2D simulation for GPU execution using CuPy (as per ongoing efforts, Memory `ad48a672...`) to enable larger grid sizes, longer simulation times, and exploration of 3D dynamics. 6. **Theoretical Analysis of Pattern Formation:** Attempt a linear stability analysis or weakly nonlinear analysis of the PDE system to theoretically predict conditions for pattern emergence. 7. **Coupling Spatial Patterns back to ID14:** Explore more sophisticated ways for the spatial aspects of `phi_field` (not just its average) to influence the ID14 system.

This research reinforces the ID14-ID26 framework as a versatile tool for exploring complex emergent behavior in hypothetical coupled systems, with the 2D model offering significantly richer phenomenological possibilities.

## 7. References

---

- Novak, D. (Prior Works). *Internal research documents and conceptual papers on ID14, ID26, and related Toy Universe constructs*. (Referenced in `paper.md`, `research.md`, and GitHub repository NovakDavid98/toyuniverse-novak)
- (Standard texts on numerical methods for PDEs, ODEs, and pattern formation, e.g., Turing, Murray, Cross, Hohenberg - to be added as appropriate)

## 8. Acknowledgements

---

The authors acknowledge the conceptual framework developed by David Novak and the computational assistance, simulation development, and analysis provided by the Cascade AI system.