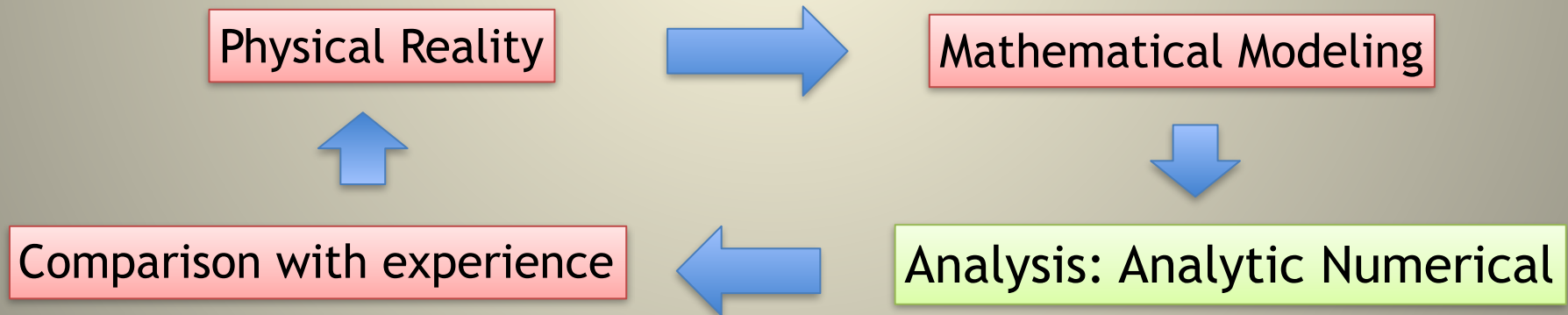


Stage Informatique NPAC 2018

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Modeling and Simulations :
Statistical Physics and **Interdisciplinary applications**



Collective Phenomena in Systems Composed of Many Simple Interacting Un

Possible Subjects

- Neural Networks (Machine Learning & Computational Neuroscience)
- Inference in Inverse Ising Models and Boltzmann Machine (Statistical Inference)
- Error Correcting Codes (Information Theory)
- Simulations of Aging in Spin Glasses (cond-mat Physics)
- Random Field Ising Model and Glasses (cond-mat Physics)

