Replacing neural networks by optimal analytical predictors for the detection of phase transitions

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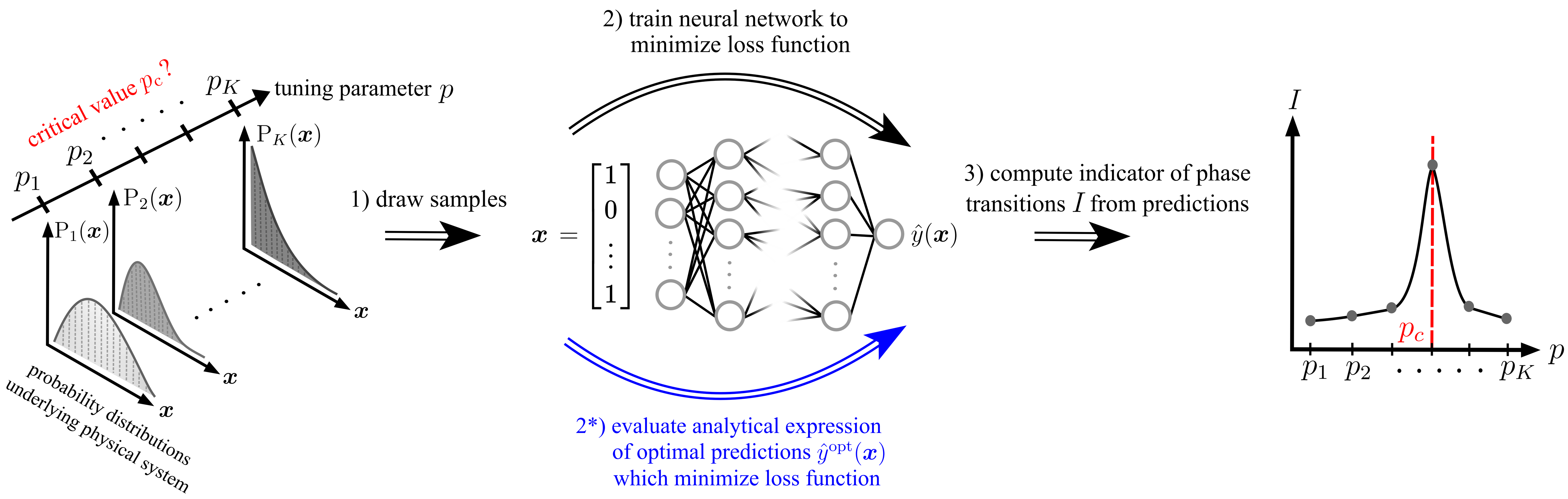
Automated detection of phase transitions from data



