Potsdam Institute for Climate Impact Research

Learning Dynamic Stability Landscapes in Synchronization Networks

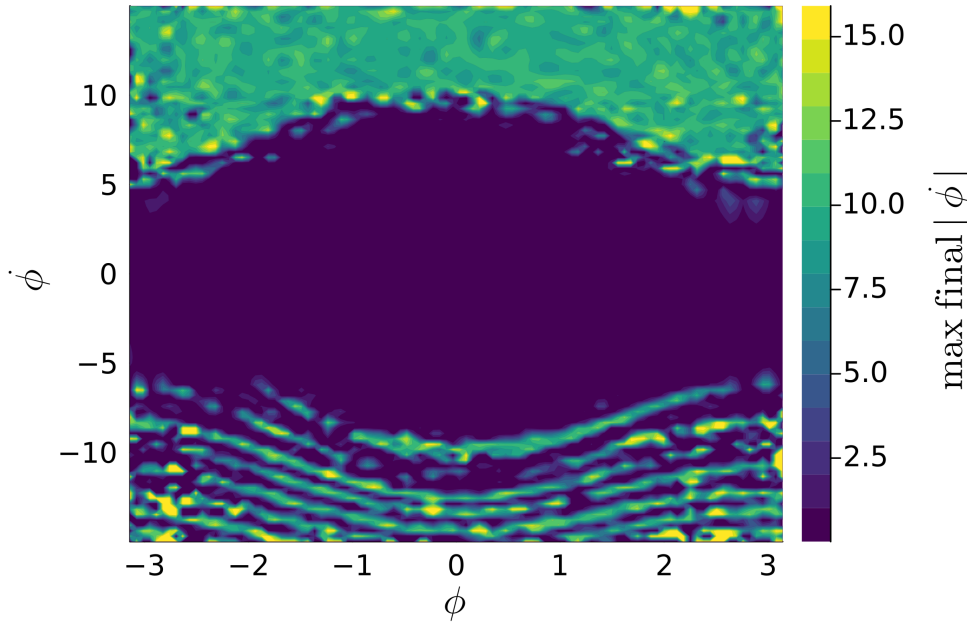
Christian Nauck, Junyou Zhu, Michael Lindner, Frank Hellmann

