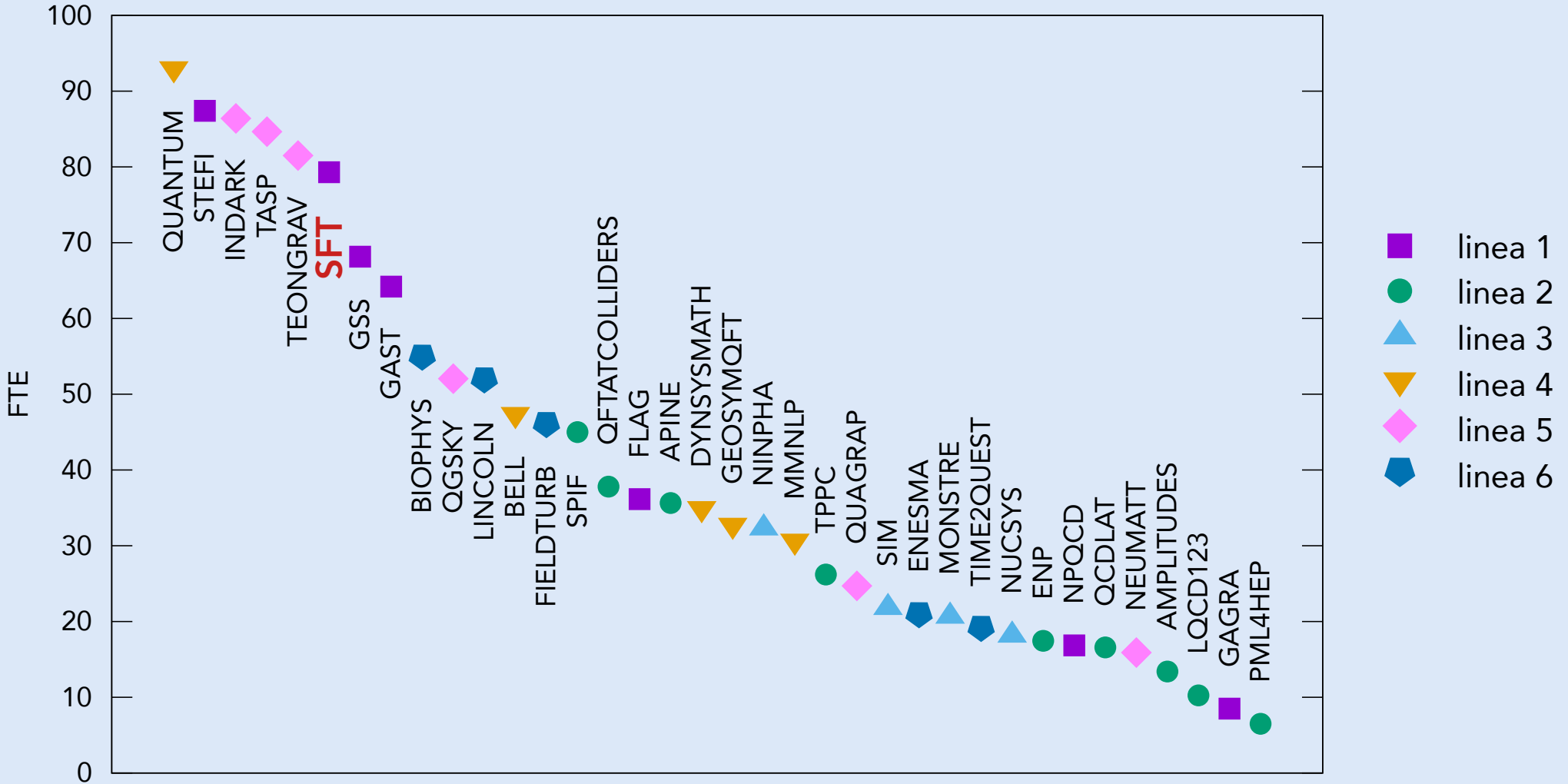
INFN - Milano - Consiglio di Sezione - 9 luglio 2024