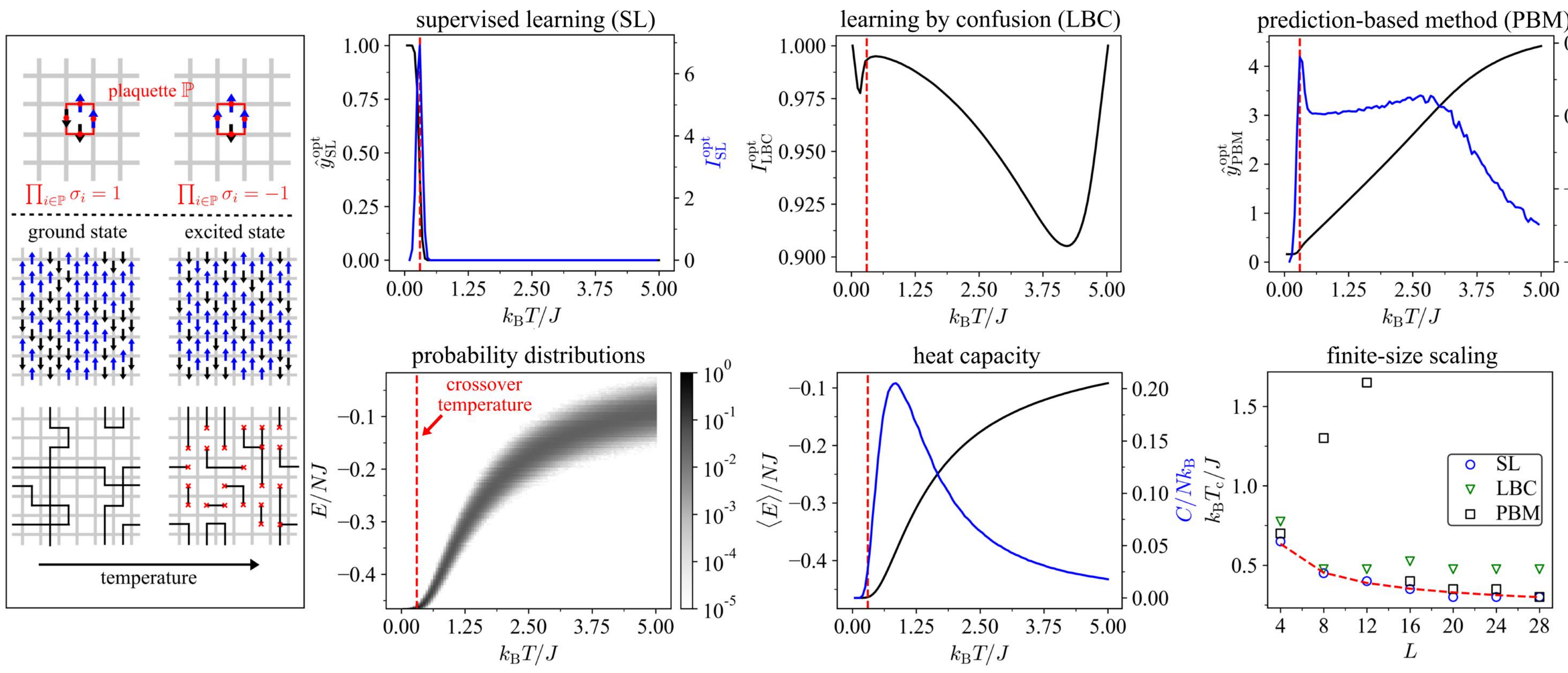
IDEA: **REPLACE NEURAL NETWORKS BY OPTIMAL ANALYTICAL PREDICTORS**

- standard workflow 1) ⇒ 2) ⇒ 3) involves neural networks
  - which are difficult to interpret and act as black boxes
  - whose training can be computationally expensive and tedious
- our approach 1) ⇒ 2*) ⇒ 3) is based on analytical expressions
  - which reveal inner workings of black-box neural networks
  - allow for efficient detection of phase transitions without training neural networks

⇒ PROCEDURE IS DEMONSTRATED ON THREE POPULAR NEURAL NETWORK-BASED METHODS

Application to classical systems

- topological crossover in Ising gauge theory: $H = -J\sum_{\mathbb{P}}\prod_{i\in\mathbb{P}}\sigma_i$

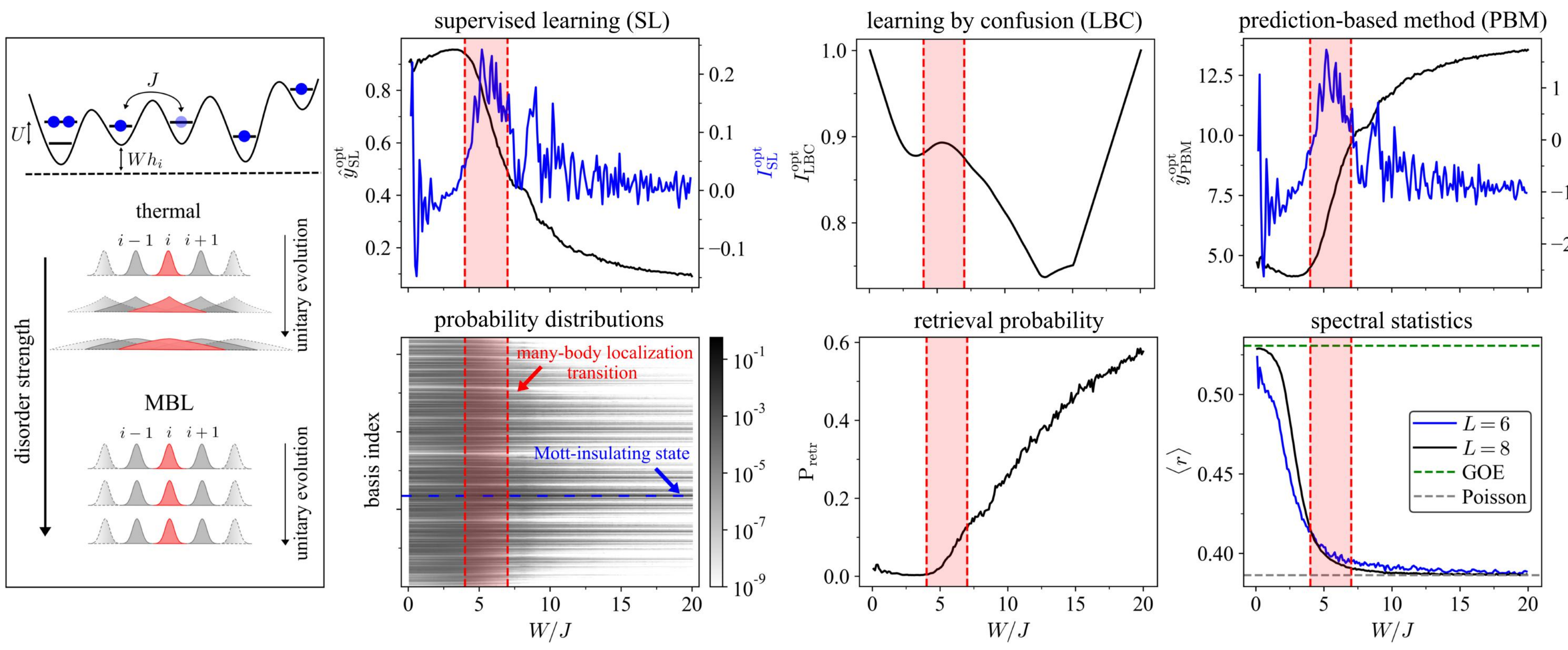


… as well as

- symmetry-breaking phase transition in Ising model
- Berezinskii–Kosterlitz–Thouless transition in XY model

Application to quantum systems

- many-body localization transition in Bose-Hubbard model: $\hat{H} = -J\sum_{i=1}^{L-1}(\hat{b}_{i+1}^\dagger\hat{b}_i + \text{h.c.}) + \sum_{i=1}^{L}\frac{U}{2}\hat{n}_i(\hat{n}_i - 1) + Wh_i\hat{n}_i$



… as well as

- first-order phase transition in XXZ chain
- Mott-insulator to superfluid transition in Bose-Hubbard model
- topological phase transition in Kitaev chain

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FNSNF Swiss National Science Foundation
QSIT Quantum Science and Technology, National Centre of Competence in Research