Real-time EFT with application to QCD matter and perhaps AI

CUHK-SZ

Yi Yin

The Nobel Prize in Physics 2024

The Royal Swedish Academy of Sciences has decided to award the Nobel Prize in Physics 2024 to

John J. Hopfield

Princeton University, NJ, USA

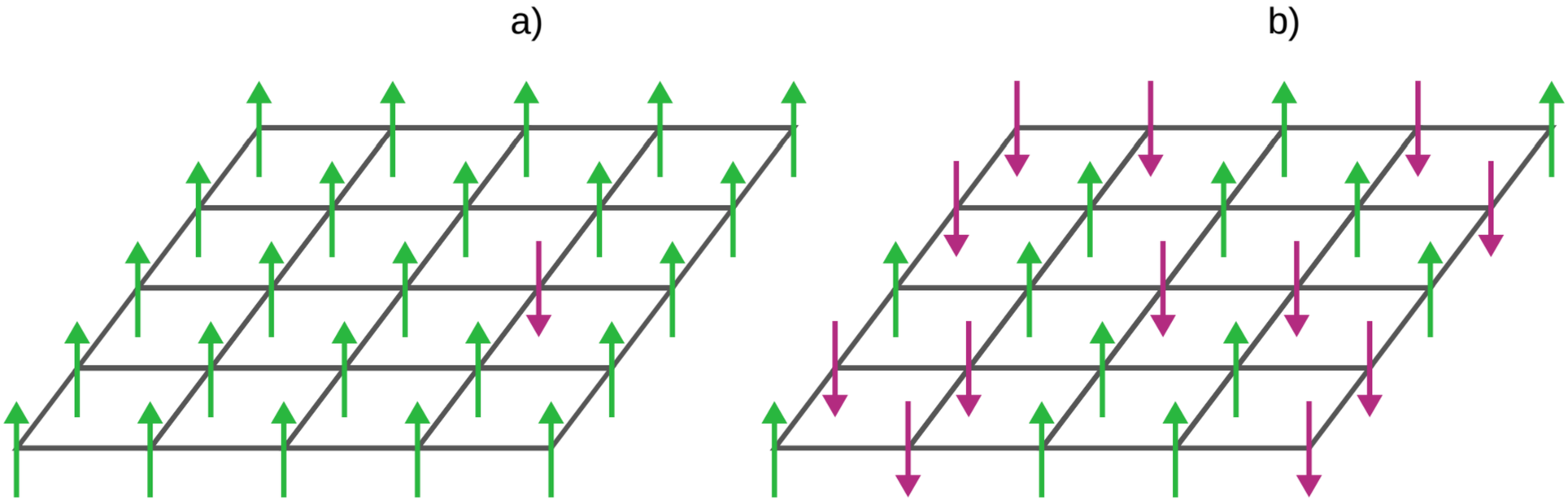
Geoffrey Hinton

University of Toronto, Canada

"for foundational discoveries and inventions that enable machine learning with artificial neural networks"

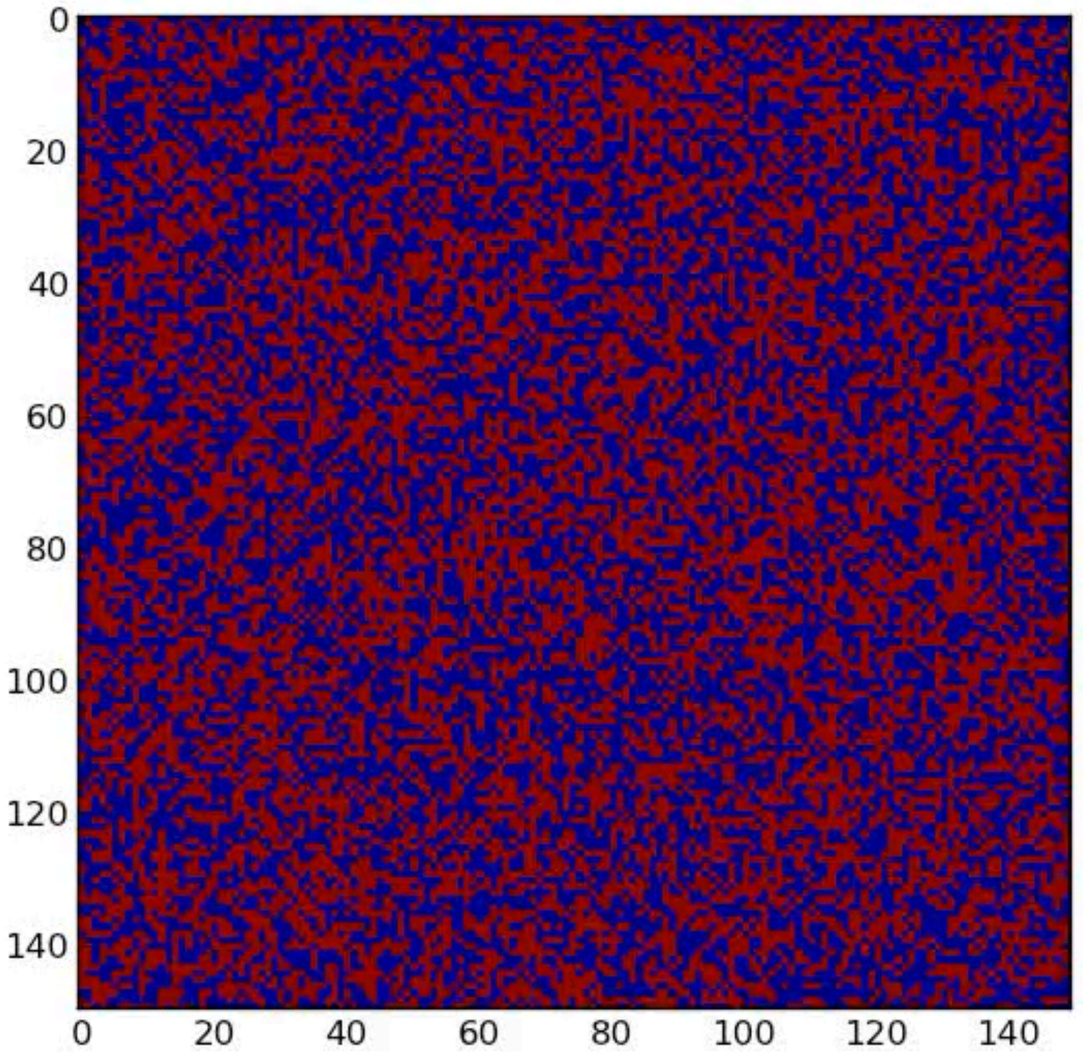
They trained artificial neural networks using physics