Neural Networks

Modeling Brain Functions

Collective Properties of Neural Assemblies

- Memory / Learning
- Decision Making

Neurons : 2 states Firing - Quiescent $S_i = \pm 1$

Exchange Information through Synapses $J_{ij} > 0$ Excitatory

$J_{ij} < 0$ Inhibitory

Reasoning / Retrieval from Memory / Decision Making S_i Dynamics

Learning : J_{ij} Dynamic
s

Spin Glasses

Ref. J.Hopfield PNAS 79 (1982) 2554

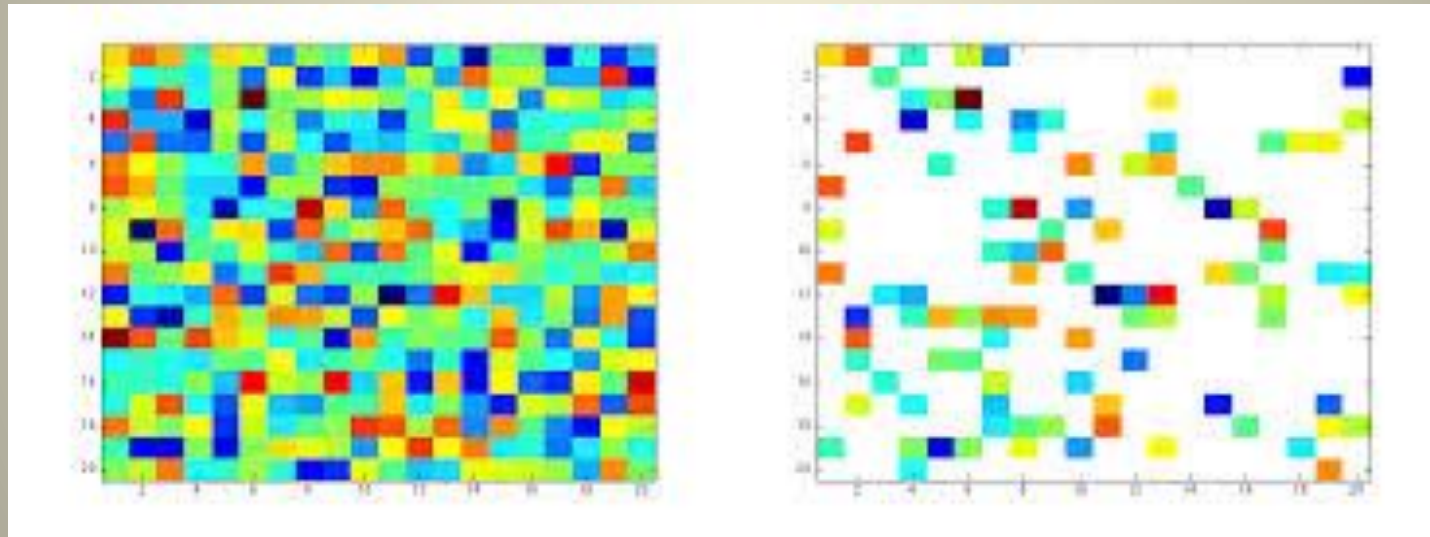
D. Marti et al. Plos One 3 (7) e2534

Machine Learning and Big Data

- Learning from data and Inference
- Possible problems
 1. The Netflix Matrix completion and Matrix factorization problem.
 2. Supervised Learning from Examples. Deep Learning and Convolutional networks
 3. Inverse Ising model
 4. Error Correcting codes

Netflix Matrix Completion

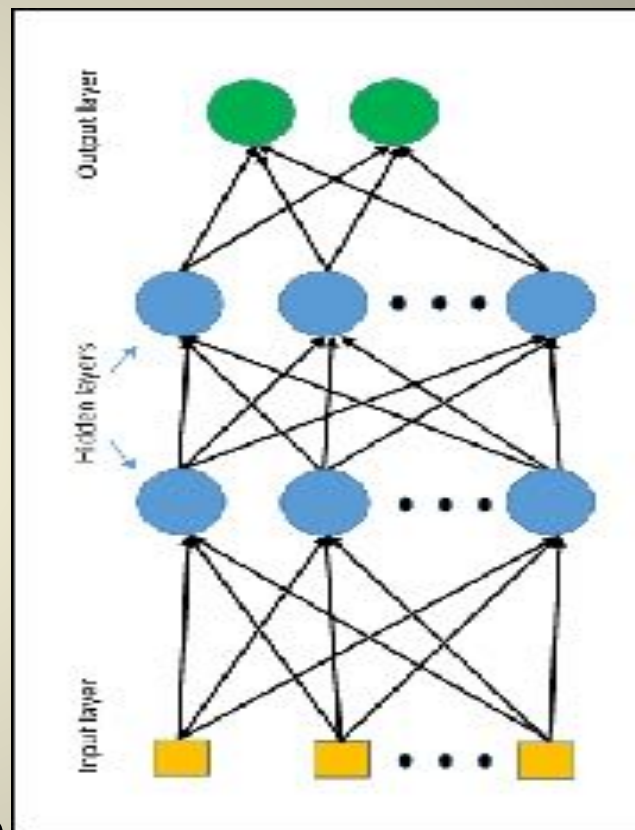
- Recommendation System, Comp. Vision, Bio-info, clustering..



