SPDEBench:

An Extensive Benchmark for Learning Stochastic PDEs

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Why learn SPDEs?

- **Random physical dynamics**: turbulence and quantum systems.
- **Challenging simulation**: rough solutions and specialized numerical schemes.
- **Learning goal**: fast surrogates for simulation and prediction.

Why benchmark SPDEs?

- **Limited datasets**, especially for singular SPDEs.
- **Stochastic discretization parameters** are often kept fixed.
- **Data generation and evaluation metrics** are often overlooked.

Seven SPDE systems, two tasks

Regular

- Dynamical Φ^4_1
- KdV and Wave
- 2D Navier–Stokes

Singular

- Dynamical Φ^4_2 and Φ^4_3
- KPZ

Fixed initial condition $\xi \mapsto u$

Varying initial condition $(u_0, \xi) \mapsto u$

Controlled data generation

Configure equation, noise, J

↓

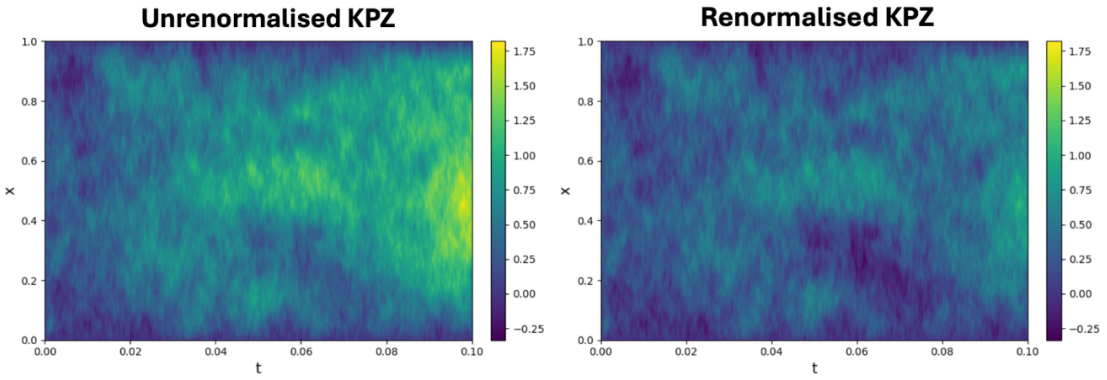
Simulate; renormalize singular systems

↓

Train baselines and evaluate

Vary noise, cutoff J, basis, grid and boundary conditions.
J is the number of retained noise modes.

Renormalization changes the data



Data comparison: relative L^2 vs. renormalized reference

KPZ	**1.512**
2D Φ^4_2	**0.227**

Models and evaluation

11 models and variants

NCDE, NRDE, NCDE-FNO

FNO, WNO, DeepONet, GT

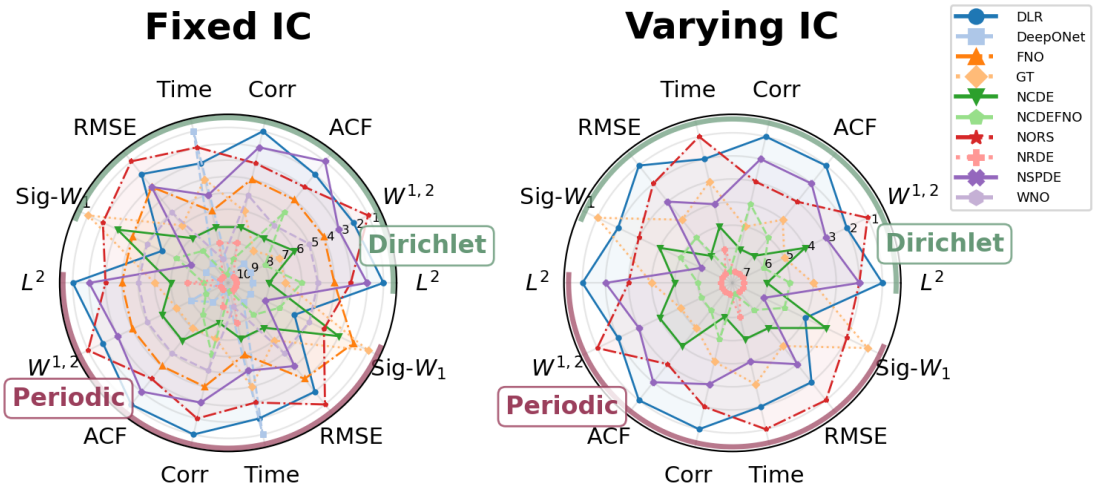
NSPDE, NSPDE-S

NORS, DLR-Net

Seven metrics

- Relative L^2 and Sobolev $W^{1,2}$ error
- Spatial correlation and temporal autocorrelation
- Path distribution: Sig-W_1

Representative results



Φ_1^4, $J = 256$, $\sigma = 0.1$ Rank 1 at the outer edge