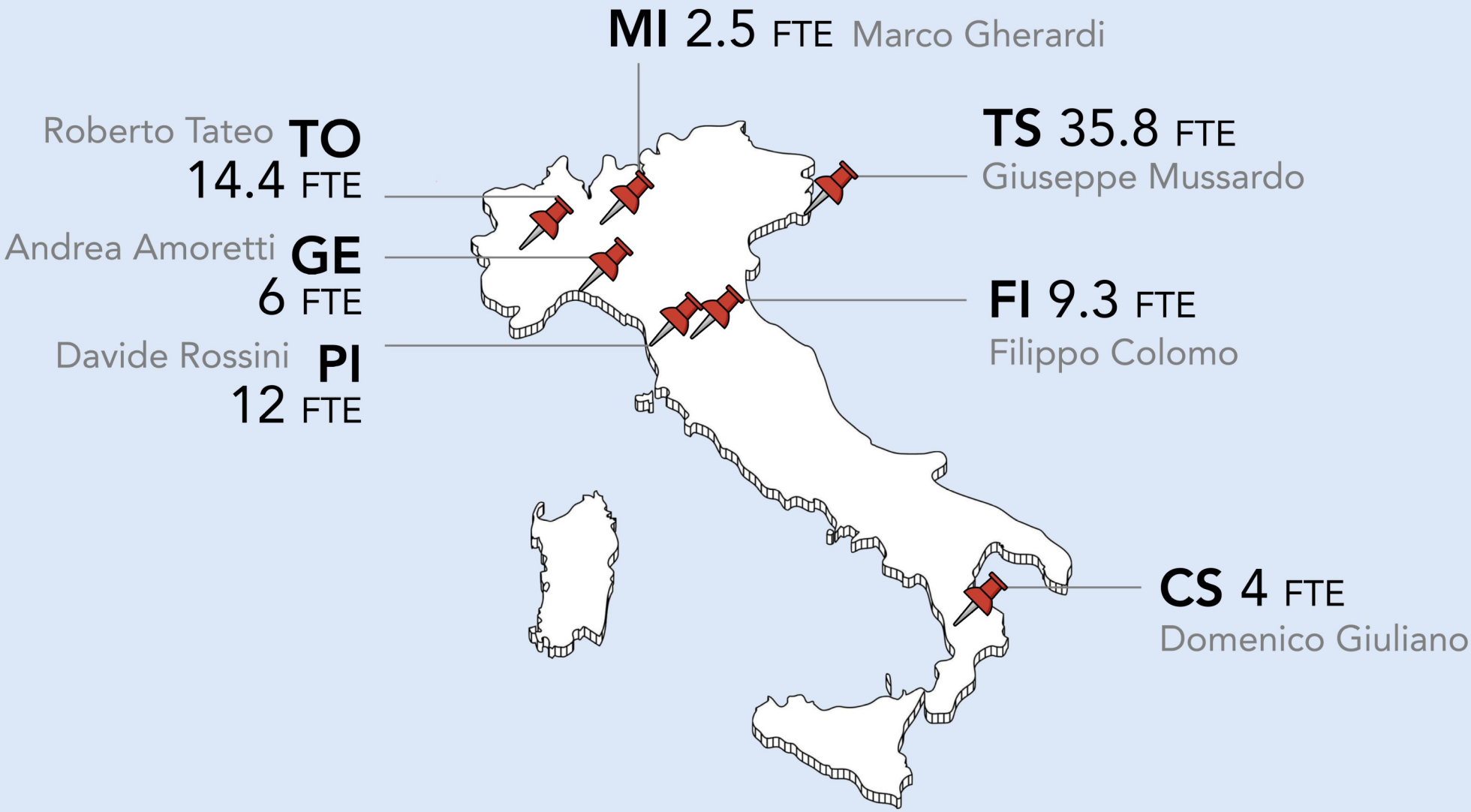
# S F T

# Statistical Field Theory

Marco Gherardi

# sesta IS per dimensione ( ~80 FTE )

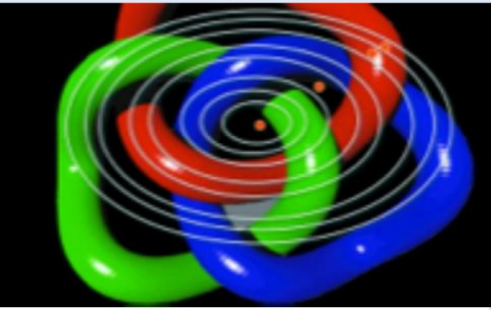


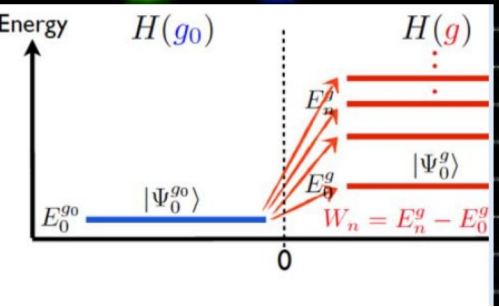

MI 2.5 FTE Marco Gherardi
Roberto Tateo TO 14.4 FTE
TS 35.8 FTE Giuseppe Mussardo
Andrea Amoretti GE 6 FTE
FI 9.3 FTE Filippo Colomo
Davide Rossini PI 12 FTE
CS 4 FTE Domenico Giuliano