- Find the lowest rank matrix that coincide with the known entries

Supervised Learning

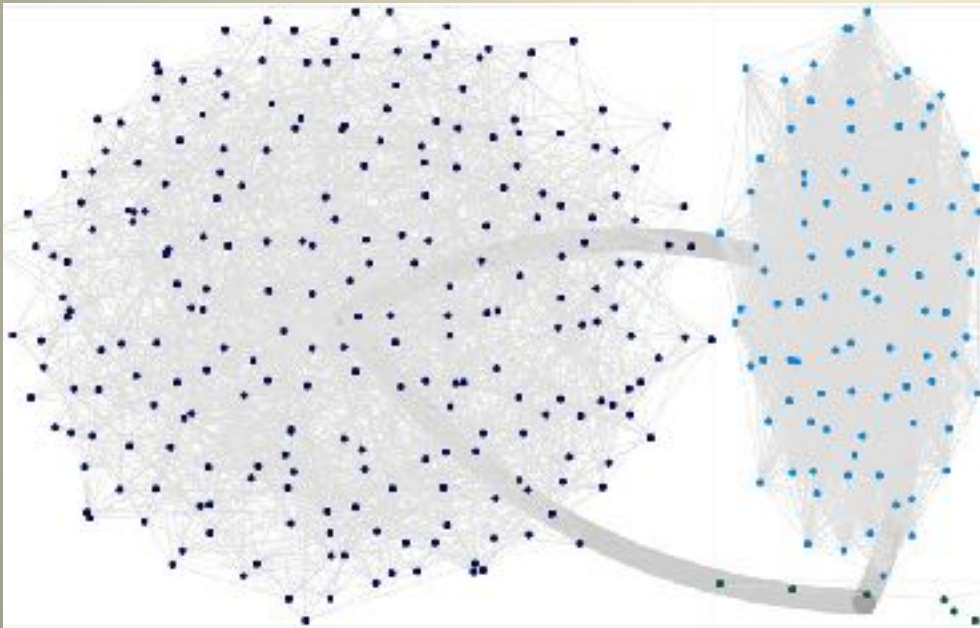
- Multilayer Neural Networks



Learning to recognize and classify from examples

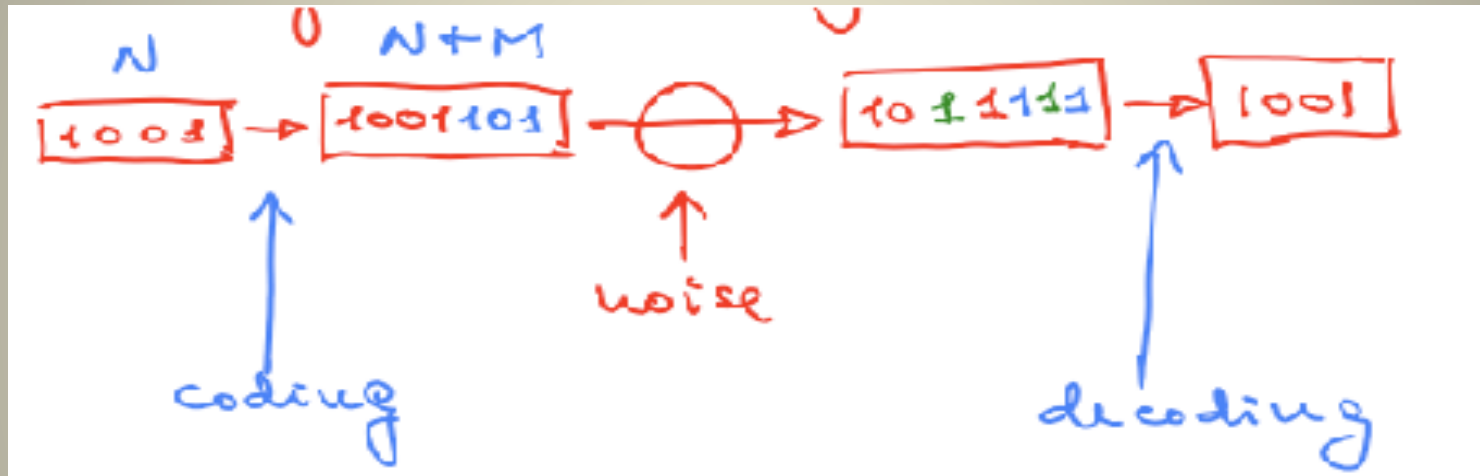
Inverse Ising Models Boltzmann Machine

$$H = - \sum_{i,j} J_{ij} S_i S_j$$



Error Correcting Codes

Transmission of a Signal through a Noisy Channel



Redundant signal

What is the maximal rate allowed by a Channel

How to decode a noisy signal ?

