Simulating the Forge Equation: Null Pulse Propagation and Causal Sets in Discrete Spacetime

Ryan Wallace
rathmon@gmail.com

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Abstract

We present a discrete simulation of the Forge pulse equation, a geometric reformulation of light propagation based on null-directed pulse density. Using a simple $(1+1)$-dimensional grid, we evolve pulse dynamics under the Forge equation $\nabla_\mu(\rho u^\mu) = \sigma$ and construct the resulting causal set. The simulation confirms compatibility with Lorentz and FLRW spacetimes, reproducing redshift and causal interval behavior. These results provide a numerical backbone to the Forge framework and open new connections to causal set theory, quantum optics, and discrete spacetime models.

1 Introduction

The Forge framework proposes a pulse-based foundation for light propagation, bypassing continuous fields by modeling discrete null-directed emission events [1]. In this work, we implement Forge as a causal lattice model in $(1+1)$D spacetime, discretizing the variational equation:

$$\nabla_\mu(\rho u^\mu) = \sigma,$$

where ρ is the pulse density, σ is the emission rate, and u^μ is a null 4-velocity.

2 Simulation Methodology

We construct a 2D grid with space $x \in [-L, L]$ and time $t \in [0, T]$, defining a scale factor $a(t)$ for FLRW spacetime. Each timestep:

- emits new pulses via a Gaussian $\sigma(t, x)$,
- propagates $\rho(t, x)$ forward along null paths (adjusted for $a(t)$),
- stores directed edges in a causal graph from source to target.

3 Results

3.1 Pulse Density Evolution

Figure 1 shows $\rho(t, x)$ over time. In flat spacetime, pulses spread symmetrically. In FLRW, propagation narrows due to $a(t)$, matching the cosmological redshift effect:

$$1 + z = \frac{a(t_{\text{obs}})}{a(t_{\text{emit}})}.$$

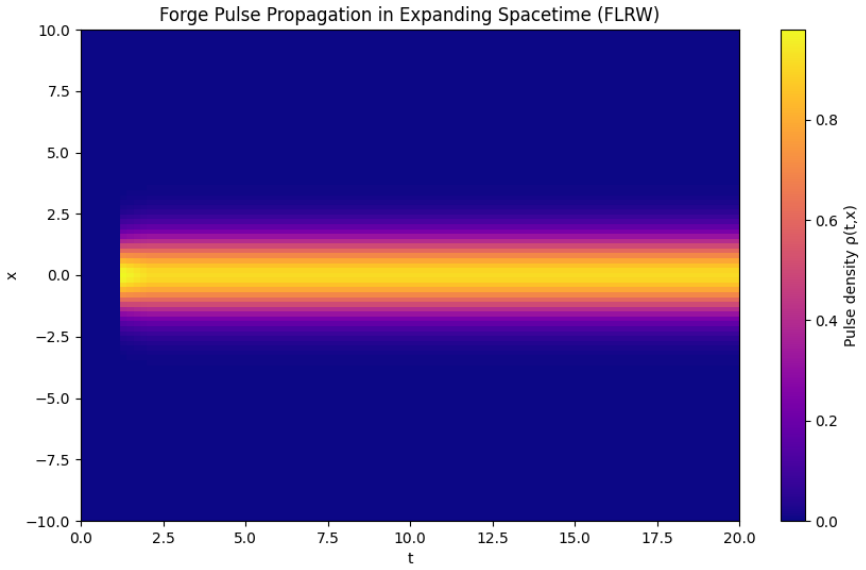

Figure 1: Pulse density $\rho(t, x)$ over time. Top: flat spacetime. Bottom: FLRW expansion.

3.2 Causal Set Structure

Figure 2 shows the directed acyclic graph built from the propagation paths. It encodes the null geodesic network implied by Forge.

4 Discussion

This work confirms that the Forge framework:

- is compatible with Lorentz and FLRW geometries,
- generates a causal set aligned with null structure,
- simulates redshift and time delay via scale-dependent propagation.

The model provides an elegant discrete realization of general-relativistic null dynamics without fields or wavefunctions. Future work will simulate Bell correlations, detector statistics, and pulse interference structures.

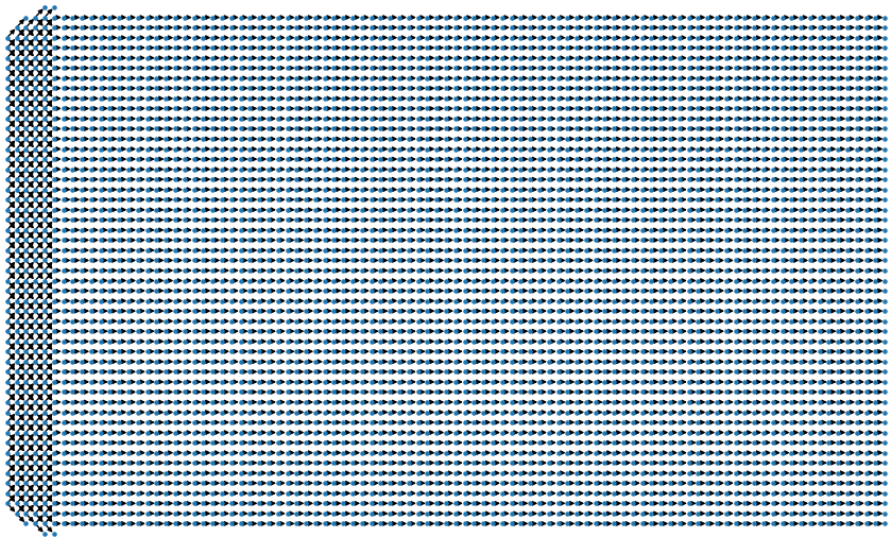

Figure 2: Causal graph of pulse propagation. Null-constrained links form a structure equivalent to a discrete spacetime.

Acknowledgments

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References

[1] Wallace, R. *Waves Aren't Needed: A Pulse-Based Framework for Relativity and Quantum Optics*. Zenodo (2025).