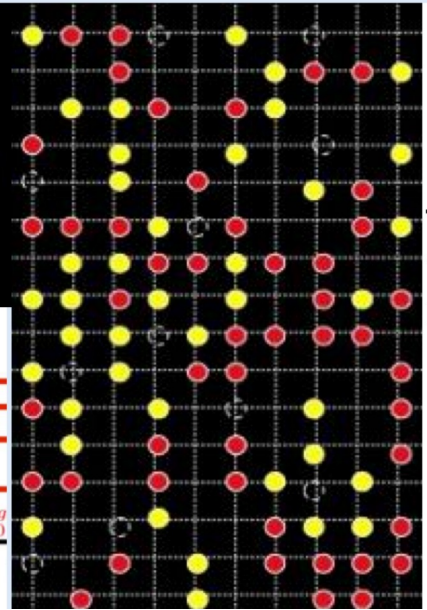
# MI

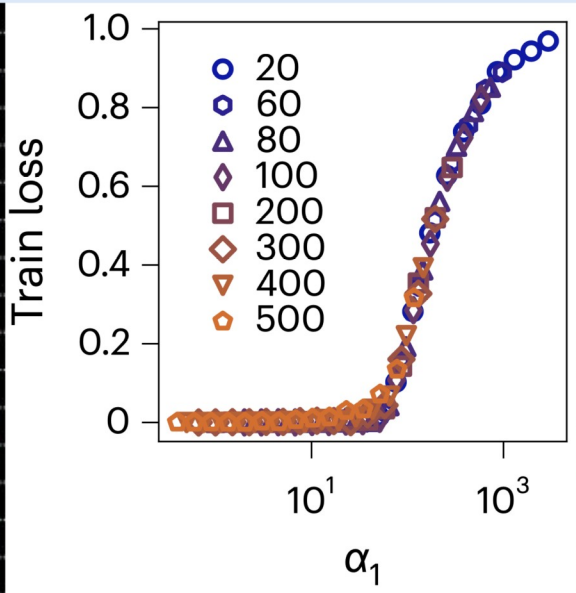
Marco Gherardi
Luca Guido Molinari
Mario Pernici
Sergio Caracciolo

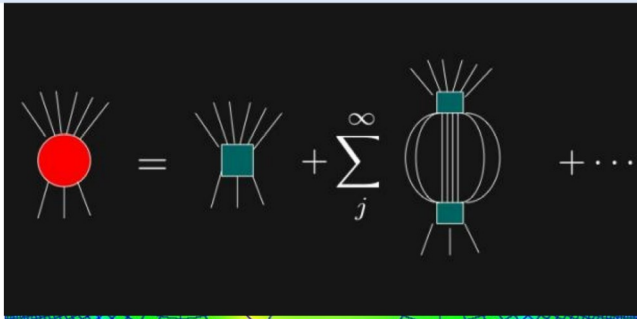
1. Quantum field theory out of equilibrium
2. **Information dynamics and computation**
3. Low-dim QFT, integrable models
4. Conformal invariance, universality classes
5. Topological phases of matter