2d Ising Model



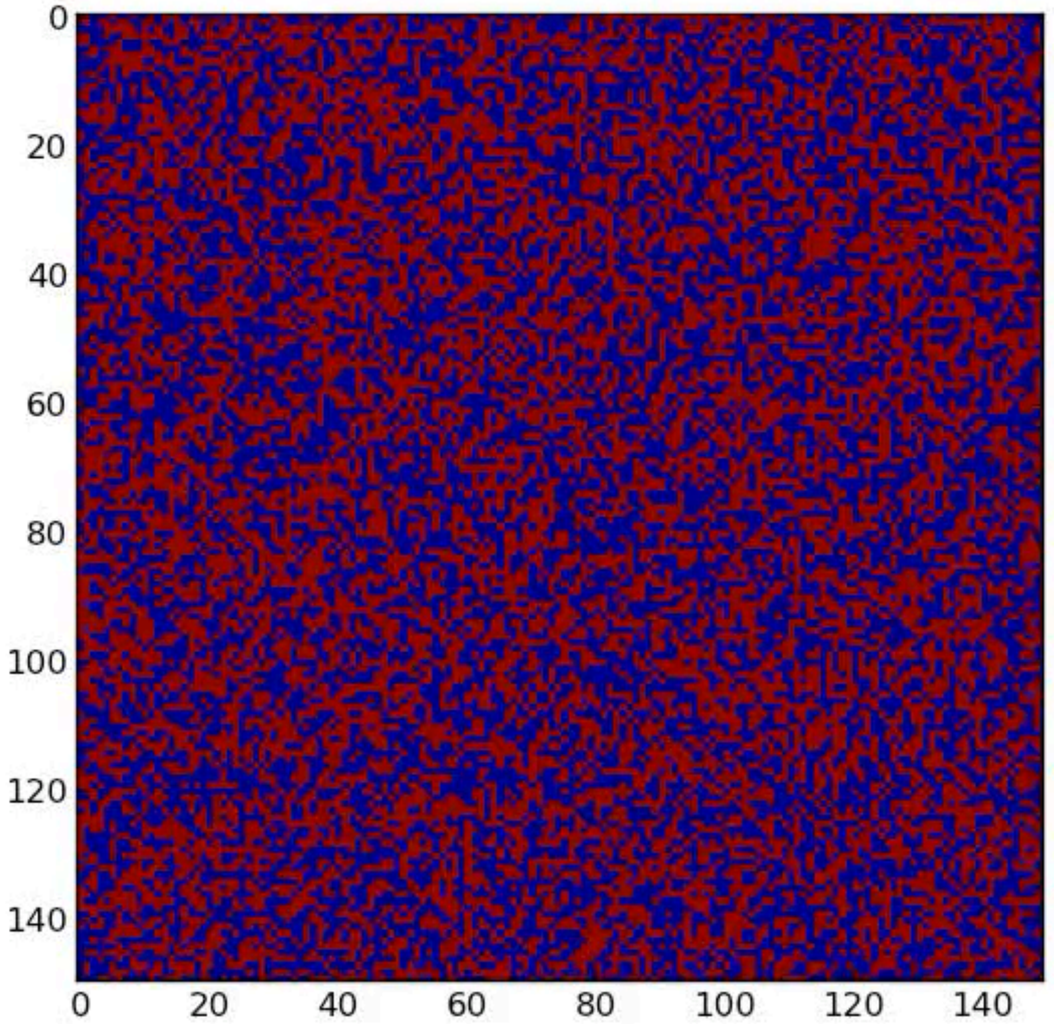
Low Temperature Phase

by B.D.Hammel

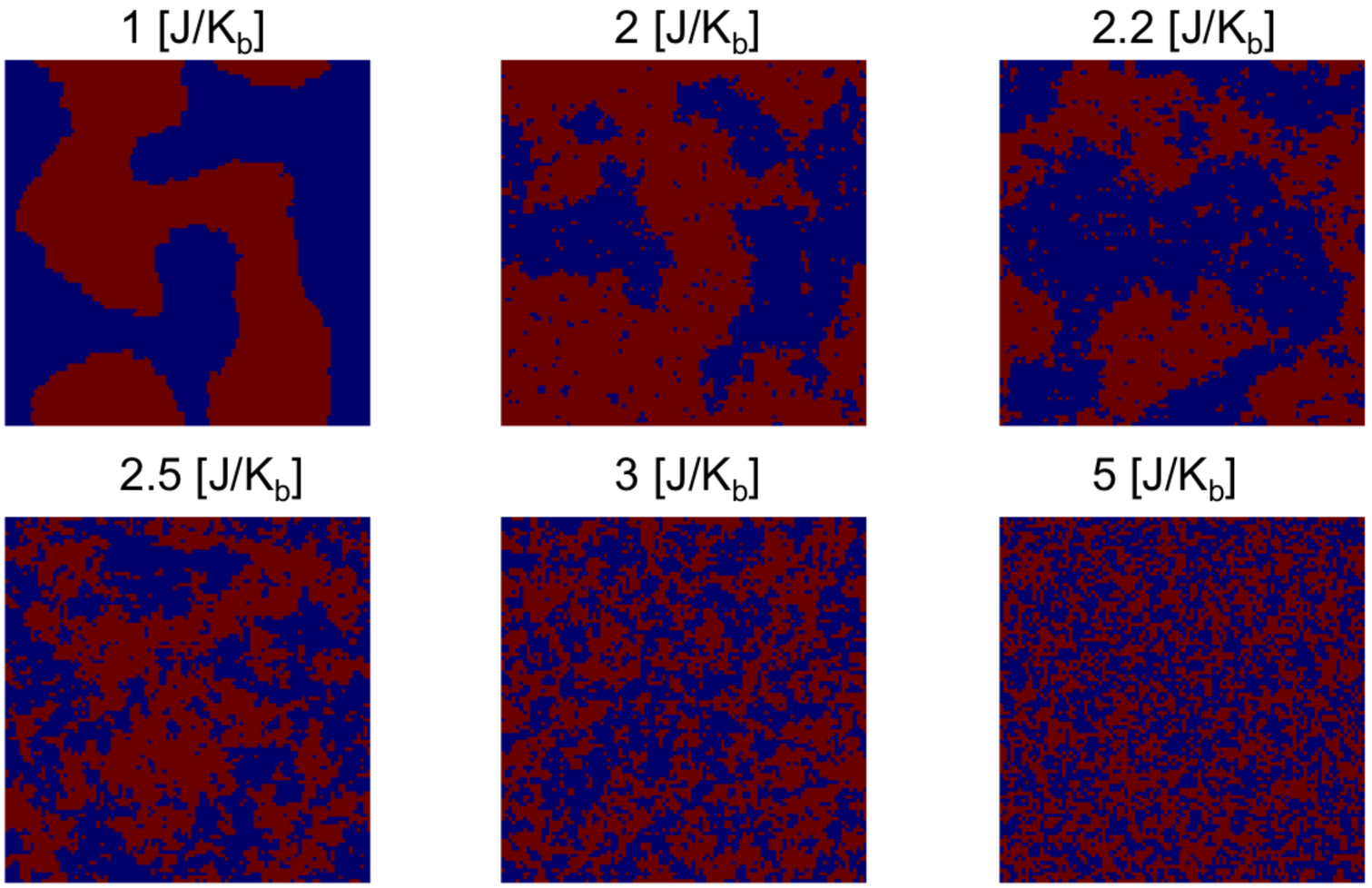


High-Temperature Phase

by B.D.Hammel



by B.D.Hammel



Statistical Physics Inspired AI

- Leveraging the phase dynamics of artificial particles (neurons, nodes, or units) to model and manipulate patterns for learning, recognition, and generative processes

