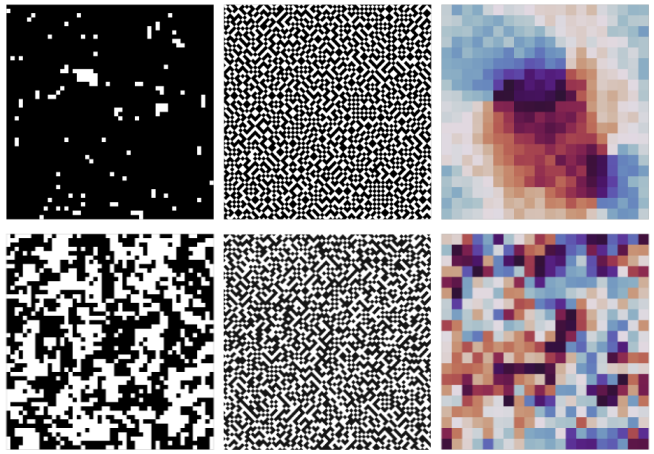


Interpretable Phase Detection and Classification with Persistence Homology

Alex Cole
Gravitation Astroparticle Physics Amsterdam (GRAPPA)
Institute for Theoretical Physics Amsterdam
University of Amsterdam, the Netherlands
a.e.cole@uva.nl

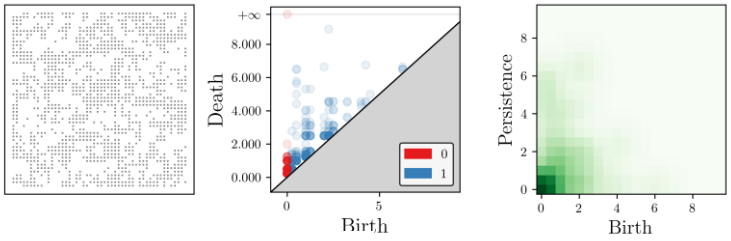
Gregory J. Loges
Department of Physics
University of Wisconsin-Madison, USA
gloges@wisc.edu

Gary Shiu
Department of Physics
University of Wisconsin-Madison, USA
shiu@physics.wisc.edu

We apply persistent homology to the task of discovering and characterizing phase transitions, using lattice spin models from statistical physics for working examples. Persistence images provide a useful representation of the homological data for conducting statistical tasks. To identify the phase transitions, a simple logistic regression on these images is sufficient for the models we consider, and interpretable order parameters are then read from the weights of the regression. Magnetization, frustration and vortex-antivortex structure are identified as relevant features for characterizing phase transitions.

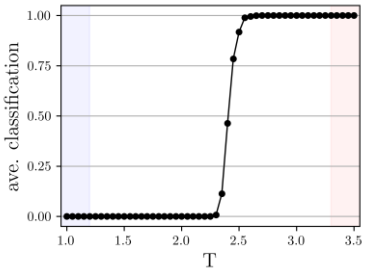
arXiv:2009.14231

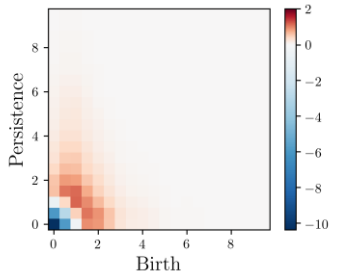
:gloges/TDA-Spin-Models

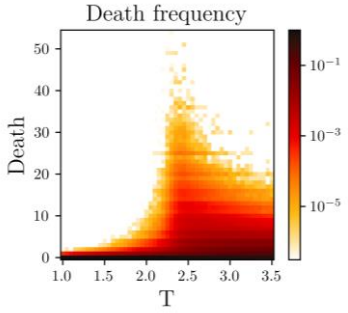


Ising model

$$H_{\mathrm{Is}} = -\sum_{\langle i,j \rangle} s_i s_j$$

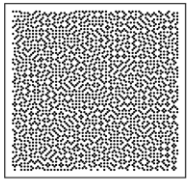


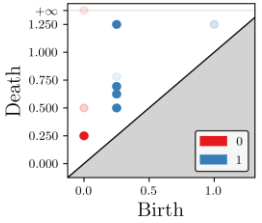


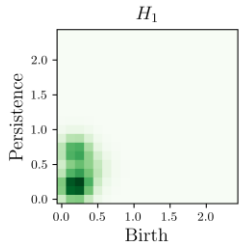


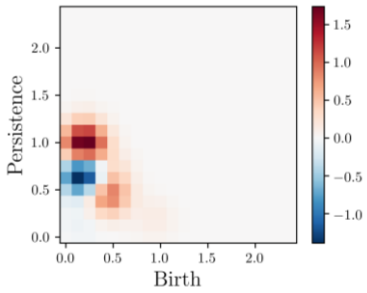
Square-ice model

$$H_{\mathrm{SI}} = \sum_{v \in \Lambda} \left(\sum_{i:v} s_i \right)^2$$









XY model

$$H_{\mathrm{XY}} = -\sum_{\langle i,j \rangle} \cos\left(\theta_i - \theta_j\right)$$