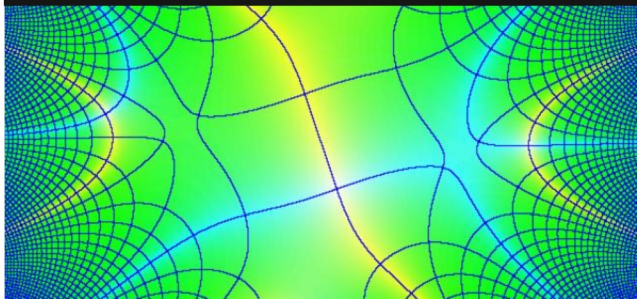






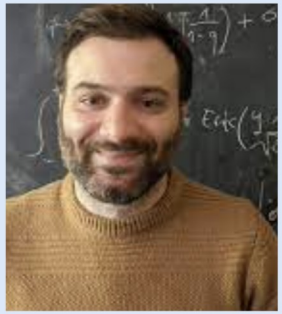



# MI

Marco Gherardi
Luca Guido Molinari
Mario Pernici

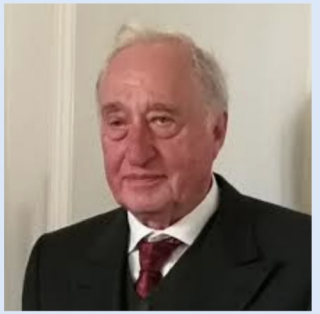
1. Meccanica statistica delle reti neurali [MG]
2. Matrici random [LGM, MP]