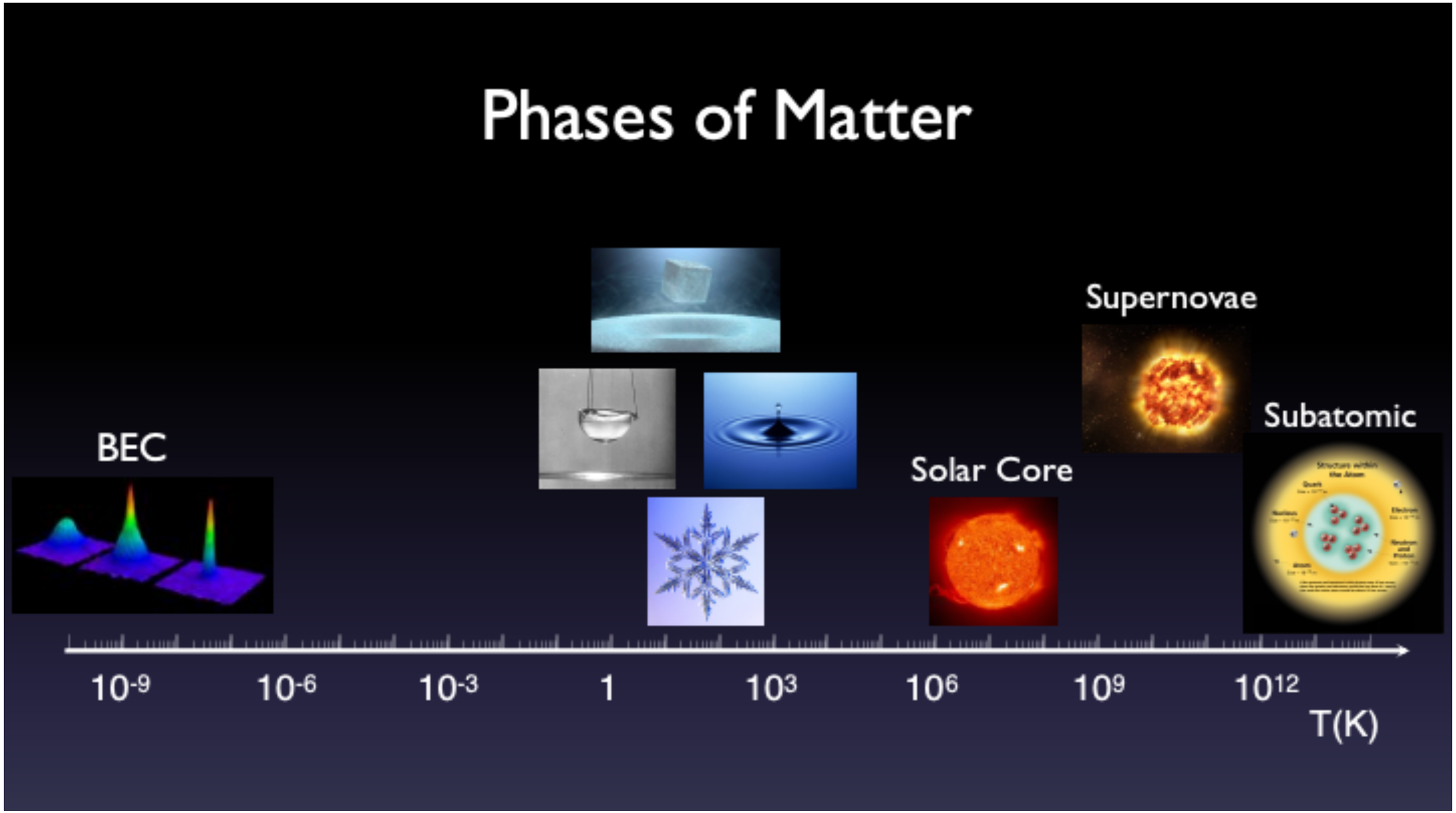
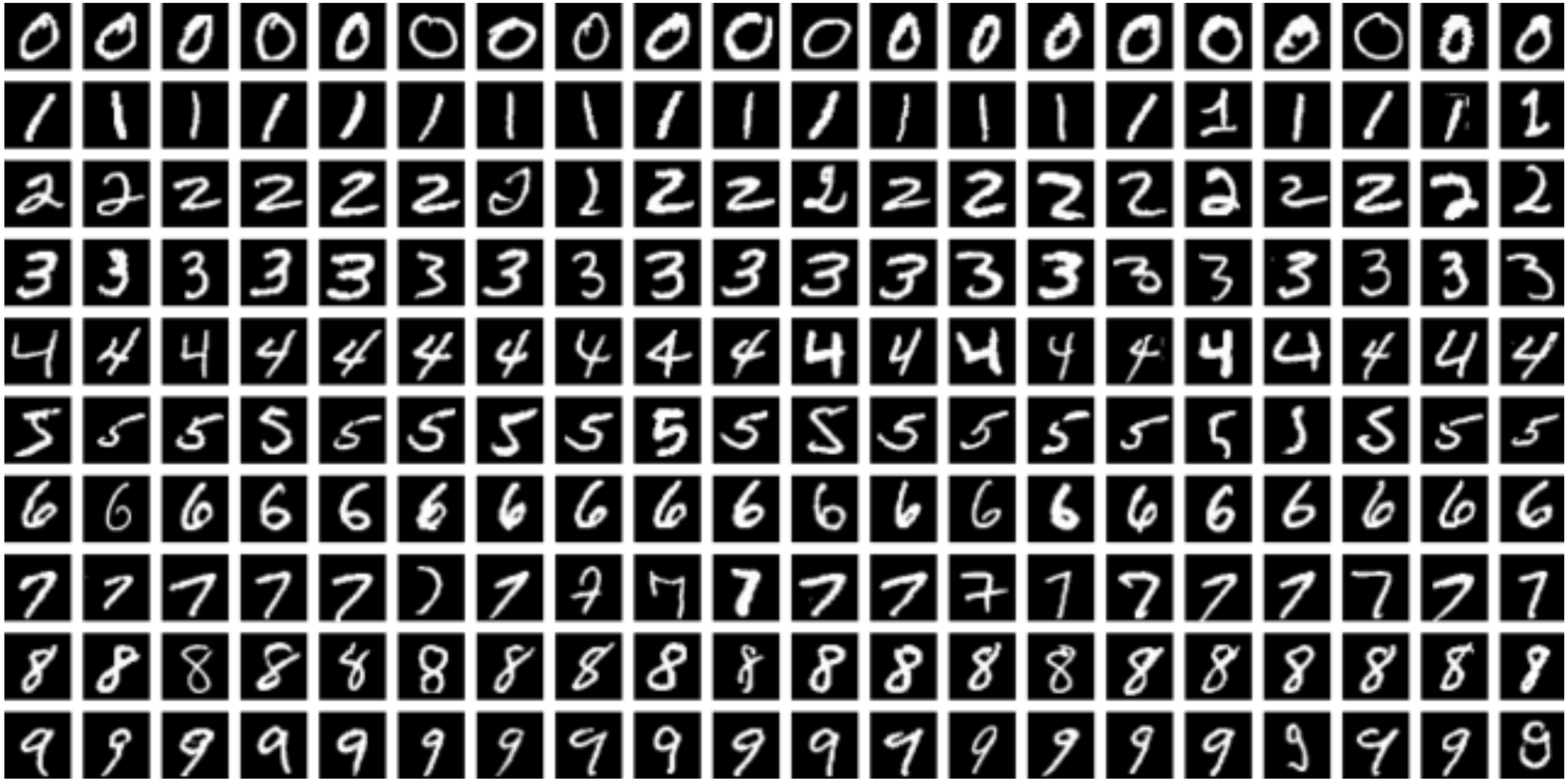