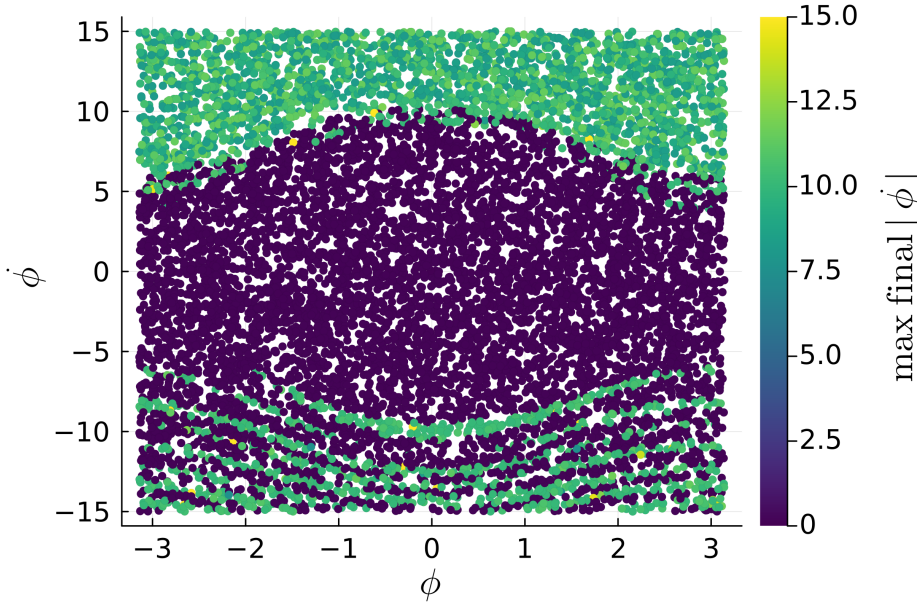
Leibniz Association

Motivation

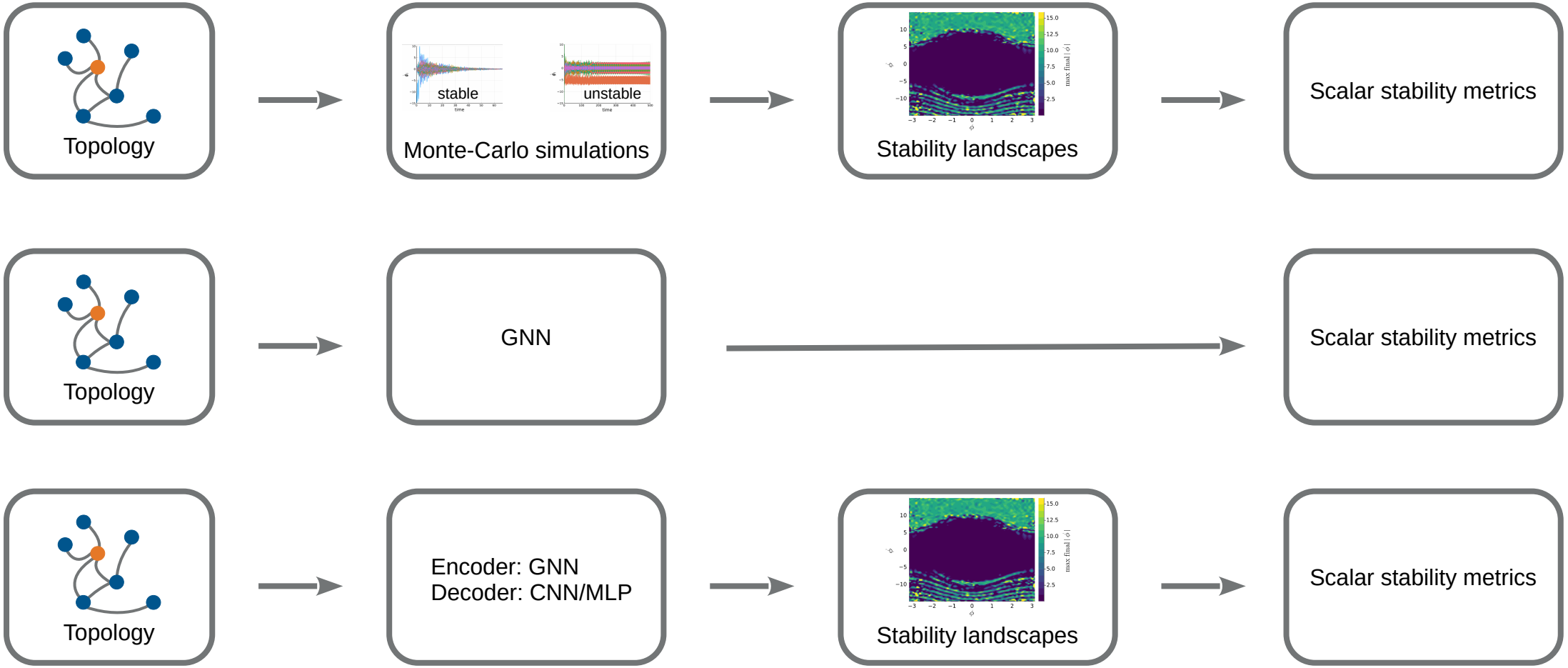
› Oscillator networks are relevant biology, neuroscience, ecology, physics, and engineering