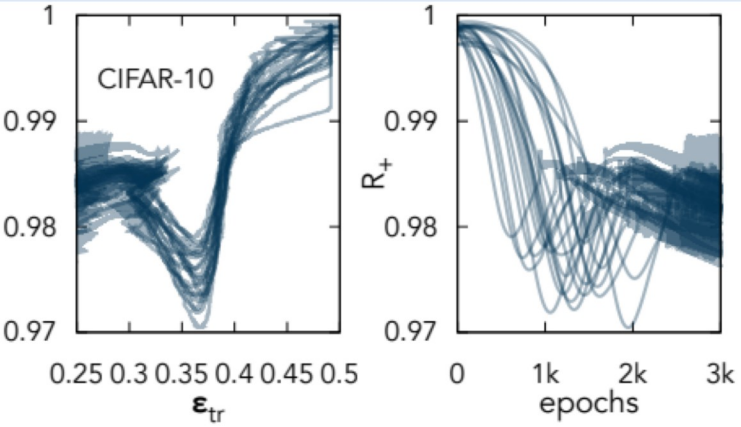
## principali collaboratori

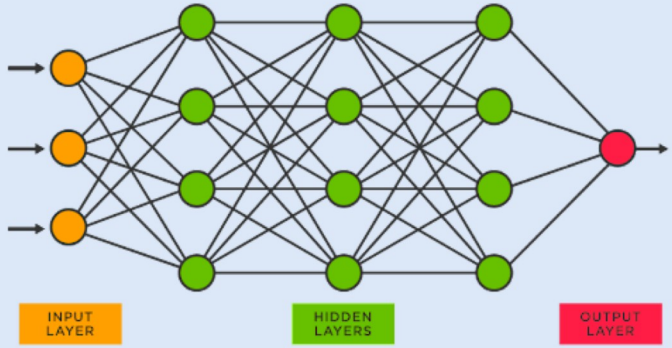

Pietro Rotondo

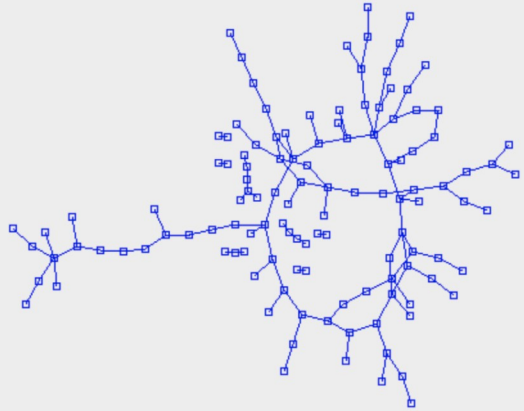

Matteo Osella


Francesco Ginelli

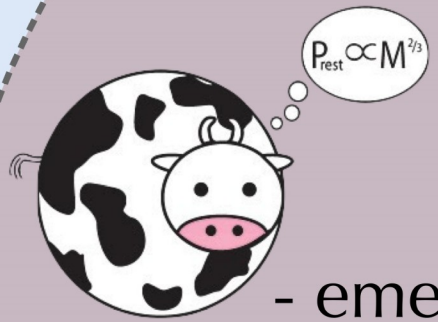

Gianni Cicuta



"STATISTICAL PHYSICS
OF DEEP LEARNING"