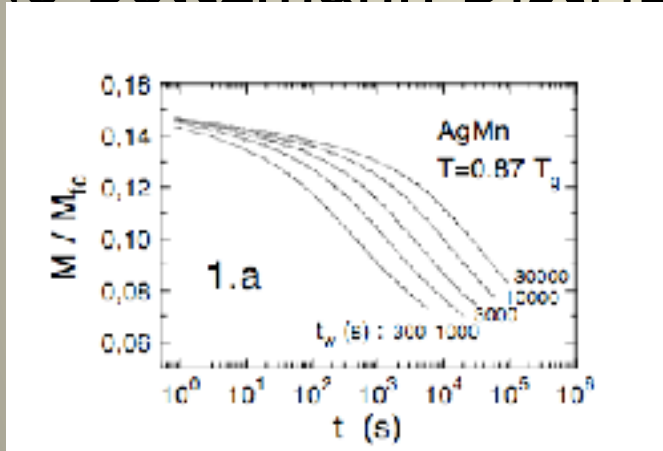
Statistical Physics

- Aging Phenomena in Spin Glasses
- Growth of correlations in Glasses
- Jamming and Avalanches in Spheres

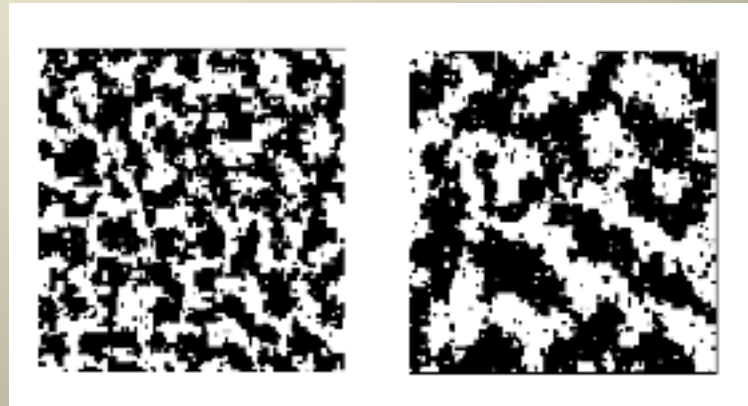
Aging in Spin Glasses

Glassy systems fail to equilibrate on Lab time scales

No Boltzmann Distribution / History dependence



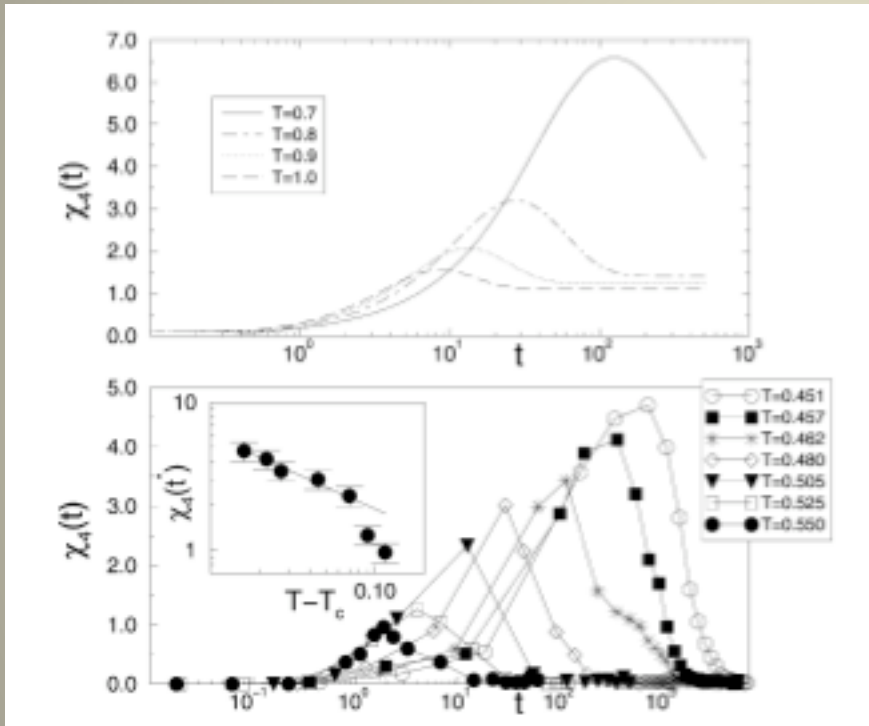
How glassy systems explore configuration space ?