Phases of Matter
BEC
Supernovae
Subatomic
Solar Core
10-9
10-6
10-3
1
103
106
109
1012
T(K)

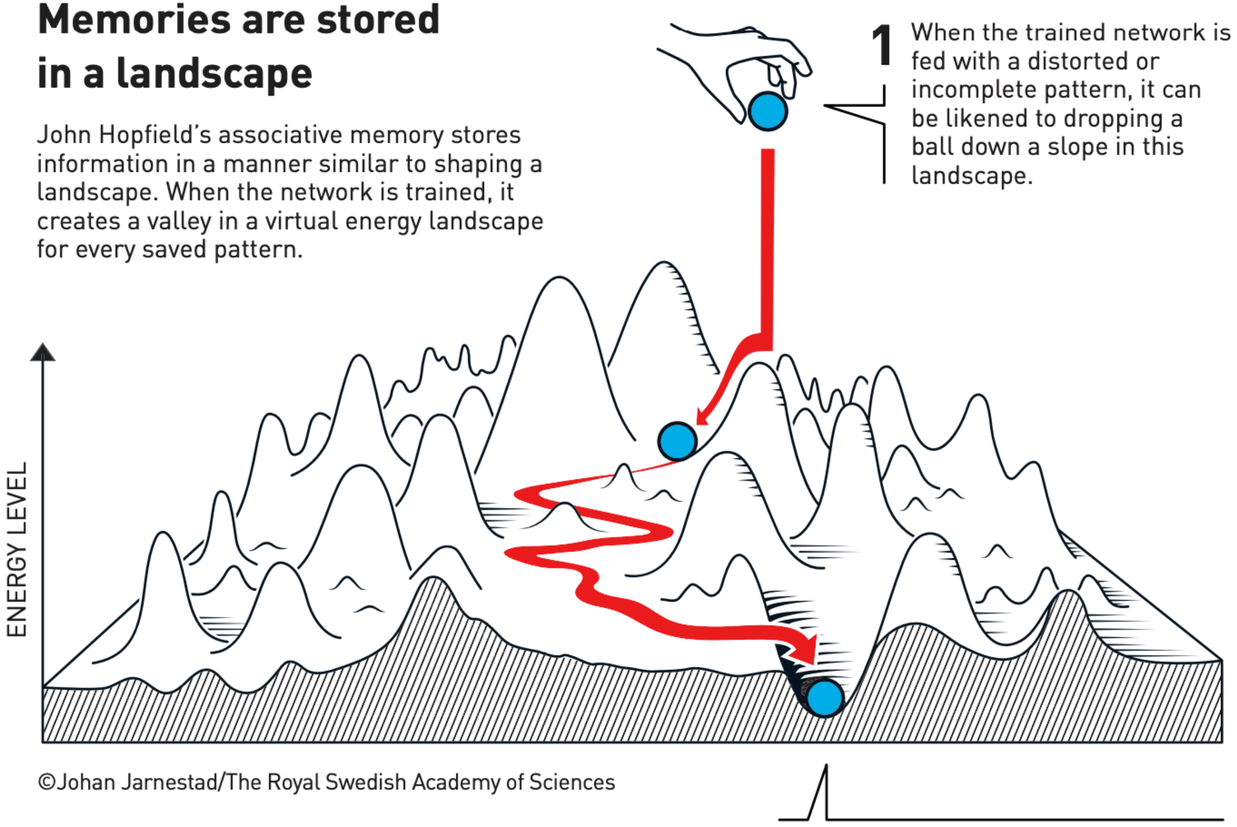
Fig. by Wei Li



Sample images from MNIST test dataset

Memories are stored in a landscape

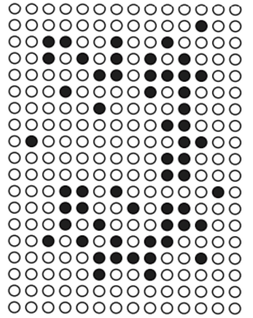
John Hopfield's associative memory stores information in a manner similar to shaping a landscape. When the network is trained, it creates a valley in a virtual energy landscape for every saved pattern.



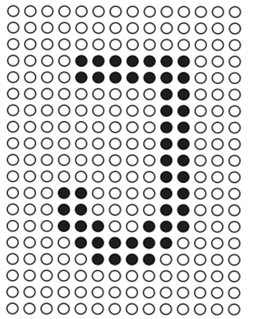
1 When the trained network is fed with a distorted or incomplete pattern, it can be likened to dropping a ball down a slope in this landscape.

2 The ball rolls until it reaches a place where it is surrounded by uphills. In the same way, the network makes its way towards lower energy and finds the closest saved pattern.

INPUT PATTERN



SAVED PATTERN



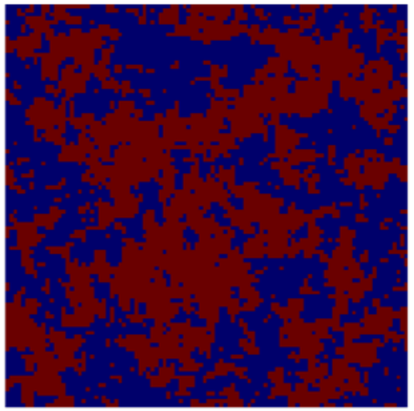
What is your favorite drink?