MODELING

- emergent phenomena
- effective theories
- simple models

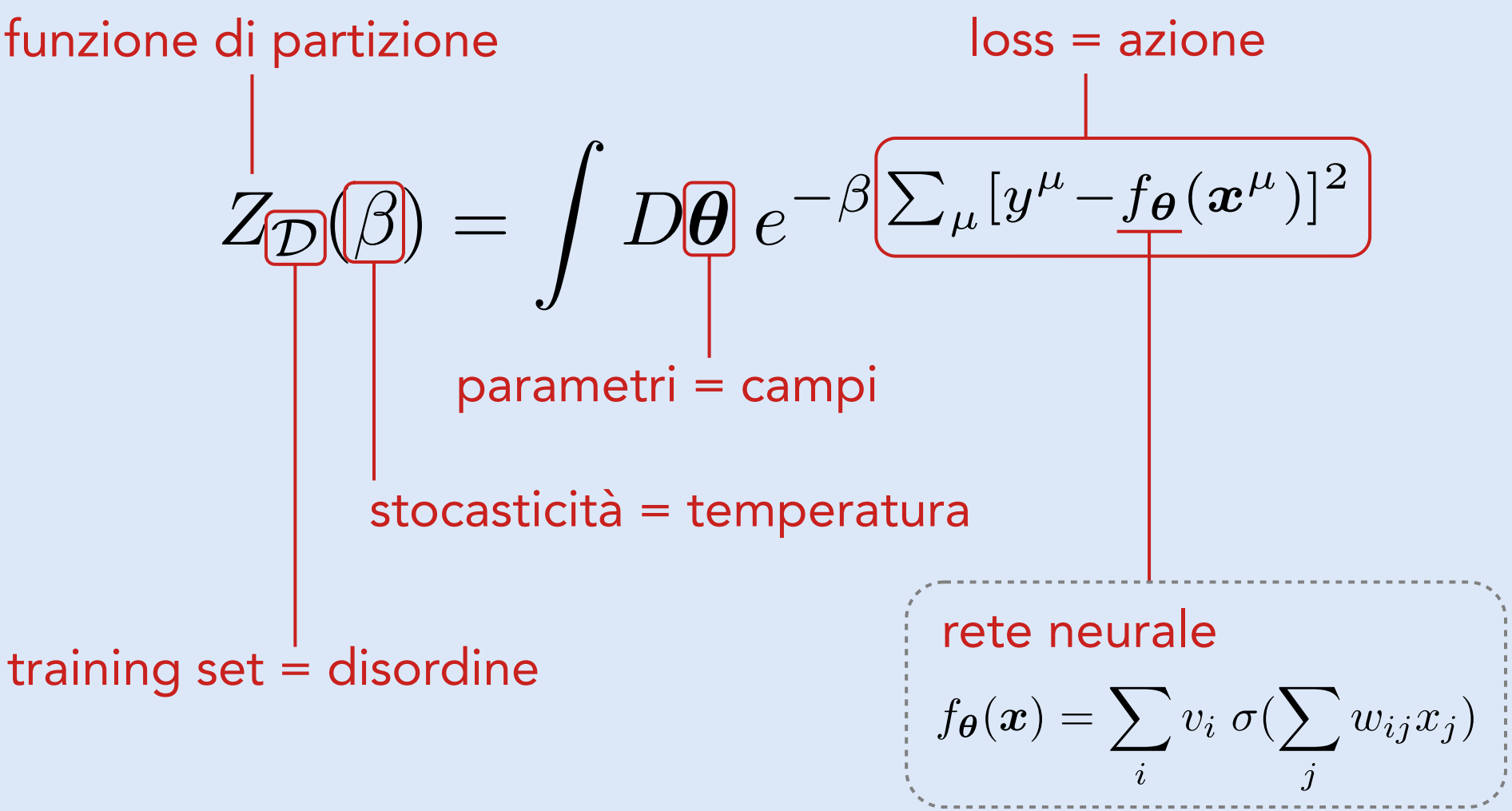
THEORETICAL

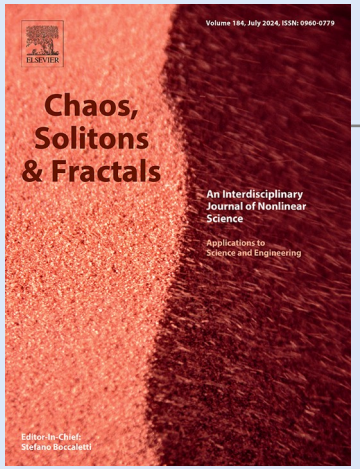
$$Z_{\mathcal{D}}(\beta) = \int D\boldsymbol{\theta}\; e^{-\beta \mathcal{L}(\boldsymbol{\theta};\mathcal{D})}$$

- analytic computations
- solvable limits

EXPERIMENTAL

look for interesting
phenomena (*in silico*)


funzione di partizione
loss = azione
$Z_{\mathcal{D}}(\beta) = \int D\boldsymbol{\theta}\, e^{-\beta \sum_\mu [y^\mu - f_{\boldsymbol{\theta}}(\boldsymbol{x}^\mu)]^2}$
parametri = campi
stocasticità = temperatura
training set = disordine
rete neurale
$f_{\boldsymbol{\theta}}(\boldsymbol{x}) = \sum_i v_i\, \sigma(\sum_j w_{ij} x_j)$

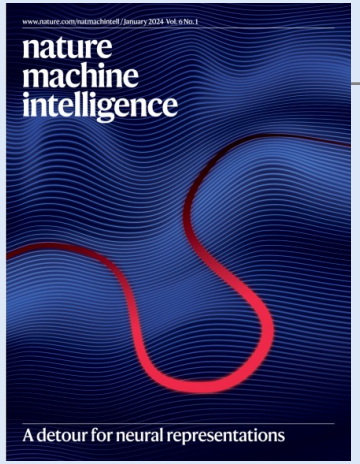



F. Bassetti, **M. Gherardi**, A. Ingrosso, M. Pastore, P. Rotondo
*Feature learning in finite-width Bayesian deep linear networks with multiple outputs and conv. layers*
arXiv:2406.03260 [stat.ML] (2024)

A. Baroffio, P. Rotondo, **M. Gherardi**
*Resolution of similar patterns in a solvable model of unsupervised deep learning with structured data*
Chaos, Solitons & Fractals 182, 114848 (2024)

R. Pacelli, S. Ariosto, M. Pastore, F. Ginelli, **M. Gherardi**, P. Rotondo
*A statistical mechanics framework for Bayesian deep neural networks beyond the infinite-width limit*
Nature Machine Intelligence 5, 1497–1507 (2023)

S. Ariosto, R. Pacelli, F. Ginelli, **M. Gherardi**, P. Rotondo
*Universal mean field upper bound for the generalisation gap of deep neural networks*
Phys. Rev. E 105, 064309 (2022)