Ref: G. Biroli JSTAT (2005) P05014

Random Field Ising Model and Glasses

Growing Correlations in Glassy Dynamics

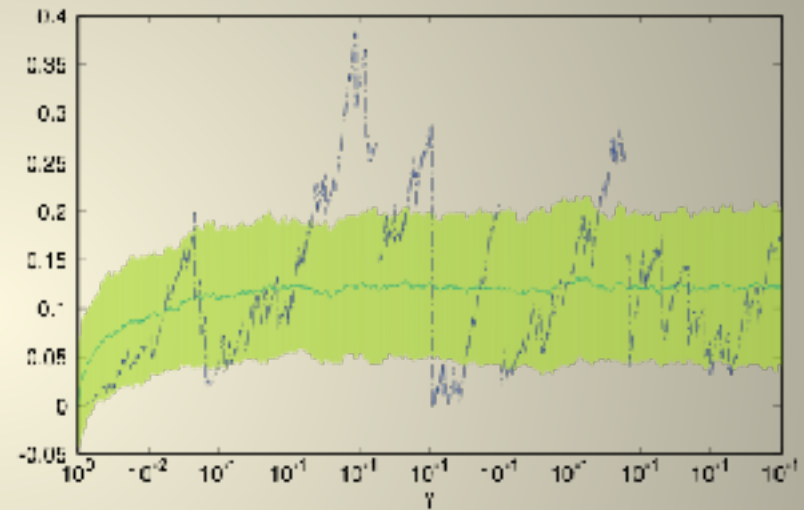
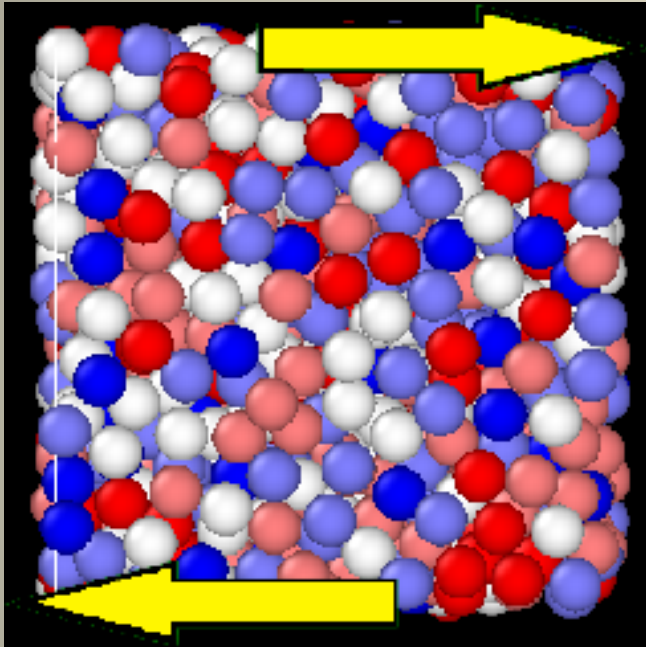


Growing correlations described by power laws

Conjecture : Same Universality class as RFIM

Simulations in a Simple Model Glass

Jamming and Avalanches in Spheres



Simulations of Classical Particle Systems

Study of glassy response

Jamming critical exponents