deepseek

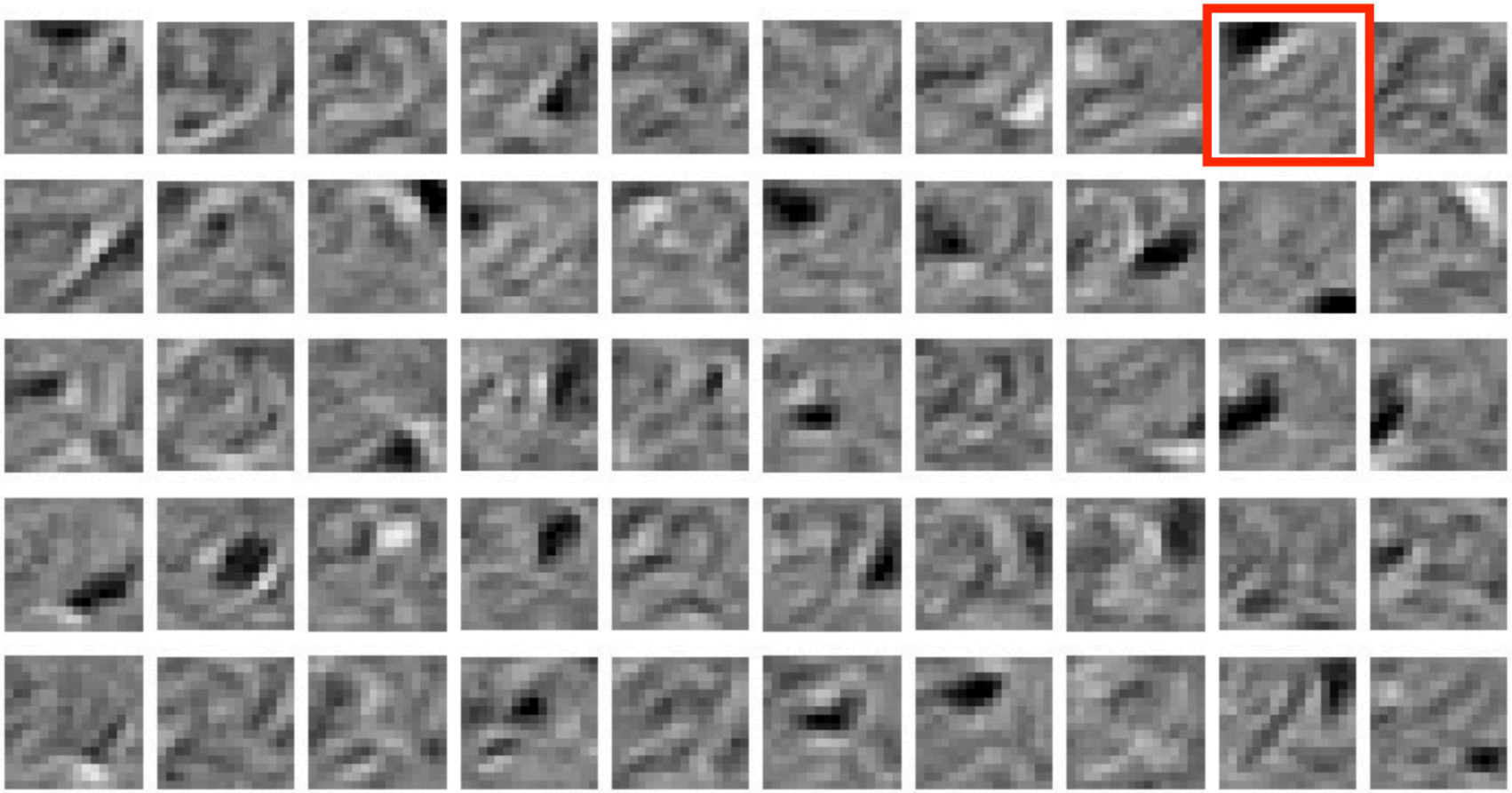
温度值	回答风格	示例回答
低温 (0.1-0.3)	严谨、客观	“作为AI，我没有个人偏好，但可以推荐水、咖啡或茶。”
中温 (0.5-0.7)	自然、略带互动	“虽然我没有味觉，但很多人喜欢冰爽的柠檬茶。你呢？”
高温 (0.8-1.0)	创意、幽默	“我幻想喝银河系星光奶茶！现实点的话...可能是魔法咖啡？”
超高温度 (1.5)	疯狂、无逻辑	“最爱火山岩浆特饮配彗星尾粉末！不过建议你先试试氧气泡泡水～”

1 [J/K_b]

2.5 [J/K_b]