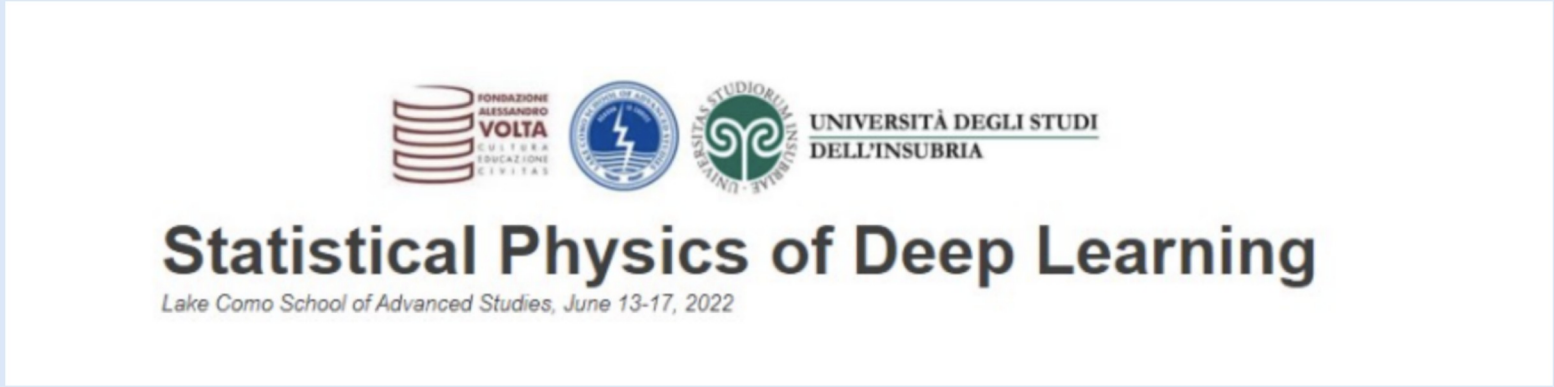



S. Ciceri, L. Cassani, M. Osella, P. Rotondo, F. Valle, **M. Gherardi**
*Inversion dynamics of class manifolds in deep learning reveals tradeoffs underlying generalization*
Nature Machine Intelligence 6, 40–47 (2024)

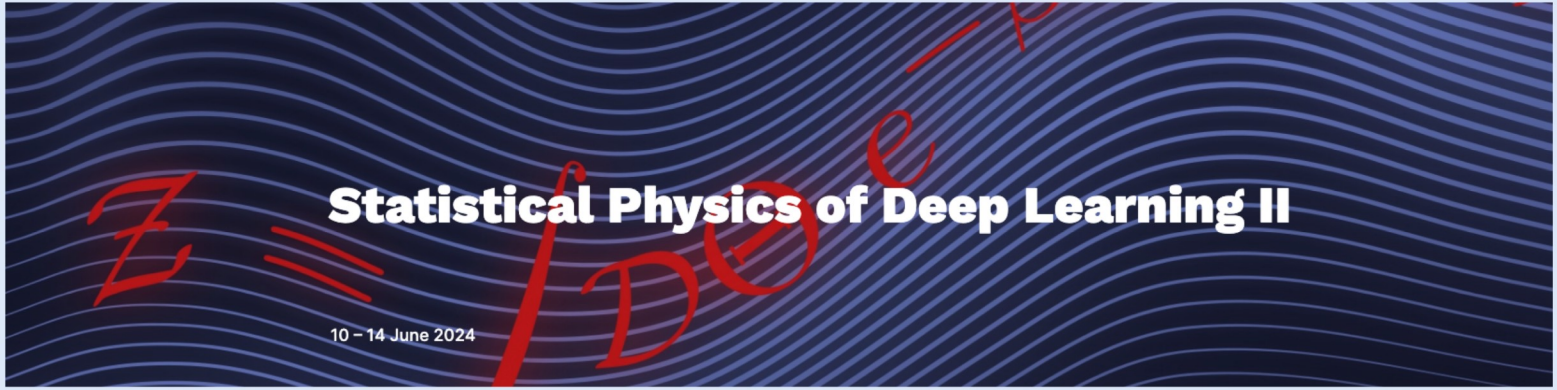
**M. Pernici**
*A random matrix model for the density of states of jammed soft spheres with applied stress*
arXiv:2404.07064 [cond-mat.dis-nn] (2024)

G.M. Cicuta, **M. Pernici**
*Sparse Block-Structured Random Matrices : universality*
Journal of Physics: Complexity 4 025004 (2023)

summer school / convegno
biennale @ Villa del Grumello, Como




Marco Gherardi
Francesco Ginelli
Alessandro Laio
Guido Tiana




Marco Gherardi
Francesco Ginelli
Sebastian Goldt
Guido Tiana