› Synchronization behavior is analyzed with stability landscapes

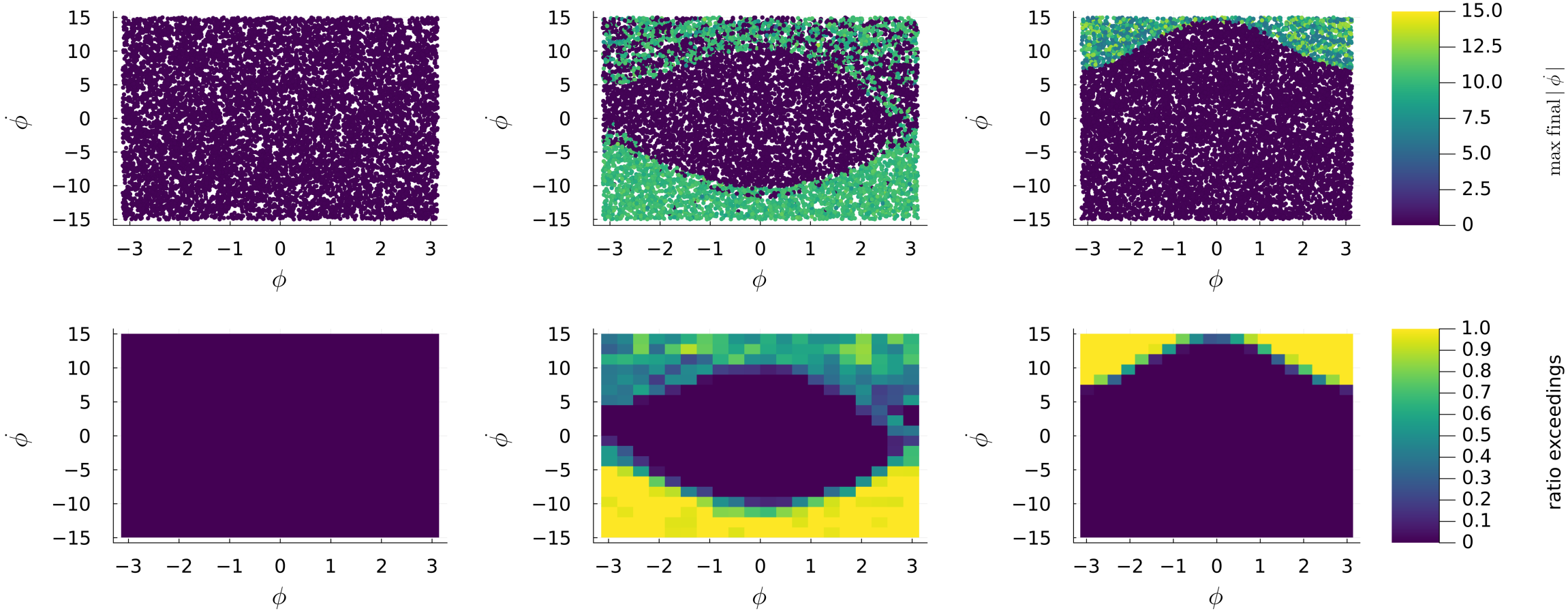




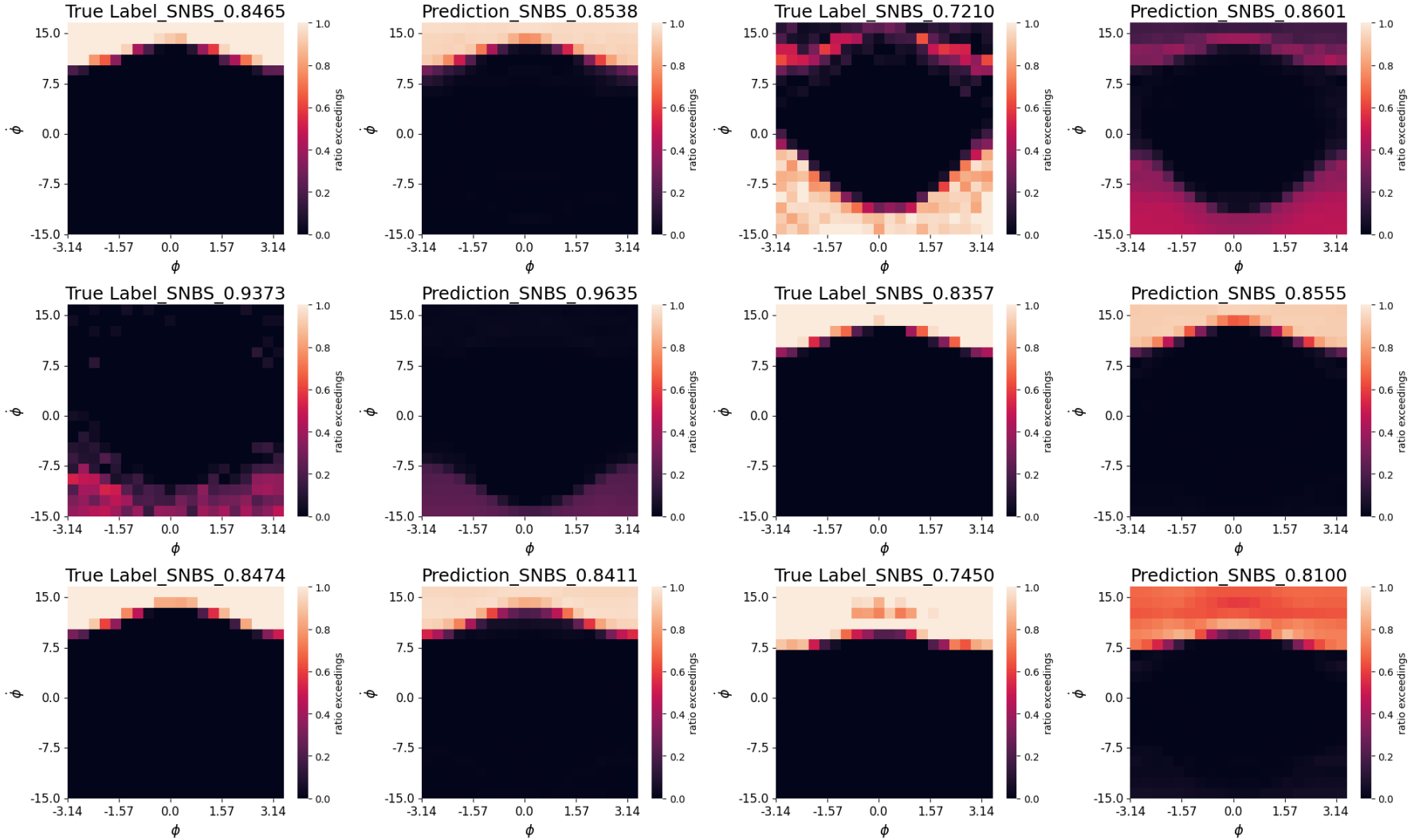
Related work and experimental setup



Publication of novel dataset



Qualitative assessment



Quantitative assessment

Table: Heatmap prediction performance measured by SSIM in %

	Model	In-Distribution	
		tr20ev20	tr100ev100
MLP	TAG	81.37 $\pm$1.58	81.41 $\pm$0.23
	DBGNN	82.63 $\pm$1.75	83.62 $\pm$0.90
CNN	TAG	84.31 $\pm$0.22	83.54 $\pm$0.10
	DBGNN	**86.69** $\pm$1.91	**84.90** $\pm$0.33

Quantitative assessment

Table: Heatmap prediction performance measured by SSIM in %

	Model	In-Distribution		Out-of-Distribution
		tr20ev20	tr100ev100	tr20ev100
MLP	TAG	81.37 $\pm$1.58	81.41 $\pm$0.23	71.11 $\pm$1.47
	DBGNN	82.63 $\pm$1.75	83.62 $\pm$0.90	75.49 $\pm$2.44
CNN	TAG	84.31 $\pm$0.22	83.54 $\pm$0.10	74.36 $\pm$0.30
	DBGNN	**86.69** $\pm$1.91	**84.90** $\pm$0.33	**81.03** $\pm$1.59

Quantitative assessment

Table: Heatmap prediction performance measured by SSIM in %

	Model	In-Distribution		Out-of-Distribution
		tr20ev20	tr100ev100	tr20ev100
MLP	TAG	81.37 $\pm$1.58	81.41 $\pm$0.23	71.11 $\pm$1.47
	DBGNN	82.63 $\pm$1.75	83.62 $\pm$0.90	75.49 $\pm$2.44
CNN	TAG	84.31 $\pm$0.22	83.54 $\pm$0.10	74.36 $\pm$0.30
	DBGNN	**86.69** $\pm$1.91	**84.90** $\pm$0.33	**81.03** $\pm$1.59