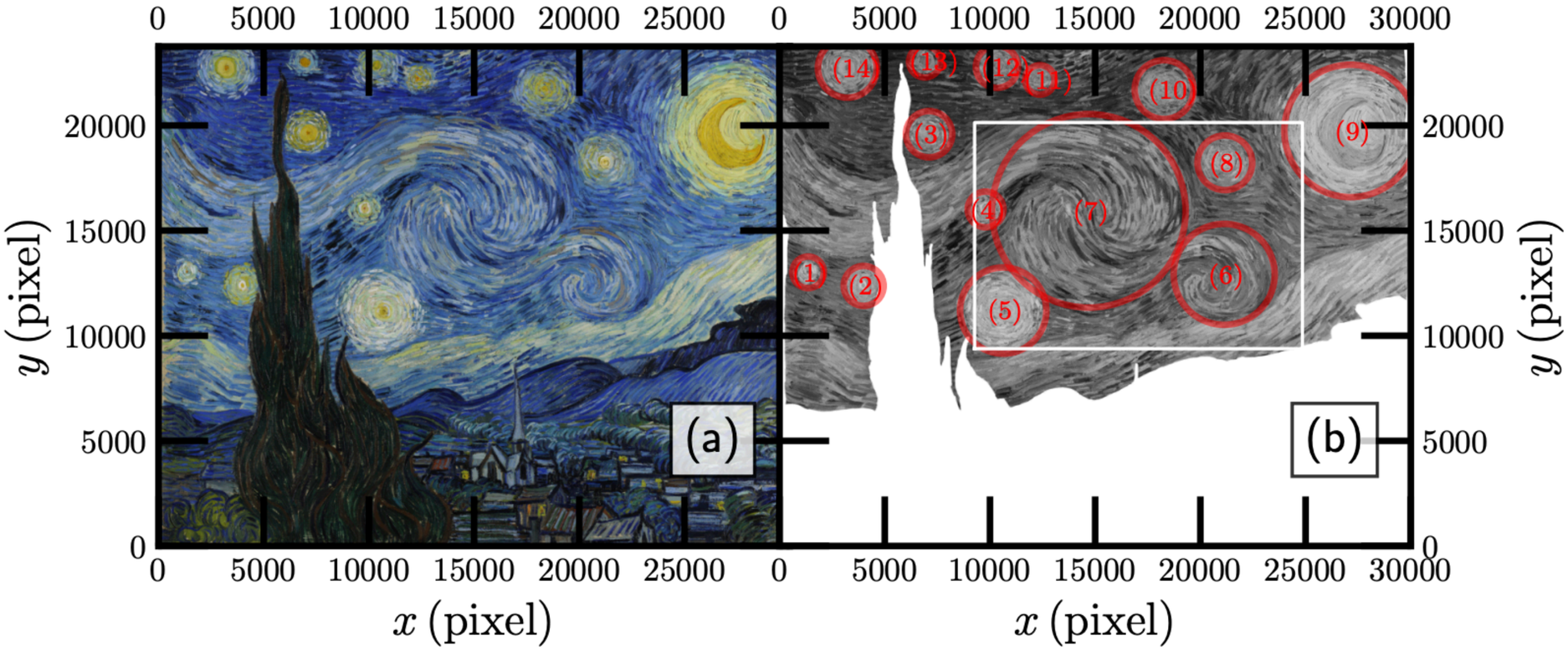


Hidden unit as a feature detector



Part II: Non-equilibrium Phases

The Starry Night and Turbulence



2310.03415

Diffusive model for AI Image Generation

Deep Unsupervised Learning using Nonequilibrium Thermodynamics

Jascha Sohl-Dickstein JASCHA@STANFORD.EDU
Stanford University

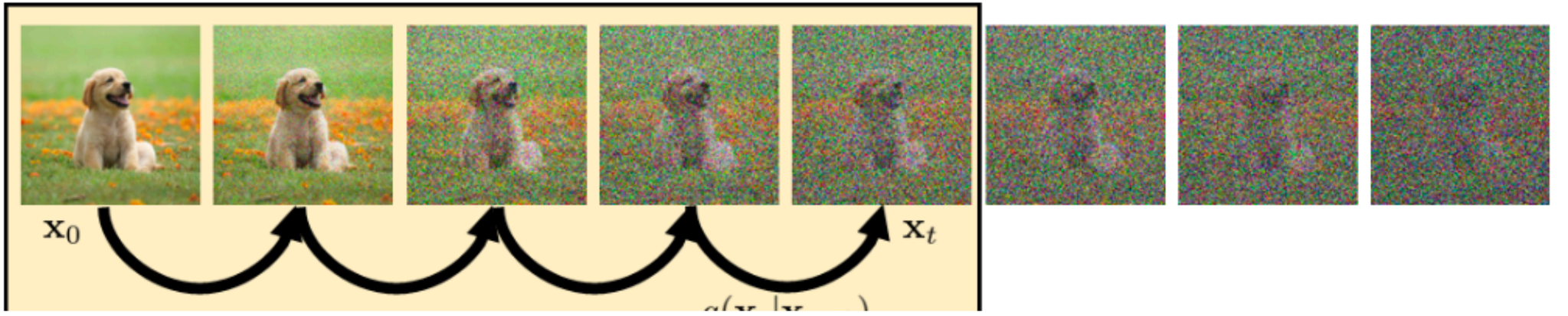
Eric A. Weiss EAWEISS@BERKELEY.EDU
University of California, Berkeley

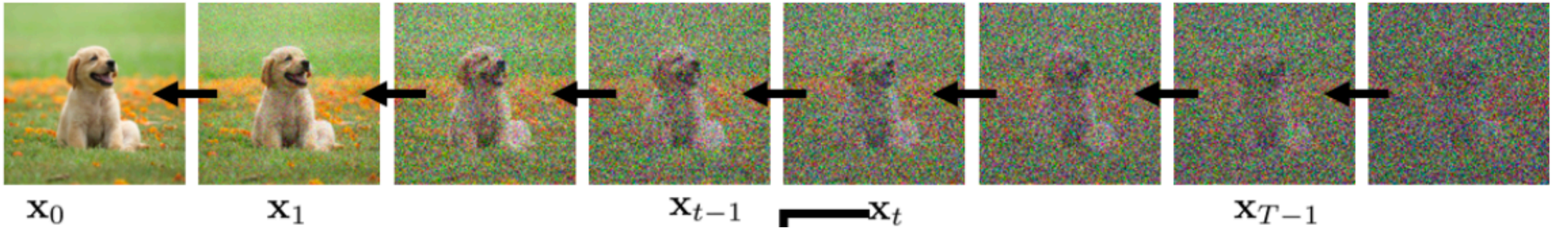
Niru Maheswaranathan NIRUM@STANFORD.EDU
Stanford University

Surya Ganguli SGANGULI@STANFORD.EDU
Stanford University

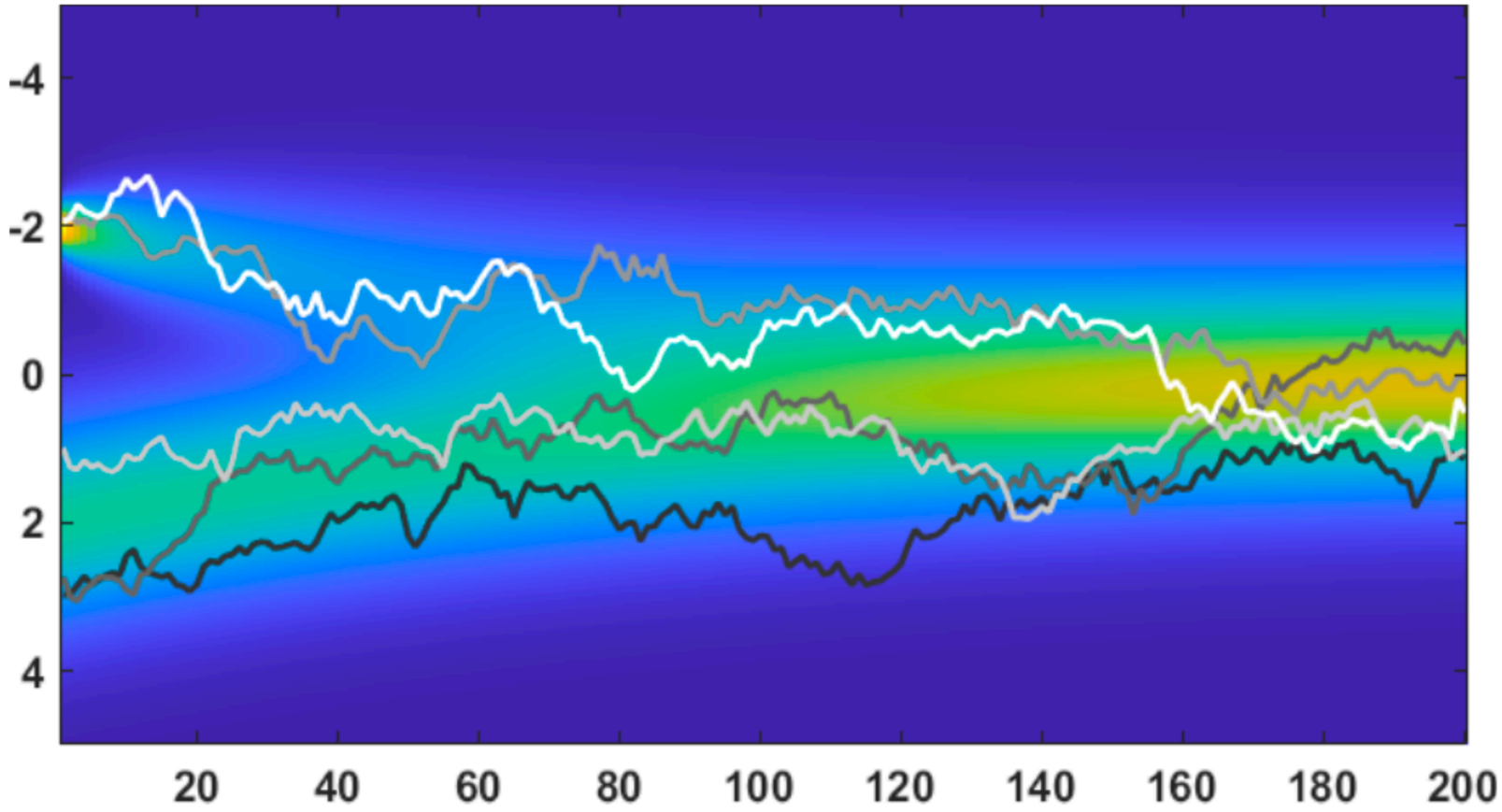
- Diffusion models are widely used for image denoising, image generation, and video generation

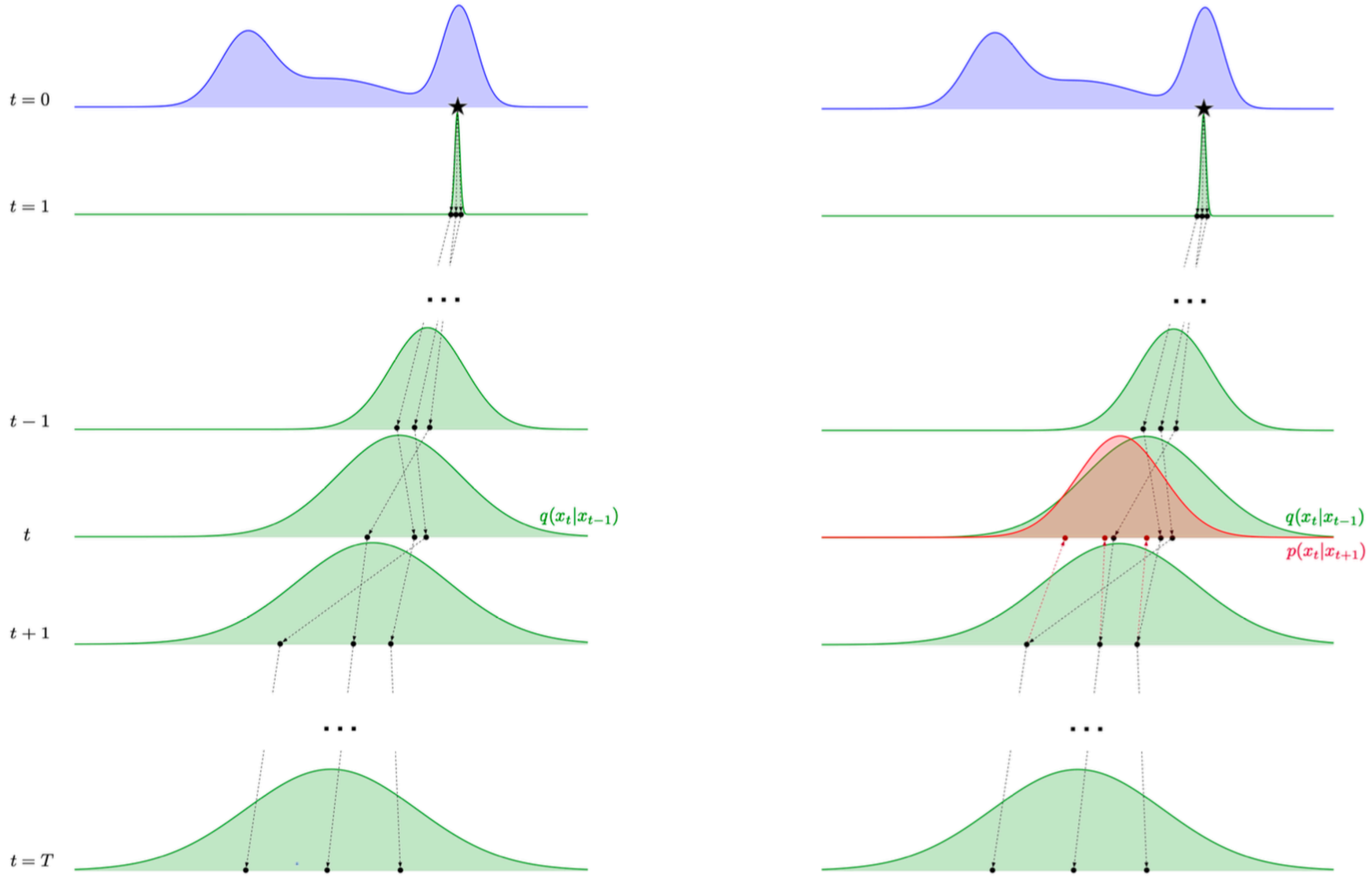
An image generated with Stable Diffusion 3.5 based on the text prompt a photograph of an astronaut riding a horse


$\mathbf{x}_0$
$\mathbf{x}_t$


$\mathbf{x}_0$
$\mathbf{x}_1$
$\mathbf{x}_{t-1}$
$\mathbf{x}_t$
$\mathbf{x}_{T-1}$

Forward Evolution




$t = 0$
$t = 1$
$t - 1$
t
$t + 1$
$t = T$
$q(x_t|x_{t-1})$
$q(x_t|x_{t-1})$
$p(x_t|x_{t+1})$