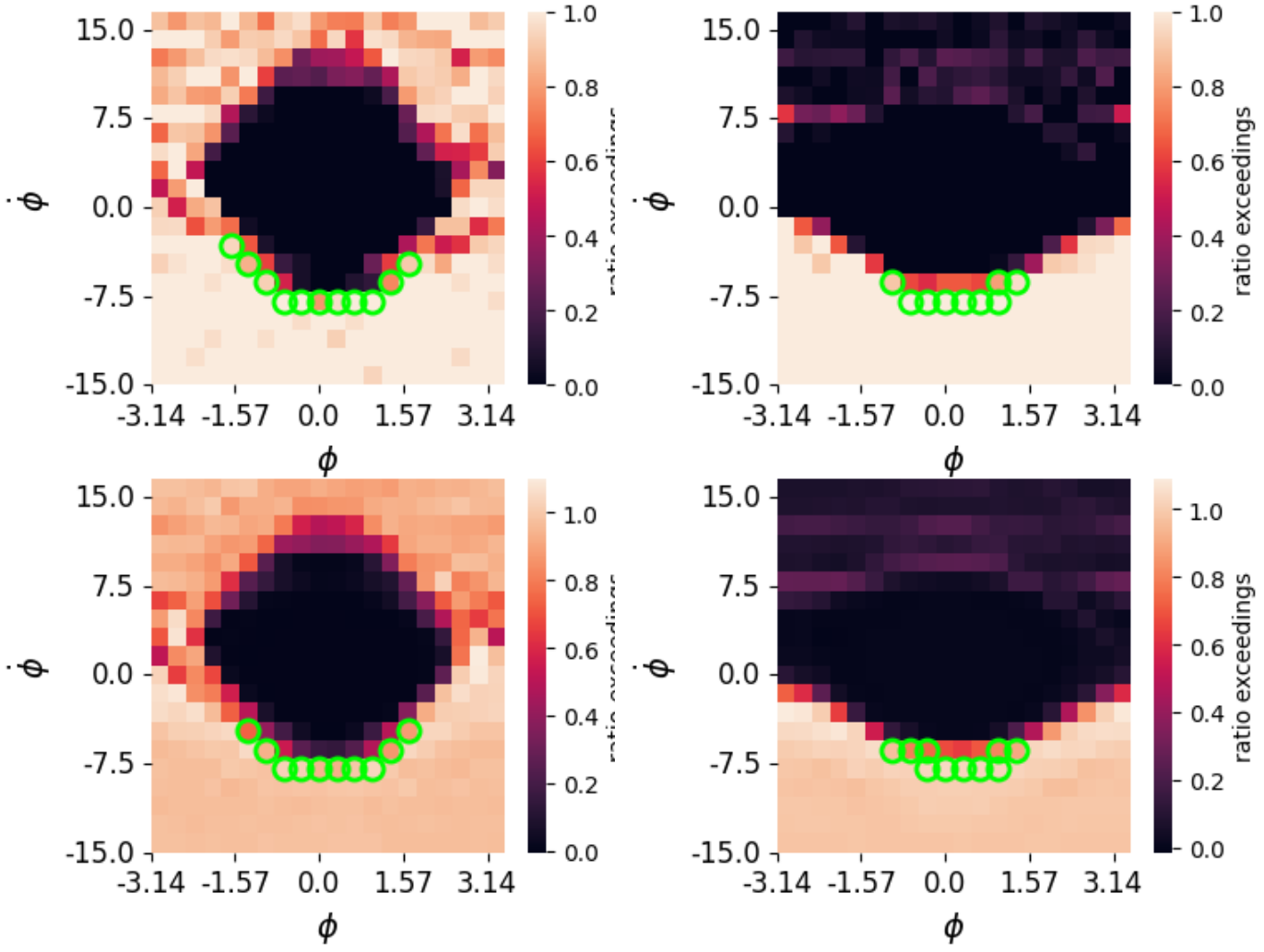
Table: Heatmap prediction performance measured by SSIM in %

	Model	Germany	France	GB	Spain
MLP	TAG	80.79 $\pm$0.24	76.76 $\pm$0.69	81.84 $\pm$0.30	75.93 $\pm$1.23
	DBGNN	54.77 $\pm$4.05	53.41 $\pm$2.29	54.22 $\pm$1.80	60.23 $\pm$6.76
CNN	TAG	**82.87** $\pm$0.26	**79.26** $\pm$0.45	**85.38** $\pm$0.83	**79.45** $\pm$0.09
	DBGNN	54.77 $\pm$4.05	53.41 $\pm$2.29	54.22 $\pm$1.80	60.23 $\pm$6.76

Down-stream task: Contingency screening

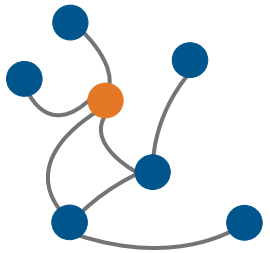
Labels

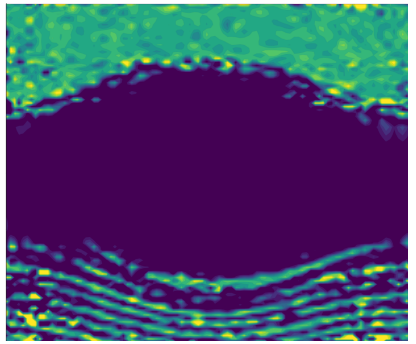
Predictions



Conclusions

- Stability landscapes of oscillator networks are learnable directly from graph topology
- ML models generalize across network sizes and generalize to real-world power grid topologies
- We hope to inspire similar graph-to-image formulations in other domains





Data and code availability

https://github.com/PIK-ICoNe/paper-companion_predicting-snbs-landscapes

https://doi.org/10.5281/zenodo.15373798

https://huggingface.co/datasets/PIK-ICoNe-landscape/Stability_Landscapes