Summary and Outlook

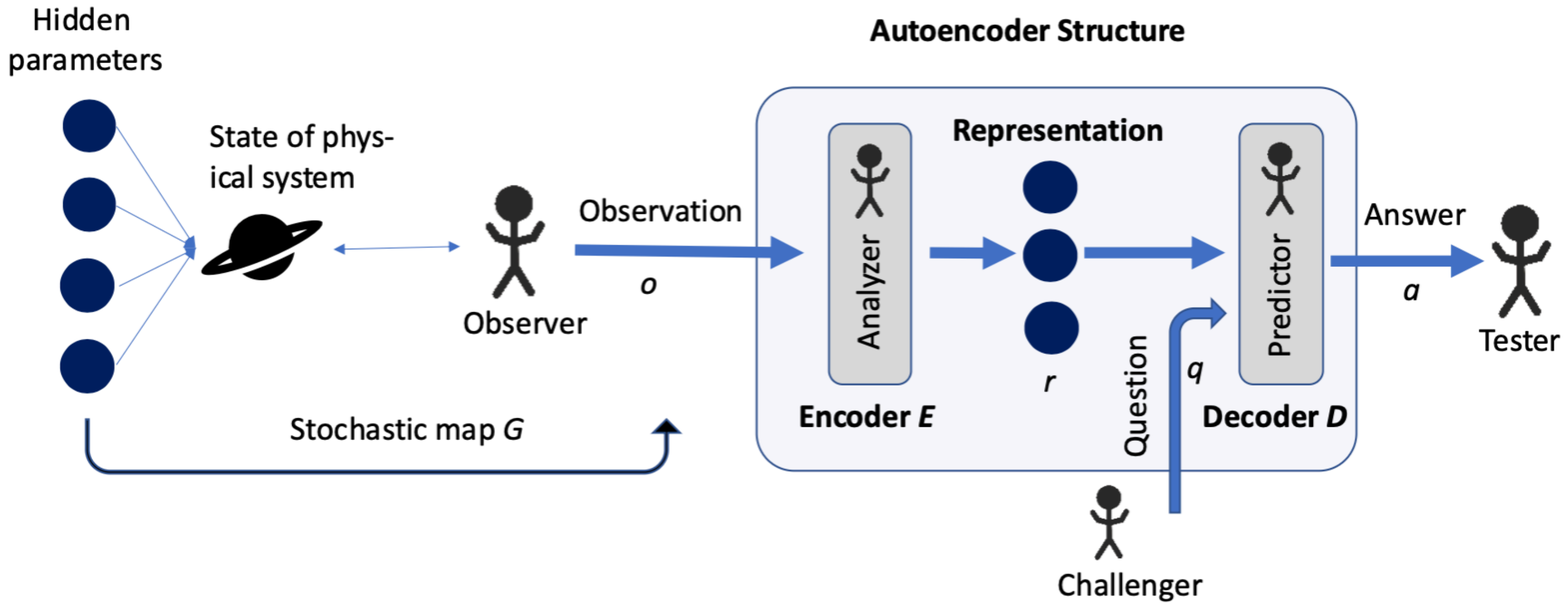


FIG. 7. **Adapted autoencoder structure for discovering physical parameters.** (Figure taken and modified from [330]). We assume that a small set of hidden parameters fully determines the state of a physical system. The mapping G from these hidden parameters to the measurement outputs of an observing agent is allowed to be stochastic. An autoencoder structure can then be employed to recover the relevant hidden parameters. Specifically, the observing agent provides the observation o to an analyzing agent (described by an encoding map E), whose task is to recover the relevant hidden parameters r necessary to respond to questions posed by a challenging agent. A predicting agent, which answers a question q based on the representation r, is modeled by a decoder mapping D. Finally, a testing agent compares the answer a given by the predicting agent with the correct answer obtained through direct measurements of the environment. Note that, in practice, the roles of the analyzer, predictor, and challenger could be performed by a single physicist.

2503.23616

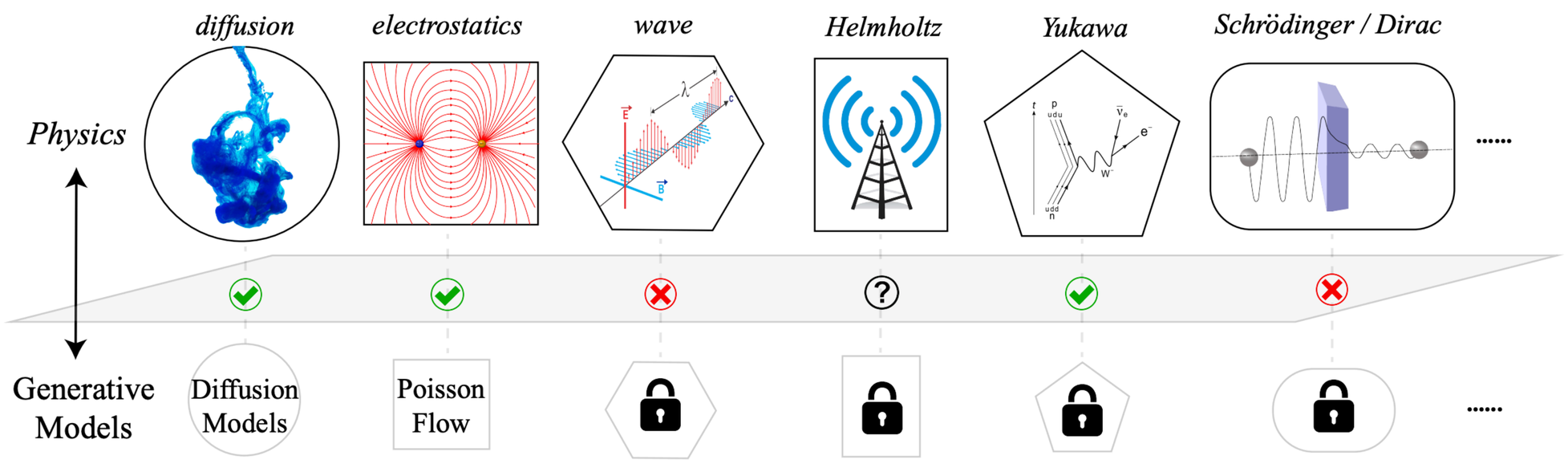


Figure 1: Duality between physics and generative models. So far only diffusion models and Poisson flow models are discovered in the literature. Can we unlock more?

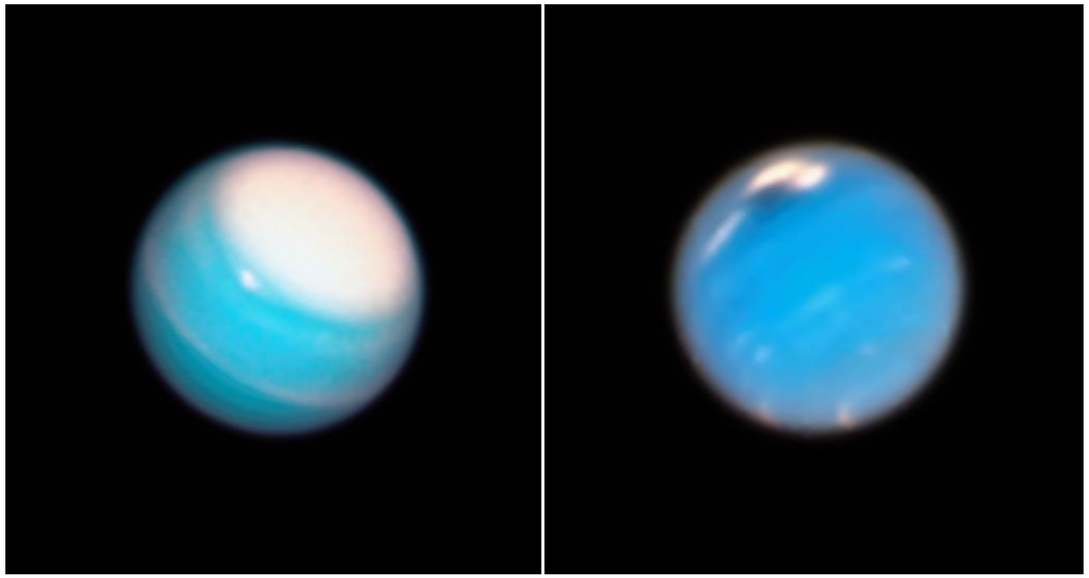
2304.02637

Outlook

- Nature is a teaching machine. We just begin to learn AI from it.

Back-up

Discovery of Neptune (海王星)



- In 1846, astronomers discovered Neptune. The discovery was made based on mathematical calculations of its predicted position due to observed perturbations in the orbit of the planet Uranus （天王星）.